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Land-use Mapping for the State of Kuwait Using the Geographical Information System (GIS)

Abstract: A land use survey was undertaken at a scale 1:100,000 for the State of Kuwait. Land use is classified into 19 map units based on field survey and interpretation of Landsat imagery. The latest topographic map coverage for the State of Kuwait was used as a base map. The Geographic Information System (GIS) was used for the storage, analysis and presentation of spatial data. Summary statistics of total areas of each map unit are presented in nine 1:100,000 map sheets, and percentage areas of the different land uses were identified. Land use is dominated by rangeland (75.12%) which is used primarily for grazing activities, and also recreational activities such as spring camping and hunting. Oil fields (7%) include areas of existing development of wells and associated infrastructure. Water reservoir areas represent the surficial extent of aquifers and natural water fields. Military areas (4%) are scattered throughout the country. Other significant land uses include the built-up areas of Kuwait City (3.5%), and agricultural areas (3%), quarries, borrow pits and dumps of building debris, communication facilities, cemeteries, parkland, encampments, power stations, racetracks and unused land (7%). Land use information can be used as the basis for future land use planning applications.

Keywords: Land management, land evaluation, rangelands, agricultural areas, urban areas, non-urban areas, survey, soil information.

خرائط استخدام الأراضي في دولة الكويت باستخدام
نظام المعلومات الجغرافي

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المستخلص: تم في هذه الدراسة إعداد خرائط لاستخدامات الأراضي لدولة الكويت بمقياس 100,000:1 تم فيها تقسيم استخدامات الأراضي إلى 19 وحدة متباينة وذلك بناء على المسح الحقلي والاستعانة بالخرائط الجوية والصور الفضائية. كما استخدمت أحدث البيانات الطوبوغرافية لدولة الكويت لإعداد خريطة الأساس التي استخدمت في الدراسة. واعتمد على نظام المعلومات الجغرافي في تخزين وتحليل وتمثيل المعلومات الجغرافية. لقد تم إحصاء المساحات والنسب الكلية للاستخدامات المختلفة للأراضي وتحديدها على تسع خرائط بمقياس 100,000:1 وبينت النتائج بأنه يغلب على طابع استخدام الأراضي في دولة الكويت الأراضي الرعوية حيث بلغت نسبتها 75,12 % تستخدم أساسا في الرعي وكذلك النشاطات الترفيهية مثل إقامة المخيمات الربيعية وممارسة الصيد. أما حقول النفط فبلغت نسبتها 7 % وتتضمن المواقع والمساحات المستخدمة حاليا لتطوير الآبار النفطية والبنية التحتية المصاحبة لها والمحددة في الصور المأخوذة بالأقمار الفضائية. كذلك مناطق خزانات المياه العذبة وقليلة الملوحة والمالحة والتي تمثل نطاقا أو مساحة سطحية من المكامن تحت الأرضية وحقول المياه الطبيعية. كذلك هنالك أراضي ومواقع مخصصة للاستخدامات العسكرية (4 %) وهي منتشرة في أنحاء عدة من البلاد. وهناك استخدامات أساسية هامة للأراضي في دولة الكويت تتضمن المناطق الحضرية (3,5 %) والأراضي الزراعية (3 %) والمحاجر ومواقع التخلص من النفايات وأنقاض البناء وكذلك مواقع الدراكيل واستغلال وجلب الرمال والمواقع المخصصة لإنشاء مرافق الاتصالات والمقابر والمتنزهات ومحطات القوى الكهربائية وحلبات السباق والمعسكرات وهي تشكل بمجموعها 7 %. وتوفر المعلومات الناتجة من هذه الدراسة قاعدة معلومات متجددة هامة لتخطيط استخدام الأراضي في دولة الكويت. كما يمكن الاستفادة من المعلومات في المقارنة باستخدام الأراضي الآتية ومجال الاستخدام في المستقبل مما يساعد متخذ القرار في التخطيط وإعداد استراتيجية استخدام الأراضي.

كلمات مدخلية أراضي–تقييم، استخدامات، أراضي زراعية، رعوية وحضرية، مسح التربة

Introduction

Kuwait lies at the northeastern corner of the Arabian Peninsula and is situated within two main physiographic regions. To the south and southwest, there is a sequence of sedimentary rocks of the Arabian platform overlying the Arabian shield, and to the north and northwest, there is the Mesopotamian plain with the Euphrates and Tigris River deltas at the head of the Arabian Gulf. Kuwait's desert can be divided into four physiographic provinces: (a) Al-Dibdibah gravelly plain; (b) southern desert flat; (c) coastal flat; and (d) coastal hills.

The surface topography is a rather 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, Wadi Al-Batin valley and small isolated hills at Al-Burqan, Umm Qudayr and Al-Wafrah. The landscape is controlled, to a great extent, by the occurrence of calcic and gypsic hardpans, locally referred to as 'gatch'. In the north of the country, gypcrete dominates, whereas calcrete is more dominant in the southern sand plain where it caps several isolated hills.

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The average gradient of the northeastward slope is about 2 m/km (Khalaf and Al-Ajmi, 1993). The landscape slopes gently from about 280 m above sea level in the extreme southwestern corner of the country to sea level towards the northeast. The southern part of the country drops across a series of low, discontinuous scarps, separated by wide plateau and plains towards the Arabian Gulf coast in the east. The western and northern parts of Kuwait lie within a large old alluvial fan, which extends from near Hafr Al-Batin in Saudi Arabia to as far as Khur Al-Hammar in Iraq and the northern shore of Kuwait Bay.

Since the discovery of oil, land use has become much more intensive in Kuwait (Khalaf and Al-Ajmi, 1993). The population according to the 1995 census was 1,575,983 people, including 655,820 nationals and the remainder expatriates (Ministry of Planning, 1995). Present land uses have tended to result in unsustainable use of rangeland environments, with degradation of perennial vegetation communities and alteration of annual vegetation in areas accessible to the public and grazing animals. Nevertheless, Kuwait's rangeland environment has deep sentimental value for Kuwaitis, who consider the desert as an integral part of their natural and cultural heritage (Hussain, 1992).

Land use in Kuwait was severely disrupted by the Iraqi invasion and occupation of Kuwait in 1990. The country was pillaged and most industry and agriculture devastated. Human resources were severely affected and many people fled the country. Severe environmental damage resulted from the detonation and destruction of 1164 oil wells (Al-Ghunaim, 1997). The resultant oil spills had a devastating effect on the terrestrial and marine ecosystems and threatened to pollute water resources. Oil fires emitted vast clouds of toxic fumes and particulates that were deposited over a wide area. Heavy vehicle traffic and military earthworks destroyed vegetation and degraded the soil, rendering it susceptible to wind erosion. Access to much of the country was disrupted by the millions of landmines and other unexploded ordnance left behind after the occupation.

Following liberation, the oil fires were extinguished and the oil sector was rapidly reactivated; however, oil lakes and contaminated soils remain threats to both the terrestrial and marine ecosystems. Unexploded ordnance throughout the State has been extensively cleared. Electricity generation and water treatment plants were bought back on-line and industry rebuilt. Currently, the industrial and agricultural sectors are in full operation and are placing increasing demands on land resources. The pressure for urban expansion grows, coastal development has sprawled south to the Saudi Arabian border and a second city is being planned at As-Subiyah.

Information on land use is published annually by the Ministry of Planning. The most recent information shows that the surface area of Kuwait is about 17,818,000 ha. It is classified into five categories in ha: cropland 44,463; tree land 22,210; pastures 17,179,100; unused cultivated land 31,817; and non-cultivable land 40,410 (Ministry of Planning, 1998). This information, however, needed to be updated with information using more advanced and precise technology, such as the Geographical Information System (GIS). GIS techniques have proven very useful in analyzing a large database as well as producing specialized maps (Machin and Navas, 1995; Adinarayana and Krishna, 1995). The objective of the study has been to prepare compilations of land use for the State of Kuwait based on field survey, interpretation of imagery and application of GIS. The land use maps provide a useful tool and information resource for land use planning, policy development and future feasibility studies.

Material and Methods

Compilation of the land use maps required identification and description of existing land use types, the creation of a classification scheme and the delineation of the corresponding map units for the nine 1:100,000 map sheets covering the country (Fig. 1) as well as data analysis and synthesis (Fig.2)

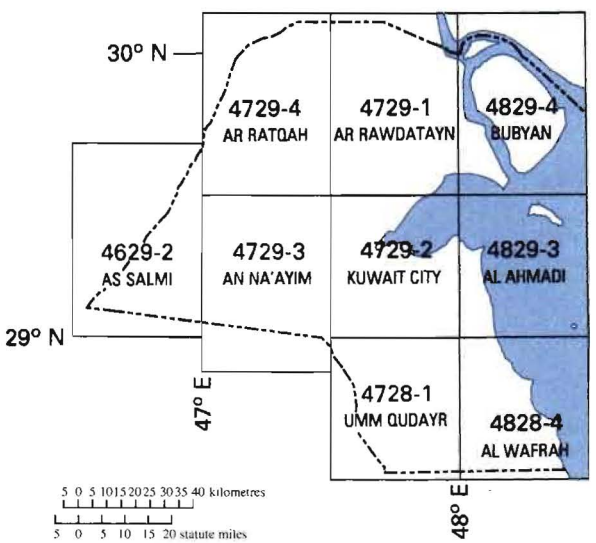

Fig. 1. Location of the nine map series in Kuwait

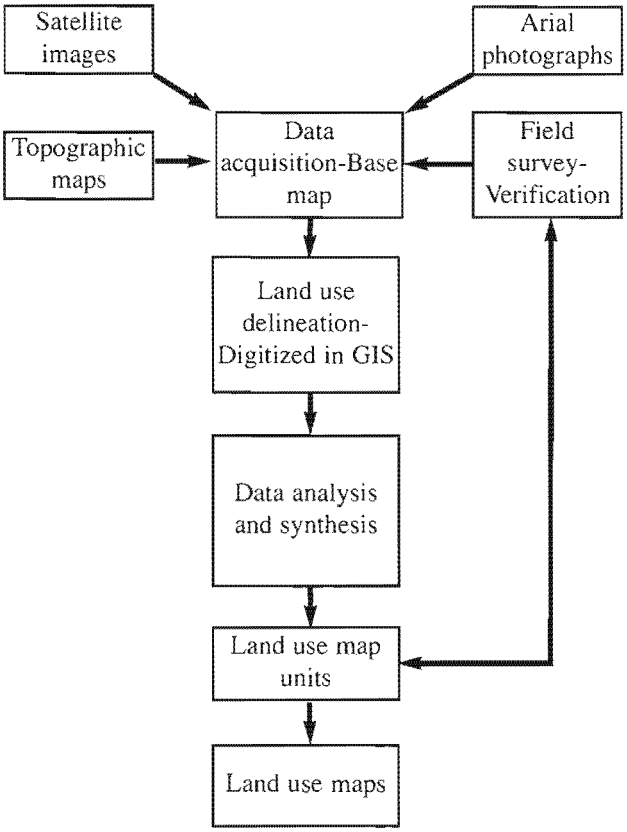

Fig. 2. Schematic presentation of land use maps development by GIS application.

Standard map compilation practice required that the latest available imagery and field survey data be used as the primary data sources for land use classification, and that the latest topographic map coverage be used for the base map. Accordingly, the Landsat Thematic Mapper satellite images from March 1995 coupled with the Spot HRV satellite images at 1:100,000 scale taken between January and April 1994 and the Kuwait 1:100,000 topographic map series, edition 3, 1995, were used. In addition, aerial photographs at 1:29,000 scale taken in 1991/1992 and field survey data gathered in April 1996 and January 1997 were used as sources of information for land use delineation. Delineation of map units was digitized and stored on the Geographical Information System (GIS).

All data sources were reviewed and the images were interpreted to determine land use signatures and patterns, which were characterized and used to develop the present land use classifications. The images and other data sources were then analyzed, the subsequent information synthesized, the land uses classified and the land use map units delineated on stable film compilation overlays that were keyed to the 1:100,000 satellite images and base maps.

Once preliminary compilations for the pilot map were completed, field verification and classification were performed to insure the accuracy of the classifications before continuing with the remainder of the compilation effort. After necessary adjustments based on the field check, the remaining preliminary compilations were completed. These compilations were then digitized and put through the map production process.

During January 1997, most of the mapped land use units were field checked. Not every mapped unit was visited. Effectively, the content and accuracy of the mapping are directly related to the 1994 and 1995 satellite images, from which most of the information was taken, and subsequent field verification of the mapping.

The specifications for the 1:100,000 scale maps are according to United States Department of Agriculture (USDA) guidelines (Soil Survey Staff, 1993). The map format design was predicated on a subdued and modified planimetric version of the Ministry of Defense 1:100,000 scale map series, edition 3, 1995. This topographic map series consists of nine A1 size, namely: As-Salmi, Umm Qudayr, Ar-Rawdatayn, Kuwait City, An-Na'ayim, Ar-Ratqah, Al-Wafrah, Al-Ahmadi, and Bubyan (Fig.1).

Results

Consistent with the specifications of the USDA Soil Survey Handbook (Soil Survey Division Staff, 1993), land use mapping of the State of Kuwait was compiled at a scale of 1:100,000. Significant land uses, which occur in Kuwait and comply with standards for mapping at a scale of 1:100,000, are outlined in the list of map units presented in Table 1. The nine 1:100,000 map sheets and percentage areas of the different land uses identified in the State of Kuwait are presented in Table 2. There are 19 land use map units identified in Kuwait. These map units are described as follows:

1) Agricultural area (A): Comprises irrigated agriculture, including open field and greenhouse cultivation, tree plantations, nurseries and large areas presently uncultivated. The unit occurs for the most part at Al-Abdali in the north, at Al-Wafrah in the south and along the southwestern margin of Kuwait City.

2) Built-up or industrial area (B): Populated areas comprising residential, business and industrial centers and associated infrastructure.

3) Communication facility (C): Only the larger

and important facilities are identified and indicated separately from the B unit (built-up or industrial area).

4) Refuse disposal area or landfill (D): The unit encompasses all principal or concentrated landfill dumps, which have been determined from the primary mapping data sources, but does not generally include areas of scattered piles or random dumping on the landscape.

5) Encampment (E): Camps comprised of concentrations of tents and other temporary structures used as dwellings or markets on a semipermanent basis. The aerial extent of the camps may vary considerably over time.

6) Intensive animal farm (F): Animal husbandry, including sheep, poultry, camels and dairy products. Farms using methods designed for improved productivity and increased output.

7) Cemetery (G): Major cemeteries outside the built-up or industrial areas.

8) Military area (M): Military installations located outside the built-up areas, which were identified from the primary data sources. These areas, which are excluded from the soil survey, may also be used periodically for traditional animal grazing.

9) National park (NP): Comprises the designated national park and protected areas. Land use includes recreation and sporadic camping. Although fenced, animal grazing is also practiced within the confines of the national park.

10) Oil field (O): The aerial extent of the oil fields, comprising wells and associated infrastructure as seen on the satellite images. Secondary land use periodically consists of traditional animal grazing.

11) Power station (PS): Areas occupied by major power stations and desalination plants.

12) Quarry or borrow pits and tailings (Q): Unit definition ranges from open pit rock and gravel quarries and crusher operations to extensive areas of borrow pits and associated tailings. The unit is found scattered throughout the country, but the most extensive areas occur in the northwest. Near built-up areas, the unit may include random dump sites or piles of debris.

13) Rangeland (R): Represents the background land use unit for Kuwait and occurs countrywide, with the exception of the tidal flats around Bubyan Island. Small settlements and isolated buildings, etc., are included in the definition of the unit, which is used extensively for traditional animal grazing. Important secondary land use includes recreational activities and sporadic camping.

14) Scrap yard (S): Prominent wrecking yards, salvage yards and scrap heaps generally located along the outskirts of the built-up or industrial areas.

15) Racetrack (T): Camel and horse racing facilities located outside the built-up areas.

16) Water reservoir (W): Large reservoirs and associated waterworks facilities located outside the built-up areas, which could be identified from the mapping data sources.

17) Water resource area (WF): Areal extent of unit delineation includes water wells, small reservoirs, pipelines and power lines associated with the water fields. Large water reservoirs are classified separately. Near built-up areas, random encampments and piles of dumped materials are found on the unit. Land use includes periodic traditional animal grazing.

18) Wooded parkland or afforestation (WP): The most extensive wooded park areas used for recreation and camping and zones of afforestation found mostly around the outskirts of the built-up areas or adjacent to major roadways.

19) Unused lands (X): Areas of barren tidal flats around the margins of Bubyan Island.

Discussion

Land use in the State of Kuwait (Fig.3) is dominated by rangeland (75.12 % of the mapped area) that is used for traditional grazing activities by flocks and herds of domestic sheep, goats and camels. Other uses of the range, particularly in areas close to Kuwait City, include recreational activities such as spring camping and hunting. The rangeland areas also include the demilitarized zone on the northern and western borders.

Oil fields cover less than 7 % of the country. Fifteen oil fields were identified. Al-Maqwa, Al-Ahmadi and Al-Burqan, immediately south of Kuwait City, together form the largest single area of

Table 1. Areas of Land Use Map Units and Their Percentage

Symbol	Name	Area (ha)	Percent
A	Agricultural Area	46,965	2.71
B	Built-up or Industrial Area	60,247	3.47
C	Communication Facility	4,483	0.26
D	Refuse Disposal Area or Landfill	3,136	0.18
E	Encampment	1,091	0.06
F	Intensive Animal Farm	6,452	0.37
G	Cemetery	100	0.01
M	Military Area	68,757	3.96
NP	National Park	33,358	1.93
O	Oil Field	117,659	6.78
PS	Power Station	1,119	0.06
Q	Quarry or Borrow Pits and Tailings	38,294	2.21
R	Rangeland	1,302,786	75.12
S	Scrapyard	643	0.04
T	Racetrack	629	0.04
W	Water Reservoir	794	0.05
WF	Water Resource Area*	90,477	-
WP	Wooded Parkland or Afforestation	5,064	0.29
X	Unused Land	42,655	2.46
Total		1,734,412	100.00

* Water resource areas traverse other land uses so they are not accounted for in the total area calculation for Kuwait or the percentage area calculations for land use or map series.

Table 2. Summary of Map Unit Areas - 1:100,000 Land Use Map Series (refer to Fig (1) for location of map series)

		As-Salmi	Umm Qudayr	Ar-Rawdatayn	Kuwait City	An-Na'ayim	Ar-Ratqah	Al-Wafrah	Al-Ahmadi	Bubyan	Total Area	
		4629_2	4728_1	4729_1	4729_2	4729_3	4729_4	4828_4	4829_3	4829_4		
Land use	Symbol	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	%
Agriculture	A	115	789	24,719	4,945			16,397			46,965	2.70
Built-up/industry	B				25,781			6,394	28,072		60,247	3.50
Communication	C			1,095	2,751				637		4,483	0.30
Refuse/dump	D				1,924	94		862	256		3,136	0.20
Encampment	E		157		934						1,091	0.10
Intensive farms	F		635		4,123	1,694					6,452	0.40
Cemetery	G				100						100	0.00
Military	M	494	2,548	1,812	2,562	13,738	39,664	7,353	586		68,757	4.00
National Park	NP	197		29,686	3,655						33,538	1.90
Oil field	O		48,470	24,858	24,725		2,246	5,373	11,987		117,659	6.80
Power station	PS		42		357			319		401	1,119	0.10
Quarry	Q	44		9,091	4,808	1,369	22,149	98	252	483	39,294	2.20
Range land	R	131,488	156,000	207,373	150,308	239,841	206,640	122,998	8,004	78,066	1,302,786	75.10
Scrapyard	S				314			329			643	0.00
Racetrack	T				489			140			629	0.00
Water reservoir	W		81		2,420			242	119		794	0.10
*Water field**	WF			6,250	39,172	48,701		854			94,977	
Parkland	WP		436		3,623				1,005		5064	0.30
Unused land	X								13	42,642	42,655	2.50
Total		**132,338**	**209,158**	**298,634**	**233,819**	**256,736**	**270,699**	**160,505**	**50,931**	**121,591**	**1,734,412**	**100**
%		**7.60**	**12.10**	**17.20**	**13.50**	**14.80**	**15.60**	**9.30**	**2.90**	**7.00**	**100**	**100**

* Note: Water resource areas traverse other land uses so they are not accounted for in the total area calculation for Kuwait or the percentage area calculations for land use or map series.

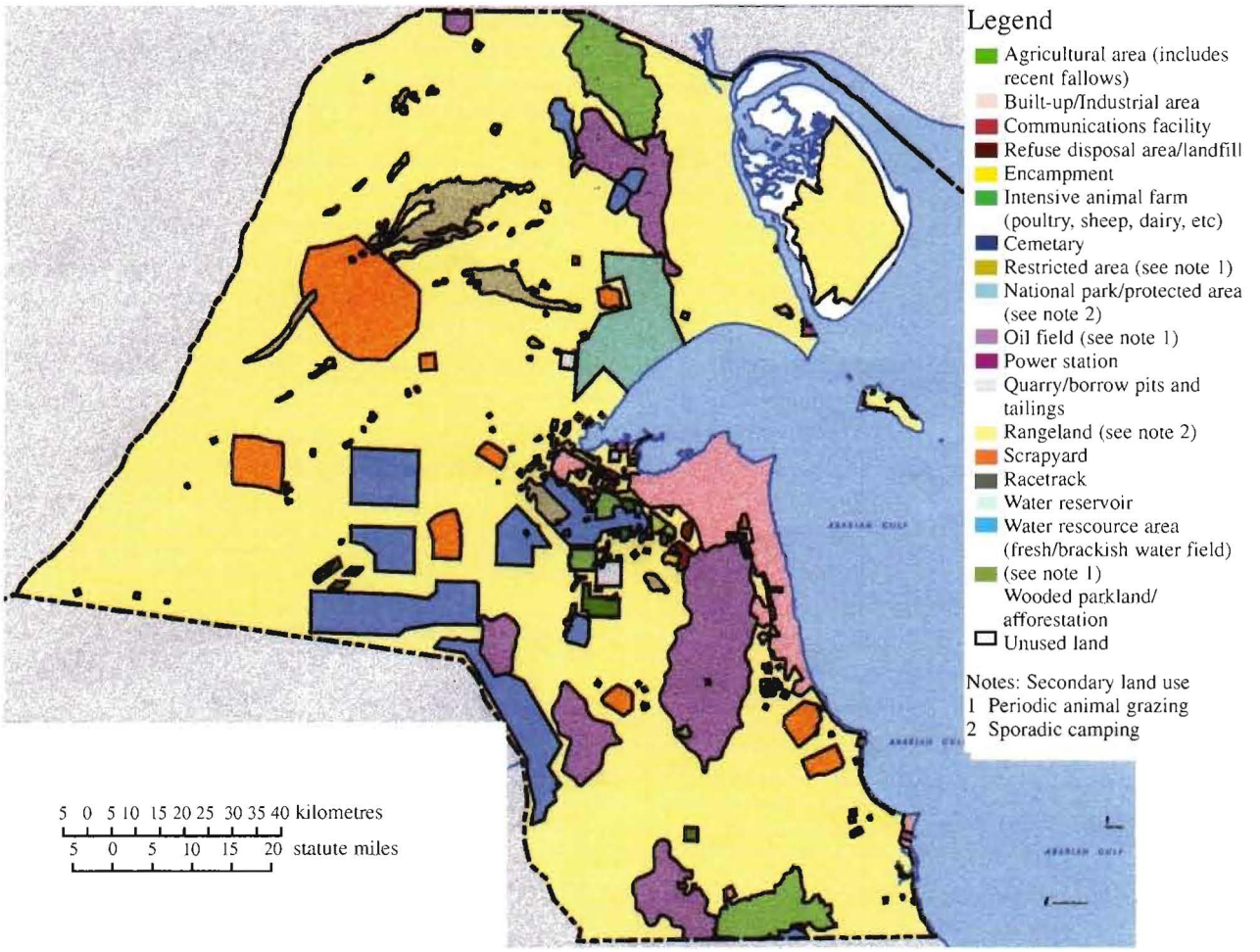

Fig. 3. Land use categories for the state of Kuwait

existing oil field development in the State. They are flanked by the smaller Zareef, Rijm Khashman and Al-Abdaliyah fields, which also extend south of Kuwait City. Umm Qudayr and Al-Manaqish lie further west and south, close to the border with Saudi Arabia. Al-Wafrah and Al-Fawaris lie in the far south of Kuwait, adjacent to Al-Wafrah farms. Ar-Ratqah lies in the extreme north adjacent to the Iraqi border. Further east below Abdali farms are the Ar-Rawdatayn and As-Sabriyah fields (the delineated area also encompasses the smaller Al-Bahrah and Keraa Al-Marw fields). The oil fields are delineated on the land use map on the basis of the visible extent of wells and associated infrastructure identifiable on the satellite images.

Water reservoir areas (fresh and brackish) represent the surficial extent of aquifers and natural water fields. Substantial fields have been identified to the west of Kuwait City, generally limited to the areas covered by the An-Na'ayim, Umm Qudayr and Kuwait City 1:100,000 map sheets. In the north of the country, two smaller fields lie adjacent to and partly intersecting with the existing oil field areas of Ar-Rawdatayn and As-Sabriyah (these areas are also used for other land uses, principally rangeland).

Military areas (3.96 %) are scattered throughout the State of Kuwait, with the largest in the northwest (Ar-Ratqah map sheet). These areas include military bases, airfields, firing ranges and training areas.

Other significant land uses include the built-up area of Kuwait City and its residential and industrial suburbs; the agricultural areas, including Al-Abdali in the north and Al-Wafrah in the south of the country, plus other smaller areas of greenhouses, tree plantations and nurseries (2.71%); an area designated for the national park (1.93%), but which continues to be used as rangeland; quarries, borrow pits and dumps for building debris, scattered throughout the State, but with significant areas in the northwest; and unused land (2.46%), comprising barren tidal flats around the margins of Bubyan Island.

Minor land uses cover the remaining areas and include communication facilities, cemeteries, refuse disposal areas, intensive animal farms (including poultry, sheep and dairy), water reservoirs, parkland, encampments, scrapyards, power stations and racetracks.

While grazing activities co-exist with oil fields, the expansion of more intensive irrigated agricultural activities within these areas is unlikely in the near future because of the extensive oil infrastructure of wells, pipelines, roads and gathering centers. Furthermore, the oil fields are extending into adjacent rangeland as exploration and development continue.

Grazing also occurs in areas underlain by water fields, and it would be inappropriate to develop these areas for irrigated agriculture due to the risk of contamination of the underground water by leachate. It is unlikely that any change in land use will occur within the existing military areas.

The vast majority of urban development in Kuwait occurs along the coastal fringe. This appears set to continue for the foreseeable future as residential and industrial development expands around the existing urban centers.

Notwithstanding these limitations, extensive tracts of land with potential for further agricultural development remain, including areas adjacent to Al-Wafrah and Al-Abdali, and to the southwest of Kuwait City. Other areas of rangeland could be developed where suitable soils and available water resources permit.

Conclusions

The land use survey provided information on type of land uses and the areas they occupy in the State of Kuwait. Most land outside the metropolitan area is owned by the State. These lands are mainly used for rangeland grazing by livestock. The rangelands are the predominant land use, covering almost three-quarters of the country. The rangeland is an integral part of Kuwait's heritage, providing herders with food, fodder and fiber products. Its value is becoming more apparent as a recreational escape for city dwellers. The comparatively insignificant role played by agriculture in the Kuwaiti economy can be attributed to a number of environmental constraints, including limited water resources, a harsh climatic regime and poor soils. However, the cooperation of private farmers with the government has facilitated and continued to promote agricultural development in the State of Kuwait. All agricultural land use relies on irrigation. Scarcity of irrigation water limits the full utilization of the arable land in Kuwait.

Due to the economic importance of the petroleum industry to Kuwait, the Kuwait Oil Company has exclusive rights to perform its operations related to the petroleum industry on all land in the State.

Other land uses in Kuwait include extractive industries and defense sites, afforestation to protect urban areas from desert winds and sand drift and small sites for communications, military, water, municipal uses, quarrying and other uses. The GIS database generated on land use assessment can be modified and updated as the need arises. The survey can help planners to maintain or create a land use pattern that is in harmony with nature.

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