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SEASONAL AGRICULTURAL VEGETATION COVERAGE AND WATER MANAGEMENT OF ALKHABRA AREA ALONG WADI AR RUMAH IN ARABIAN PENINSULA USING LANDSAT TM.

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Agricultural coverage of the mapping system in the midstream of wadi Ar-Rumah valley in Arabia peninsula area have been seasonally monitored, classified and evaluated. The relationship between a satellite image Landsat TM of the study area and the corresponding meteorological parameters of the area has been discussed. The water consumption of the vegetated areas has also been evaluated. The actual target of this study is to understand the seasonal variation in agricultural vegetation cover along wadi Ar Rumah area using 12 months of Landsat/TM images and the associated water consumption from irrigation.

Keywords: Saudi Arabia, Al Qassim, Wadi Ar-Rumah, agriculture vegetation cover, water management.

Saudi Arabia is a part of the hot desert extending from Sahara in Africa in the west to the Thar desert in Indo-Pakistan sub-continent in the east. Vegetation, water and solar radiation are the controlling factors of the natural environment of Saudi Arabia (Foody, 2002). The production of the thematic maps, such as those depicting land cover, using an image classification is one of the most common applications of remote sensing (Foody, 2002). Many researchers used this technique to achieve this aim (Thomas *et al.*, 2002; Rogan *et al.*, 2002; Ju *et al.*, 2003). Changes in vegetation cover are amongst the more obvious of the alterations that mankind has caused to the global environment. Historically these changes have been local or regional in effect, though widespread. For many reasons, then, the detection and monitoring of vegetation cover dynamics is highly desirable (Rees *et al.*, 2003). Remote sensing clearly has a potential role to play in order to monitor fragile arctic ecosystems, although they have yet to be fully investigated (Tommervika and Hogdad, 2003). This paper detect

AlQassims land vegetation cover change (mainly agriculture), and whether space observations are useful to study variation in vegetation growth along wadi Ar Rumah (AlSultan *et al.,* 1998). Studying AlQassim area along Wadi Ar Rumah is important for several reasons: i) Better understanding the current status of land cover/use of desert ecosystem. ii) Observing the land cover system in an active agriculture and populated area for the benefit of the desert agriculture and settlement landscape. It has to be mentioned that the total water supply that comes from ground water about 75-85%. The total volume is estimated to be 900000 million m^3 in the ground water reserves, which was formed in the last Ice age, 15000 to 30000 years ago (Alibrahim, 1991). For the last 30 years, the crop cultivation was successfully performed by center pivot irrigation system using extracted ground water. This agricultural method is mainly progressing in Al Qassim district (AlSultan *et al.,* 1997).

LOCATION AND GENERAL DESCRIPTION OF THE STUDY AREA

Saudi Arabia physical geography can be divided into five geographic regions: (i) the western highlands, (ii) the central plateau, (iii) the northern deserts, (iv) the *Rub al Khali* desert, and (v) the eastern lowlands. The central plateau geographic region, the mountains of *Hejaz* and *Asir* slope eastward toward the central plateau, also called *Najd.* Little vegetation can be found in most of this region (Figure. 1). In parts of the rocky plateau. fertile oasis support large farm communities; Al Qassim is one of these oasis. During the rainy season in the peninsula, nomadic herders bring their animals to feed on patches of grass that grow in the region for a short time after occasional rainfall. The peninsula terrain is varied but on the whole fairly barren and harsh, with salt flats, gravel plains, and sand dunes but with few permanent streams. In the south, is the *Rub Al Khali* (Empty Quarter), the largest sand desert in the world. In the southwest, the mountain ranges of *Asir* province rise to over 2700 m. There is no precipitation during the months from June to September. The months from January to March are of the highest precipitation. The mean annual precipitation of the past twenty years is 110 mm., which is very low, and it is characterized by an irregular distribution both in quantity and frequency.

The study area, Alkhabra along Wadi Ar Rumah in the Arabian peninsula between 12°N and 32°N latitude and between 20°E and 35°E longitude (Figure 2). This particular geographical position gives the area great bioclimatic diversity. The desert of the Arabian peninsula is located as a part of the hot desert which extends from the *Sahara* in Africa in the west to the *Thar* desert in Indo-Pakistan sub-continent in the east. The overall climate falls within desert and arid climates, except the *Asir* province where the temperature is lower and the rainfall is greater than that of the remaining part of the peninsula. The area is also subjected to a significant problem with regard to desertification. Wadi Ar Rumah is also the main dry river in the peninsula; its midstream part comes through Al Qassim oasis located at the center of the peninsula desert.

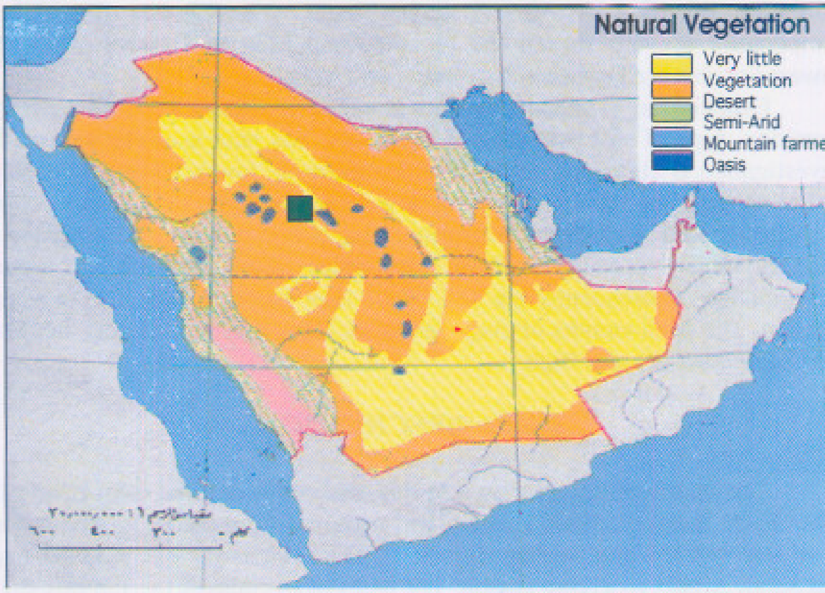

Fig. (1). Geography of Saudi Arabia (Atlas of Saudi Arabia and World, 1996).
(■ Location of Study area).

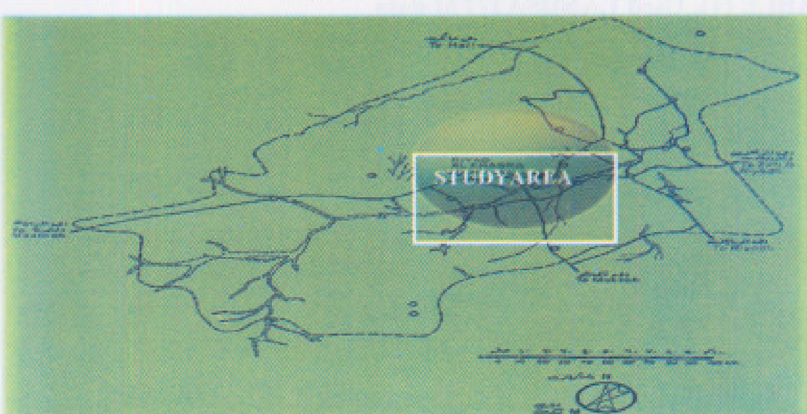

Fig. (2). Location of Alkhabra, the study area in central of Saudi Arabia.

Ar Rumah Wadi starts from the two big volcanic mountains in the north and the south of Al-Madenah(AlSultan, 1998). The main part of Ar Rumah passes through Al Qassim oasis which is one of the main agricultural region of the kingdom of Saudi Arabia (AlSultan, 1997).

The maximum monthly temperature ranges between 38.6°C and 43.1°C in summer with a minimum of 20.8°C to 24.1°C. During winter, the maximum monthly temperature ranges from 18.19°C to 24.1°C with a minimum of 5.3°C to 10.9°C. It has been observed that the highest temperature prevails during the months from May to October while the lowest are observed between November and March.

Evaporation is mostly dependent on solar radiation, wind velocity, humidity, type of soil, and type of vegetation and land use. The area under investigation is characterized by high temperature, low humidity, high solar radiation and hot winds during summer. Accordingly, Al Qassim region provides conditions for high evaporation rates. It varies from 133mm/day in January to 575 mm/day in June. This value highly exceeds the annual precipitation, consequently the soil of the area becomes deficit in moisture content. The peak months of evaporation are June, July and August, but May and September are also high.

DATA DESCRIPTION

The multispectral data used in this analysis is derived from Landsat 5 TM digital imagery. This imagery was acquired from the King Abdul Aziz City For Science and Technology (KACST), which was downloaded from the Saudi Arabia receiving station. The dates of the images used in this study can be seen in table (1).

TABLE (1). Used LANDSAT/TM data

Images No.	Observation date
Image-1	19 Jan 1994
Image-2	28 Feb 1994
Image -3	17 Apr 1994
Image-4	20 Jun 1994
Image-5	23 Aug 1994
Image-6	24 Sep 1994
Image-7	26 Oct 1994
Image-8	27 Nov 1994

METHODOLOGY

Image Processing

The study area was extracted from the full scenes, and prepared for image processing analysis as subscenes. Each subscene is 512 pixel * 400 line, i.e. of 18432 ha. Resampling program has been used for the image registration by selecting 10 GCP points in each image site, making January images the basis for registration, and registering all images to it. A composite image of the three bands (421) has been formed for every month to detect the vegetation cover in the study area.

About 30 years ago, it has been advantageous to perform crop cultivation by centre pivot irrigation system in Saudi Arabia. This method has been mainly progressing in Al Qassim district (AlSultan *et al.*, 1997). In the present study, analysis of Landsat data for all the 12 months of the year have been carried out using supervised classification method (Maximum Likelihood Classification) which was adopted for classifying the total amount of planted vegetation cover. Many researchers also used the Maximum Likelihood method in their study (Donoghue and Mirommet, 2002).

This method uses training data sets of distinct spectral signatures that have been selected within the areas of exactly known identity of agricultural vegetation. Classification was carried out to estimate the percent coverage of agricultural land during each month of the year. Remote sensing software in window PC environment has been developed and used for the classification.

The study area has been visited by the researchers, where ten representative sites were selected as training sites. The location of these sites and the descriptive classification title for it is fed into the computer to generate the signatures of the classification process. The accuracy assessment was detected using 10 points distributed randomly in the study area and a reference map to this area, an error matrix is produced to represent the overall classification accuracy of the resulted classes.

Detection Seasonal Vegetated Cover and its Relationship to Water it Consumption

The amount of agriculture cover in the study area was detected from the image processing of the 12 satellite images, one for each month. The seasonal variation in vegetation cover was detected by a comparative analysis of the percent cover of vegetation in each image. This was also related to the corresponding water consumption of crops cultivated in the study area. Estimates of water consumption were acquired from the Ministry of Agriculture that is responsible of the irrigation and cultivation activities in the area under study. Cumulative sum of these water consumption values was calculated and related to the amount of vegetation cover in hectares per month and consequently per year. When relating the water consumption of the study area per year to the total available water in the reservoir, water management practices can be defined and evaluated.

RESULTS

Image Processing

Colour composites produced for the study area are presented in figures (3 and 4), for february and June, respectively. These months were selected as these represent the most contrasting seasons as it pertains to greenness and dryness. Generally the tones of red are indicative of vegetation cover. The rounded shapes that appear in red are cultivated fields resulting from pivot irrigation system. From these figures it is clear that the February image exhibit more vegetation cover because of the growing of wheat season. Wheat was seeding in november, the beginning of the winter.

It is also observed that from May the amount of agriculture is less. This is because of the harvesting time of wheat in April. The observed percentage of agricultural land cover from May to September represent other crops such as alfalfa, barely and also trees such as palm date which grow all the year round. The spectral signatures used for the classification is presented in the figure (5). This figure shows that the crops planted in the study area are very similar spectrally, and therefore were treated collectively in calculating total water consumption (m^3). Figure (5), shows the detailed signatures based on mean value that used in the classification process.

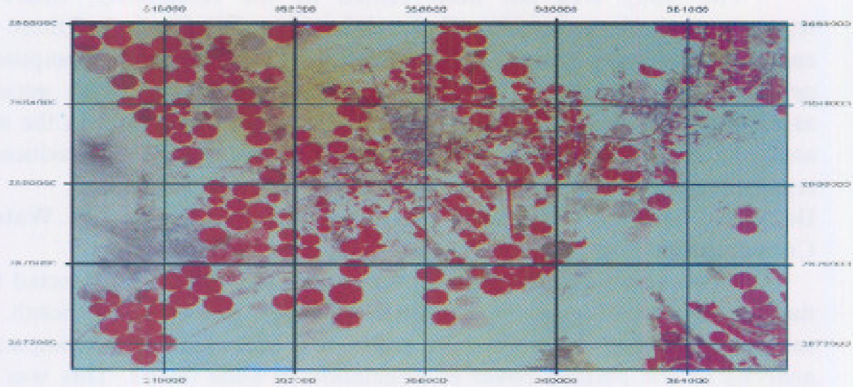

Fig. (3). Landsat TM February 28, 1994 of Riyadh Al Khabra subscene (RGB= TM bands 421).

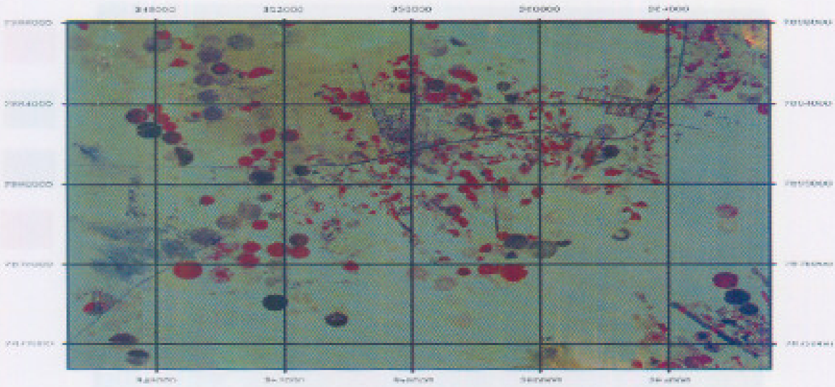

Fig. (4). Landsat TM June 20, 1994 of Riyadh Al Khabra subscene (RGB= TM bands 421).

Fig. (5). Mean plot of signatures.

From the results of classification analysis the percent cover of the agricultural areas is plotted in figure (8), while the classified images resulted are presented in figures (6 and 7). From these figures it appears that Landsat data can provide the extent (increase or decrease) of vegetation cover on temporal basis due to changes in spectral characteristics of the land cover over time. Due of cloud in some of satellite images, the percentage of land cover for March and December have been considered the same as the previous months February and January, respectively.

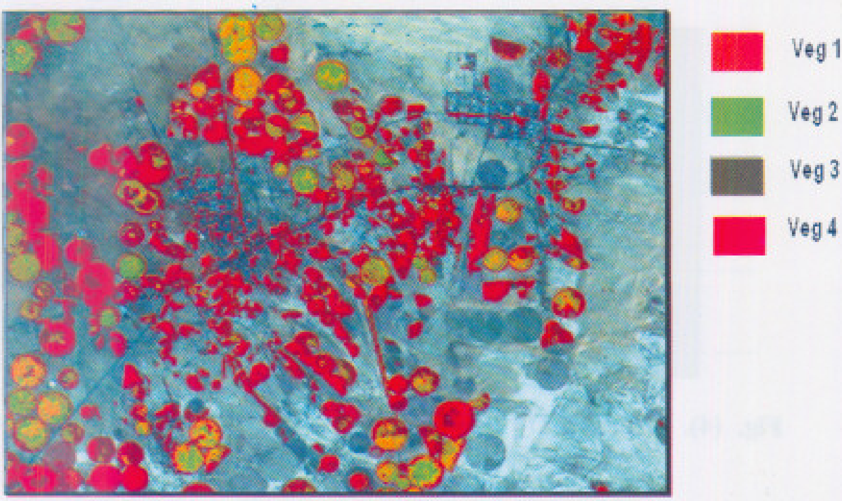

Fig. (6). The classified image obtained using Maximum Likelihood classifier of February, 1994. Veg 1 denotes to alpha alpha, Veg 2 barley, Veg 3 palm tree, Veg 4 Wheat.

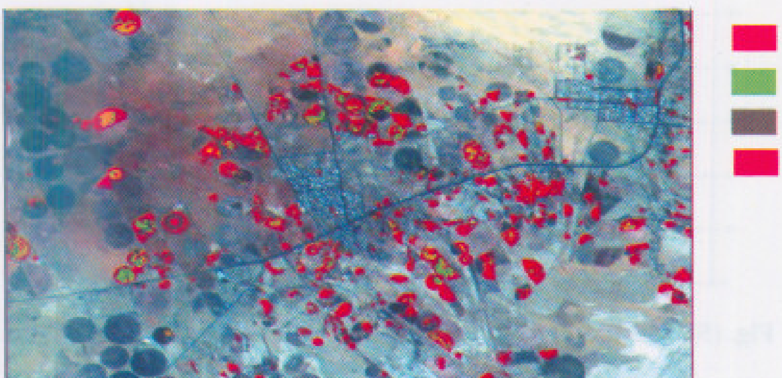

Fig. (7). The classified image obtained using Maximum Likelihood classifier for June, 1994. Veg 1 denotes to alpha alpha, Veg 2 barley, Veg 3 palm tree, Veg 4 Wheat.

The error matrix indicating the overall accuracy is shown in table (2). The accuracy of classification based on February classified image is calculated to be 90%. This accuracy considered accepted for the purpose of this research.

TABLE (2). Error matrix.

		Classified Map				
		Veg 1	Veg 2	Veg 3	Veg 4	Total
Reference Map	Veg 1	0	0	0	1	1
	Veg 2	0	3	0	0	3
	Veg 3	0	0	2	0	2
	Veg 4	0	0	0	4	4
	Total	0	3	2	5	10

The agrometerological data are plotted in figure (9). This figure shows that the net water requirement (cubic metre/hactare) of grains (wheat), forages (alfalfa) and trees (date palm).

It is observed and resulted from figures (8 and 9) that the extent of agricultural land cover is less during May to October but the water consumption is high, while water consumption is low when the extent of vegetation cover is more in the winter season.

Water Consumption Assessment

From landsat image curve in figure (8), it can calculated the total area coverage (ha) and water consumption data can be calculated in the following manner:

Image area in hectares:

1 pixel = 30 * 30 = 900 meter square = 900/10000 ha = 0.09

$$\frac{512 \text{ pixel} * 400 \text{ lines} * 30 * 30 \text{ meter square}}{10000 \text{ meter square}} = 18432 \text{ ha}$$

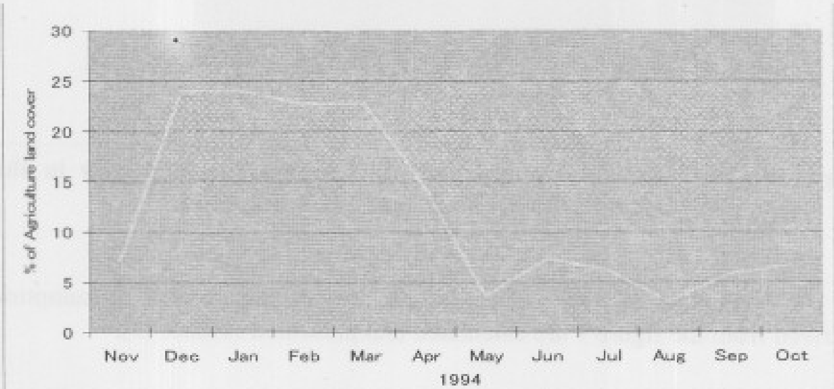

Fig. (8). Agricultural cover transition of Al Qassim area along Wadi Ar Rumah from Landsat TM data analysis.

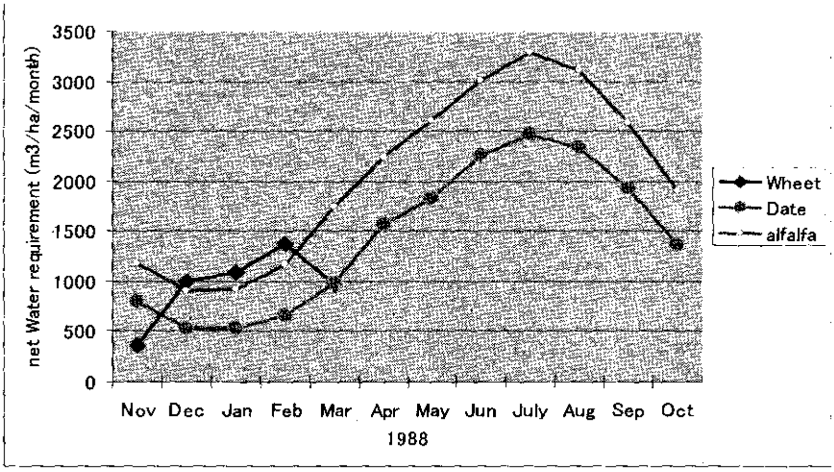

Fig. (9). Net water requirement for wheat, date and alfalfa in the mid-stream of Wadi Ar Rumah, Saudi Arabia. (Data resource Dept. of Agr., Saudi Arabia)

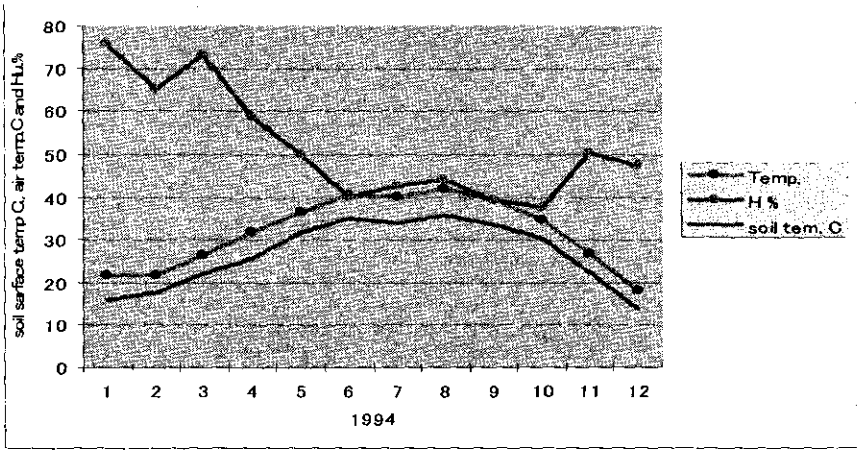

Fig. (10). Surface soil temperature, air temperature, humidity in the mid-stream of Wadi Ar Rumah, Saudi Arabia.

Vegetation coverage per month and the associated water consumption derived from the figure 9 are calculated and presented in table (3).

TABLE (3). Water consumption (m^3) /month in the study area.

Month	Percent cover from the image (18432ha)	Area (ha) /month	Sum of water consumption (m^3) for total agriculture /ha	Water consumption (m^3) /month
January	24	4423.68	2500	11059200
February	22.8	4202.50	3350	14078361.6
March	22.8	4202.50	2750	11556864
April	14.5	2672.64	3850	10289664
May	3.6	663.55	4500	2985984
June	7.3	1345.54	5350	7198617.6
July	6.2	1142.78	5880	6719569.92
August	3.1	571.39	5500	3142656
September	5.9	1087.49	4500	4893696
October	6.7	1234.94	3300	4075315.2
November	7.1	1308.67	2450	3206246.4
December	24	4423.68	2450	10838016
Total		27279.36	46380	90044190.72

Water reservoir = 9×10^{11} m^3
% of water usage of Al Khabra along wadi Rumah :
$[90044190.72 / 9 \times 10^{11}] \times 100 = 0.0100$

Table (3) demonstrates the total area of cultivations of Alkhabra area (ha), along Wadi Ar Rumah. This area is derived from the results of MLC classification. The cultivated area is mainly wheat, alfalfa, barley and palm trees. By knowing the water consumption (m^3)/crop/ha/month, the above calculations were used to estimate total water consumptions (m^3) for the three crops in the entire cultivated area in Alkhabra area. The cumulative sum of which would indicate the total amount (m^3) of water consumption (for irrigation) in Alkhabra area /year.

The amount is estimated to be about 90044190.72 m^3, which constitutes about 0.01% of the total water in the reservoir (9×10^{11} m^3). This parameter is considered to be an indicative of water consumption from the reservoir and calls for similar calculation for neighboring cultivated area in order to assess the amount of water used for irrigation in AlQassim along Wadi Ar Rumah area, and the future sustainability of water use. It is also important to carry out specialized studies on rates of reservoir recharge in the area under study in order to assess the water budget of this irrigation method (pivot), and consequently ground water management schemes.

CONCLUSION

The assessment of agricultural land cover in the study area could be done successfully with the help of remote sensing satellite data. An assessment of water consumption in the area could also be done. The information derived through similar studies can provide the Government with necessary data for crop estimation and water budget planning in the country. This would help achieve a sustainable development in the future. It is also concluded that water consumption rate per month can be estimated using the classification of land cover and the consumption rate for each particular crop.

REFERENCES

Alibrahim Abdulla Ali (1991). Excessive use of ground water resource in Saudi Arabia: Impact and policy options, AMBIO Vol.20, Feb. 1991. (Tucker, C. J.; J. R. Townshend and T.E. Goff), African land-cover classification using satellite data, 1985. *Science*, 227: 369-375.

AlSultan Sultan; S. Tanaka; A. Hoyano and T. Sugimura (2000). Monitoring of vegetation growing along wadi Ar Rumah, KSA using C-band of Radarsat, L-band of Jers-1 with Landsat TM data. *Adv. Space Re, COSPAR.*, Vol. 26 (7): 1155-1158.

AlSultan Sultan; S. Tanaka and T. Sugimura (1998). Desert greening in Wadi Ar Rumah watershed system in 1998 observed by remote sensing. *Proceedings of Japanes conference on remote sensing*, p. 245, 246.

AlSultan, S.; S. Tanaka and T. Sugimura (1997) Seasonal change of vegetation and water along wadi Ar-Rumah in Al-Qassim area, KSA using Landsat. *Proceedings of Japanese conference on remote sensing*, p.43-44.

Donoghue, D. N. M. and N. Mironnet (2002). Development of an integrated geographical information system prototype for coastal habitat monitoring. *Computers and Geosciences*, 28: 129-141.

Foody, G. M. (2002) Status of land covers classification accuracy assessment. *Remote Sensing and Environment*, 80: 185-201.

Ju, J. C.; E. D. Kolaczyk and S. Gopal (2003). Gaussian mixture discriminant analysis and sub-pixel land cover characterization in remote sensing. *Remote Sensing and Environment*, 84: 550-560.

Rees, W.G.; M. Williams; P. Vitebsky (2003). Mapping land cover change in a reindeer herding area of the Russian Arctic using Landsat

TM and ETM+ imagery and indigenous knowledge. *Remote Sensing of Environment,* 85: 441–452.

Rogan, J.; J. Franklin and D. A. Roberts (2002). A comparison of methods for monitoring multitemporal vegetation change using Thematic Mapper imagery. *Remote Sensing and Environment*, 80: 143-156.

Thomas, V.; P. Treitz; D. Jelinski; J. Miller; P. Lafleur and J. H. McCaughey (2002). Image classification of a northern peatland complex using spectral and plant community data. *Remote Sensing and Environment*, 84: 83-99.

Tømmervika Hans; Kjell Arild Høgdab; Inger Solheimb (2003). Monitoring vegetation changes in Pasvik (Norway) and Pechenga in Kola Peninsula (Russia) using multitemporal Landsat MSS/TM data. *Remote Sensing of Environment*, 85: 370–388.

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التغطية الخضرية الزراعية الموسمية وإدارة المياه بمنطقة الكوبارة بوادي الرمح-شبة الجزيرة العربية - المملكة العربية السعودية

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تم تقييم وتقسيم ورصد التغطية الزراعية بوسط وادى الرمح الذى يقع بشبة الجزيرة العربية. كما ناقشت هذه الدراسة العلاقة بين صورة القمر الصناعى لاند سات وبيانات الارصاد الجوية بمنطقة الدراسة وكذلك تقييم الاستهلاك المائى بمناطق الخضرية والهدف من هذه الدراسة هو فهم الاختلافات الموسمية للتغطية الزراعية الخضرية بوادى الرمح وذلك باستخدام صور أقمار صناعى شهرية من القمر الصناعى لاند سات ويصاحب لهما قراءات الاستهلاك المائى.