The use of multi-temporal Landsat TM imagery to detect land cover/use changes in Al-Hassa, Saudi Arabia

Yousef Aldakheel and Abdulrahman Al-Hussaini*
Water Studies Center, King Faisal University, Hofuf, Saudi Arabia;

* Imam University, Hofuf, Saudi Arabia

Abstract:

Remote sensing techniques are used to explore and monitor earth resources: soil, sub soil, water, vegetation and minerals. However, within the usage of remote sensing techniques can be extended to monitor and record the temporal changes that might occur within these resources, due to human activities or natural processes.

In this work vegetation, soil salinization, and urban area of Al-Hassa oasis was monitored by analysis of multi-temporal Landsat TM images over the period 1987-1998. The scope of work which is temporal classifications of the area include image overlay, differencing, and principal component analysis.

This procedure allowed the study of the dynamics of environmental changes that could happen to soil and vegetated area over the study area. Such changes might happen either naturally or man-made which can contribute to or result in dessertification of a particular region.

Among the three methods implemented, image overlay and image differencing analysis were relatively straight forward. However, PCA required more multi-spectral imaging of combined multi-date data sets to highlight differences distinctly attributable to changes in the environment and landscape structure. Therefore, the interpretation of the results was scene-dependent; and the land development processes that occurred between the dates of imaging were fully noticed.

Introduction:

By using the remote sensing and GIS techniques we can detect the specific changes in the area. Temporal analysis is a major application of remotely sensed data to detect specific changes by the use of multi-date data sets to discriminate areas of land cover/use change between dates of imaging. Data from the Landsat TM, with its synoptic and regular coverage offers the potential for detection and inventory of disturbance and other changes that occur in land use, cover type, and cover condition in areas of research interest.

Therefore, in this study, land cover/use changes showing great concentration development demand on an environment were analyzed by using the multi-date Landsat TM imagery for Alahsa Oasis, Saudi Arabia, using different change detection methods, so as to assess their ability to detect specific changes.

Al-Hassa is one of the largest oases of the world and located in the southern part of the eastern region of Saudi Arabia. The region of Al-Hassa, with its center at the town of Al-Hofuf, is about 70 km towards the interior of the country from the Gulf coast near Al-Uqayr at elevations of 130 to 160 meters above sea level. It is situated between 25^{o} 05' and 25^{o} 40' northern latitude and 49^{o} 55' eastern longitude (figure 1).

The study area is covered by large dune area extends between the northern part of the region to the northern border of the eastern part of the oasis. There is a plain between the region and the west coast of the Arabian Gulf slopes with a very gentle gradient towards the east. This plain area is covered by sand dunes originating in the Al-Jafurah desserts (covers the south east of Arabian Peninsula). The landscape of the area, outside of the palm trees belt proper is dominated by a mantle of eolian sand estimated to reach in places a thickness of over 30 meters, interrupted by sabkhah and low measa, the component strata of which have a nearly horizontal position. The northern sabakhah serve as catchment basins for highly saline drained water accumulated in Winter season. Main cultivated crops in the Al-Hassa area are date palm, alfalfa, vegetables, and some fruits. The most serious problem in the region is soil salinity that develop as a result of natural soil forming processes. The lack of the amount of irrigation water for cultivation raise the requirements to have proper management methods and adequate planning for the area. For the amelioration of salt affected soils and their effective utilization for successful plant production, it is necessary to establish rigorous management and frequent monitoring for these area.

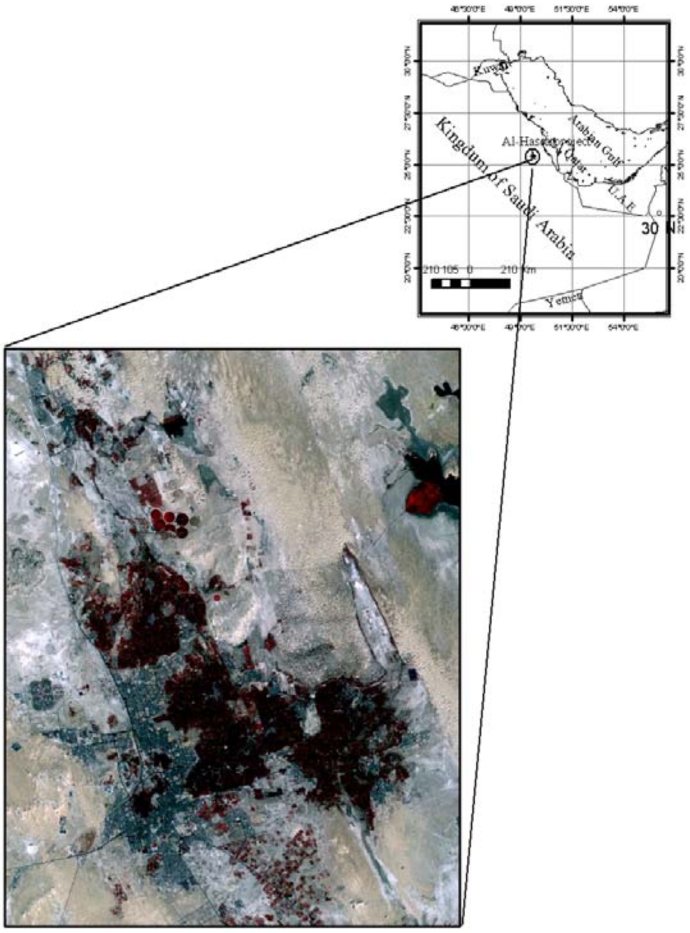

Figure 1. Location of the study area

Method:

The temporal analysis is a good process to detect the change which happened on an area. So to qualify or quantify the changes, there are many digital change detection techniques. The most common used are image overlay; image differencing; principal component analysis that are addressed and tackled in this paper.

Image overlay:

The simplest way to produce a change image is to utilize a photographic comparison of a single band of data from the two dates. The image is prepared by making a photographic two color composite showing the two dates in separate color overlay. The colors in the resulting image demonstrate the changes in reflectance values between the two dates. Features, for example, that are bright on date 1, but dark in date 2 will appear in the color of the first photographic overlay. However, features that are dark on date 1 and bright on date 2 will appear in the color of the second overlay. But features that are unchanged between the two dates will be similar brightness in both overlays and so will appear as the color sum of the two overlays (Virag and Colwell, 1987).

Image differencing

Another procedure is to register simply two images and prepare a temporal difference image by subtracting the digital values for one date from those of the other. The difference in the areas of no change will be very small, and areas of change will reveal larger positive or negative values (Lillesand and Kiefer 1987, Mather 1999).

Principal component analysis (PCA)

PCA can be used to detect and identify temporal change when registered Landsat TM images are merged and treated as a single data set. When this is used, new sets of co-ordinate axes are fitted to the image data. The first new axis or component will account for maximum variance. Subsequent axes (components) will account for smaller portions of the remaining variance. Changes to be anticipated are of two types: first, those that would extend over a substantial part of the scene, such as changes in atmospheric transmission and soil water status; and second, those that were restricted to parts of the scene, such as the construction of roads or the destruction of green areas (Campbell 1996, Jensen 1996, Richards, 1990, Ingebritsen and Lyon 1985, Schott, 1997).

Data source and application to the area of interest

Data and test site

In order to detect the changes with multi-date data sets and to make comparative assessments, a three of square images (approximately 536 by 465 pixels) test sites, located in the Al-Hassa oasis, Saudi Arabia were selected (figure 2). The test areas contain a wide range of land use types found within growing changes vegetation, urban, and wet areas. The Landsat TM imagery recorded on two different dates. Band numbers of the multi-date imagery were arranged as 1-6 and 7-12 for the 1987 and 1998 data sets, respectively.

Image overlay

In the simplest change detection procedure, the single band change image was prepared by color coding TM band 3 from the 1987 data as red and from the 1998 data as green (figure 2). Band 3 of the Landsat TM image, which records data in the red portion of the visible spectrum, was selected because it provides the best discrimination of rural to urban land conversion among the land cover groups in the study area. As can be seen in the change image, features that were brighter in TM 3 on the first date appear red, features that were brighter on the second date appear green, and features of equal brightness on both dates appear in shades yellow. The residential areas coded as bright green, can be seen clearly as a major change in the sub-scenes. However, the success of this method depends on the change end points responses. If the change end points have dissimilar responses in the selected spectral band, then a single band change image may show many changes. The relationships between image color and land cover/use changes as a result of visual comparison of the multi-date image with ancillary land cover/use information are clearly overlooked.

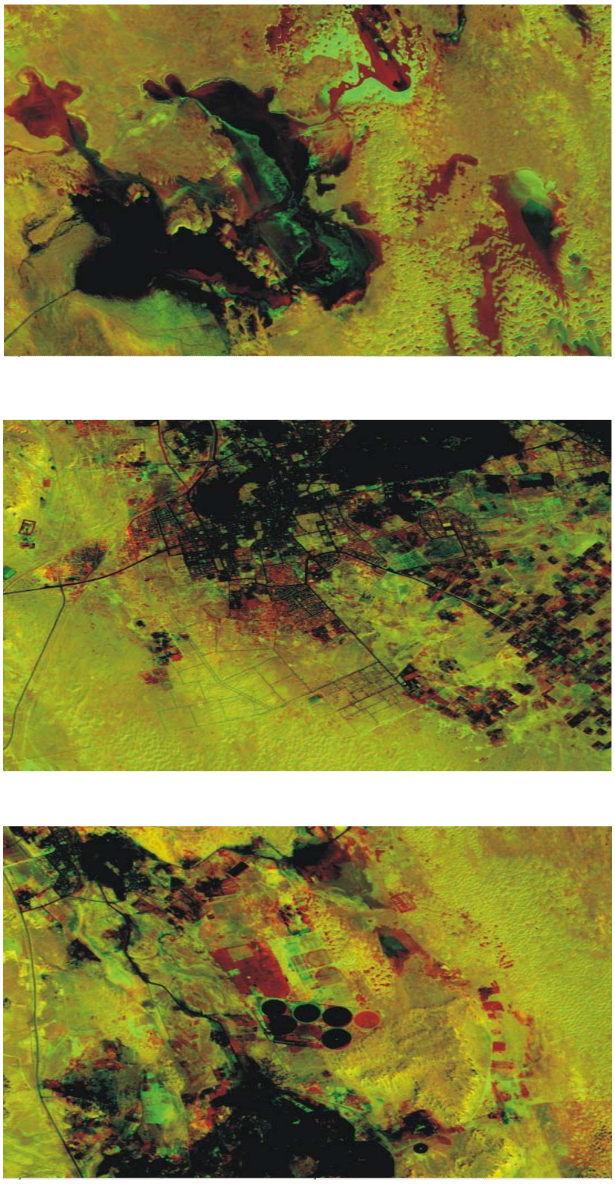

Figure2. Composite images of the test areas, TM scene of 1987-1998.
Top: WetLand (sabkha), middle: urban area, and lower: vegetation

Image differencing

Image differencing was carried out on a pair of co-registered images of the same area taken at different times to assess the degree of change that has taken place between the dates of imaging. The difference image is shown in figures 4. In figure 3, areas of no change were represented by a mid-gray, while areas that were darker in 1998 than they were in 1987 had values between 130 and 240. Thus the major change, the construction of the residential area and urban development as well as vegetation patterns, can be seen in figure 3 as a brighter average area. Areas that were lighter in 1998 had values between 0 and 120. To assist the interpretation and understanding of changes occurring between the dates of imaging, a color composite of difference images was also generated (figure 3).

Principal component analysis (PCA)

The purpose of PCA is to define the number of dimension that are present in a data set and to fix the coefficients specifying the positions of that set of axes which point in the direction of the greatest variability in the data (Jensen 1996, Mather 1999, Schott, 1997). The standardized PCA (depending on a correlation matrix between the bands) was applied to the multi-date data set. The relationships between variance and co-variance of principal components (PCs) is presented in table 1. From analysis of eigen value matrices table 2, it was seen that the first four components contain about 80% of the total scene variance. Moreover, eignvector values for different scene components are tabulated in table 3.

PCA (image) 1 was equivalent in effect to a total brightness image, while PCA 2 represented changes in brightness occurred in the overall scene between dates. PCA 3 and 4 were interpreted as attributable to changes in greenness and wetness. The remaining PCAs were accounted for 1.86% of the inter-image variability (table 2). A false color composite image PCs 2, 3, and 4 was constructed (figure 4). This combination was chosen to suppress effects caused primarily by differences in brightness, and to enhance the spectral contrasts caused by the lower order components.

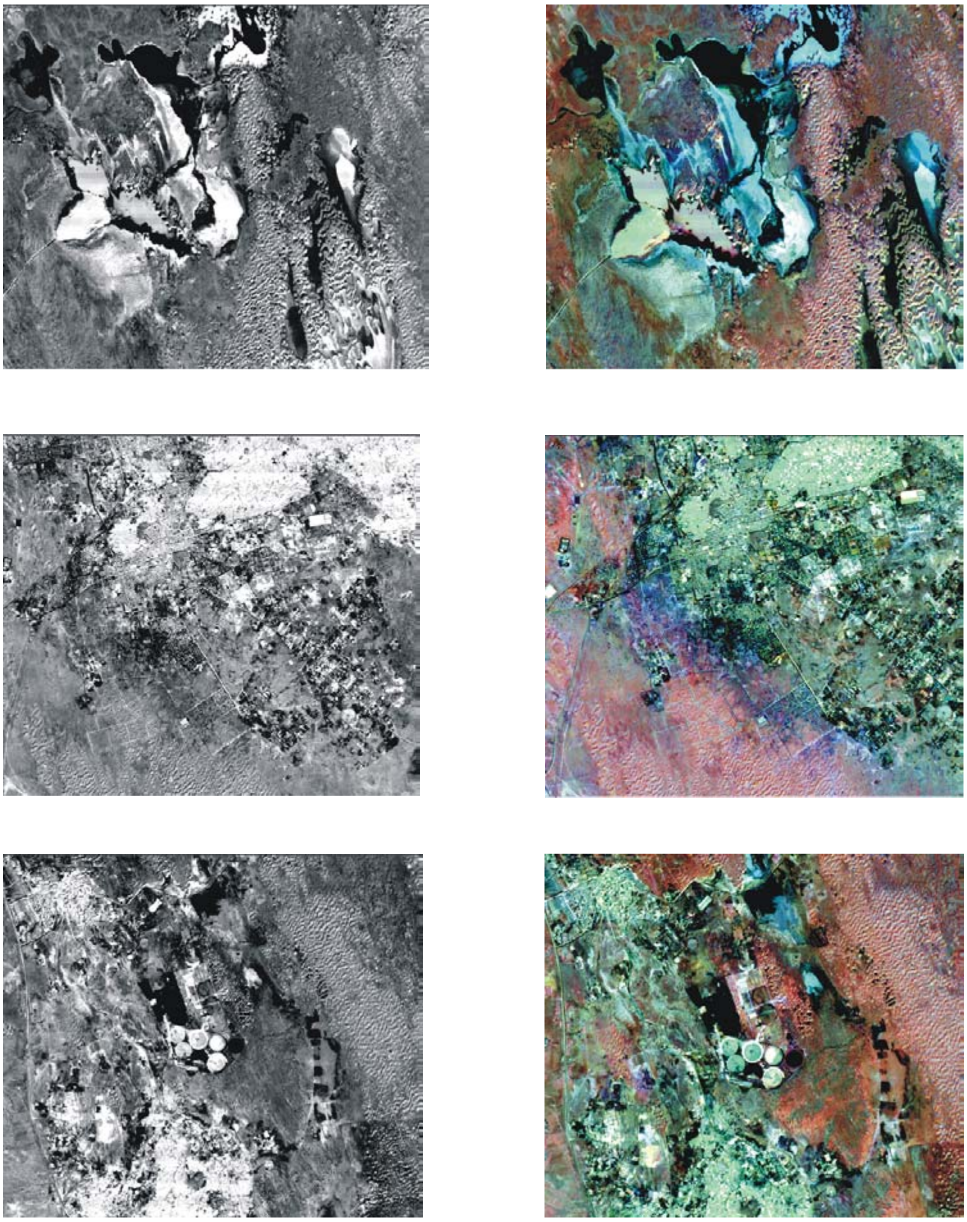

Figure 3. Band 1-7 differenced image results, bands 8-3 for black and white images, and bands 10-5; bands 8-3; and bands 6-1 for color composite images (lwoer right).

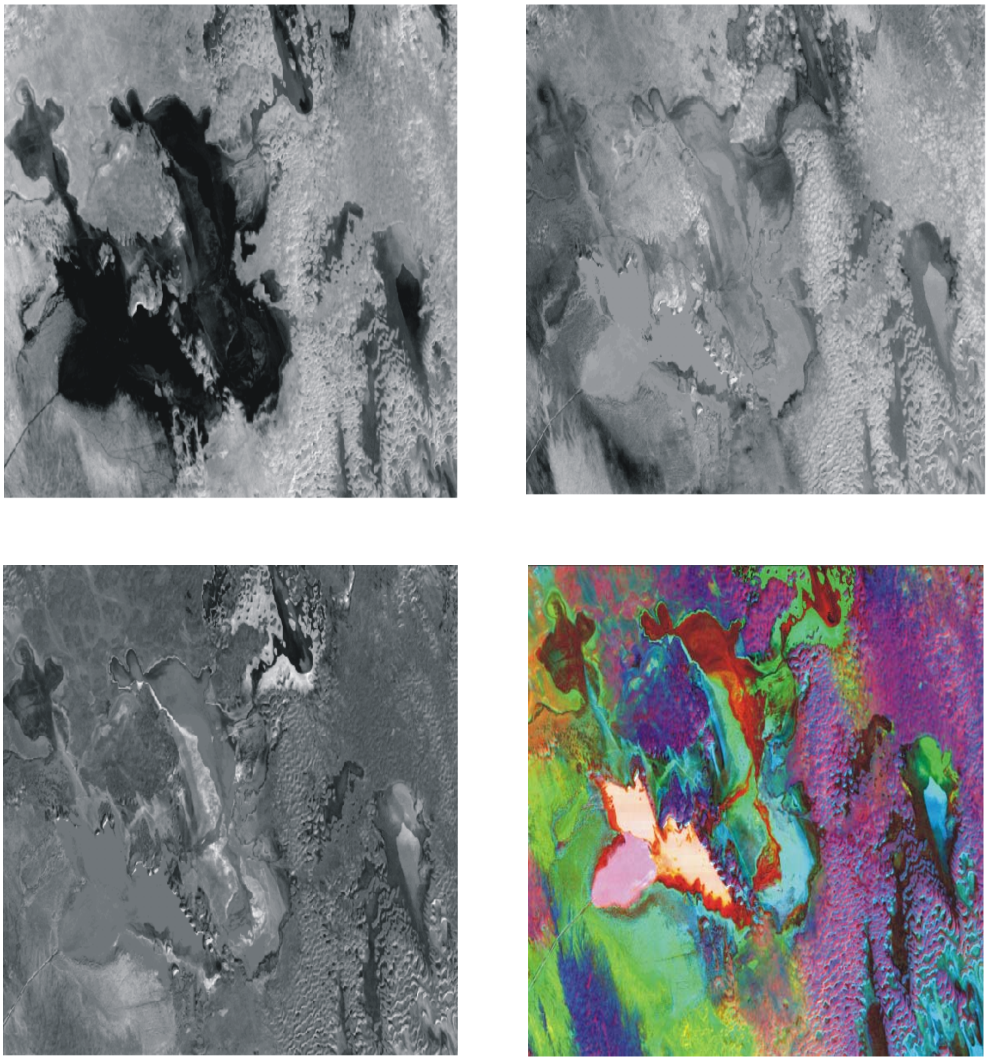

Figure 4. Blake and White images are PC 1, 2, 3, respectively
and a color composite is of PCs 4, 3,2.

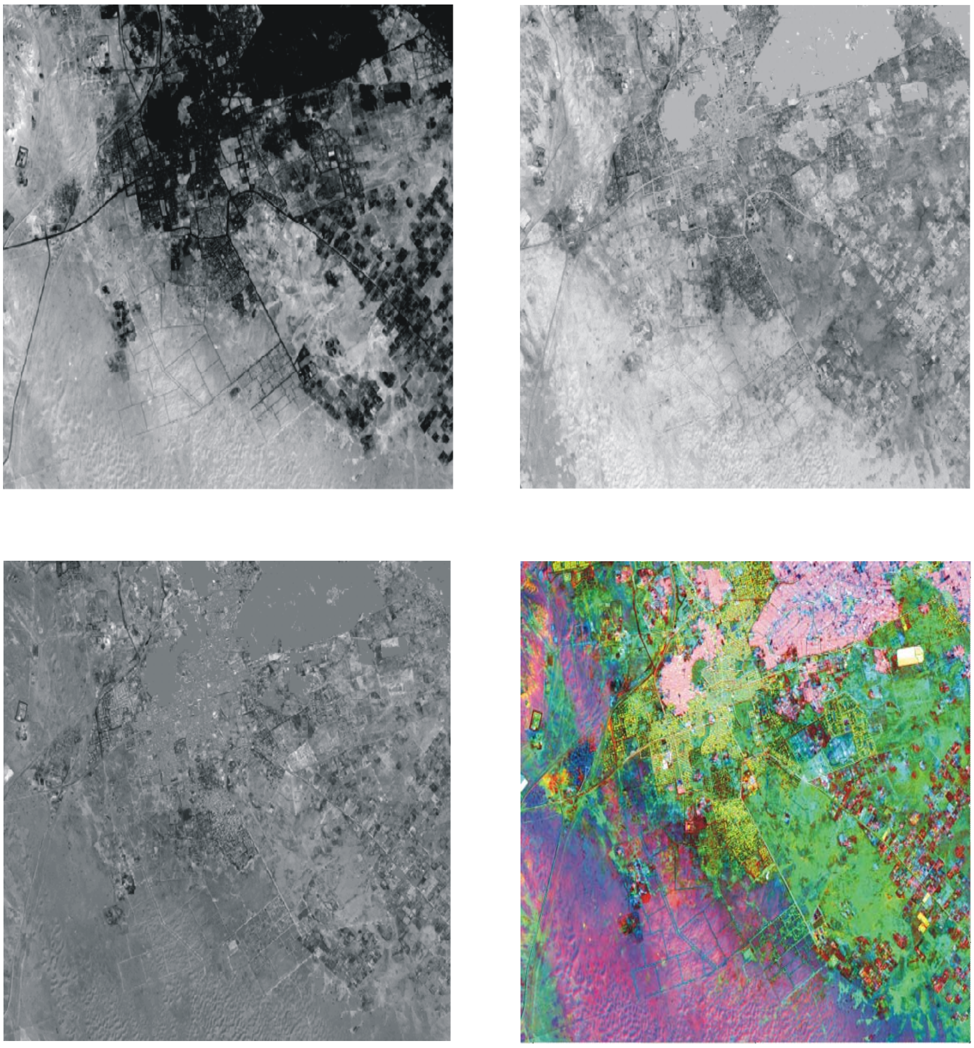

Figure 4.. Continued... (Urban area).

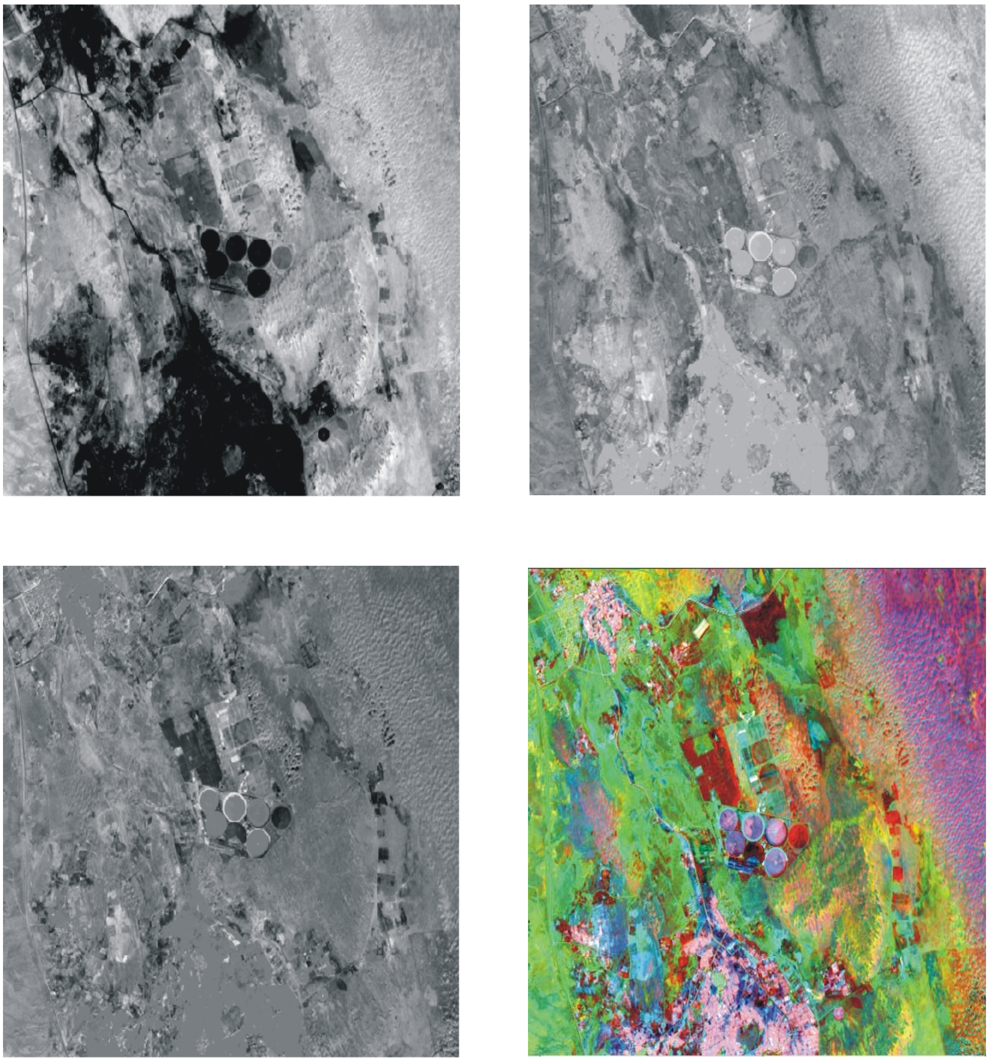

Figure 4.. Continued... (Vegetation)

Table (1)

Cumulative covariance matrix

Var/covar	PCI1	PCI2	PCI3	PCI4	PCI5	PCI6	PCI7	PCI8	PCI9	PCI10	PCI11	PCI12
Pcaa1	2954	2493	2097	2050	1502	1307	2327	2030	1758	1714	1438	1221
Pcaa2		2437	2266	2337	1733	1834	2048	2066	1978	2023	1828	1719
Pcaa3			2296	2444	1819	2103	1816	2017	2065	2171	2035	1980
Pcab1				2714	1920	2364	1779	2084	2199	2378	2240	2206
Pcab2					1793	1890	1341	1585	1681	1760	1783	1782
Pcab3						2580	1240	1756	2004	2199	2249	2397
Pcac1							2989	2730	2446	2414	1983	1777
Pcac2								2849	2739	2808	2436	2349
Pcac3									2780	2908	2608	2584
Pcad1										3166	2812	2809
Pcad2											2752	2787
Pcad3												2985

Table (2)

percentage variation and eignvalues for different scene component

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Variability	79.97	9.21	7.67	1.29	0.71	0.49	0.24	0.17	0.10	0.07	0.06	0.03
Eigenvalues	9.6	1.1	0.92	0.16	0.08	0.06	0.03	0.02	0.01	0.01	0.01	0.00

Table (3)

Eignvector values for different scene coponent

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Eigen vec1	0.243	-0.603	2097	2050	1502	1307	2327	2030	1758	1714	1438	1221
Eigen vec2		2437	2266	2337	1733	1834	2048	2066	1978	2023	1828	1719
Eigen vec3			2296	2444	1819	2103	1816	2017	2065	2171	2035	1980
Eigen vec4				2714	1920	2364	1779	2084	2199	2378	2240	2206
Eigen vec5					1793	1890	1341	1585	1681	1760	1783	1782
Eigen vec6						2580	1240	1756	2004	2199	2249	2397
Eigen vec7							2989	2730	2446	2414	1983	1777
Eigen vec8								2849	2739	2808	2436	2349
Eigen vec9									2780	2908	2608	2584
Eigen vec10										3166	2812	2809
Eigen vec11											2752	2787
Eigen vec12												2985

Conclusion

This study shows that; land use patterns change over time in response to economic, social and, environmental forces. Understanding the nature of change in the use of land resources is essential knowledge to facilitate proper planning, management, and regulation of the use of land resources. The change detection procedure is a most appropriate method in given situation to monitor significant impact on land cover/ use changes in Al-Hassa. However, this depends on the type of the application (environmental land use and other targets of interest), and the amount of detail needed. We have used (in this study) three change detection methods that were employed to observe and analyze land cover/use changes in the Al-Hassa oasis with multi-date satellite data. Among the three methods implemented, image overlay and image differencing analysis were relatively simple. However, PCA required more multi-spectral imaging of a combined multi-date data sets to highlight differences distinctly attributable to changes in the environment and landscape structure. Therefore, the interpretation of the results was scene-dependent, and the land development processes that occurred between the dates of imaging was fully noticed.

Since each of the change image procedures used had some merit with regard to either ease of production, information content, or interpretability. The effective implementation of the more sophisticated procedures requires more a priori knowledge of the area and the availability of the scenes to study the land cover/land use in any area.

Remote sensing and GIS are very advanced technologies in obtaining information about the feature or process and its interpretation in a very effective way. However, multi-temporal imagery technique is a very effective tool for qualitative as well as quantitative assessments of land use/land cover, desertification monitoring, crop monitoring, urban developments and mineral exploration. In this context, there is a need to develop a methodology based on remote sensing and GIS techniques, which will provide regular information concerning salinization threat and land use management in Al-Hassa area.

Acknowledgments:

We acknowledge the Space Research Institute, King Abdulaziz City for Science and Technology (KACST) for providing the satellite imagery and King Faisal University for the financial support of the study. Thanks to Mr. Masoud Abdel Atti, Water Studies Center, KFU for his technical assistance.

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استخدام صور لاندسات تي ام لفترات زمنية مختلفة لرصد التغيرات في الغطاء الأرضي و استخدامات الأراضي في الأحساء بالمملكة العربية السعودية

يوسف بن يعقوب الدخيل - عبدالر ن بن ابراهيم ا سي *

مركز الدراسات المائية وقسم الأراضي و المياه – جامعة الملك فيصل

الأحساء - المملكة العربية السعودية

* قسم الجغرافيا – كلية الشريعة و الدراسات الاسلامية

جامعة الامام محمد بن سعود الاسلامية - الأحساء - المملكة العربية السعودية

الملخص:

تتناول هذه الورقة دراسة التغيرات في الغطاء النباتي و المناطق الحضرية و السبخات في واحة الأحساء (٣٠٠ كم شرق الرياض) ، حيث سيتم فحص ما تقدم من خلال تحليل صور الأقمار الصناعية المأخوذة في أوقات زمنية مختلفة خلال الفترة من ١٩٨٧- ١٩٩٨م ، و هي تشمل دمج شرائح الصور و تحديد الفروق و الاختلافات و تحليل العناصر الرئيسة و المكونات الأساسية و التصنيف حسب الفترة الزمنية المذكورة . و من بين الأساليب الثلاثة التي تم اتباعها ، كان أسلوبا دمج الصور و التمييز بينها مباشرين في ايضاح نتيجة التغير في الغطاء الأرضي ، أما أسلوب تحليل العناصر الرئيسة لمجموعات البيانات ذات التواريخ المتعددة ، فقد ألقى الضوء على الفروقات التي يمكن عزوها بوضوح للتغيرات في البيئة و في شكل المناظر الطبيعية على السواء .