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Assessment of Temporal Land Cover Changes in Saudi Arabia Using Remotely Sensed Data

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Abstract: The natural vegetation in desert environments is a precious resource. Space imagery can be very useful in monitoring the vegetation in a large country like Saudi Arabia. The goal of the study was to assess the temporal land cover changes from 1990 to 2006 and in-season changes in vegetation during the years 2000 and 2006, in Dirab region of Saudi Arabia. Landsat TM and ETM+ images were used for the study. Normalized Difference Vegetation Index (NDVI) supported by GIS (ArcMap) was employed to detect the land cover and vegetation changes. Results revealed significant changes in land cover and vegetation of the region during the study period. The mean NDVI values of the region ranged from 0.091728 during September 2000 to 0.462475 during January 2006. Similarly, the maximum NDVI of the region increased from +0.373933 in September 2000 to +0.995817 in January 2006. The in-season variations observed in vegetation of the region were mainly due to changes in agricultural crop cover. Such studies on temporal analysis of land cover changes can help in monitoring the pattern of land cover changes and in planning for attaining sustainability of land use pattern. The results could be integrated with socio-economic information to develop strategies for efficient utilization of available natural resources in the region.

Key words: Land Cover mapping · In-season vegetation changes · Landsat imagery · NDVI · Temporal changes

INTRODUCTION

The natural vegetation is of crucial importance to the stability of the fragile desert ecosystem of Saudi Arabia. Periodic monitoring of temporal land cover changes in such environments would help in effective management of the scarce natural resources. The expansions of urbanization, lack of planning and socio-economic factors determine land use and land cover changes [1]. The human activity and the environment are the interactive components, which affect land use and land cover changes [2]. Land degradation due to urbanization can be observed using remotely sensed data [3] at local, regional and global scales [4,5]. Recent developments in remote sensing coupled with availability of multi-temporal satellite images have provided a better opportunity to study and understand land cover changes in an effective manner [6]. Studies on land cover changes have assumed greater importance in an era of rapid urbanization [7].

Temporal landsat images are very useful for assessing land use land cover changes and changes in vegetation [6-8]. The landsat imagery with coarse resolution are more effective in land cover mapping of larger areas [9] and can be used to provide a more meaningful linkage between surface energy fluxes and remotely sensed observations across multiple years [10]. Bagour *et al.* [11] used NDVI and PCA techniques to analyze AVHRR data for change detection of the vegetation cover in northeastern part of Saudi Arabia due to the Gulf war. Kelarestaghi, *et al.* [12] performed NDVI, PCA, tassel cap transformation and data fusion on Landsat ETM+ data for land use change detection. Time series data from Landsat images offer several unique advantages, such as coverage of larger area,

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repetitiveness and uniformity in pictorial aspect. These images delineate many major features on the earth's surface, such as natural vegetation, crops, surface water, soils and geology. The synoptic view and high resolution of the Landsat images offer a viable technological solution for monitoring vegetation changes. However, the use of satellite remote sensing for land cover changes depends on adequate understanding of landscape features, imaging systems and information extraction methodology employed in relation to the aims of the analysis. The main goal of this study was to determine using Landsat TM and ETM+ imagery, the temporal land cover changes from 1990 to 2006 and to assess in-season changes in vegetation in 2000 and 2006 in Dirab region of Saudi Arabia.

MATERIAL AND METHODS

Description of the Study Area: The area under study was about 50 km west of Riyadh and located between 24° 20´ 35" and 24° 30´ 51" N Latitude and 46° 31´ 41" and 46° 45´ 34" E Longitude. The study area (Dirab) had a dry continental climate with hot summer and cold to moderate winters. The average temperature was 35° C. The geology of the area was predominantly sandstone with subordinate limestone from Mesozoic age. The sedimentary formation, which underlaid Dirab, was a part of an extremely thick sequence of rock bed that dipped easterly of the Arabian shield. The water-bearing sandstone and limestone beds store substantial volume of water and constitute an important alluvial aquifer.

The general topography of Dirab region is steeply undulating terrain dissected by valleys. There are two valleys in the area: Lida valley and Al-Awsat valley, which are exploited mainly for their high agricultural potential. Wheat, alfalfa and other crops are grown primarily with the use of central pivot irrigation system. However, the poor quality of water is not conductive to growth of crops; and in some cases, this has forced many farmers with large holdings to limit their agricultural activity.

Multi Temporal Satellite Data: The landsat TM and ETM+ data for the period from 1990 to 2006 were used to study the land cover and vegetation changes in Dirab region of Saudi Arabia. Satellite images of path 165/043 and 166/043 covered the study area (Figure 1). The Landsat TM and ETM+ data were acquired from Global Land Cover Facility (GLFC) for the five different dates (Table 1). The features of Landsat Images are presented in Table 2.

Land Cover Mapping and In-season Vegetation Change Detection: Remote sensing change detection based on multitemporal, multispectral and multisensor imagery has been developed over several decades and provided timely and comprehensive information for planning and decision-making. Landsat TM and ETM+ data were used to calculate the NDVI and identify the trend in vegetation changes for the study period. The Erdas Imagine Professional 10 software was used for satellite image processing. Raw images were imported into Erdas

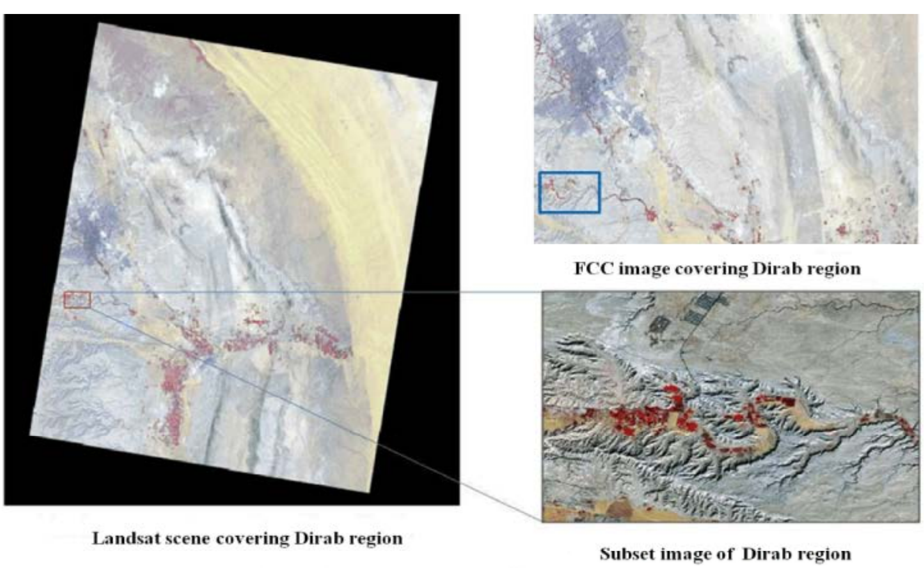


Fig. 1: Location map of the study area

Table 1: Details of data obtained from archive of the Global Land Cover Facility

S.N.	ID	WRS:P/R	Acquisition date	Data Set	Source
1	203-839	166.043	07/09/1990	TM	USGS
2	212-570	166.043	02/09/2000	ETM+	USGS
3	212-509	165.043	16/12/2000	ETM+	USGS
4	219-178	166.043	22/01/2006	ETM+	USGS
5	219-121	165.043	04/03/2006	ETM+	USGS

Table 2: The specifications of Landsat data

Spectral Bands	Spatial Resolution (m)		Spectral Resolution (µm)	
Band	TM	ETM+	TM	ETM+
1. Blue	30	30	0.45 - 0.52	0.45 - 0.52
2. Green	30	30	0.52 - 0.60	0.53 - 0.61
3. Red	30	30	0.63 - 0.69	0.63 - 0.69
4. Near IR	30	30	0.76 - 0.90	0.78 - 0.90
5. Middle IR	30	30	1.55 - 1.75	1.55 - 1.75
6. Thermal IR	120	60	10.4 - 12.5	10.4 - 12.5
7. Middle IR	30	30	2.08 - 2.35	2.09 - 2.35
8. Panchromatic	-	15	-	0.52 - 0.90

software and subset images of Dirab region (study area) were generated from two different Landsat scenes (Fig. 1). After subsetting of the study area with reference to geographic co-ordinates, digital numbers (DN) were converted to Normalized Difference Vegetation Index (NDVI) values. Normalized Difference Vegetation Index (NDVI) values were derived using the following formula of Rouse *et al.* [13]:

- NDVI = NIR-R / NIR+R

Where, NIR is reflectance in Near Infrared band and R is reflectance in red band. The wavebands representing near-infrared and visible-red region were extracted from each Landsat dataset to calculate the Normalized Difference Vegetation Index (NDVI) values. The Principal Component Analysis (PCA) was used to reduce noise, multiband correlation and compress information in bands [14-21]. All the digital numbers (DN) of image pixels were exported into Excel to obtain actual values of NDVI using statistical equations. The NDVI maps of the study area were prepared using ArcMap software (Figures 2-6). These NDVI values and maps were used to detect the changes in vegetation over the study period.

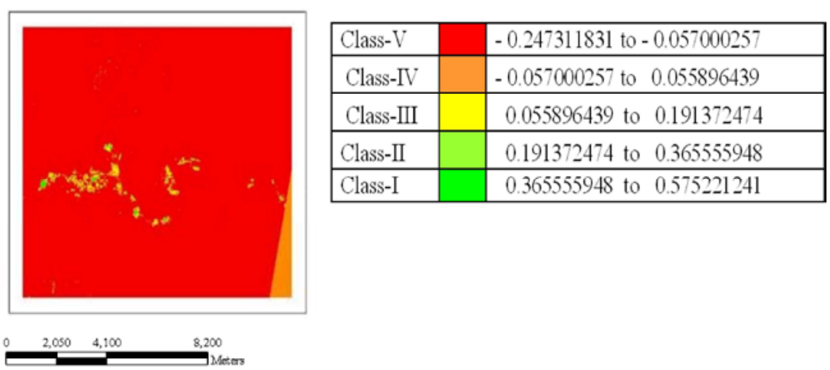


Fig. 2: NDVI map of Dirab region (07/09/1990)

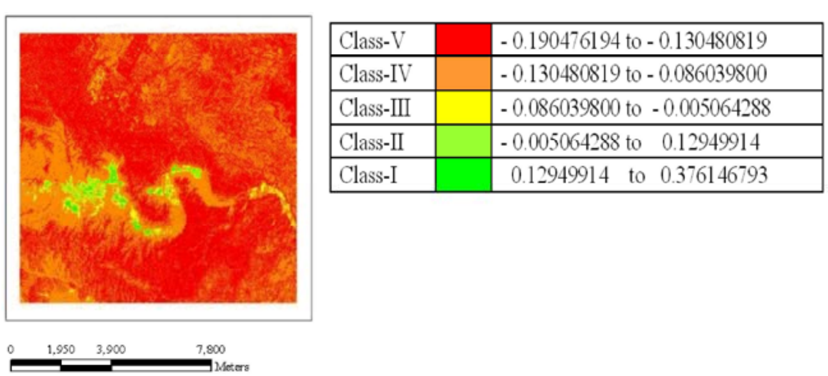
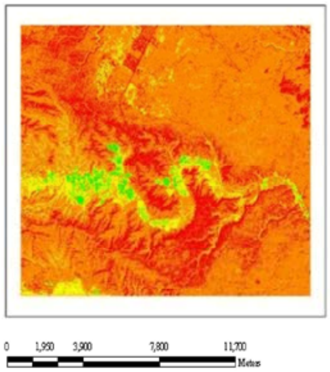
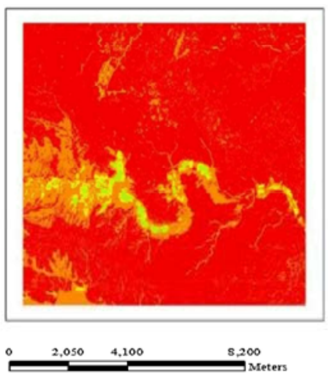


Fig. 3: NDVI map of Dirab region (02/09/2000)



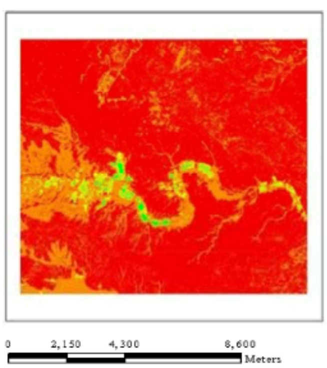
Class-V		-0.571428597 to 0.078072315
Class-IV		0.078072315 to 0.117266336
Class-III		0. 117266336 to 0.234848398
Class-II		0.234848398 to 0.442016792
Class-I		0. 442016792 to 0.856353581

Fig. 4: NDVI map of Dirab region (16/12/2000)



Class-V		-0.070866145 to 0.101312333
Class-IV		0.101312333 to 0.193700785
Class-III		0.193700785 to 0.365879263
Class-II		0.365879263 to 0.685039369
Class-I		0.685039369 to 1

Fig. 5: NDVI map of Dirab region (22/01/2006)



Class-V		-0.292035401 to -0.107494571
Class-IV		-0.107494571 to -0.026296605
Class-III		-0.026296605 to 0.136099326
Class-II		0.136099326 to 0.376002405
Class-I		0.376002405 to 0.649122834

Fig. 6: NDVI map of Dirab region (04/03/2006)

RESULTS AND DISCUSSION

Because of sparse vegetation, it is always intrinsically difficult to analyze vegetation cover in arid regions using remote sensing data. NDVI values generally range from -1.0 to +1.0, where negative values represent clouds, snow, water and other non-vegetated surface and positive values represent vegetated surfaces. The NDVI values increase as the quantity of green biomass increases. Higher NDVI values indicate more “green” cover type [15] and increase in biomass per unit area, and vice versa. The NDVI maps of the study area from 1990 to 2006 and five NDVI classes are presented in Figures 2-6. The data revealed significant changes in vegetation, vigor and density in response to biophysical conditions including soil type, nature of vegetation, weather and anthropological factors. The mean NDVI values (Table 3 and Figure 7) ranged from 0.091728 (September 2000) to 0.462475 (January 2006).

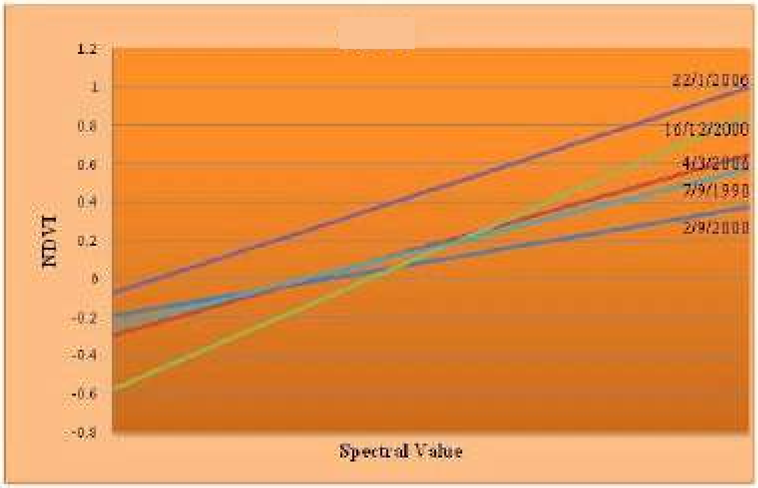


Fig. 7: Temporal changes in NDVI values

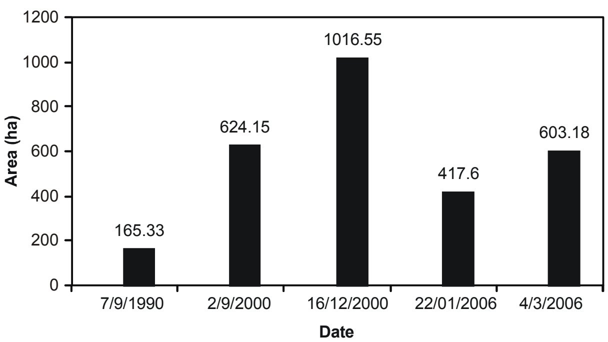


Fig. 8: Area under healthy biomass based on NDVI values (Class-I and II)

This indicates that the vegetation in the study area had a higher active biomass during January 2006 than during any other period. The in-season maximum NDVI values, during the year 2000, increased from 0.373933 during September to +0.850776 during December. The sowing of wheat crop in the region is generally performed during the months of October and November. As a result there was an increase in the maximum NDVI values during December. During the year 2006, the in-season maximum NDVI values decreased from 0.995817 during January to 0.645446 during March. This decrease is attributed to the harvest of the predominantly grown alfalfa crop which took place between January and March 2006. The results also indicated that the period of maximum vegetation in the region was in January. For the years from 1990 to 2006 the maximum NDVI values were observed to gradually increase from 0.373933 in September to 0.850776 in December and ultimately reach the highest NDVI value of 0.995817 in January and decreased thereafter to 0.645446 during March. The temporal changes in the area under healthy biomass based on NDVI values from Class I and II are presented in Figure 8.

Table 3: The temporal variation in NDVI values from 1990-2006

Date	Min. NDVI	Max. NDVI	Mean NDVI
07/09/1990	-0.247312	0.572008	0.162348
02/09/2000	-0.190476	0.373933	0.091728
16/12/2000	-0.571429	0.850776	0.139673
22/01/2006	-0.0708661	0.995817	0.462475
04/03/2006	-0.292035	0.645446	0.176705

The largest area under healthy biomass of 1016.55 ha was observed during December 2000, however, the smallest area of 165.33 ha was observed during September 1990. The temporal NDVI changes clearly depicted the nature of seasonal variation in the vegetation of the region due to anthropological factors. The major activity in the area that influenced the changes in vegetation was the agricultural activity. The sowing season generally started during October and November and hence there was a gradual build up of the biomass and consequent increase in NDVI values due to growth and development of agricultural crops until wheat crop is harvested in March and April. However, fluctuations in the vegetation of the area were due to cultivation of alfalfa, which is a multi-cut crop generally harvested at an interval of 60 days. Bagour *et al.* [11] concluded that imagery of August month was not ideal for measuring vegetation in north eastern part of Saudi Arabia, because the vegetation was at a seasonally low level and there was little vegetation in the desert study area. The study area (Dirab region) was also a desert ecosystem and the only vegetation observed was the biomass of agricultural crops grown in the region under center pivot irrigation systems.

CONCLUSION

The present study analyzed the land cover changes in Dirab region of Saudi Arabia using multi temporal TM and ETM+ data from 1990 to 2006. NDVI maps created for comparing temporal land cover changes indicated significant changes in vegetation of the region. The mean NDVI values ranged from 0.373933 (September 2000) to 0.995817 (January 2006). The area under healthy biomass in the region ranged from 165.33 ha in September 1990 to 1016.55 ha in December 2000. The use of Landsat imagery and NDVI mapping were found to be quite useful in assessing temporal land cover changes.

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REFERENCES

1. Manonmani, I.K., 2010. Spatio Temporal Analysis of Land Use in Fringe Area using GIS a Case Study of Madurai City, Tamil Nadu. Int. J. Geomatics Geosci., 1(2): 264-270.
2. Prakasam, C., 2010. Land use and land cover change detection through remote sensing approach:A case study of Kodaikanal taluk, Tamil Nadu. Int. J. Geomatics Geosci., 1(2): 150-158.
3. Srivastava, S.K. and R.D. Gupta, 2003. Monitoring of Changes in Land Use/ Land Cover using Multi-sensor Satellite Data, 6th International Conference on GIS/GPS/RS: Map India, pp: 28-31.
4. Csaplovics, E., 1998. High Resolution space imagery for regional environmental monitoring-status quo and future trends. Int. Arch. Photogramm. Remote Sens., 32(7): 211-216.
5. Foody, G.M., 2002. Status of Land Cover Classification Accuracy Assessment. Remote Sens. Environ. 80: 185-201.
6. Diallo, O. and A. Diouf, 1991. AVHRR monitoring of savanna primary production in Senegal, West Africa: 1987-1988. Int. J. Remote Sens., 12(6): 1259-1279.
7. Alhammadi, M.S. and E.P. Glenn, 2008. Detecting date palm trees health and vegetation greenness change on the eastern coast of the United Arab Emirates using SAVI. Int. J. Remote Sens., 29(6): 1745-1765.
8. Baboo, S.S. and M.R. Devi, 2010. Integrations of Remote Sensing and GIS to Land Use and Land Cover Change Detection of Coimbatore District. Int. J. Comp. Sci. Eng., 2(9): 3085-3088.
9. Pirasteh, S., S.A.Ali and H.J. Hussain, 2005. Greenrey (Green Space) Percentage Estimation Using Band Ratio, NDVI From Landsat Enhanced Thematic Mapper (ETM)-2002 & An Application Of Geographic Information System (GIS) Techniques, Dezful-Andimeshk, Khuzestan South-West Iran. 8th annual international conference, New Delhi, India.
10. Malika, B., A.D. Dale, F.F. Lynn and H.Y. Michael, 2010. Monitoring Vegetation Phenological Cycles in Two Different. Semi-Arid Environmental Settings Using a Ground-Based NDVI System: A Potential Approach to Improve Satellite Data Interpretation. Remote Sens., 2: 990-1013.
11. Bagour, M.H., S. Al-Mahlafe, A. Jacob and A. Fahsi, 2006. Change detection of the vegetation cover based upon Advanced very High Resolution Radiometer (AVHRR) data. Res. J. Agric. Biol. Sci., 2(6): 341-348.
12. Kelarestaghi, A., H.Ahmadi, M. Jafari and J. Ghodosi, 2006. Land use changes detection and spatial distribution using digital and satellite data, case study: Farim Drainage Basin, northern of Iran. J. Biaban, 11(2): 33-47.
13. Rouse, J.W., R.H. Haas, J.A. Schell and J.A. Deering, 1974. Monitoring vegetation systems in the Great Plains with ERTS. Proceedings of the Third Earth Resources Technology Satellite-1Symposium, NASA, Greenbelt, MD, pp: 301-317.
14. Jensen, J.R., 2005. Introductory digital Image Processing: a remote sensing perspective 3rd Ed Prentice Hall Series in Geographic Information Sci., ISBN 0-13-145361-0.
15. Deering, D.W., J.W. Rouse, R.H. Haas and J.S. Schell, 1975. Measuring forage production of grazing units from Landsat MSS data. Proc. Tenth International Symposium on Remote Sensing of the Environment, Ann Arbor, MI, pp: 1169-1178.
16. Eastman, J.R., 2006. IDRISI Andes Guide to GIS and Image Processing, Worcester, USA: Clark Labs.
17. Fenglei, F., W. Yunpeng and W. Zhishi, 2007. Temporal and spatial change detecting (1998-2003) and predicting of land use and land cover in Core corridor of Pearl River Delta (China) by using TM and ETM+ images. Environ. Monit. Assess., 137(1-3): 127-147.

18. Ricotta, C. and G.C.F. Avena, 1999. The influence of principal component analysis on the spatial structure of multispectral dataset, Int. J. Remote Sens., 20(17): 3367-3376.
19. Rigina, O. and M.S. Rasmusen, 2003. Using trend line and principal component analysis to study vegetation changes in Senegal 1986 -1999 from AVHRR 8km data Danish. J. Geogr., 103(1): 31-42.
20. Soffianian, A., M. Ahmadi Nadoushan, L. Yaghmaei and S. Falahatkar, 2010. Mapping and Analyzing Urban Expansion Using Remotely Sensed Imagery in Isfahan, Iran.World Appl. Sci. J., 9(12): 1370-1378.
21. Taghizadeh Mehrjardi, R., S. Mahmoodi, M. Taze and E. Sahebjalal. 2008. Accuracy Assessment of Soil Salinity Map in Yazd-Ardakan Plain, Central Iran, Based on Landsat ETM+ Imagery. Am. Euras. J. Agric. Environ. Sci., 3(5): 708-712.