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LAND COVER CHANGE ASSESSMENT OF VAAL HARTS IRRIGATION SCHEME USING MULTI-TEMPORAL SATELLITE DATA

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Abstract: Land cover change (LCC) is important to assess the land use/land cover changes with respect to the development activities like irrigation. The region selected for the study is Vaal Harts Irrigation Scheme (VHS) occupying an area of approximately 36, 325 hectares of irrigated land. The study was carried out using Land sat data of 1991, 2001, 2005 covering the area to assess the changes in land use/land cover for which supervised classification technique has been applied. The Normalized Difference Vegetation Index (NDVI) index was also done to assess vegetative change conditions during the period of investigation. By using the remote sensing images and with the support of GIS the spatial pattern of land use change of Vaal Harts Irrigation Scheme for 15 years was extracted and interpreted for the changes of scheme. Results showed that the spatial difference of land use change was obvious. The analysis reveals that 37.86% of additional land area has been brought under fallow land and thus less irrigation area (18.21%). There is an urgent need for management program to control the loss of irrigation land and therefore reclaim the damaged land in order to make the scheme more viable.

INTRODUCTION

Land cover change (LCC) is a general term use for the Earth's terrestrial surface modification by human activities and this regarded as the main reason for global environmental change. The analysis of temporal and spatial process of land use change and familiarity of the key drive factor in this process along with its role help to in depth understand the driving mechanism which causes land use change, and in addition they are valuable scientific basis of the regional management, decisions and sustainable use of land (LI Rui *et al.*, 2002). The land use/land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use/land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes. Irrigation is a vital factor for the development of agriculture, especially in South Africa, where rainfall which serves as the natural source of water is highly variable in amount and distribution. It is of importance to assess the land use/land cover changes with respect to the development activities like irrigation. Most of the LULC classification efforts in the past three decades used single or a selected few remote sensing images (Foody, 2002). Such classifications provide little or no information on the temporal dynamics of LULC classes, highly limiting their use (DeFries and Los, 1999). Comparison of times classified outputs and Normalized Difference Vegetation Index (NDVI) images using change detection software can be performed to study the land cover and vegetation vigor transformation (Singh, 1989; Fung, 1990). According to Groten, 1993, the collection of accurate, timely information of vegetation is always important, but the collection of such information is expensive, time consuming and often impossible (Eastman and Fulk, 1993), therefore an alternative is the measurement of vegetative amount and condition based on an analysis of remote sensing spectral measurement. Brogaard and Prieler (1990) in the interim report submitted to the Institute for Applied Systems analysis described how Landsat MSS can be used for the identification of broad land cover changes of the Western part of Horqin steppe, Inner Mongolia Autonomous Region. Van Trinh *et al*. (2004) used Landsat images for studying land use dynamics and soil degradation in Tamduong district of Vietnam. Eranani and Gabriels (2006) used Landsat data from 1976 to 2002 to detect changes in land cover in the Yazd-Ardakan basin, Iran. Latifovic *et al.* (2005) analyzed the land cover change of the Oil Sands Mining Development in Athabasca, Canada using information extraction method applied to two Landsat scenes. The objective of this study is the assessment of Land cover change of Vaal Harts Irrigation Scheme using multi-temporal satellite data.

METHODOLOGY

The study area Vaal-Harts Irrigation Scheme (VHS) lies in the east of Fhaap Plateau on the Northern Cape and North West province border covering areas from Jan Kempdorp in the south to Taung (the Dry Harts River) in the north in South Africa (Grove, 2006). The area is located in a summer rainfall area which battles with low, seasonal and irregular rainfall. The average rainfall is 442 mm per year (Jager, 1994). The average precipitation in summer months, October to February differs between 9.1 and 9.6 mm/day while in July precipitation is only 3.6 mm/day. The common crops grown in the area are wheat/barley, maize, groundnuts, cotton and other permanent crops like lucerne, Pecan nuts, grapes, olives and some other fruits (Grove, 2006; Ojo *et al.*, 2009). Figure 1 shows the map of study area cutting across three provinces (Northern Cape, North West and Free State) in South Africa.

To assess the irrigation development in the VHS through land use/land cover and vegetative change analysis, remote sensing and GIS were applied. Landsat imageries data of 1991, 2001 and 2005 were used to assess the changes in land use/land covers that have occurred over a period of 15 years. The Landsat imageries were downloaded from the website of the Global Land Cover Facility (GLCF) of the University of Maryland,

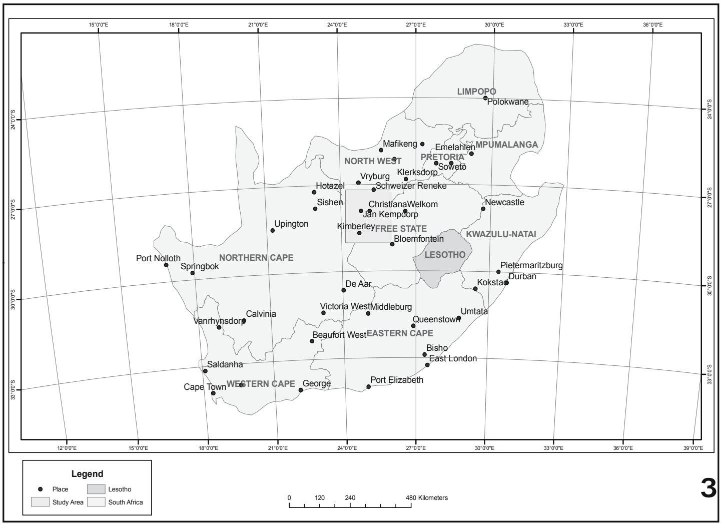

Fig. 1. Map of study area in relation to South Africa

Maryland, USA. Figures 2a and 2b show the mosaic images for 1991, 2001 and 2005 used for the pre-processing. The mosaic digital data were pre-processed and geo-referenced to remove systematic and non systematic errors. The digital classification was based on the widely popular supervised classification technique. The images were classified into four different land use/land cover categories. The Normalised Differential Vegetative Index (NDVI) proposed by Tripathi *et al*. (1997), was applied to give better results in the re-classification of salt-affected lands. The NDVI index expressed in equation 1 was used for quantification of land use/land cover.

$$\mathrm{NDVI} = \left[\left(\frac{Band4 - Band3}{Band3 + Band4}\right)\right] \tag{1}$$

For this study, band selection was done through the aid of reflectance properties of features, correlation matrix of the bands and spectral reflectance curve of known features (during the series of field visits) in all bands. Spectral profile was generated from the image using ERDAS IMAGINE 9.1. The different band combinations used for the analysis:

1. Combination of band 4, band 3 and band 2;
2. Combination of band 3, band 4 and band 2;
3. Combination of band 3, band 2 and band 1;
4. Combination of band 4, band 5 and band 3.

Soil maps and soil data were obtained from Agricultural Research Council (ARC), while the topographic/Base map (scale: 1:50,000) was obtained from Department of Water Affairs. The maps were converted into digital by scanning and imported into

ArcView GIS 3× software for the pre-processing and processing stages. The following software was used for this study:

1. ArcGIS 9.2. This was used for displaying and subsequent processing and enhancement of the image;
2. ERDAS IMAGINE 9.1. This was also used to compliment the display and processing of the data; and
3. IDRISI Taiga. This was used for the development of land use land cover classes and subsequently;

RESULTS AND DISCUSSION

The resulting soil surface terrain from GIS analysis in forms of topographic map and digital elevation maps (DEM) of the study area are as shown in Figures 3a, 3b and 3c. The static land use land cover distribution for each study year is presented in Tables 1, 2 & 3 From Table 1 in year 1991, the settlement area occupied 28.78% (10,453.26 Km^2) of the total land mass with pockets of building around VHS, fallow land 41.4% (15,038.31 Km^2), water body 0.87% (315.52 Km^2) and irrigation land area 28.95% (10,515.09 Km^2) The study further revealed that fallow land is the largest of the four classes. In 2001 from Table 2, the settlement area has decreased to 18% (6,537.80 Km^2) in the study area;

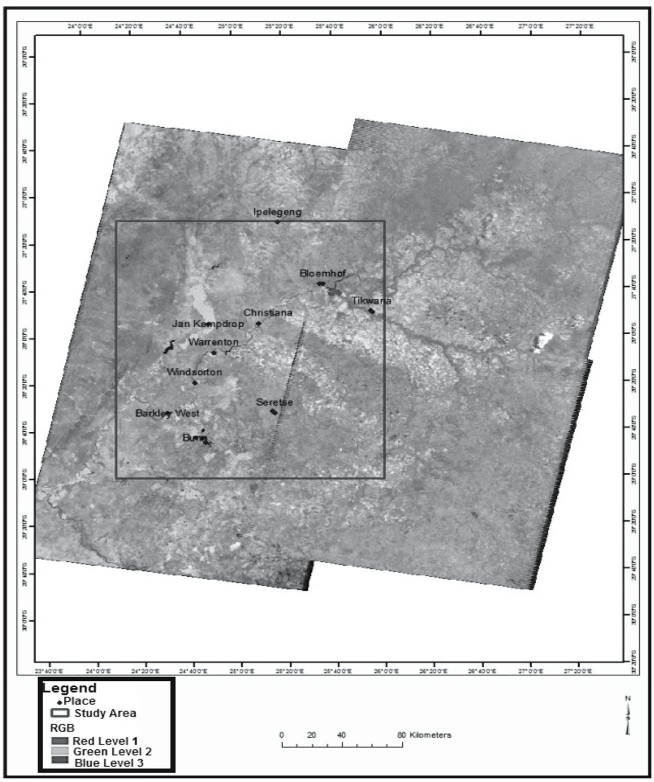

Fig. 2a. Mosaic image of the Landsat data used 1991–2005

Fig. 2b. Mosaic image of the Landsat data used 1991–2005

water body and fallow land have increased to 1.0% and significant 66. 48% respectively, irrigated/farming activities decreased to 14.52%. From Table 3, the year 2005 shows a further drop in settlement area to be 9.61%, while there was a significant reduction in water body (0.39%), bare surface increased to 79.26% and cultivated/irrigation land dropped to a low 10.74%. This change depicts that decrease in settlement area is proportional to decrease in cultivated land. The spatial variation in land use-land cover for the period 1991 to 2005 is as represented in Figures 4, 5 and 6. The period 1991 to 2005 reveals a drastic change in the normal course of cultivated land. The year 2005 has shown a remarkable growth of follow areas depicting a scenario of a likelihood of salinity problem. The process has led to elimination of the crop, forest and scrub lands. The later period resulted in a rapid decline in the water bodies mainly because of the increase in the salinity problem and high temperature over the scheme with years. Figures 7, 8 and 9 showed he results of the vegetation index (NDVI) indicating rather scarcity of vegetation as a whole in the high salinity area of VHS thus confirming the ground truth on the field. Minimum to lower threshold represented negative change in NDVI, lower to upper threshold represented no change in NDVI, upper threshold to maximum value represented positive change in NDVI.

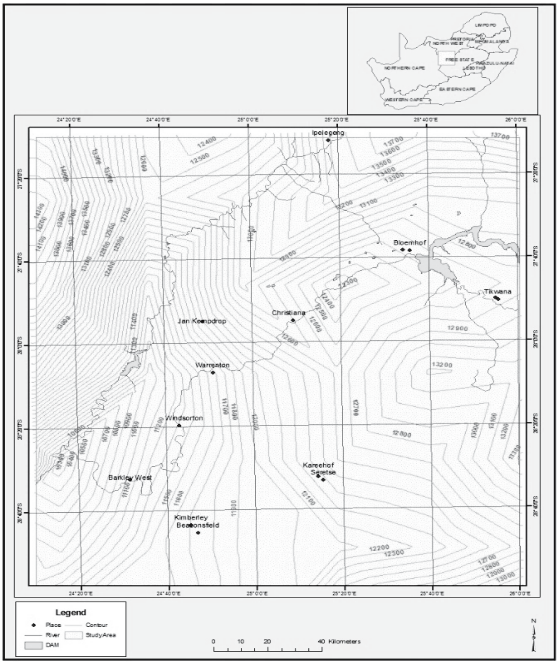

Fig. 3a. Topography map of the study area. Source: GIS analysis

Fig. 3b. Digital Elevation Model (DEM) of the study area. Source: GIS analysis

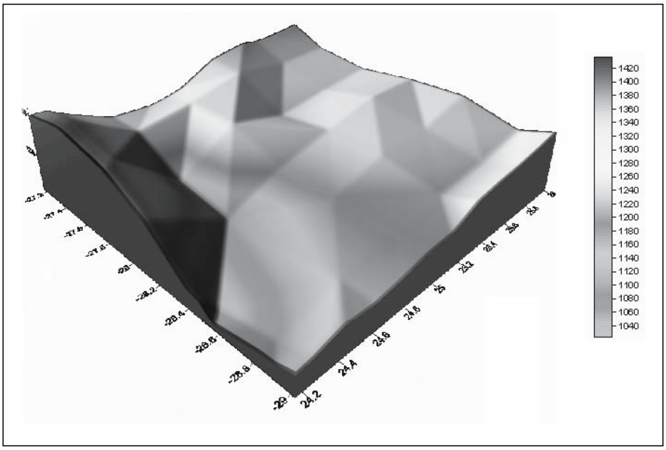

Fig. 3. Digital Elevation Model (DEM) of the study area in 3D. Source: GIS analysis

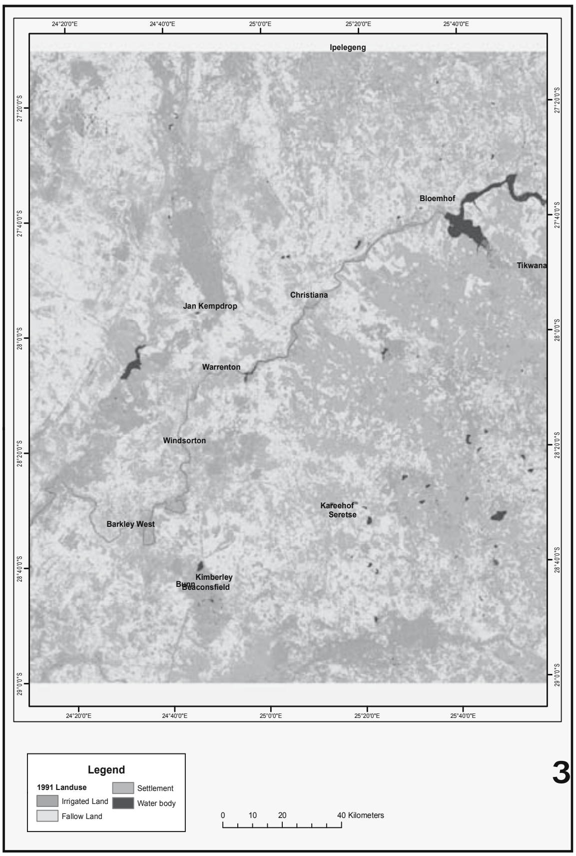

Fig. 4. Land use-land covers for 1991. Source: GIS analysis

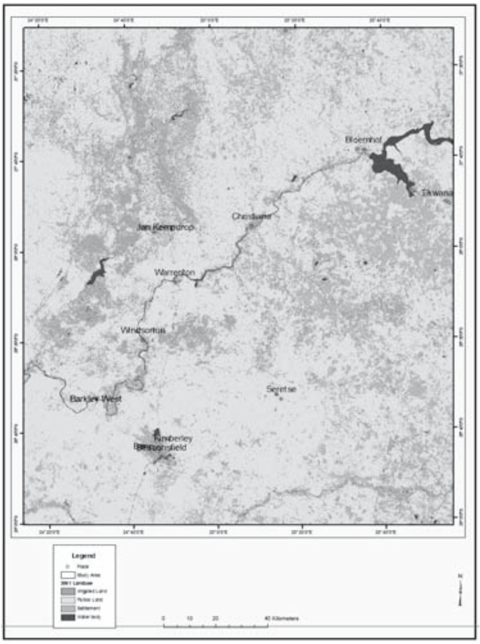

Fig. 5. Land use-land cover for 2001. Source: GIS analysis

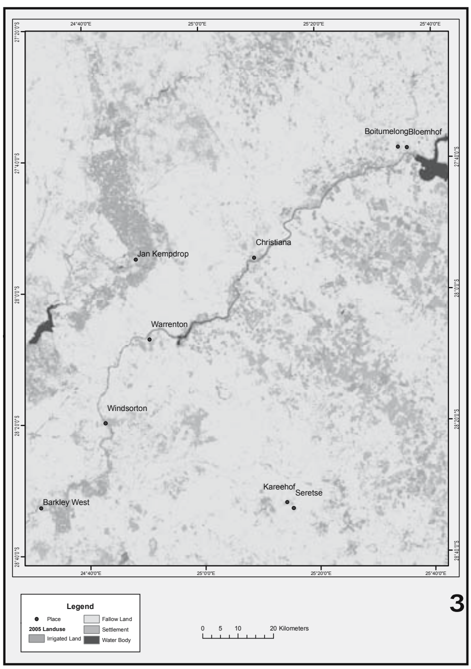

Fig. 6. Land use-land cover for 2005. Source: GIS analysis

Table 1. Area of land-use patterns (1991)

Land-use Type	Area (Km^2)	Percentage (%)
Irrigated Land	10 515.09	28.95
Fallow Land	15 038.31	41.40
settlement	10 453.26	28.78
Water body	315.52	0.87
TOTAL	36,325.00	100

Table 2. Area of land-use patterns (2001)

Land-use Type	Area (Km^2)	Percentage (%)
Irrigated Land	5 272.96	14.52
Fallow Land	24 148.47	66.48
settlement	6 537.80	18.00
Water body	362.79	1.00
TOTAL	36,325.00	100

Table 3. Area of land-use patterns (2005)

Land-use Type	Area (Km^2)	Percentage (%)
Irrigated Land	3 900.70	10.74
Fallow Land	28 790.35	79.26
settlement	3 489.91	9.61
Water body	141.23	0.39
TOTAL	36,325.00	100

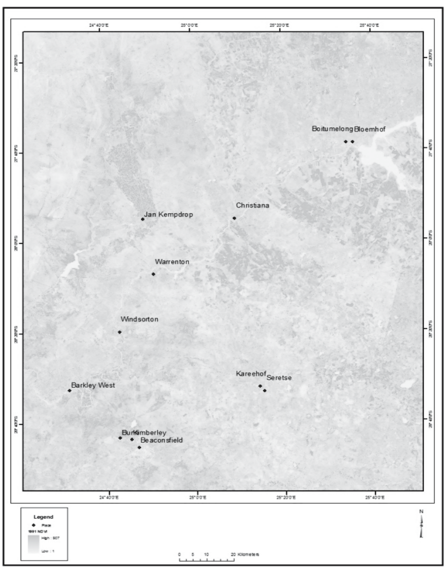

Fig. 7. NDVI 1991

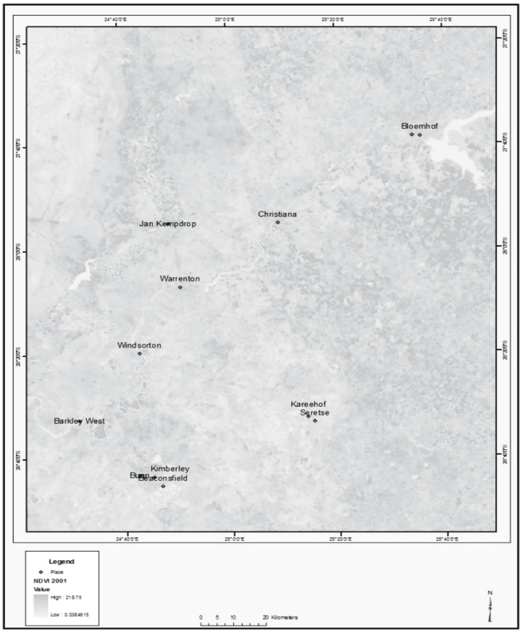

Fig. 8. NDVI 2001

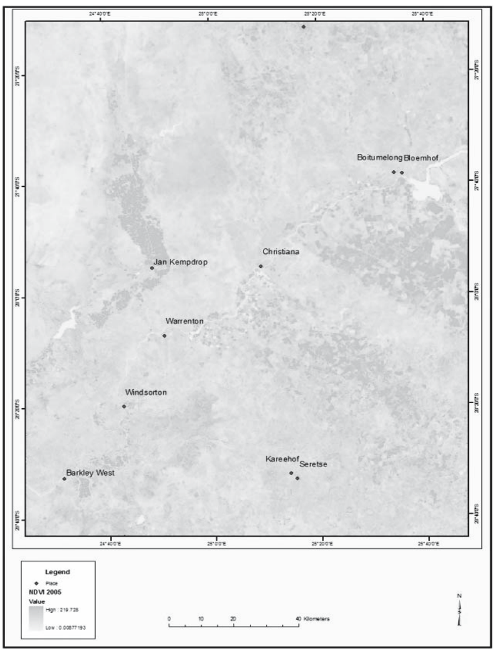

Fig. 9. NDVI 2005

CONCLUSION

Land evaluation helps to know the different land use/land cover classes and trend (decrease or increase) over time. Between the period of 1991 and 2005 there has been a significant increase in the spatial variation of VHS. After the initial decrease in farm land between 1991 and 2001, the scheme witnessed a steady drop in this land use in 2005 and indeed may continue in this trend if not checked. During the period of analysis, the substantial LCC was observed in VHS. The percentage of follow land has increased by 37.86%, settlement or built-up area decreased by 18.17%, water bodies by 0.48% and cultivated/irrigated land area also decreased by 18.21%. These changes are a result of a combination of factors which need to be investigated in the irrigation scheme. The satellite images of study area acquired during 1991–2005 periods have offered a rich source of information about changes in land use/land cover and NDVI index in VHS over a period of 15 years. The study showed the importance of using Remote Sensing and Geographic Information System techniques in change detection and land uses monitoring, therefore planning should be embarked upon to have sustainable land management and development that is eco-friendly.

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