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CHANGES OF ARTIFICIAL SURFACES IN EL FASHER CITY: RESULT OF THE CONFLICT IN DARFUR-SUDAN

Salah Eldin HAMID

Changes of artificial surfaces in El Fasher city: result of the conflict in Darfur-Sudan

Abstract: Identification of urban growth and its change using satellite data are an important sphere of interest. Darfur in western Sudan has been affected by the war since 2001 where hundreds of thousands of IDPs moved and stayed in El Fasher city the capital of the northern Darfur State, so the identification of change in the city is important. In this paper, we used the Landsat ETM+ subset to identify the change in El Fasher city. This paper describes the stage of the classification process for LU/LC classification and changes in urban land in El Fasher city over a 5-year period. Subset of Landsat ETM+ images of 2001 and 2005 dates were used in this study. The images interpreted using unsupervised and supervised classification methods. Result showed an overall classification accuracy of 84.00% and 85.33% respectively for five classes and the Kappa coefficient of 0.7327 and 0.7640 respectively.

Keywords: Landsat ETM+, LU/LC classification, change detection of artificial surfaces, Darfur

1. Introduction

Land use and land cover (LU/LC) change is an essential issue in monitoring and managing Earth's surface. During recent decades, remotely sensed imagery became a major data source for LU/LC change detection because of the advantages of temporal data, synoptic view, fast data acquisition and digital format suitable for computer processing (Liang, 2004).

Darfur covers about one-fifth of Sudan. The arid climate, the drought and the competition for scarce resources over the years have contributed to recurring conflict between the nomadic and farmers, particularly over the land and grazing right (Totten, 2010). In the early months of 2003 a rebellion in Darfur began (Flint and De Waal, 2008). The civil war and the Darfur conflict played out against a growing competition for land and resources between settled farmers and predominantly nomadic (Hagan and Rymond-Richmond, 2009), resulted in, migration; refugees in neighbouring countries, and movement of internally displaced persons (IDPs). According to the United Nations there were 1.65 million IDP inside Darfur (Totten, 2010) reaching 1.8 million by the end of 2004 (Barltrop, 2011). The movement of IDPs reflected negatively in the big cities of Darfur, such as Nyala, El Geneina and El Fasher. One of the cities affected by the war from 22 locations in North Darfur (Totten, 2010), where it displaced hundreds of thousands of IDPs to El Fasher town, and the city expanded significantly towards the west in Abu Shouk and Al Salam to the north. Urban extent tends to be guided by definitions of the range of irreversible urban artificial structures on the surface of the Earth. Such structures support a range of residential, commercial, industrial, public open space and transport land uses (Rashed and Jürgens, 2010). Artificial surfaces in the study area represent the urban land and include residential, commercial, industrial, public open space, transport and IDPs camps.

Mapping of urban growth is important, and it needs a minimum of two temporal images to detect the change. Since El Fasher, is one of the cities affected by the war where it displaced hundreds of thousands of IDPs change monitoring in the city is important. We used in this paper the Landsat Enhanced Thematic Mapper Plus (ETM+) data to identify the change in El Fasher city.

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1.1 Objectives

The satellite data can provide fast, compatible and rich information about urban LU/LC change. The overall objective of the study was to detect an urban growth in El Fasher between 2001 before the conflict, and 2005 after conflict, based on the comparison of satellite data from multi-temporal Landsat ETM+ images. The objectives of the study are as follows:

1. To determine artificial surfaces change of El Fasher city for the years 2001, and 2005, using Landsat 7 collected data.

2. To identify and evaluate the urban changes in El Fasher city through tracking changes from multi-temporal Landsat images using post-classification comparison.

3. Increase awareness about using remote sensing data for urban planning in Darfur, and helping decision makers and planners to monitor the artificial surfaces in El Fasher city in the future.

1.2 Study Area

Study area is El Fasher city, the capital and the largest town in North Darfur state Fig. 1, located between latitude 13°38′ N and longitude 25°20′ E (Casey, 2007). El Fasher is a capital Darfur since 1790 (O'Fahey, 2004). El Fasher located at an elevation of about 2,400 feet (700 m) above mean sea level (Fig. 2 and Fig. 3) and has the population of 178,500 in 2001 increased to 264,734 residents in 2006. The conflict in Darfur created new camps, called Abu Shouk and Al Salam (Casey, 2007). Because of the war most of the farmers come to El Fasher as IDPs and live in Abu Shouk and Al Salam IDP camps (Schimmer, 2008), which is now a normal extension of the city. We selected this area as an application site mainly due to the dramatic change of artificial surfaces. The building materials of the town are (soil, deadwood, dead twigs and dead litter) concrete, rock aggregates, and limestone.

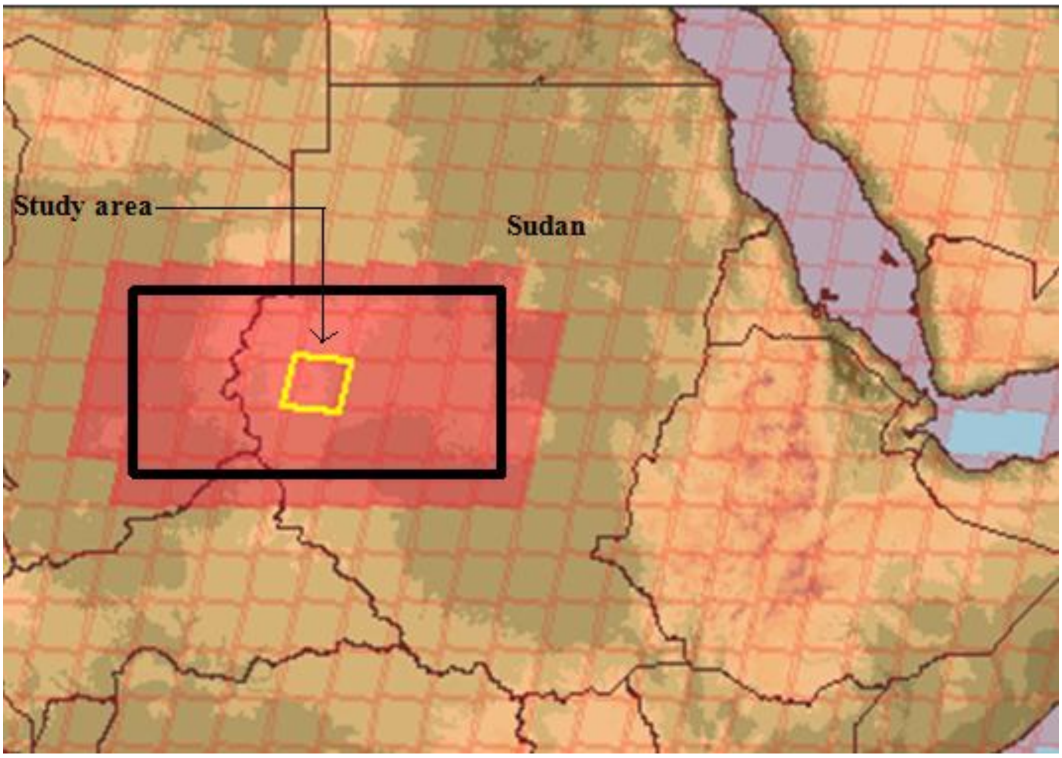

Fig. 1 Area of study (yellow) (http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp)

Fig. 2 Different landscapes from El Fasher (https://www.google.com/maps/)

Fig. 3 El Fasher landscape, United nation camp (red) (https://www.google.com/maps/)

The town characterized by semiarid climatic conditions (the annual rainfall is less than 500 mm per year; the average temperature of this city varies between a mean minimum of 22° C in winter and a mean maximum of 37° C in summer). LU/LC in the study area dominated by urban land, herbaceous and bushy vegetation (H.B. vegetation), barren land, forests, and water bodies (Tab. 1). Urban land includes structures, such as residential, commercial and industrial buildings, and El Fasher airport. H.B. vegetation land includes croplands such as corn, wheat and pasture/hay planted for livestock grazing. Barren land characterized by bare rock, sand, clay, or other earthen material with no green vegetation present. Forests are mainly mixed. Water bodies refer to all areas of open water, including lakes, streams, and ponds.

Tab. 1 Details of the LU/LC classes of the study area

Land Cover Type	Description
Urban land	All residential, commercial and industrial areas, IDP camps, open space, villages, settlements, transportation infrastructure, and airport.
H.B. vegetation	All agricultural and cultivated areas, natural vegetation herbs, and bushes.
Barren land	Fallow land, earth and sand land in-fillings, bare, exposed soils and mountains.
Water bodies	Lakes, ponds, canals, reservoirs and wetlands.
Forest	Mixed forest, grassland, marsh vegetation, vegetable, and shrubs,

2. Background

2.1 Satellite Remote Sensing for Urban Applications

Remote sensing data are especially important in areas of rapid LU changes, where the updating of information is tedious and time-consuming via traditional surveying and mapping methods. In the recent years, remote sensing data and GIS techniques are widely being used for mapping, monitoring, measuring and modelling the urban growth, LU/LC, and sprawl (Balram and Dragicevic, 2010).

2.2 Urban Land Cover and Land Use

Most urban LU associated with surfaces that characterized by combinations of different kinds of LC: buildings, vegetation, roads, water, bare soil, etc. (Rashed and Jürgens, 2010). Studies of urban LU and LC are the backbone of urban remote sensing. Although the goals of many studies differ, most begin with the identification and classification of the LC or LU within the urban scene. (Rashed and Jürgens, 2010). Urban areas are composed of a variety of materials, including different types of artificial materials (e.g., concrete, asphalt, metal, plastic, glasses etc.), soils, rocks, minerals, and green and non-photosynthetic vegetation (Weng, 2010).

2.3 Urban land change detection

Studies of urban change over both space and time have become increasingly important as the world's urban population continues to grow. Detection of artificial surfaces changes is one of the most interesting aspects of the analysis of multi-temporal remote sensing images (Grano and Duro, 2008). Change detection, is the process of identifying differences in image scenes taken at different points, by observing at different times (Nussbaum and Menz, 2008), (Congalton and Green, 2009), and it is very useful in applications, such as LU changes analysis, assessment of burned areas, and studies of cultivation shifting or assessment of deforestation (Grano and Duro, 2008). Change detection can be performed both comparing the spectral behaviours in the multi-temporal images and comparing among them the classification maps obtained each date. In the first case, changes can be highlighted, in the second one transition between different canopies or LU can be identified (Gomarasca, 2009).

3. Material and methods

3.1 Data and software used

The first step in investigating changes of objects on the Earth's surface is to choose data sources that match the target features. Selection of appropriate satellite data sources is one of the necessary prerequisites for remote sensing change detection (Li, Chen and Baltsavias, 2008). In the study, we selected images acquired from the same sensors, with the same spectral and spatial resolutions, and at the same seasonal timeframe in order to minimize unwanted variances due to the changing factors such as sun angle and the influence of seasonal variations on LU/LC analysis (Li, Chen and Baltsavias, 2008).

The data used for the urban growth change detection included two Landsat ETM+ (30 m) images with four-year intervals correspond to the World Reference System (WRS-2) path 178, row 51. Scene acquired in 2001, and 2005 (Tab. 2). These data were downloaded free of cost in 20.08.2013 from the Global Land Cover Facility (GLCF) archive of Maryland University USA from this link (http://www.glcf.umiacs.umd.edu/index.shtml), in the form of a compressed file (tar.gz extension) consist of eight bands of visible and infrared data. These data have geometrically corrected to the Universal Transverse Mercator coordinate system (UTM) (zone 35) based on the World Geodetic System (WGS84) datum and ellipsoid data as Level-1 metadata, GeoTIFF file extension, produced by USGS. These satellite data consist of eight separate files, one for each band. Tab. 3. shows the Landsat ETM+ bands used in the study including the Reference data Training and validation data collected using the Google Earth at http://earth.google.com.

These datasets were utilized and processed using the Earth Resources Data Analysis System (ERDAS Imagine ver. 9.1) software. The software was used for overall image processing, such as displaying images, preparing, editing information, change detection, and analysis.

Tab. 2 The data used in the study area

Satellite	Sensor	Path/row	Reference datum	Acquisition date
Landsat-7	ETM+	178/051	WGS84	2001-11-12
Landsat-7	ETM+	178/051	WGS84	2005-10-22

Tab. 3 Bands and resolutions of Landsat ETM+ used in the study

Band No	Description	Spectral resolution (µm)	Spatial resolution (m)
1	Blue	0.45 - 0.515	30
2	Green	0.525 - 605	30
3	Red	0.63 - 0.69	30
4	Near IR	0.75 - 0.90	30
5	SWIR	1.55 - 1.75	30
7	SWIR	2.09 - 2.35	30

3.2 Digital image processing

From this dataset, a series of enhanced colour composites produced, as information sources for the interpretation of LU/LC classification (Liu and Mason, 2009). The subsets covering study area for analysis selected from Landsat ETM+ scenes 2001 & 2005. The methodology adopted for this study took into consideration several image preprocessing operations, image enhancement and interpretation. Prior to image classification, six Landsat ETM+ bands (1, 2, 3, 4, 5 and 7) stacked, contrast stretching applied, the spectral signatures studied, and in order to produce a test area, false colour composites from bands 2 (blue), 4 (green), and 7 (red) selected and used as suitable band combinations.

3.3 Image Classification

The classification process: traditionally, thematic classification of an image involves several steps, such as feature extraction, training areas, and labelling pixels (Schowengerdt 2007). The classification methodology approach involves generating an independent classification for each subset of the image. These classifications of the study area involve five classes, namely, urban land, H.B. vegetation, barren land, forests and water bodies (Tab. 1). Image classification performed separately for each subset used ISODATA unsupervised algorithm and supervised classification. In ISODATA method fifty spectral classes produced, with maximum iteration of 20 and 0.095 convergence threshold, the result labelled referencing to Google map and my background knowledge of the study area, but results were not satisfactory, so a second, and third unsupervised classification ran for confused classes, and the final classification image with five classes was performed. For supervised classification, Google Earth images used as reference data, for training sites selection and preparing LU/LC classification. 149 and 119 training area selected, for subset 2001 and 2005 respectively, based on image interpretation keys from Google Earth and my background knowledge of the area. Spectral signature files generated to be used maximum likelihood classification (supervised classification). Five LU/LC classes created from each satellite image. These results used as a base map for the post-classification sorting. Manual recoding method used to remove the confused class's cells, mostly between forest and water; the water pixels selected and recoded them to the forest. Finally, 7 × 7 pixel majority convolution filters applied to the two LU/LC images, merge the classes of the same type and refined the classification result.

The urban land change for El Fasher city detected based on a comparison of two independent classification results for dates 2001 and 2005, and we defined area of change. Finally, the accuracy of the classified image determined by selecting 300 of an independent stratified random sample of pixels using the stratified random method in ERDAS IMAGINE software to represent the different LU/LC classes in the area. The overall accuracy, producer's accuracy, and user's accuracy calculated based on the error matrix for each classified image, as well as the Kappa statistic.

4. Results

4.1 Urban land detection

The two images of El Fasher town between the two intervals 2001-2005, visually interpreted and classified based on supervised and unsupervised classification methods, which produced five LU/LC classes named: urban land, H.B. vegetation, barren land, forests, and water bodies (Tab. 4, Fig. 4 and Fig. 5). The scale of image in figures is approximately 1:200 000 and the data in the table represent the total area of each LU/LC class in each year as calculated from the image by the software. The area urban land in the 2001 image was 3416.76 hectares. In 2005, the amount of urban land class had increased significantly, becoming 5027.22 hectares. The total area of change in urban land was 1610.45 hectares; this change of urban land from 2001 to 2005 is likely to be a result of the movement of people from villages and rural areas to the town due to the time of war. The extended area generates two large IDP camps (Abu Shouk and Al Salam) arranged by the Government and United Nation Mission in Darfur (UNMID). The other classes also changed either by levelling down (water bodies, vegetation, and barren land) or by extension. These changes in LU/LC have led to changes in the composition of image fractions. Urban land change determined by differencing between subsequent periods of time separated by five years intervals in average.

Tab. 4 Area of LU/LC classes and the change detection

LU/LC class	Area in hectares		
	Image 2001	Image 2005	Changed detected
Water Bodies	2983.05	756.81	-2226.24
Urban land	3416.76	5027.22	+1610.46
H.B. vegetation	39798.1	37708.7	-2089.4
Barren land	23261.00	19734.5	-3526.5
Forests	3289.95	9521.55	+6231.6
Total area	72748.86	72748.78	-0.08

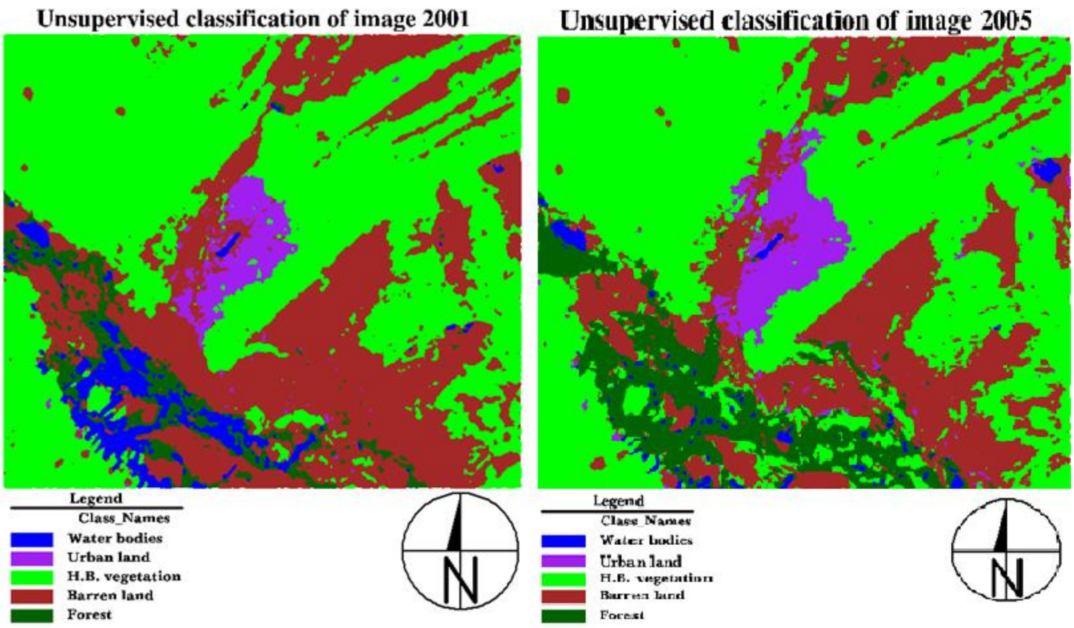

Fig. 4 Unsupervised classification of two images

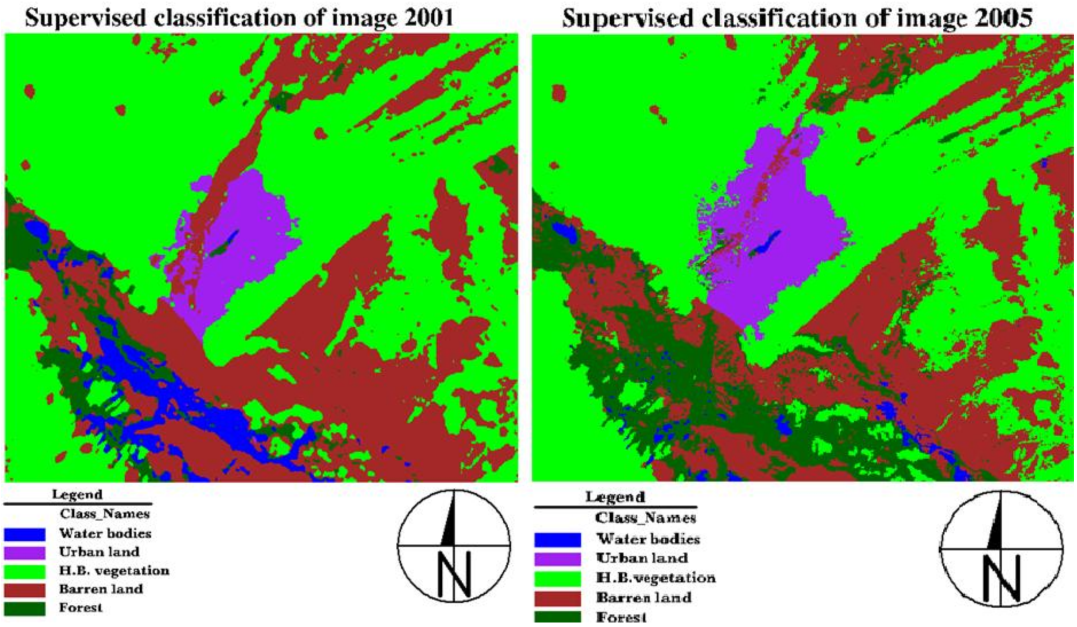

Fig. 5 Supervised classification of two images

4.2 Accuracy Assessment

The overall accuracy of the LU/LC classes 2001 and 2005 determined to be 84.00% and 85.33% respectively and overall the Kappa statistics was 0.7327 and 0.7640 respectively for the same images shown in Tabs. 5 to 8. The producer and user's accuracy of urban class obtained was 77.78% and 50.00% respectively with the Kappa of 0.4845 for the 2001 image and for the 2005 image; the producer and user's accuracy were 81.25% and 61.90% respectively with the Kappa of 0.5976.

Tab. 5 Accuracy assessment and the Kappa statistics for the 2001 image (supervised classification)

LU/LC class	Reference Totals	Class Totals	Number Correct	Accuracy		
				Producers (%)	Users (%)	Kappa
Water bodies	11	12	8	72.73	66.67	0.6540
Urban land	9	14	7	77.78	50.00	0.4845
H.B. vegetation	154	164	148	96.10	90.24	0.7995
Barren land	108	96	81	75.00	84.38	0.7559
Forest	18	14	8	44.44	57.14	0.5441
Total	300	300	252			
Overall classification accuracy = 84.00%						
Overall Kappa statistics = 0.7327						

Tab. 6 Confusion matrix for image 2001(supervised classification)

LU/LC Class		Reference image					
		Water bodies	Urban land	H.B. vegetation	Barren land	Forest	Total
Classified image	Water bodies	**8**	0	0	1	3	12
	Urban land	0	**7**	2	5	0	14
	H.B. vegetation	0	0	**148**	16	0	164
	Barren land	3	2	3	**81**	7	96
	Forest	0	0	1	5	**8**	14
	Total	11	9	154	108	18	300

Tab. 7 Accuracy assessment and the Kappa statistics for the 2005 image (supervised classification)

LU/LC class	Reference Totals	Class Totals	Number Correct	Accuracy		
				Producers (%)	Users (%)	Kappa
Water bodies	4	3	3	75.00	100.00	1.0000
Urban land	16	21	13	81.25	61.90	0.5976
H.B. vegetation	165	156	146	88.48	93.59	0.8575
Barren land	83	81	63	75.90	77.78	0.6928
Forest	32	39	31	96.88	79.49	0.7704
Total	300	300	256			
Overall classification accuracy = 85.33%						
Overall Kappa statistics = 0.7640						

Tab. 8 Confusion matrix for the 2005 image (supervised classification)

LU/LC Class		Reference image					
		Water bodies	Urban land	H.B. vegetation	Barren land	Forest	Total
Classified image	Water bodies	**3**	0	0	0	0	3
	Urban land	0	**13**	2	6	0	21
	H.B. vegetation	0	2	**146**	8	0	156
	Barren land	0	1	16	**63**	1	81
	Forest	1	0	1	6	**31**	39
	Total	4	16	165	83	32	300

Conclusions

Against the background outlined above, it can be concluded that the classification methods, which applied to Landsat ETM+ images obtained from 2001 and 2005 will be useful for identification of the dramatic extension of artificial surfaces in El Fasher city after the violent conflict in Darfur, and the intensive migration towards the big cities. The study also demonstrates the benefits, of using the multi-temporal and multi-spectral satellite data and remote sensing technology providing information that can be used for the analysis of urban land, especially IDPs and refugee camps in El Fasher town and North Darfur State. These results could be supported the decision makers in the context of monitoring and manage the changed area in the time of crisis and conflict situations.

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R e s u m é

Zmeny zastavaných areálov v meste El Fasher: dôsledok konfliktu v sudánskom Darfúre

V príspevku sú pomocou údajov diaľkového prieskumu Zeme identifikované a hodnotené zmeny zastavaných areálov v El Fasher, hlavnom meste Severného Darfúru, ktoré sú dôsledkom viac ako päťročného (2001 – 2005) sťahovania ľudí z vidieka do mesta pre vojnový konflikt. V procese riešenia problému sa použili satelitné snímky Landsat ETM+ (s rozlíšením 30 m) z rokov 2001 – 2005, zaznamenané vo svetovým referenčným systémom (World Reference System-2) – WRS-2. Na testovanie referenčných údajov a ich verifikáciu sa použili mapy Google Earth. Súčasťou aplikovaného prístupu bola selekcia satelitných údajov, ich klasifikácia, identifikácia zmien zastavaných areálov a prezentácia výsledkov. Použitím algoritmu ISODATA (nekontrolovaná klasifikácia) a metódy maximálnej vierohodnosti (kontrolovaná klasifikácia), bolo identifikovaných päť tried využitia krajiny/krajinnej pokrývky (LU/LC): zastavané areály, bylinná a krovinová vegetácia, neproduktívne – opustené areály, lesy a vodné areály. Výsledky ukázali, že zastavané areály sa zväčšili z 3 416,76 ha v roku 2001 na 5 027,22 ha v roku 2005, teda o 1 610,46 ha. Triedy LU/LC boli identifikované

s celkovou presnosťou 84,00 % (pre rok 2001) a 85,33 % (pre rok 2005). Producentská presnosť zastavaných areálov dosiahla hodnoty 77,78 % (pre rok 2001) a 81,25 % (2005) a užívateľská presnosť 50,00 % (2001) a 61,9 % (2005).

Obr. 1 Skúmané územie (vyznačené žltou farbou)

Obr. 2 Rôzne typy krajiny v okolí El Fasher

Obr. 3 Krajina v okolí El Fasher (tábor vysťahovalcov je vyznačený červenou farbou)

Obr. 4 Nekontrolovaná klasifikácia snímok z rokov 2001 a 2005

Obr. 5 Kontrolovaná klasifikácia snímok z rokov 2001 a 2005

Tab. 1 Charakteristiky tried využitia krajiny a krajinnej pokrývky (LU/LC) skúmaného územia

Tab. 2 Použité satelitné snímky Landsat 7 ETM+

Tab. 3 Spektrálne pásma a priestorové rozlíšenie satelitných snímok Landsat 7 ETM+

Tab. 4 Rozlohy tried LU/LC a ich zmien

Tab. 5 Výsledky hodnotenia presnosti klasifikácie snímky z roku 2001 pomocou koeficienta Kappa (pre kontrolovanú klasifikáciu)

Tab. 6 Matica chybovosti výsledkov klasifikácie snímky z roku 2001 (kontrolovaná klasifikácia)

Tab. 7 Výsledky hodnotenia presnosti klasifikácie snímky z roku 2005 pomocou koeficienta Kappa (pre kontrolovanú klasifikáciu)

Tab. 8 Matica chybovosti výsledkov klasifikácie snímky z roku 2005 (kontrolovaná klasifikácia)