Monitoring and Assessment of Land Use/Land Cover Changes in Elgezira-Aba Locality, White Nile State, Sudan using geospatial technology[1]

Magzoub Mahgoub Hassan[2]& Mohamed Salih Dafalla Mohamed*[3]

[2]Former M.Sc. student at the Institute of Desertification and Desert Cultivation, University of Khartoum.
[3] Dept. of Soil & Environment Science, Faculty of Agriculture, University of Khartoum
*Corresponding author: mohamedsalihdafalla@yahoo.com

Abstract: Desertification as major environmental problem in Sudan seriously affected the livelihood and food security of population. Poor land use and climatic variability are the major causes of the desertification. This study focused on assessing and mapping of chanes land use and land cover (LU/LC) as drivers to desertification processes in the ElGezira-Aba Locality, White Nile State, Sudan. Two images (173/51) acquired by ETM+ and OLI/TIRS for years 2000 and 2016 were analyzed. Standard digital image processes were performed including layer stacking, supervised image classification, area calculation, accuracy assessment and post-classification change detection. In the years 2000 and 2016, respectively, forest covered 3838 Ha(15 %) and 1449 Ha (5.9 %), open forest covered 2749 Ha (11 %) and 1085 Ha (4.5%), grassland covered 2354 Ha (10 %) and 1315 Ha (5.4 %), rainfed mechanized agriculture covered 377 Ha (2 %) and 1914 Ha (8 %), irrigated scheme covered 2255 Ha (9 %) and 5051 Ha (20.8 %), fallow land covered 3791 Ha (5 %) and 1577 Ha (6 %), bareland covered 3938 Ha (16 %) and 1425 Ha (5.9 %), sand dunes covered 998 Ha (4 %) and 1165 Ha (4.8 %), water

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[1]*Part of a thesis submitted by the first author in partial fulfillment of the requirement for M.Sc. degree (Desertification) at Institute of Desertification and Desert Cultivation, University of Khartoum, Sudan.

bodies covered 2219 Ha (9 %) and 3605 Ha (14 %) and urbanization covered 1794 Ha (7 %) and 5698 Ha (23 %). Overall classification accuracies for years 2000 and 2016, respectively were 86.39 % and 87.89 %, while overall kappa statistics were 0.8452 and 0.8594. Pronounced decrease in vegetation cover (forest, open forest and grassland) was recorded in favors of agriculture (irrigated scheme, rainfed mechanized agriculture)and urbanization. Sand dunes and Water bodies were increased. The dominant desertification processes were vegetation deterioration and wind erosion as a result of inappropriate agricultural activities, overgrazing and expansion of urban areas. The study concluded the necessity of protection natural resources by adoption of proper urban and land use planning in addition to use of geospatial technologies in monitoring of these resources.

Keywords: Desertification, Land Use/Land Cover, White Nile State, Sudan.

INTRODUCTION

Desertification is land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities (UNCCD 1992).Human activities such as agriculture, overgrazing and deforestation considered the major causes of desertification with both physical and socio-economic impacts (SNAP 2006).Several semi-arid lands of the world are vulnerable to environmental change (IPCC 2014). Land degradation and desertification are the most pressing environmental problem of the Sudan (SNAP, 2006, Mustafa and Mahdi, 2008). Elsammani (1986) concluded that the land degradation in the Sudan is induced by poor agricultural practices. The climate change induced desertification by influencing rate and intensity of extreme events like droughts and floods which have a huge impact on vegetation cover and productivity (Hameed *et al.* 2011; IPCC 2014).
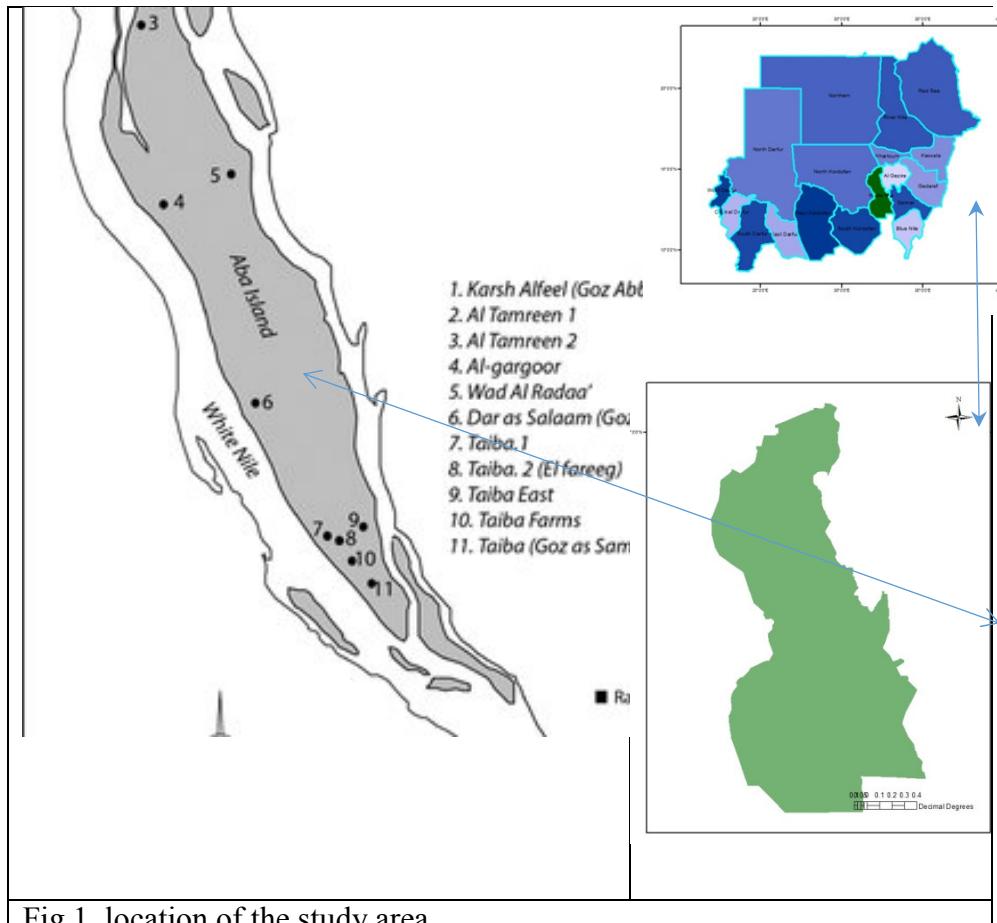
The White Nile State is under very high risk of desertification among the most affected areas in the arid and semi-arid zones (SNAP 2006, El Gunaid *et al.* 2013). The prevalence of the open grazing system of livestock raising, traditional agricultural practices, and traditional water distribution has contributed greatly to desertification (Mustafa and Mahdi,

2008, Eltahir *et al.* 2009; Ries, 2010; Hameed *et al.* 2011).Mapping of land cover is important for global monitoring studies, resource management, and planning activities (Aspinalls and Hill 2008, El Gunaid *et al.,* 2013). Land use changes mostly accompanied by alterations in land cover that always imply changes in ecosystem functions. The monitoring of landscape dynamics is essential component for identification extent and nature of changes and allows for the evaluation of the consequences for ecosystem functions (Liu *et al.* 2009).

Remote sensing and GIS techniques have proven to be timely accurate and cost effective tools in developing countries for land degradation assessment and desertification studies (Abdelnasir 2013;Eltoum *et al.* 2015, Dawelbait *et al.* 2017). Accuracy assessment of image classification quantifies errors of confusion and omission during digital image classification (ElGunaid 2014). The overall accuracy compares how each of the pixels is classified versus the actual land cover conditions obtained from their corresponding ground truth data. Producer's accuracy measures errors of omission, which is a measure of how well real-world land cover types can be classified. The user's accuracy measures errors of omission, which represents the likelihood of a classified pixel matching the land cover type of its corresponding real-world location. Error matrices have been used in many land classification studies and they were an essential component of this research (Elhag *et al.* 2014, Suliman 2016).Change-detection is the process of identifying difference in the state of an object or phenomenon (Singh1989). Remote sensing techniques were intensively used in many studies on land-use/land-cover change dynamics (Mohamed *et al.* 2011, Dafalla *et al.* 2009), monitoring shifting cultivations (Bruzzone 2000), natural recourse assessment (Dafalla *et al.* 2009), analysis of deforestation processes (Hame 1998), identification of vegetation changes (Chavez 1994) and monitoring of urban growth (Merril 1998).This study aimed at assessing and monitoring of land use/land cover changes during the period 2000-2016 as indicators of desertification in Elgezira-Aba district, White Nile state.

MATERIALS AND METHODS

The study area was Elgezira-Aba areathat comprised three locations namely: hajarAssalaya, ELdebybat and Eltmreen. Elgezira, White Nile State, Sudan. It lies between latitude 13º 23' 30" and 13º 10' 30" N and longitude 32º 34' 30" and 32º 34 '30 "E. It covers 24287.8 hectare (Fig.1).

1. Karsh Alfeel (Goz Abu
2. Al Tamreen 1
3. Al Tamreen 2
4. Al-gargoor
5. Wad Al Radaa'
6. Dar as Salaam (Goz
7. Taiba.1
8. Taiba. 2 (El fareeg)
9. Taiba East
10. Taiba Farms
11. Taiba (Goz as Sam
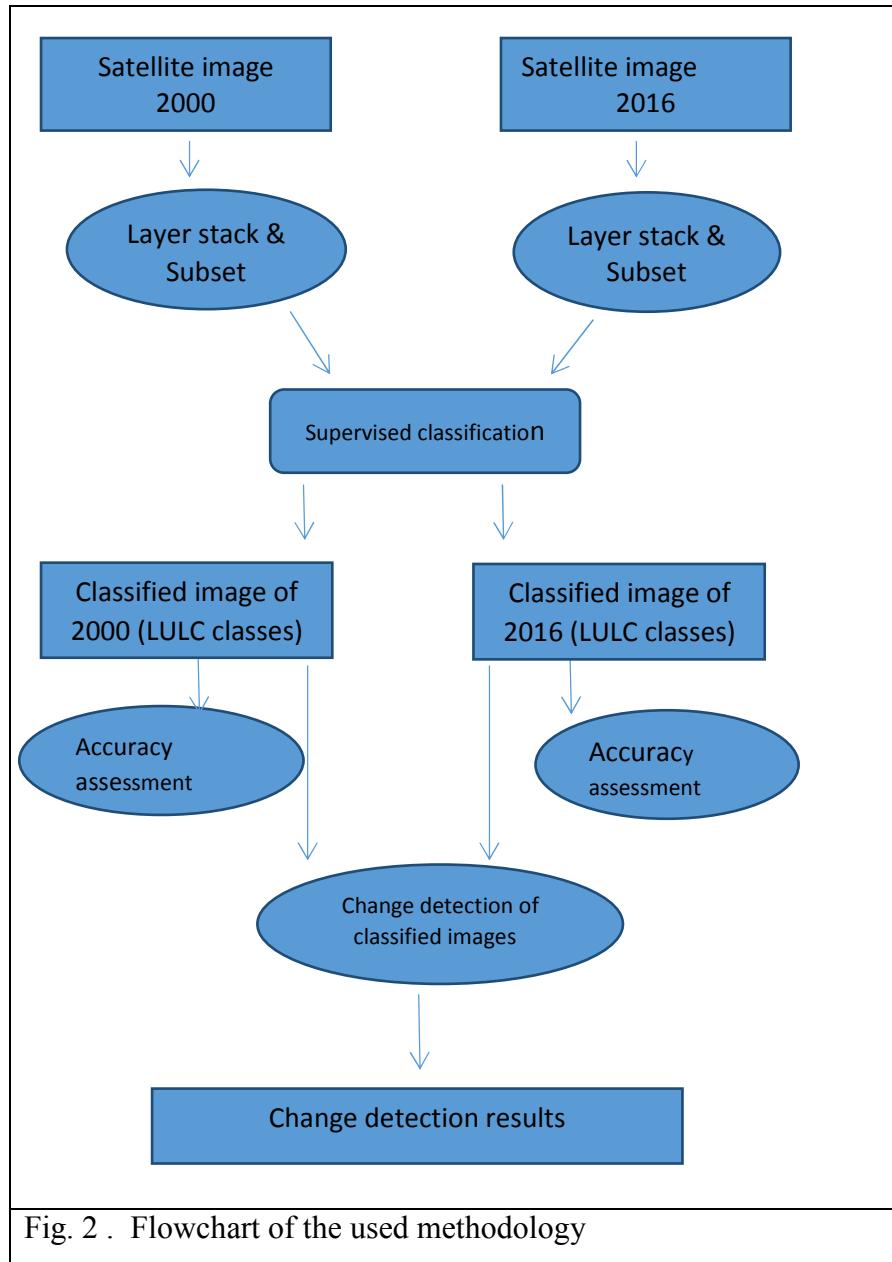
Fig.1. location of the study area

The vegetation cover in the study area is predominantly short-season grasses (ephemerals) and scattered acacia bushes, that including the most important species of gum Arabic: *Acacia senegal* and *Acacia seyal* in addition to other shrubs and trees. Land tenure in the study area is private

ownership by inheritance, governmental and private ownership besides illegal ownerships within the frame of this tenure. The people heavily relies on rainfed agriculture in addition to Gaffa Schemes in east of Elgezira-Aba. Fodder crops and vegetable are cultivated in most area, and irrigated from the White Nile River.

Soil types are cracking clays (Vertisols), stabilized longitudinal sand dunes and flat sandy soils. The adopted open system of grazing led in some instances to intrusion of animals into agricultural land. The predominant desertification processes include wind erosion and vegetation degradation (Mukhtar 2011). According to Mohamed and Alwaia (2004), non-erodible particles (%) constitutes about 4.5 - 90.6 and wind erosion 0.0 - 410.6.

The methodology flowchart (Fig.2) illustrates the main materials and methodology used in this study. In this study two images (path/row 173/51) were acquired by Enhanced Thematic Mapper Plus (ETM+) with nine bands in year 2000; and the Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) with eleven bands in year 2016. The two images were freely downloaded from the Global Land Cover Facility (GLCF) archive of Maryland University, (USA) and United States Geological Survey (USGS) website. The image of year 2000 was used as the reference while year 2016 was the recent one. Field work was conducted in December 2016 and February 2017 to collect ground control points for better understanding of the patterns of land cover in the study area and further in classification and accuracy assessment. Land Cover Classification System (LCCS) software version 1.0, Africover - East Africa project Nairobi, Kenya, FAO 2000 was applied. Subsets of images enclosing the study were clipped using the area of interest tool. Bands 4, 5 & 2 (RGB) were combined during visual interpretation for recognition of the apparent land use/land cover classes and selection of the training samples for the supervised classification. The dominant land use/land cover classes were then determined and quantified using supervised and unsupervised classification. Accuracy assessment of the classification was performed and Kappa coefficient was computed using 255 random distributed check sites. Post classification change detection approach was applied to detect changes during the addressed period 2000-2016 by

recognizing changes in extent of various LULC classes from the classified images of 2000 and 2016.The changes in LULC classes will be interpreted to asses desertification and recognize the prevailing desertification process in the study area such as deterioration in vegetation cover and soil erosion.

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│  ┌──────────────────┐              ┌──────────────────┐       │
│  │ Satellite image  │              │ Satellite image  │       │
│  │      2000        │              │      2016        │       │
│  └──────────────────┘              └──────────────────┘       │
│                                                               │
│     ( Layer stack &  )              ( Layer stack &  )        │
│     (    Subset      )              (    Subset      )        │
│                                                               │
│              ┌─────────────────────────────┐                  │
│              │  Supervised classification  │                  │
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│                                                               │
│  ┌──────────────────┐              ┌──────────────────┐       │
│  │ Classified image │              │ Classified image │       │
│  │ of 2000 (LULC    │              │ of 2016 (LULC    │       │
│  │    classes)      │              │    classes)      │       │
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│                                                               │
│     (  Accuracy   )                  (  Accuracy   )          │
│     ( assessment  )                  ( assessment  )          │
│                                                               │
│              (  Change detection of  )                        │
│              (  classified images    )                        │
│                                                               │
│          ┌─────────────────────────────┐                      │
│          │  Change detection results   │                      │
│          └─────────────────────────────┘                      │
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│  Fig. 2 .  Flowchart of the used methodology                  │
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Fig. 2 . Flowchart of the used methodology

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RESULTS AND DISCUSSION

The results section illustrates the major LULC classes and their dynamic changes in the study area during the period 2000-2016. These changes were linked to the prevailing desertification processes in the study area which were reflected in deterioration of vegetation cover and soil erosion by wind.

Dominant Land Use/Land Cover Classes in 2000
The major LULC classes in the area are illustrated in Figs.3&4. Bare land covered 3938.6 Ha (16.19 %),forest scattered in the eastern and western parts around the rive White Nile and occupied 3838.68 Ha (15.78 %),fallow land dominated on the eastern part in the irrigated scheme and covered 3791.7 Ha (15.59 %), open forest land was confined to the central part around the river white Nile and covered 2749.77 Ha (11.30 %),grassland covered 2354.45 Ha (9.68 %),irrigated scheme confined to the eastern bank of the river White Nile and covered 2255.9 Ha (9.3 %),water bodies occupied the central part of study area and covered 2219.85 Ha (9.12 %),urbanization dominated the central part and covered 1794.87 Ha (7.38 %),sand dunes covered the eastern part of the study area and extended over 998.46 Ha (4.10 %), rainfed mechanized agriculture scattered on the eastern part and covered 377.82 Ha(1.6 %).

Table1shows that the overall accuracy was 86.39 % and overall kappa was 0.845. The producer's accuracy was accounted to be 75 % for water bodies, 89.5 % for forest, 85.7 % for grassland, 81.3 %, for open forest land, 83.3 % for irrigated scheme, 100 % for rainfed mechanized agriculture, 94.44 % for urban area 96.3 for bare land, 78.8 % for fallow land and 100% for sand dunes. User's accuracy for LULC classes were 100% for water bodies, 85 % for forest, 75 % for grass land, 92.82% for open forest land, 76.92 % for irrigated scheme, 75 % for rainfed mechanized agriculture, 89.49 % for urban area, 83.87% for bare land, 92.87 % for fallow land and 80 % for sand dunes.
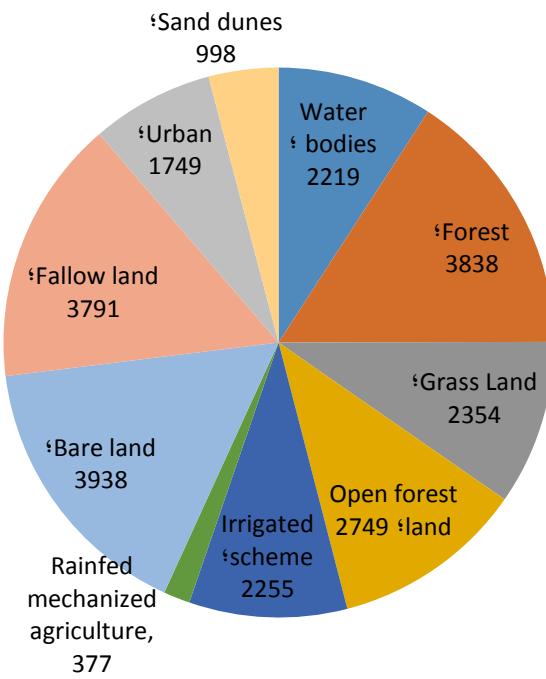
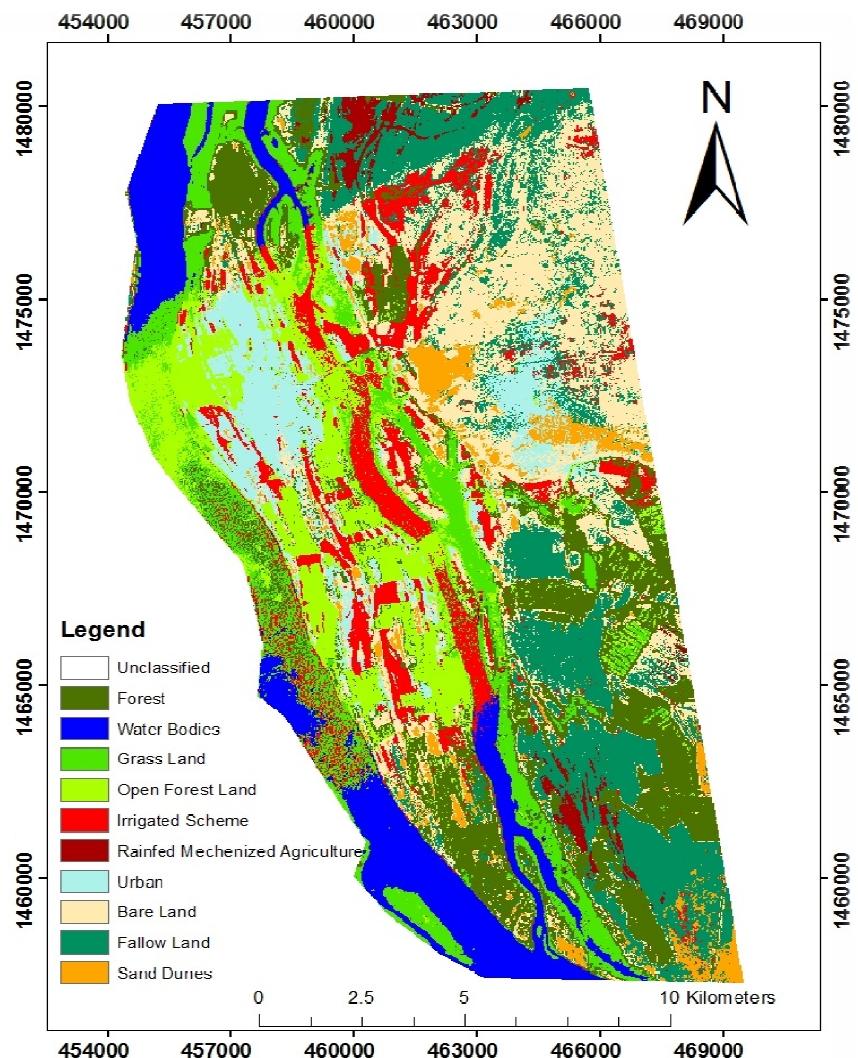Fig. 3. Extent (Ha) of the dominant LULC classes (2000).

Fig. 4. Major LU/LC classes in the study area (2000)

Table 1.Accuracy Assessment of classified image (2000)

Class Name	DWL	WB	GL	OPL	IS	RMA	UA	BL	FLL	SD	Total	User Accuracy (%)
F	17	0	1	0	0	0	0	0	2	0	20	85.0
WD	0	15	0	0	0	0	0	0	0	0	15	100.0
GL	1	3	12	0	0	0	0	0	0	0	16	75.0
OFL	0	1	0	13	0	0	0	0	0	0	14	92.9
IS	1	1	0	1	10	0	0	0	0	0	13	76.9
RMA	0	0	0	0	0	6	0	0	2	0	8	75.0
UA	0	0	1	1	0	0	17	0	0	0	19	89.4
BL	0	0	0	1	2	0	0	26	2	0	31	83.8
FLL	0	0	0	0	0	0	1	1	26	0	28	92.8
SD	0	0	0	0	0	0	0	0	1	4	5	80.0
Total	19	20	14	16	12	6	18	27	33	4	169	86.4
Producer's Accuracy (%)	89.5	75	85.7	81.3	83.3	100	94.4	96.3	78.7	100		

Overall Classification Accuracy = 86.4 %
Overall kappa Statistics = 0.84
In this table and the similar one the abbreviations denotes the following: WB (water bodies), F (Forest), GL (Grassland), OFL (open forest land), IS (irrigated scheme), RMA (Rainfed mechanized agriculture), BL (Bare land), FLL (Fallow land), UA (Urban area), SD (Sand dunes).

Dominant Land Use/Land Cover Classes in 2016

The dominant LULC classes are distributed in a very similar pattern to that of 2000, but areas covered by each class have changed (Figs5and6). Urban area covered 5698.19 Ha (23.5%), while irrigated scheme covered 5051.38 Ha (20.8 %),water bodies confined to the western part occupied 3605.26 Ha (14.8 %),rainfed mechanized agriculture covered 1914 Ha (7.9 %), while fallow land covered 1577 Ha (6.5 %),forest covered 1449 Ha (5.95 %), while grassland covered 1315 Ha (5.4 %) and open forest land covered 1085 Ha (4.46 %). On the other hand bare land covered 1525.89 Ha (5.87 %), and sand dunes confined to eastern part of the study area and covered 1165.7 Ha (4.79 %).
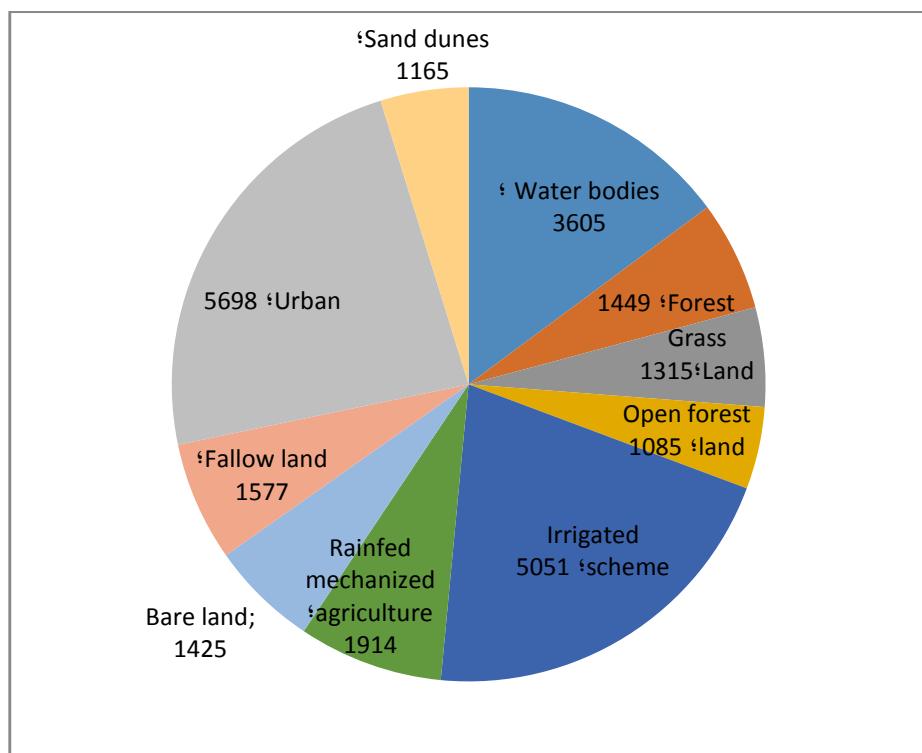
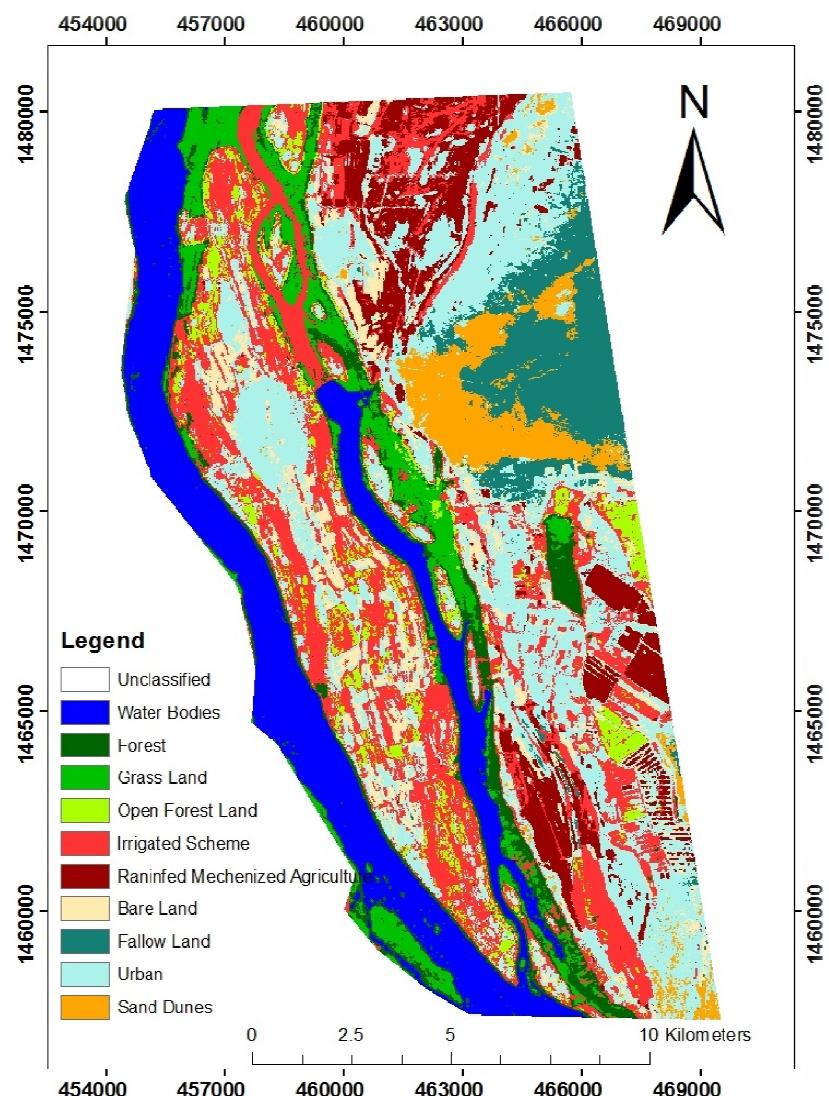Fig.5. Extent (Ha) of the dominant LULC classes (2016)

Fig.6. Major LU/LC classes in the study area (2016)

Table 2 shows that the overall accuracy was 87.89 % and overall kappa statistic was 0.95. The Producer's accuracy were 100 % for water bodies, 82.3% for forest, 82.3 % for grass land, 53.3% for open forest land, 85 % for irrigated scheme, 95% for rainfed mechanized agriculture, 90 % for urban area, 66% for bare land, 100% for fallow land and 84% for sand dunes. LULC classes recorded different User's accuracy percentage as follows: water bodies (100%), forest (93%), grass land (100 %), open forest land (66.67 %), irrigated scheme (86.79%), rainfed mechanized agriculture (100%), urban area (81.67 %), bare land (66.67 %), fallow land (88.24 %) and sand dunes (91.67%).The overall accuracy was higher in comparison with other studies (Dafalla *et al*. 2009 and Mohamed *et al*. 2011).However, variation in producer accuracy regarding rainfed mechanized agriculture and grassland could be attributed to spectral similarity resulting from dry nature of the trees, crop and bare land (Dafalla *et al*. 2009).

Change detection and desertification indicators
Changes in LULC classes during the period 2000-2016 are presented in Table 3. Positive changes were recorded for water bodies (62.41 %), grassland (44 %), rainfed mechanized agriculture (406 %), irrigated scheme (124 %), fallow land (58.4 %), bare land (64%), urban areas (21 7%) and sand dunes (16.7 %). On the other hand negative decreases were recorded for forest (-62.24) and open forest land (-60 %). The predominant positive changes indicated increase in human activities in agriculture and urbanization coupled with increase of sand dune, while the negative ones indicated a decrease in vegetation cover. The dominancy of agricultural activities in the area was attributed to increase in population as indicated by accompanied increase in urban areas, this agreed with findings of Abdelnasir (2013). The positive increase in water bodies could be attributed to remedies activities of hyacinth. The changes in LULC classes showed desertification processes of vegetation degradation and wind erosion as indicated by decrease in vegetation cover and increase of sand dune. Vegetation deterioration could be attributed to human activities related to agricultural land expansion, urbanization overcutting, overgrazing, (Mustafa and Mahdi 2008).

Table 2.Accuracy Assessment of classified image (2016)

Class Name	WB	F	GL	OFL	IS	RMA	BL	FLL	UA	SD	Total	User Accuracy (%)
WB	38	0	0	0	0	0	0	0	0	0	38	100.0
F	0	14	1	0	0	0	0	0	0	0	15	93.0
GL	0	0	14	0	0	0	0	0	0	0	14	100.0
OFL	0	0	0	8	2	1	1	0	0	0	12	66.7
IS	0	0	2	4	46	0	0	0	1	0	53	86.8
RMA	0	0	0	0	0	20	0	0	0	0	20	100.0
BL	0	2	0	1	1	0	10	0	1	0	15	66.7
FLL	0	0	0	0	0	0	0	15	0	2	17	88.2
UA	0	0	0	2	5	0	4	0	49	0	60	81.7
SD	0	1	0	0	0	0	0	0	0	11	12	91.7
	38	17	17	15	54	21	15	15	51	13	256	87.9
Total Producer's Accuracy (%)	100	82.3	82.3	53.3	85.2	95.2	66.7	100.0	90.1	84.6		

Overall Classification Accuracy = 87.9%
Overall kappa Statistics = 0.85

Table 3.Changes in land use/land cover classes during 2000-2016

Class Name	Area (Ha)		Change (Ha)	Change (%)
	2016	2000		
Water bodies	3605	2219	1385	62.4
Forest	1449	3838	-2389	-62.2
Grass Land	1315	2354	-1039	-44.1
Open forest land	1085	2749	-1664	-60.5
Irrigated scheme	5051	2255	2795	123.9
Rainfed mechanized agriculture	1914	377	1536	407.4
Bare land	1425	3938	-2512	-63.7
Fallow land	1577	3791	-2214	-58.4
Urban	5698	1749	3903	223.2
Sand dunes	1165	998	167	16.7

CONCLOUSIONS

Based on the finding of the study the following conclusions can be drawn:

1. The major dominant LULC classes are water bodies, forest, grassland, open forest land, Irrigated scheme, rainfed mechanized agriculture, bare land, fallow land, Urban and Sand dunes.
2. Positive and negative changes were accounted in land use/land cover during the addressed period with pronounced increases in agricultural lands (rainfed or irrigated), urban areas and sand dune and remarked decrease in vegetation (forest, open forest and grassland).
3. Land use land cover changes indicated prevalence of desertification processes of vegetation degradation and wind erosion.
4. Human activities related to settlement and crop production initiated changes in land use land cover.
5. Sand encroachment was predominant and accelerated by deterioration in vegetation cover. Water bodies increased resulting for the clearance and removal activities of hyacinth. Protection of the natural resource and restore the degraded lands in the study area.
6. Necessity for sustainable land planning to govern agricultural and urban expansion.
7. RS and GIS techniques are time and cost effective tools for monitoring natural resource.

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مراقبة وتقدير التغييرات في استخدام و غطاء الأرض بالجزيرة ابا ولاية النيل الابيض، السودان باستخدام التكنولوجيا المساحية الجغرافية

مجذوب محجوب حسن[1] و محمد صالح دفع الله[2]

1 طالب ماجستير بمعهد التصحر وزراعة الصحراء، جامعة الخرطوم
2 قسم علوم التربة والبيئة، كلية الزراعة جامعة الخرطوم

المستخلص: يعتبر التصحرالقضية البيئية الكبري في السودان و يؤثر بشكل خطير علي سبل كسب العيش و الامن الغذائي للسكان. يعد الاستخدام الغير مرشد للاراضي و التغييرات المناخية من الاسباب الرئيسية للتصحر. ركزت هذه الدراسة علي التخريط و التقييم للتغير في استخدامات الاراضي و الغطاء الارضي كمؤشرات علي عمليات التصحر في محلية الجزيرة ابا. حُللت صورتين (51/173) تم اخذهما بواسطة المرئيات الفضائية الامريكية (ETM+& OLI/TIRS) للاعوام 2000 و 2016. أُجريت عمليات تحليل رقمي قياسية للصور اشتملت علي تجميع الطبقات و التصنيف المحكم و تحديد المساحات و تقييم دقة التصنيف و تحديد التغير بعد التصنيف. في العامين2000 و 2016 علي التوالي، غطت الغابات مساحة 3838 هكتار(15%) ،1449 هكتار (5.9 %) و الغابات المفتوحة 2749 هكتار (11 %)، 1085 هكتار (4.5 %) و اراضي الحشائش 2354 هكتار (10%)،1315 هكتار (5.4 %) و الزراعة المطرية الالية 377 هكتار (2 %)،1914 هكتار (8 %) و المشاريع المروية 2255 هكتار (9 %) ،5051 هكتار(20.8%) و الاراضي البور 3791 هكتار (15 %) ،1577 هكتار (6%) و الاراضي الجرداء 3938 هكتار (16%) ، 1425 هكتار (5.9%) و الكثبانالرملية 998 هكتار (4 %) ، 1165 هكتار (4.8%) والمياه 2219 هكتار (9%)، 3605 هكتار (14 %)و المناطق السكنية 1794 هكتار (7 %)، 5698 هكتار (23%). بلغت دقة التصنيف العام لصور العامين(2000 و 2016) علي التوالي 86% ، 87 % بينما بلغ مقياس كابا قيم 0.84 ، 0.86 لنفس السنوات. سُجل نقصان كبير في الغطاء النباتي (الغابات و الغابات المفتوحة و اراضي الحشائس) لصالح الزراعة (المشروع المروي و الزراعة المطرية الالية) و التمدد السكاني. ازدادت الكثبان الرملية و

المياه. عمليات التصحر السائدة هي التدهور في الغطاء النباتي و التعرية الريحية. نتج التدهور في الاراضي من الانشطة الزراعية غير المرشدة و الرعي الجائر و التمدد السكاني. خُلصت الدراسة إلي اهمية حماية الموارد الطبيعية بتبني خطط سليمة للتمدد السكاني و استخدام الاراضي بالاضافة الي استخدام تقانات الجغرافيا المكانية لمراقبة هذه الموارد.

الكلمات المفتاحية: التصحر، استخدام الارض و الغطاء الارضي، ولاية النيل الابيض، السودان