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Land-cover mapping using Landsat Data in a section of Greater Kordofan region of Sudan

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Abstract

Mapping land cover is fundamental way to support environmental survey and monitoring of ecosystem transition status. This study aimed to map the major land cover categories in order to shed more light on natural environmental processes and human induced in West Kordofan Region. We classified land cover categories by using supervised classification based on Maximum Likelihood Classifier. Then, in 2015 we found that, sand is one of the major land cover categories with 8374.56 km^2; others land cover includes water, vegetation, agriculture and bare lands with percentage area of 0.09 %, 20.4 %, 17.06 % and 55.09 % respectively. We also found that Landsat ETM+ is a powerful tool for land cover mapping, and we obtained a classification map with an overall accuracy of 85.7 % and Kappa statistic at 0.80. The resultant represents constant reality in discrete land cover categories, showing where and how land deterioration is likely to occur. This study can contribute to future policies and planning in the region.

Keywords: Monitoring, Semi-Arid, Vegetation Cover, Human Induced, Satellite Images

1. Introduction

Mapping land cover in ecologically sensitive environment such as West Kordofan Region is essential to locate, assess, and rank areas at risk (Diouf and Lambin, 2001, Chen *et al*., 2015) [6, 4]. Furthermore, analysis vulnerability, and improving land use planning to meet sustainable goals require for an effective land management (Seto *et al*., 2002) [22], (Turner *et al*., 2007) [23]. West Kordofan Region has been experienced some considerable amount of pressure during last two decades due to desertification and land degradation (Khiry *et al*., 2015) [16]. Desert encroachment and intensive human activities induced dramatic changes in land cover across the region (Dawelbait and Morari, 2012) [5]. During last 17 years, the desert south border has moved into south part of the region with an average of 90 -100 km (El Gamri *et al*., 2009, Elhag, 2006) [7, 9]. Consequently, this rate of desert encroachment leads to gradual and prolonged vegetation loss over extensive areas in the region. According to (Dawelbait and Morari, 2012, Ayoub, 1998) [5, 2] desert is continued moving to south at rate of 5-6 km per year. As the result, desertification across the region has transformed a vast area into arid zone and therefore created large area that has no sufficient quality life-supporting natural resources base and climatic conditions. Importantly, this permanent loss of vegetation cover leads to declining of *Acacia Senegal* natural stands, which is an important indigenous tree species in the region (Yagoub *et al*., 2017) [24], but up to date detailed land cover map for West Kordofan Region and their geographical coverage still unknown. Therefore, mapping West Kordofan Region land cover is urgent to public and scientific society, ranging from societal needs to sustainable land cover management. Remote sensing has long been distinguished as an effective tool for large-scale land cover monitoring (Rogan *et al*., 2003, Hansen and Loveland, 2012, Schulz *et al*., 2010, Foody, 2001, Rawat and Kumar, 2015) [19, 14, 21, 10, 18], and they are useful for land cover mapping. It was, therefore, used efficiently in a number of land cover classification, mapping, and change detection studies using different satellite images with various resolutions (Baker *et al*., 2006, Friedl *et al*., 2002, Hansen *et al*., 2000, Hansen *et al*., 2013) [3, 11, 13, 15]. This success of remote sensing satellites is attributed to a range of advantages including wide range of geographical coverage and multi-spectral bands in each image.

Moreover, premise of using remote sensing data is basically based on availability and accessibility of freely Landsat archived data, which offers a unique opportunity for mapping land cover of almost any region on Earth and assess natural and human disturbances. Therefore, combination of remote sensing and geographic information system (GIS) techniques made possible to classify and mapping the major land cover categories in West Kordofan Region. In this context, our main objective is to explore the possibility of mapping the major land cover categories using Landsat ETM+ images and GIS techniques in West Kordofan Region. In addition, we specifically want to find out a scientific answer for the following questions:

1) How accurately can Landsat ETM+ images map the major land cover categories in West Kordofan Region?

2) Can we identify the spatial coverage of each land cover category based on the produced map and, if so, how accurate the map?

2. Materials and methods

2.1 Study area

West Kordofan Region is located in semi-arid zone of Sudan, and its administrative boundary includes eight Landsat ETM+ images with the path/row: 174/53; 175/51; 175/52; 175/53; 176/50; 176/51; 176/52; 176/53 in World Reference System -2 (WRS-2) (Fig. 1). The study area extended over an area of approximately 113815 km^2 with an altitude ranging from 986 to 393 meter above sea level (masl). The climate is semi-arid with annual rainfall between 300 - 400mm, from July to October. Mean annual temperature is about 19.8 C°, but the daytime temperature can rise as high as 44.8C° during summer (El Gamri *et al*., 2009) [7]. Natural vegetation consists of trees, bushes, and grass. *Acacia Senegal* natural stands are considered as an important indigenous tree species that producing gum Arabic. The main economic activities of population inhabited based on mixed crop-livestock production system.

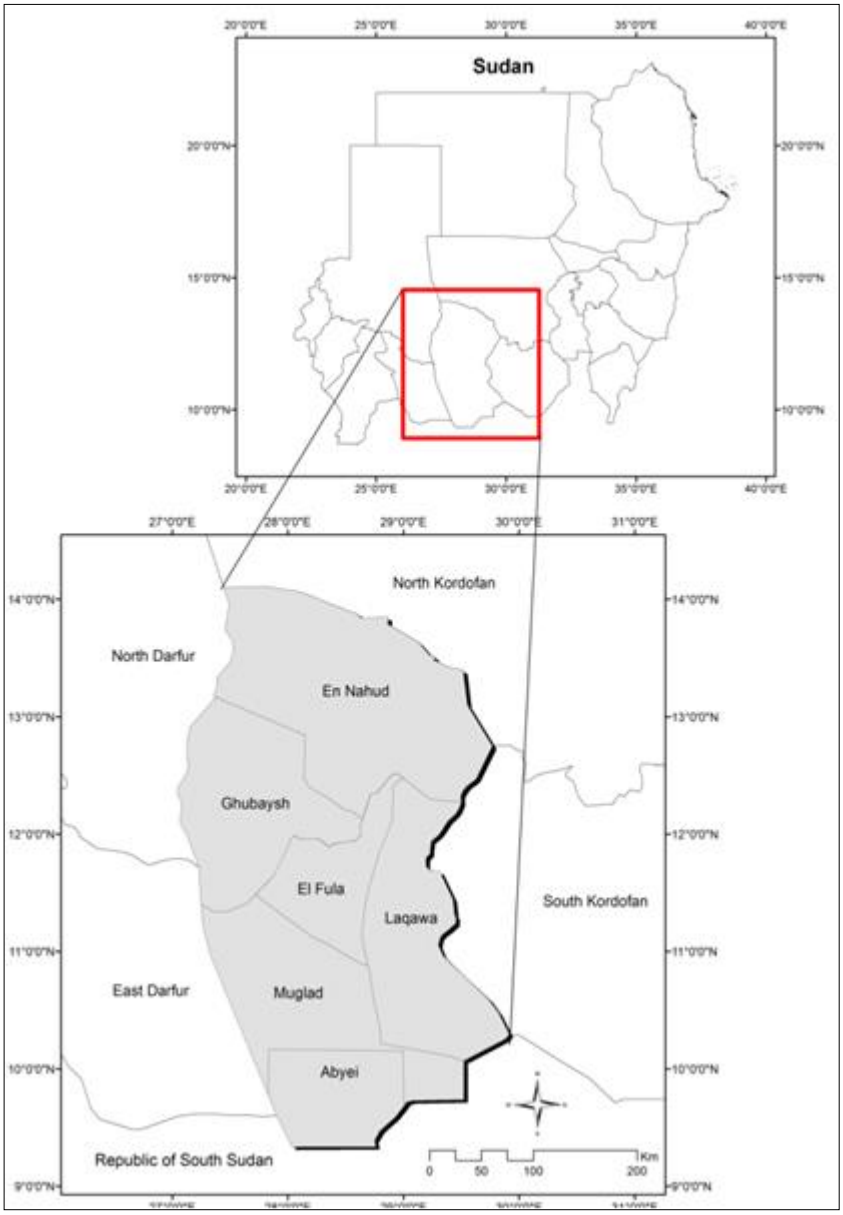

Fig 1: Location of study area

2.2 The data used in this study

The data used in this study were divided into satellite data and ancillary data. Ancillary data included ground truth data for the land cover classes. The ground truth data were in the form of reference data points collected using Golbal Positioning System (GPS) from January to March 2015 used

for image classification and accuracy assessment. Satellite data consisted of a set of eight Landsat Enhanced Thematic Mapper Plus+ (ETM+) images located by satellite path/row 176/50, 176/51, 176/52, 176/53, 175/51, 175/52,175/53 and174/53 were used. These images were downloaded free of cost from archive database at http://glovis.usgs.gov/. Also, the SRTM (Shuttle Radar Topography Mission) DEM data (30 m resolution) were acquired and used to generate elevation information. (Fig. 2b). The Landsat ETM+ and SRTM data characteristics are shown in Table 1.

Table 1: Characteristics of Landsat ETM+ images and SRTM data used in this study

Datasets	Date	Spatial resolution scale, m	Spectral bands	Swath, km	Source	Format
Landsat 7 ETM+L1T	Nov. 2015	30	8 bands	185	http://glovis.usgs.gov/	GeoTiff
SRTM	Nov. 2015	30	1 band	Global	https://earthexplorer.usgs.gov/	GeoTiff

2.3 Image pre-processing and classification

Image pre-processing prior to classification is immensely needed and has a primary unique objective of establishing more direct affiliation between obtained data and biophysical features as well as for producing spatially corrected land cover map. All images were pre-processed in ENVI 5.1 for geo-referencing, mosaicking, radiometric and atmospheric correction and sub-setting of the images based on the study area shape file. The images were studied by assigning per-pixel signatures and differentiating land cover into five classes on the bases of specific Digital Number (DN) value of different land cover features. The categorized land cover classes were water, vegetation, agricultural land, bare land, and sand (Fig. 2). For each of the predetermined land cover category, training samples were selected by delimiting polygons around representative sites. Subsequently, spectral signatures for each respective land cover category generated from the satellite images were recorded by using pixel enclosed by these polygons. A satisfactory spectral signature is the one that guarantees there is minimal confusion between different land cover categories to be mapped. Next, maximum likelihood classifier was used for supervised classification of the image. It is the sort of image classification that is mainly controlled by the analyst as the analyst chooses the pixels that representative of the desired classes. To improve the classification accuracy and reduction of mis-classified pixels, post-classification refinement was therefore applied for simplicity and effectiveness of the method. Importantly, using medium spatial resolution data such as that of Landsat ETM+ mixed pixels are a common issue; especially for the dynamic area characterized by heterogeneity and complex features. The issue of mixed pixels was addressed by visual interpretation. To enhance the classification accuracy and therefore the quality of land cover map produced, visual interpretation is very important. Thus, visual analysis, ground truth data, and local knowledge, considerably improved the result obtained using supervised classification technique.

	Land cover classes	**Descriptions**
	Water	The area covered by seasonal water bodies which considered as the primary source of domestic uses.
	Vegetation	Represents open natural vegetation cover, e.g. *Acacia senegal* tree (Hashab or gum Arabic tree), shrubs, and grasses. It is the main source of fuel wood and grazing.

	Agriculture land	Consists of a land put under any form of crop cultivation such as annual cropping.
	Bare land	Areas with no vegetation cover at all and exposed soil surface as well as urban areas.
	Sand	Area characterized by ongoing or recent sand encroachment.

Fig 2: Descriptions of major land cover categories in the study area

2.4 Accuracy assessment

Assessment of classification accuracy of produced land cover map was carried out to determine the quality of information derived from the satellite image. For the accuracy of produced land cover map, stratified random method was used to represent different land cover category in the study area. The accuracy assessment carried out using 150 points, based on ground truth data and visual interpretation. Overall accuracy, user's and producer's accuracies were then calculated (Table 2). Moreover, Kappa statistic was also derived for estimating degree of classification accuracy as it not only account for diagonal elements but for whole confusion matrix elements.

3. Results

Fig. 3 shows distributions of ground truth points or GPS location points collected during the field survey. The map in Fig. 4 indicates the image false color composite of Landsat ETM+ 2015. Analysis of digital elevation model (DEM) reveals that the terrain sloping of West Kordofan Region from northeast to south (Fig. 5). Maximum elevation occurs at eastern part of the study area approaching 986 masl which represented by small hills, while minimum level of land ranges between 393 to 451 masl. Fig. 6 shows the land cover map produced by supervised classification method using Landsat ETM+ images. The land cover categories are described and defined as Fig. 2.

Table 2: Summary of classification accuracies (%) for Landsat ETM+ image, 2015

Land cover type	User's	Producer's
Water	64.3	75.0
Vegetation	81.5	81.5
Agriculture land	85.7	85.7
Bareland	93.7	88.2
Sand	82.4	87.5
Overall accuracy	85.7	
Kappa statistic	0.801	

The produced land cover map (Fig.6) shows the total surface area of West Kordofan Region is 113815.31km^2. Overall accuracy and Kappa coefficient of land cover map categorized five land cover categories (water, vegetation, agriculture land, bare land, and sand) are 85.7% and 0.801 respectively (Table 2). The magnitude of the surface area percentage under each land cover category is graphically depicted as pie chart in Fig. 7. Extent of land cover coverage and their respective distributions are summarized in Table 3. Among all land cover categories, bare land class had the largest extent covering about 62693.08 km^2 (55.09%) of the land surface (Table 3 and Fig. 7). The next large categories included vegetation 23258.44 km^2 (20.4%) and agriculture land 19443 km^2 (17.06%). Sand covered about 8374.56 km^2 totaling 7.36% of the land surface area. The smallest category was water with 46.22 km^2 (0.09%) representation.

4. Discussion

However, water class represented the seasonal water courses that occupy approximately 46.22 km^2 (0.09 %) from the total area of West Kordofan Region, which makeup the natural network drainage systems. This result indicated that the water supplies were limited, which means the entire region is depends on rainfall and ground water as the primary sources for domestic uses (Ali and Mustafa, 2010) [1]. Despite of limited water supply and challenges existed in West Kordofan region, but it impacts amplified by recent trends such as rapid environmental change, economic growth and of course the climate change. Vegetation cover only represents 20.4 % (Table 3). The vegetation density at the north part of the region is rather low compared with the south part. However, in semi-arid areas, vegetation cover is often limited in diversity and complexity. More details of vegetation cover are given in (Fig. 4 and Table 3). Species like *Acacia senegal* (Gum Arabic tree), is indigenous tree that comprises pure stands distributed over large area ranging from 451 to 565 masl (Fig. 3) which is play an important role in gum Arabic production and sand dunes encroachment stability. Identifying the drivers of vegetation loss is important as these conditions are replicated elsewhere in West Kordofan Region. The drivers of vegetation loss are perhaps the most important factors in the context of conserving natural resources in semi-arid areas such as *Acacia senegal* stands. With the human activities, pressure on vegetation cover is increasing with growing demand for fuel wood, charcoal, agriculture expansion (both large- and small-scale farming) and pasture for livestock.

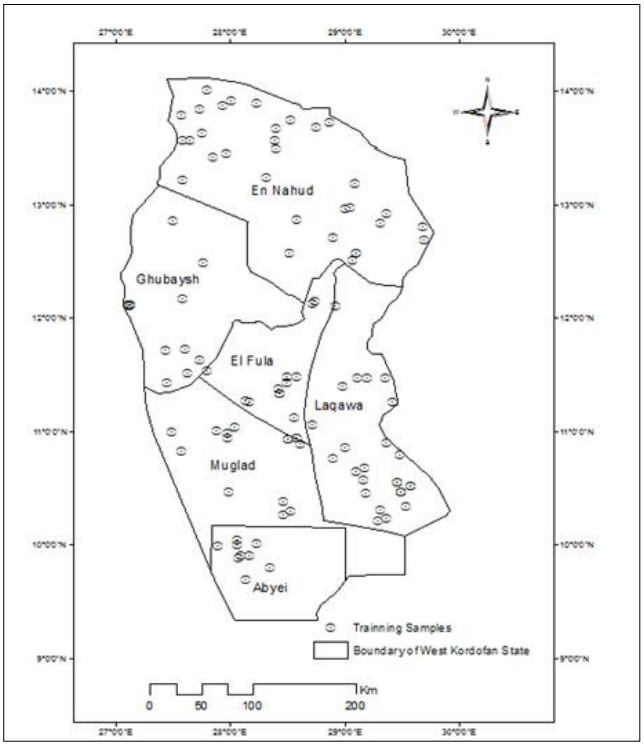

Fig 3: Location of Ground truth Points collected during the field survey that carried out from January to March 2015 in West Kordofan Region

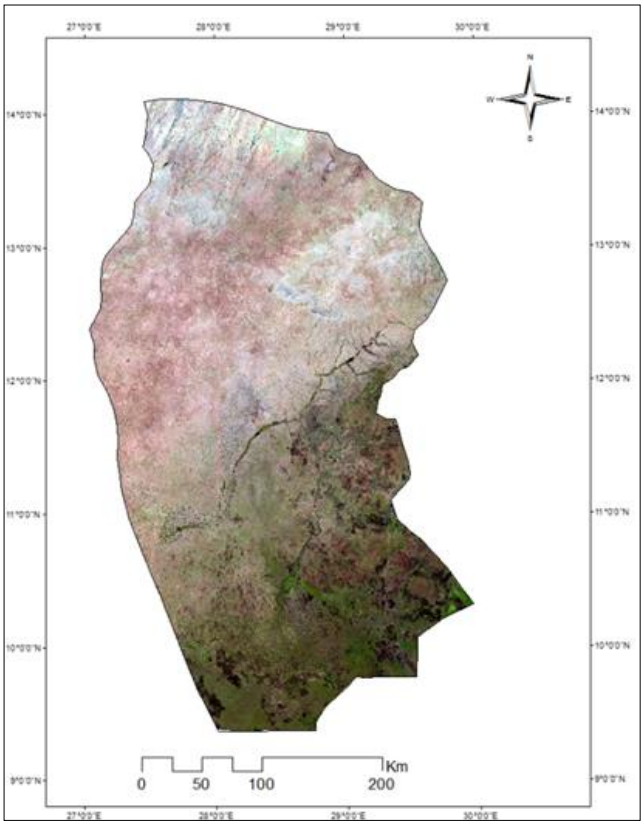

Fig 4: False color image of Landsat ETM+ 2015 bands (6, 5, and 3) shown in red, green and blue filter

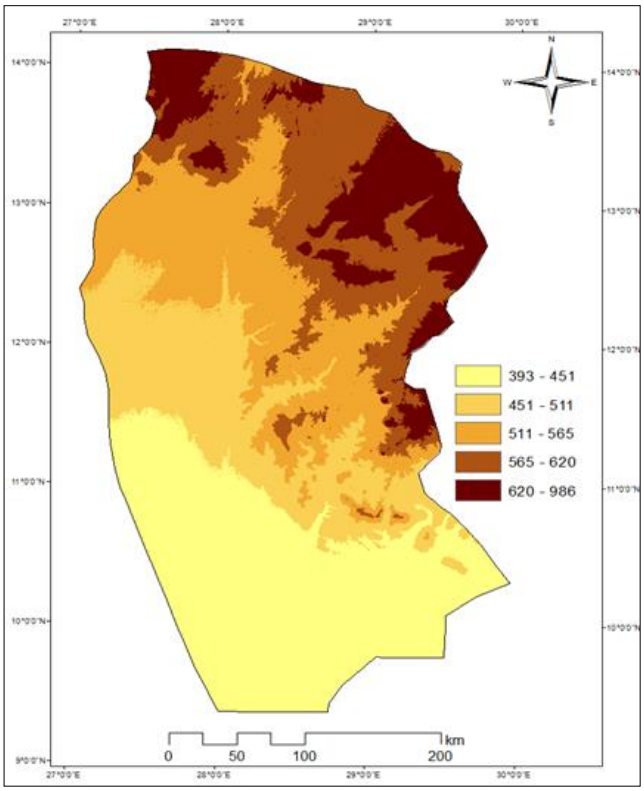

Fig 5: West Kordofan Region topographic map produced from the SRTM DEM

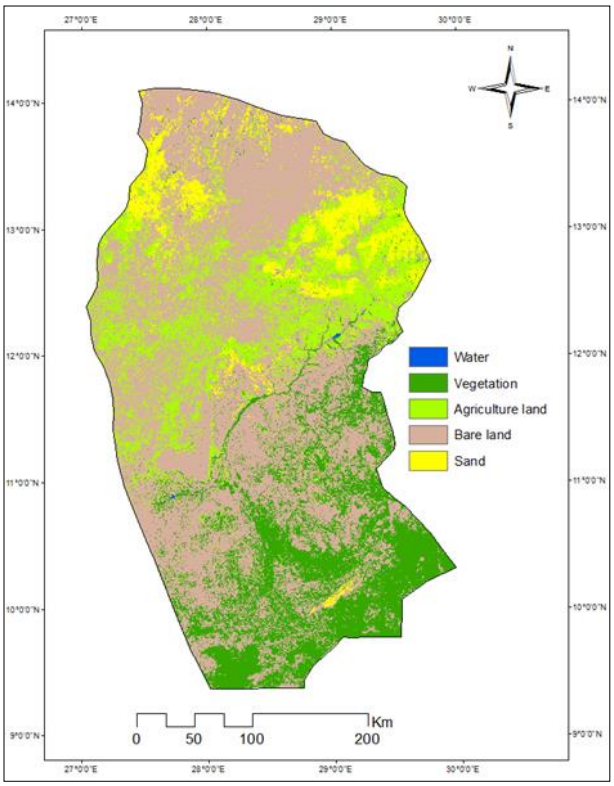

Fig 6: Thematic map representing the major land cover categories in West Kordofan Region

Table 3: Area coverage of different land covers categories in km^2 and (%), 2015

S. No	Land cover type	Area in km^2	Area in %
1	Water	46.22	0.09
2	Vegetation	23258.44	20.4
3	Agriculture land	19443.00	17.06
4	Bare land	62693.08	55.09
5	Sand	8374.56	7.36
	Total	113815.31	100

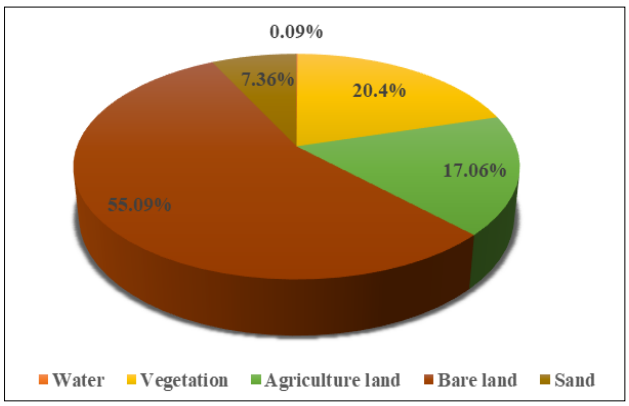

Fig 7: Percentages of land cover categories in 2015

The loss of vegetation cover due to human activities and rapid sand encroachment might over time lead to severe deterioration or multidimensional environmental changes as already being reported by (Yagoub *et al*., 2017) [24].

Agriculture class was typically used to describe farming practices that rely on rainfall which spread from 451 to 565 altitudes and becomes sparse in south part of West Kordofan Region due to ongoing conflicts. Agriculture land only cover 19443.00 km^2 (Table 3) from the total area of the region in 2015. Rain-fed agriculture is dominant land use systems have already confirmed by (Laki, 1994, Elagib, 2009) [17, 8]. Results also show that a systematic movement of desert south boundary into south part of the region is affecting the rain-fed agricultural land and expanding desert area. Sand encroaches upon rain-fed agricultural land is due to prevailing of wind direction which is most frequent during winter. With time agricultural land and vegetative area will colonize by sand dunes due to raid sand encroachment.

Bare land, the largest class of land cover categories in West Kordofan Region with 62693.08 km^2 that constitute 55.09 % (Table 3) of the total region area, it is more than two times of rain-fed agriculture land. Bare land may seem is most vulnerable to being arid area due to continuing desert movement, and therefore creating an extensive area that has no sufficient quality life-supporting natural resources base as well as weather conditions of the region.

Finally, in the northern region a sand dune (Locally called Gouz) spread over an area ranging from 511 to 620 mbsl (Fig. 3) covering about 8374.56 km^2 equal to 7.36 % from the total region area (Fig. 4 and Table 3). The magnitude of sand encroachment was driven by various factors, which operated with different intensity in the region. For example, expansion of rain-fed agriculture, over grazing and cutting trees to supply wood and charcoal for domestic uses.

4. Conclusion

Land cover map of West Kordofan Region was achieved by using supervised classification technique based on maximum likelihood classifier. The result demonstrated that how Landsat ETM+ images can be used for mapping land cover in a large-scale area where traditional surveying methods may not be possible. As the semi-arid region, this study contributes to the effort to provide land cover map in the region. Overall, these are needed for improving land use planning and monitoring when focusing on sustainable land resources management. Besides, there are increasing demands for land cover maps that providing biophysical information, such as vegetation cover or agricultural land cover. This result also provides a general perspective for natural environmental processes studies in relation to biophysical resources management. Finally, the produced land cover map which representing the constant reality in discrete land cover categories will helps to start debates amongst researchers and decision policy makers on the impact of human induced, desert encroachment processes and uncertainty in climatic conditions of the region.

5. Acknowledgements

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6. Author contributions

M. A. Hassan designed and wrote the article with substantial inputs from Xiaoli Zhang and M. Abbaker Ibrahim and Mohammed Ishag Arbab reviewed the article. Both authors contributed in the interpretation of the results, and outline of the article, through regular discussion over the past two years.

7. Conflicts of Interest

The authors declare no conflict of interest.

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