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Assessing Change in EL-Rawashda Forest Using Landsat and Field Data, Eastern Sudan (1988-2018)

Mohammed Ishag Arbab[a]*, Mahgoub Suliman Mohamedain[a], Abdelaziz Karamalla Gaiballa [a], Mohammed Abdelmanan Hassan [b], Sabit Ersahin[c]

[a]*College of Forestry and Range Science, Sudan University of Science and Technology, Khartoum, P.O.Box 407, Khartoum, Sudan*
[b]*Faculty of Forestry Sciences, University of Zalingei, P.O.Box 06, Sudan*
[c]*Faculty of Forestry, Cankiri Karatekin University, Cankiri, Turkey*

Abstract

Assessing and monitoring forest cover change researches are useful in providing information necessary to support policies and decisions to conserve, protect and manage the forest on a sustainable basis. This research deals with assessing the past and a recent change in EL-Rawashda Forest using multi-temporal Landsat images for the years 1988, 1998, 2007 and 2018 and field verification data. In addition to that linear Regression Trend (Slope) analysis that simulates the spatial trends of vegetation cover has been calculated from NDVI results to reflect the changes. The results showed that there was a significant change in EL-Rawashda Forest cover over the past 30 years. Moreover, the study found that the increment of agricultural activities inside EL-Rawashda Forest through the toungya agroforestry system was one of the main causes of forest trees clearance. Furthermore, the results of the Slope analysis revealed that change in the forest cover was accounted for 56% of the total area, with almost 3.11% rate of deterioration. These results emphasized that the forest cover change has impacts on the climate change and forest ecosystem. Therefore, the study results were useful in providing necessary inputs to refine policies and decisions for management and improvement of forests in the area.

Keywords: Forest cover, Satellite images, Linear Trend, Climate change, NDVI.

* Corresponding author. Tel.: 00249911221548.
E-mail address: mohammedeshag1@yahoo.com.

1. Introduction

About 12% of Sudan territory is covered by forests which are considered as the primary source of energy and other human necessities. Most of these forest located in the South and Western part of the Sudan. It contains nearly 1393 million metric tons of carbon in wood, leaves, roots and soil. In addition, to playing a significant role in regulating the climate, forest provides a variety of functions for human and ecosystem, including environmental, economic and social benefits. Moreover, forests contribute largely to livelihood and food security and provide fuel-wood and charcoal which are the main source of energy in almost the entire developing countries. Population and particularly in the semi-arid region are continuously changing the land use system to secure their foods through clearance of forest for agricultural practices.

Land use and land cover has a climate impact and play a vital role in changing the local, regional and global environment. Deforestation is the first threat for Sudan's forests, not only because it causes habitat degradation and biodiversity loss, but also it degrades the environment and has an impact on the environment by releasing Co_2 to the ecosystem. As a result, the release of Co_2 to the atmosphere causes changes in the carbon cycle balance and alters the energy budget. Voiding deforestation could reduce these impacts significantly. Forest management, including minimalizing and preventing deforestation, is a potential climatic strategy and helps to secure the various forest functions. Several studies used Landsat data to highlight the fact that during a few last decades vegetation cover (e.g. forests) has been remarkably declining.

Assessing forest over time allows the decision-makers to observe the change. Regular and accurate assessing of forest cover change and change drivers provide a piece essential information to support policies and management practices to conserve, protect and sustainably management of forest to ensure its different functions. Remote sensing data integrated with Geographical Information System tools are continuously in developing. However, these techniques can help to overcome almost all barriers and challenges in arid and semi-arid areas. Due to its cost-less means for assessing and monitoring aspects such as vegetation degradation and more generally for most types of land use and land cover changes. The aim of this paper is to assess the effects of change in EL-Rawashda forest using Landsat and filed verification data for the period from 1988 to 2018.

2. Materials and methods

2.1. The study area

El-Rawashda forest is located in the eastern part of Sudan at Gedaref state. It geographically situated at latitude 14°.2 N and longitude 35°. 6 E (Fig.1). The forest covers approximately 25290 ha. The climate of the forest is typically semi-arid climate characterized by hot summer and cold winter. Often, the wet season starts in August and continues up to mid-October. The rainfall pattern raining from 400 to 800 mm with an annual average of 600 mm mainly in the period of July – September (Musa, 2017).

The Gedaref region soils are uniform most of the area has deep dark cracking and heavy clay soil, and it is classified as verity soils and generally intensively cracked (Ministry of Agriculture, 1973). The soil clay fraction varies from 61 % to 73%, coinciding with the increase in rainfall. The origin of the soil material is believed to be the Ethiopian high lands. Yet, extensive areas of cracking clay were derived from the decomposition of rocks in suit (Babiker, 2009).

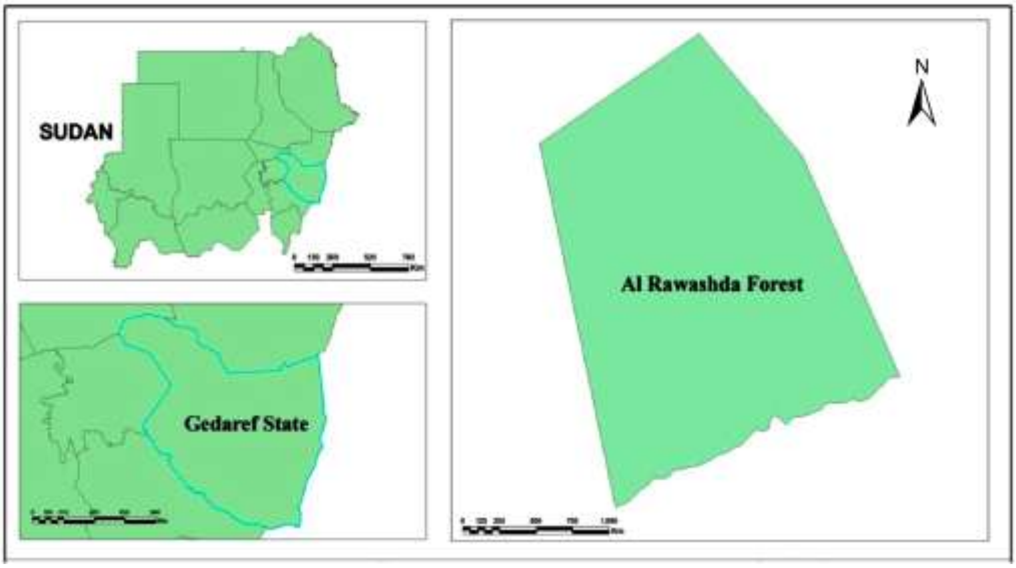

Fig. 1. Location of EL-Rawashada forest in Sudan

2.2. Data Acquisition

This study used Landsat archive data which include (Landsat TM, ETM+ and Landsat 8 OLI) for the years 1988, 1998, 2007 and 2018, respectively. All imagery was located by satellite path/row 171/50and characteristics of the data can be seen in Table 1. These images were downloaded from http://glovis.usgs.gov/ and https://earthexplorer.usgs.gov/. In addition, a detailed field survey that covers the entire study area has been carried out from November to December 2018. Verification data in terms of training sites and observations were obtained. A total of 75 training points were collected using the handhold Global Positioning System (GPS), Fig.2, showing the distribution of GPS points across the study area.

Table 1. Characteristics of Landsat data used in this study

Datasets	Date	Spatial resolution scale / m	Spectral bands	Swath, km	Format
Landsat 5	Dec. 1988	30	7 bands	183	GeoTiff
Landsat 5	Dec. 1998	30	7 band	183	GeoTiff
Landsat 7	Nov. 2007	30	8 band	183	GeoTiff
Landsat 8	Nov. 2018	30	11 band	183	GeoTiff

2.3. Data pre-processing

For change detection, various requirements of pre-processing, for example, geometric correction, radiometric and atmospheric corrections are the most important to avoid errors results produced from these problems. In this study, all downloaded images were level-1 products which were rectified, geometrically and topographically corrected. Image pre-processing for all the images such as filling missed pixels and registration were carried out using software ENVI 5.1 and ArcGIS 10.3.

2.4. NDVI categorization

The normalized difference vegetation index (NDVI) is a numerical indicator that uses the visible band (red) and near-infrared bands of the electromagnetic spectrum to assess and analyze vegetation cover whether the target being observed contains live green vegetation or not, for that we used NDVI to assess and monitor the changes in EL-Rawashda forest from 1988 to 2018. The range of NDVI values was derived based on the following equation:

$$NDVI = \frac{NIR - R}{NIR + R}$$

Where: NIR= near infrared, R= red

The given values range between -1 and +1, where values less than 0 represent areas that contain no vegetation and values greater than 0 represent pixels or areas in which vegetation is increasing (Hassan et al, 2018).

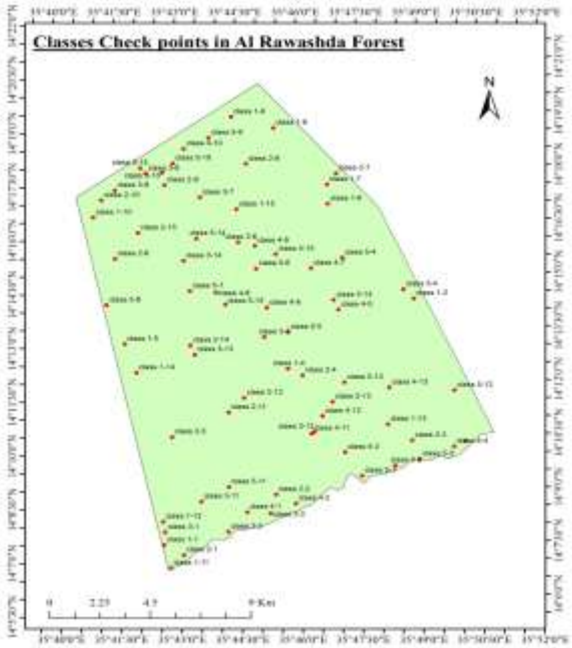

Fig. 2. Location and distributions of the training sites collected through the field survey.

2.5. Accuracy assessment

Assessment of final produced land cover maps were carried out to determine the quality of information derived from the Landsat data. For the accuracy, the classified image of 2018 was assessed by using 75 reference points that collected through the field survey and then compared the observed (reference points) label of every sample to the map label and the results summarized in confusion matrix. User's and producer's accuracies were then calculated for each land cover category as shown in Table 2. While maps for 1988, 1998 and 2007 were assessed using high-resolution image of Google Earth Pro.

Table 2. Classification accuracy assessment of 2015 classified forest cover map.

Categories		Class types determined from reference source					Total	UA
	Plots	BL	GLT	HDS	HDT	AG		
Class types determined from classified map	BL	14	1	0	0	0	15	93.33%
	GLT	0	13	0	1	1	15	86.66%
	HDS	0	2	12	0	1	15	80%

HDT	0	0	0	15	0	15	100%
AG	0	0	0	0	15	15	100%
Total	14	16	12	16	17	75	Total 92%
AP	100%	81.25%	100%	93.75%	88.23%		

2.6. Linear Trend (Slope):

Linear regression trend analysis that simulates the spatial trends of vegetation cover in point as well as can reflect different period of vegetation was calculated using ArcGIS10.3 according to the following Formula (Yagoub *et al*, 2017).

$$\theta\ slope = \frac{n \times \sum_{i=1}^{n} i \times NDVI_i - \sum_{i=1}^{n} \sum_{i=1}^{n} NDVI_i}{n \times \sum_{i=1}^{n} i^2 - \left(\sum_{i=1}^{n} i\right)^n}$$

Where:

i = the annual number

n = monitoring period (the cumulative number of years)

NDVI = NDVI mean value of the i year

Slope = pixel NDVI trends of the slope, if, indicating that the pixel NDVI value in n years is increasing, otherwise it is decreasing.

Slope study is categorized into deferent ranges refer to Yagoub (2017) witch significant improvement ($\theta > 0.03$), moderate improvement ($0.025 < \theta > 0.035$), mild improvement ($0.015 < \theta > 0.025$), no change ($-0.015 < \theta > 0.015$), Mild degradation ($-0.025 < \theta > -0.015$), Moderate degradation ($-0.035 < \theta > -0.025$) and Significant degradation ($\theta < -0.035$) , and the statistics of the study area in 1988-2018 vegetation changes and the percentage of each class area.

3. Results and discussions

The results of NDVI categorization revealed a thematic forest cover maps with five classes: Bare Land (BL), Grassland with Scattered Tress (GLT), High Density Shrubs (HDS), High-Density Trees (HDT) and Agricultural area in term of Toungya (AG). Fig. 3 and Fig. 4. showing the spatial distribution of different forest classes and their spatial coverage during the study lifespan (1988-2018), respectively. The change that has been occurred in the forest between 1988 and 2018 can be seen clearly in Fig.3.

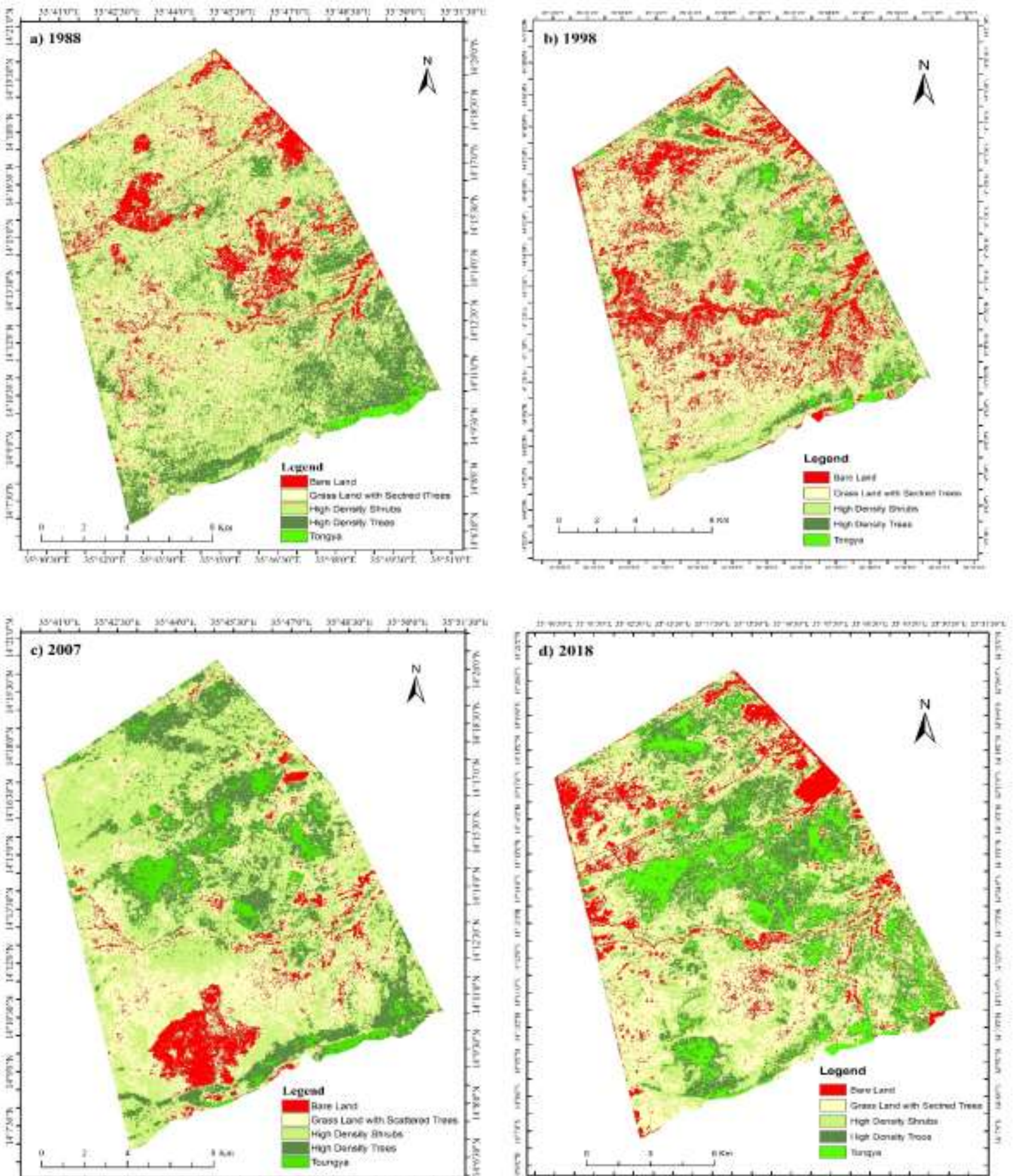

Fig. 3. El-Rawashda forest cover maps (a) 1988; (b) 1998; (c) 2007; (d) 2018

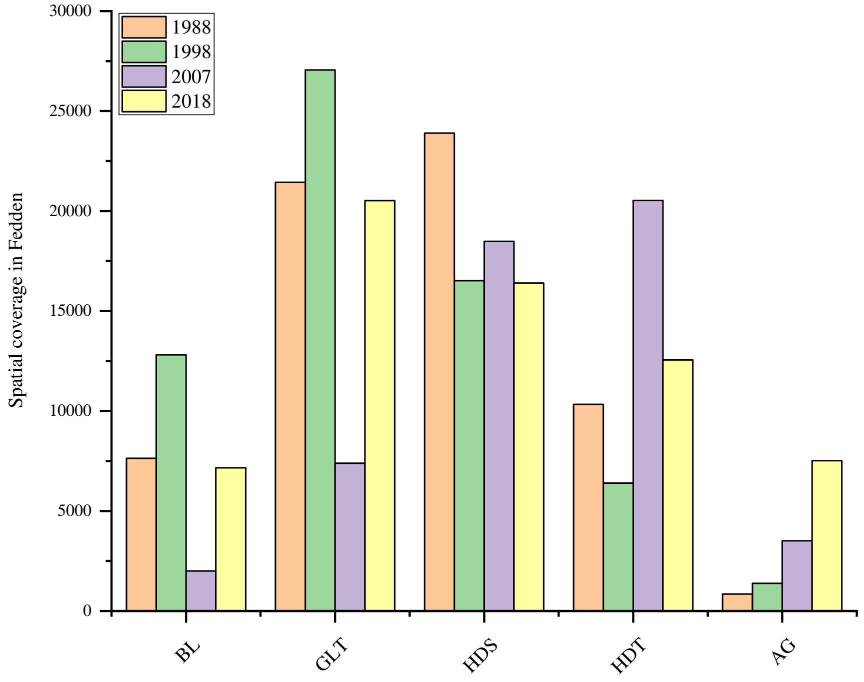

Fig. 4. Spatial coverage of different classes in EL-Rawashda forest from 1988 to 2018.

The produced forest cover map of 1998 depicted that, the GLT cover the largest portion of the forest area (27052 Fed) flowed by HDS (16516 Fed) and next is BL with an area of (12807 Fed) flowed by HDT with spatial coverage of almost (6399 Fed) and in the last AG with the cover area (845.8 Fed).

Form 1998 forest cover map the GLT was increased rapidly compared with the 1988 map and the AG also increased toward the forest center. While HDS and HDT were decreased over half. In 2007 the HDS occupying highest area (26365.9 Fed) flowed by GLS with high area coverage (16860.4 Fed) and then HDT with area coverage (12359.3 Fed) followed by BL with a cover of (5059.1 Fed) and in the last the AG with coverage (3511.7 Fed).

Forest cover map of 2007 showed that a clear decrease in forest cover NDVI and increase in AG, which was attributed to locusts attack in that year according to FAO annual report for the general situation of the desert locust and prediction 2007 in addition to fire effects. The forest cover map of 2018, showed that the highest land coverage was recorded by GLT (20520.8 Fed), HDS (16399.3 Fed), HDT (12559 Fed), flowed by AG with approximately an area of (7514 Fed) while BL cover only (7163 Fed). The forest cover map of 2018 showed that a clear change occurred when compared with previous years like AG expansion inside the forest under toungya system and increase of the GLT. The decrease of trees cover compare with previous situation of EL-Rawashada forest and that may be attributed mainly to the FNC management plan strategy.

Based on calculating by the linear regression analyze principle slope (θ) value between -1 and 1 of mean annual-NDVI in EL-Rawashda forest during the period of 1988 - 2018 by using Arc-GIS 10.3. The spaced reclassified from low to high value into seven categories which includes: significant degradation, moderate degradation, mild degradation, no change, mild improvement, moderate improvement and significant improvement.

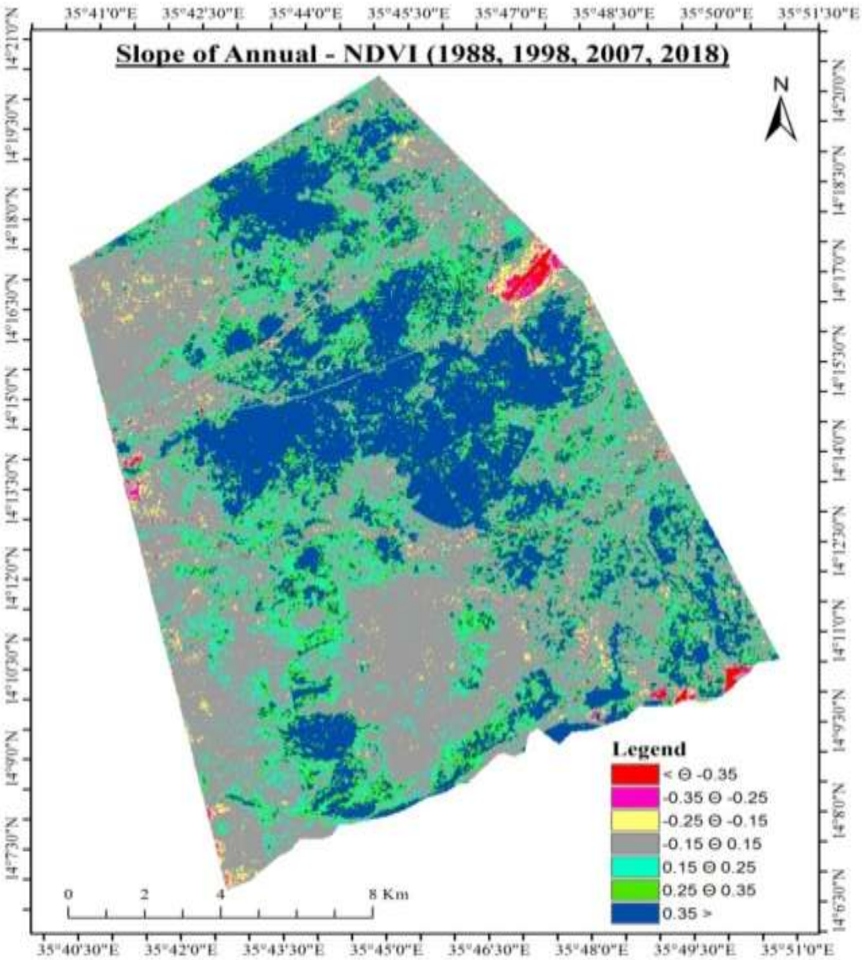

Fig. 5. Distribution of annual NDVI value over the study area slope (1988-2018).

Table 3. Statistical result of trend of mean annual-NDVI change simulated in El-Rawashada forest during 1988 – 2018

No.	Category	Θ Slope Range	Mean NDVI	
			Area / Fed	% of total area
1	Significant degradation	$\theta < -0.035$	244.5	0.38
2	Moderate degradation	$-0.035 < \theta > -0.025$	382.3	0.60
3	Mild degradation	$-0.025 < \theta > -0.015$	1367.6	2.13
4	No change	$-0.015 < \theta > 0.015$	28737.4	44.79
5	Mild improvement	$0.015 < \theta > 0.025$	8841.9	13.78
6	Moderate improvement	$0.025 < \theta > 0.035$	6700.1	10.44
7	Significant improvement	$\theta > 0.03$	17883.9	27.87

Fig. 5 and Table 3 shows there is generally improved of vegetation cover in the center and northern part of EL-Rawashada forest, while in the eastern, southern part and some margin area were degraded. The spatial variation of vegetation cover in order is: significant degradation is an area of 244.5 fed account 0.38 % of the total area; moderate degradation is an area of 382.3 fed account 2.1 % of the total area; mild degradation is an area of 1367.6 fed account 2.13 % of the total area; no change is an area of 28737.4 fed account 44.79 % of the total area; mild improvement an area of 8841.9 fed account 13.78 % of the total area; moderate improvement is an area of 6700.1fed account 10.44 % of the total area and significant improvement in an area of 17883.9 fed account 27.87 % of the total area.

4. Conclusion

Landsat imagery a significant difference in the forest covers from 1988 to 2018. The Slope analysis map indicates that the change in the El Rawashda Forest reached almost 56 % divided between degradation and development. Further, the Slope map indicates that the vegetation cover was developed especially in the center while the field observation showed there is a positive change in AG areas. Climate change and anthropogenic influences were the major factors of el Rawashda Forest cover change beside the forest management practices. To be mentioned clear-cutting and tree clearance for cultivation were the main causes of forest cover change. These results showed the usefulness of Landsat imagery and field data to highlight the impacts of El Rawashda Forest cover change on the climate of the area and changing the forest ecosystem. Moreover, the study results could provide necessary input to refine the policies and decisions and further to improve forest management in the area.

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