

Research Application Summary

Impacts of land use/land cover dynamics on desertification in gum Arabic belt, Ennuhud locality, West Kordofan State, Sudan

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Abstract

Desertification is a challenging issue in sub-Sahara Africa and Arab world. It is results from destruction of natural resources, agricultural lands and their political and social disturbances. Monitoring of desertification and land degradation is a very important task in the context of global climatic change and worldwide desertification dynamic. Ennuhud locality is one of the key areas for gum production in Sudan, besides other land use activities. However, the locality is characterised by its vulnerability to desertification. This paper presents results of application of remote sensing techniques in land use/land cover analysis in areas vulnerable to desertification in Ennuhud locality, West Kordofan State. It is also highlights the role of the gum Arabic belts as a natural barrier against desertification since the *Acacia senegal* tree is considered as a tolerant tree species in harsh environment. The data is based on collection of 254 control point with the aid of GPS and Land sat satellites imagery for 2014, 2002 and 1994. The total area covered within the locality was 117188.6 ha. Other data were obtained from secondary sources. The result of LULC classification showed five classes: Hashab stands, grass/bush land, mixed woody vegetation, Bareland/agriculture and residential area. The overall increase in Hashab stands was 7%, with grass/bush land showing an increase of about 6%, mixed woody trees also showed an increase of about 6% and residential area increased by 1.6% while the area of baobab trees/citrus gardens and the area of Bareland/agriculture diminished by 17.6% and 3%, respectively. The Accuracy of the classification was performed in terms of producer and user accuracy in addition to Kappa statistic. The study also included mapping of LULC status and resources-base using remote sensing technology and consequently monitoring the deterioration and desertification in gum Arabic belt on large scale. It is concluded that that the reduction in forest land and the increase in bare land/agriculture gives a sign of desertification. The different transformation in land use systems resulted in an instability of the resource use.

Key words: *Acacia senegal*, Ennuhud locality, desertification, remote sensing, West Kordofan, vulnerable areas

Résumé

La désertification reste un défi majeur en Afrique subsaharienne et dans le monde arabe. Elle résulte de la destruction des ressources naturelles, des terres agricoles et des perturbations politiques et sociales. Le suivi de la désertification et de la dégradation des terres est très important dans le contexte du changement climatique mondial et de la dynamique mondiale de désertification. La localité d'Ennuhud est l'une des zones clés pour la production de gomme au Soudan, en plus d'autres activités des formes d'utilisation des terres. Toutefois, cette localité se caractérise par sa vulnérabilité à la désertification. Cet article présente les résultats de l'application des techniques de télédétection dans l'analyse de l'utilisation des terres/couverture terrestre dans les zones vulnérables à la désertification dans la localité d'Ennuhud, dans l'Ouest de l'État de Kordofan. Il met également en évidence le rôle des ceintures de gomme arabique en tant que barrière naturelle contre la désertification. Les données sont obtenues à partir de 254 points de contrôle à l'aide de GPS et d'images satellitaires Landsat pour 2014, 2002 et 1994. La superficie totale couverte dans la localité était de 117188,6 ha. D'autres données ont été obtenues de sources secondaires. Le résultat de la classification a montré cinq classes: peuplements Hashab, les formations herbeuses, la végétation ligneuse mixte, les terres nues/agricoles et zone résidentielle. L'augmentation globale dans les peuplements de Hashab était de 7%, les formations herbeuses montrant une augmentation d'environ 6%, la végétation ligneuse mixte a également augmenté d'environ 6% et la superficie résidentielle de 1,6% tandis que la superficie des baobabs/jardins d'agrumes et la superficie des terres nues/agricoles a diminué de 17,6% et 3%, respectivement. La précision de la classification a été aussi réalisée. L'étude a également inclus une cartographie du statut des formes d'utilisation des terres et couverture végétale à l'aide de la télédétection et, par conséquent, le suivi de la détérioration et de la désertification de la ceinture de gomme arabique à grande échelle. La réduction du couvert forestier et l'augmentation des terres nues/agriculture donnent un signe de désertification. La transformation différente des systèmes d'utilisation des terres a entraîné une instabilité de l'utilisation des ressources.

Mots clés : *Acacia senegal*, localité d'Ennuhud, désertification, télédétection, Ouest Kordofan, zones vulnérables

Introduction

Arid and semi-arid regions are some of the most active areas of environmental research (UNEP, 1992) and (Khiry *et al.*, 2015). A key characteristic of most arid ecosystems is that the relation between vegetation dynamics and environmental variations in climate, soils and negative impacts of anthropogenic activities (Westoby *et al.*, 1998) and (Khiry *et al.*, 2015). The region affected by drought and desertification in Sudan lies between the latitudes 12° N and 18° N and covers the country from east to west (Khiry, 2006). Remote sensing has been recommended for long time as a cost-efficient method for monitoring change in arid environments (Khiry *et al.*, 2015). In respect to this, there are many efforts in has been exerted to develop different remotely sensed methods for mapping and monitoring the degradation in dry land areas (Eman *et al.*, 2013). There are several factors affecting accurate retrieval of vegetation parameters in arid regions using remote sensing. Furthermore, remote sensing of arid regions is difficult

and needs innovative techniques (Pickup, 1993; Ray, 1995). The spatial complexity of arid regions restricts the use of traditional remote sensing approaches (Khiry *et al.*, 2007) and (Mona *et al.*, 2011). This is mainly because the changes in geographical location often do not indicate structural or functional variations. Although studies at the global scale have documented changes in ecosystem in arid lands, there has been a shortage of global ecological information on dry lands. Accordingly, many other means of mapping and monitoring the changes in arid regions have been developed (Flores *et al.*, 2007). The term land use is defined as a series of activities undertaken to produce one or more goods or services. A given land use may take place on one, or more than one, piece of land and several land uses may occur on the same piece of land (Gregorio and Jansen, 1998). While the term land cover is the observed physical cover, as seen from the ground or through remote sensing, including the vegetation and human constructions (buildings and roads) which cover the earth's surface. Water, ice, bare rock or sand surfaces count as land cover (Gregorio and Jansen, 1998), so it is very difficult to differentiate between the two terms the land use and the land cover. Consequently, remote sensing techniques was used to map land use/land cover dynamics in areas vulnerable to desertification and to highlight the role of the gum Arabic belts as a natural barrier against desertification. This is because *Acacia senegal* tree is considered as tolerant tree species in harsh environment in Ennuhud locality, West Kordofan State.

Methodology

Study area. The target area located within Ennuhud locality in West Kordofan State, Sudan. It is situated between latitudes 12.60° to 13.03° N and longitudes 28.23° to 28.55° E, path and row 176/51 (Figure 1). It covers an area of 117188.6 ha. Traditional agriculture is the main human activity in this area beside gum Arabic production as off season activity. Also the livestock took part as one of the important activities in this area.

Data acquisition. The data were acquired from different sources, these are: 1) remote sensing data set in term of satellite imagery, 2) Field ground control points and 3) supporting literature review which was taken from relevant secondary sources. Satellite data were obtained from land sat dated 2014, 2002 and 1994 corresponding to land sat satellite 8, 7 and 5, respectively. The images were pre-processed for atmospheric correction and enhancement by the aid of Quantum GIS (version 2.6.1). Unsupervised/supervised classification were performed using ERDAS software (version 9.2). Accuracy assessment was done via calculation of user accuracy, producer accuracy and overall all accuracy as well as kappa statistic ($K^{\wedge}$). And finally, confusion matrices was achieved. The supported field data for images classification and accuracy purposes, a ground survey was conducted and a number of 254 ground control points were taken using Garmin Geographical positioning system (GPS) with Accuracy of 1. While literature review were collected from scientific publications, books and reports.

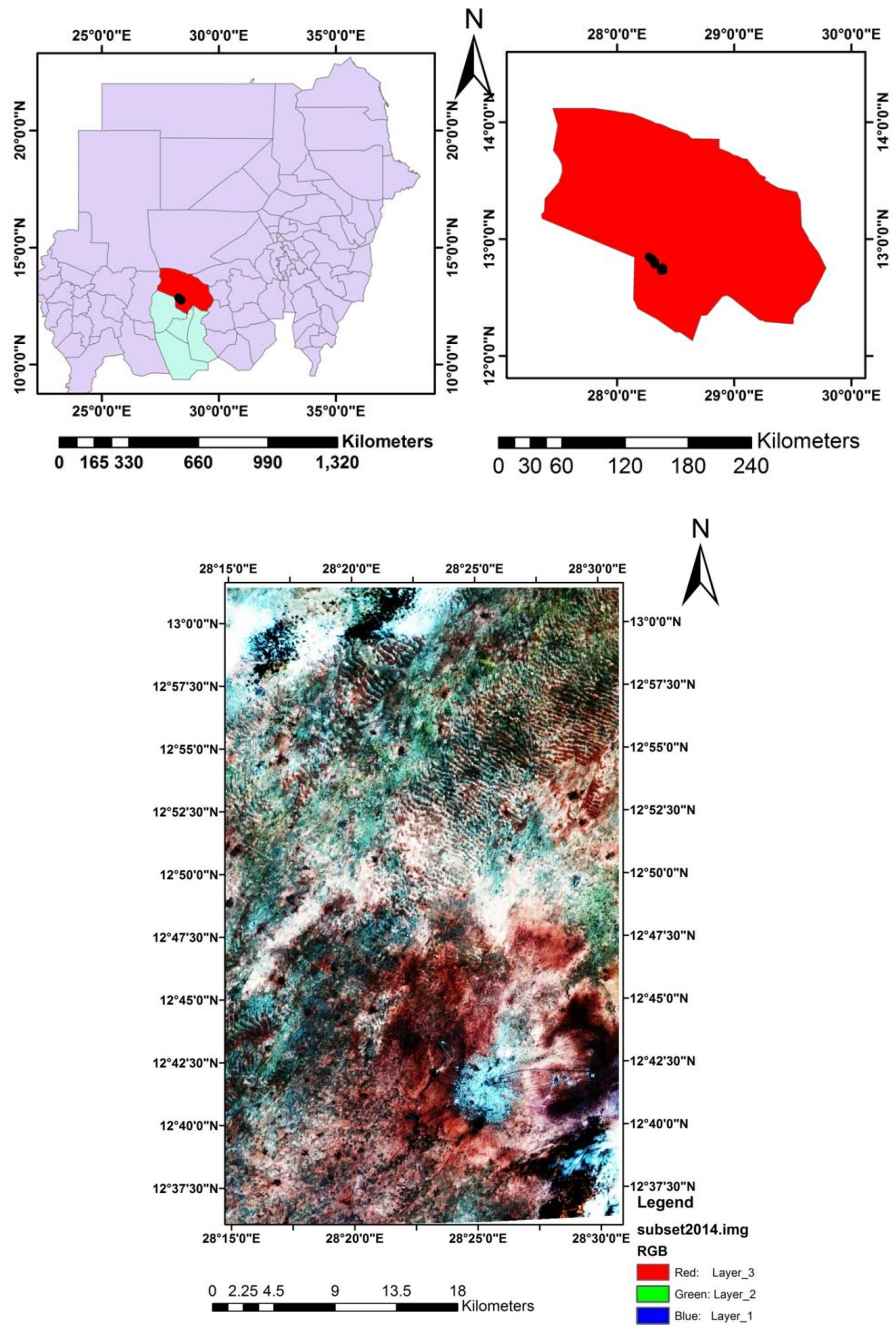


Figure 1. The study area

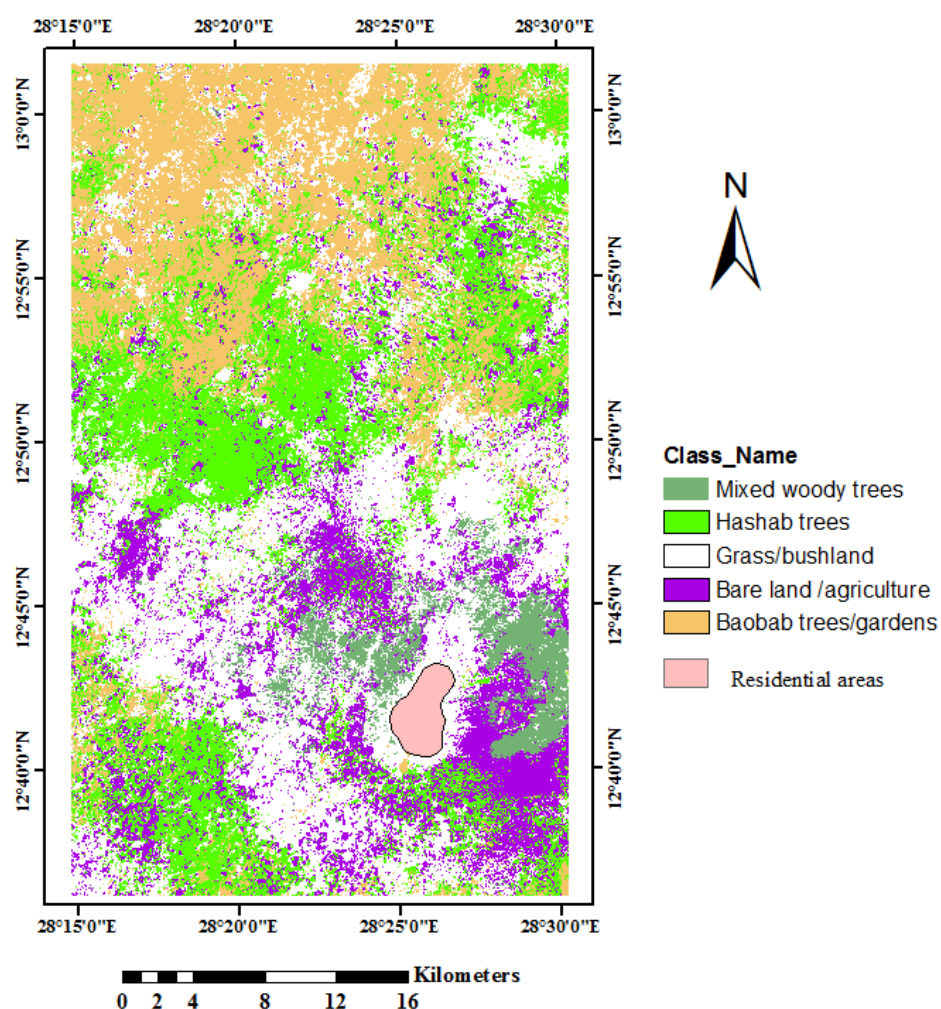
Results

Land use land cover temporal analysis. The supervised classification of images resulted in six classes for land uses in the study area: Hashab trees, grass/bush land, mixed woody trees, baobab trees and gardens, and bare land/ agriculture, while the residential areas was masked out and then added as class number six (Table 1 and Figures 2-4) due to the fact that this class is mixed with rangeland since the houses were from local building materials mainly straw.

Table 1. Land use land cover distribution in Ennuhud locality

	Area1994/ha	%	Area2002/ha	%	Area2014/ha	%
1	32317.50	27.6	29002.43	24.7	40785.67	34.8
2	30160.29	25.7	34988.78	29.9	37479.16	32.0
3	6015.54	5.1	12114.65	10.3	12758.28	10.9
4	28651.44	24.4	25307.39	21.6	8020.905	6.8
5	18850.17	16.1	13804.94	11.8	15076.38	12.9
6	1193.63	1.0	1970.354	1.7	3068.15	2.6
Total area/ha	117188.6	100.0	117188.6	100.0	117188.6	100.0

1= Hashab trees, 2= Grass/Bushland, 3= Mixed woody trees, 4= Baobab trees and gardens, 5= Bareland/ agriculture, 6 = Residential areas

**Figure 2. Temporal analysis of land use land cover classification in Ennuhud locality in 1994**

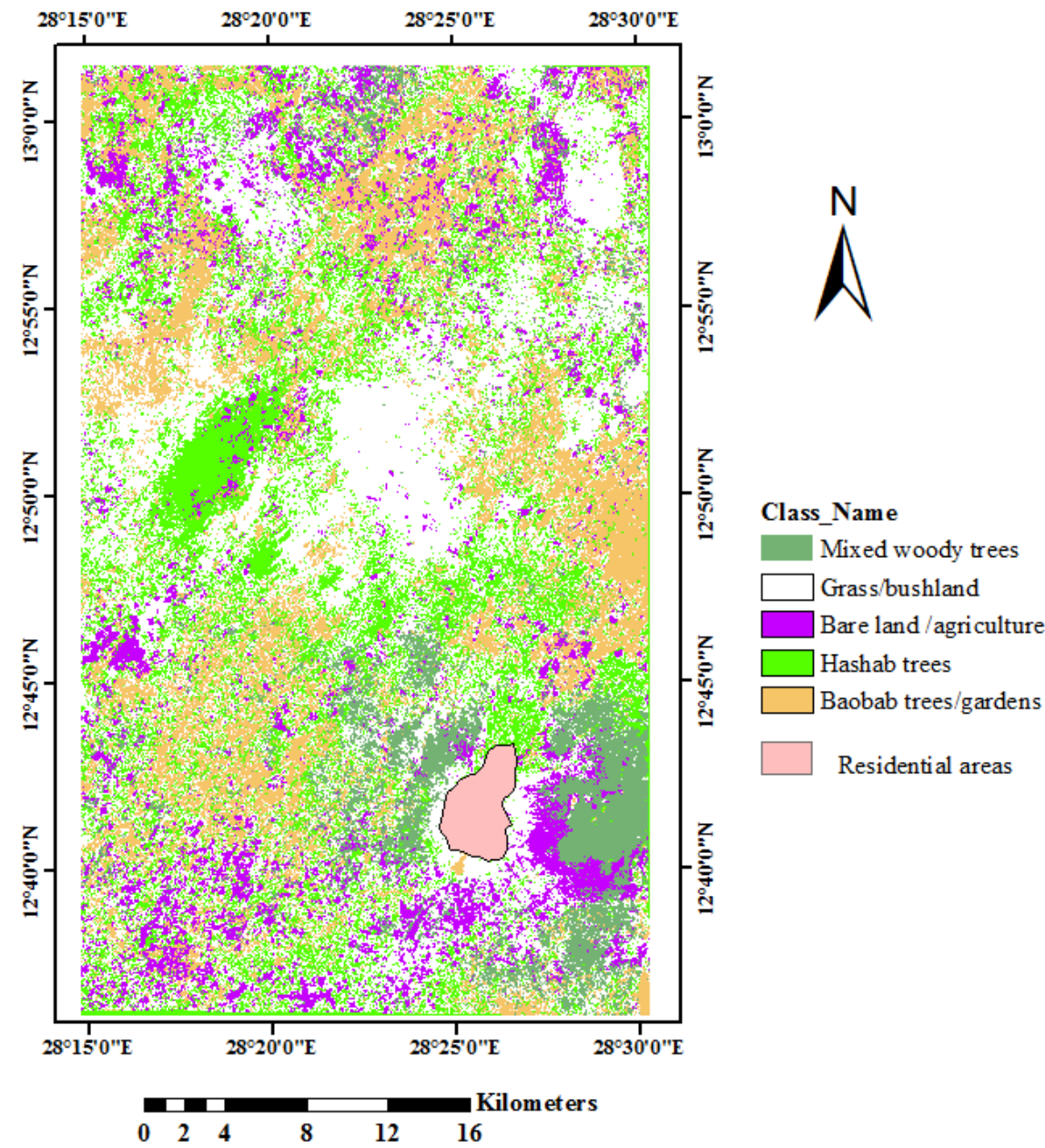


Figure 3. Temporal analysis of land use land cover classification in Ennuhud locality in 2002

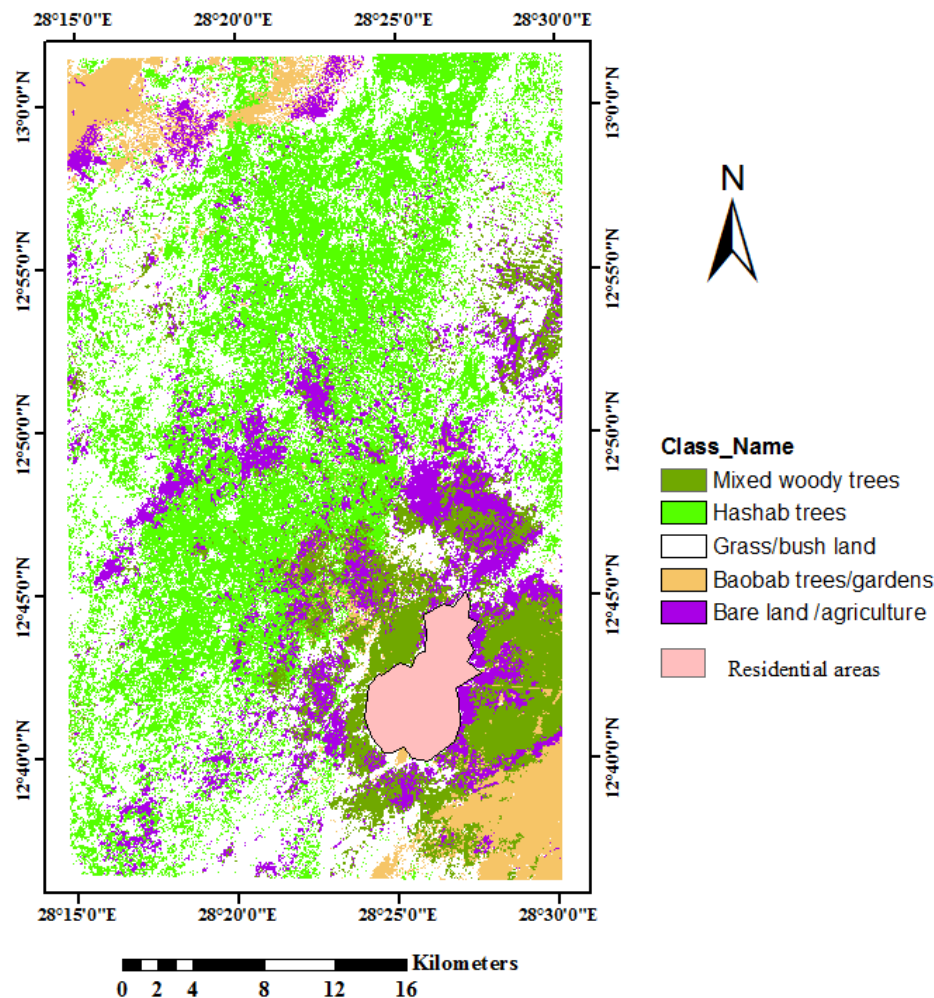


Figure 4. Temporal analysis of land use land cover classification in Ennuhud locality in 2014

Transformation of land use/land cover in Ennuhud site. During years from 1994 to 2002, as it is presented in Table 2, the land use land cover structure (LULC) in the gum arabic belt is obviously changed, and a reciprocal conversion between different types of LULC took place frequently. The dynamics of land use land cover is characterised mainly by the decreasing in forest dominated by *Acacia senegal* stands by about 3% from 28% to 24 %, the loss in this class was distributed among the class of grass/bushland, mixed woody trees and residential areas. While the class of Baobab trees and garden; and the class of bare land /agricultural showed a decreasing trends.

With referenced to the second study period during 2002 and 2014, the land use land cover dynamics is presented in Table 3. The results showed an increase in the *Acacia senegal* class by about 10% from 24.6% to 34.1%. The increasing in this class in the expense of class of mixed woody trees. Also the class of grass/bushland is slightly increase by about 1%. Also the class of mixed woody trees decreased by 8.4% and the class of bareland/agriculture is also decreased while the class of baobab trees and gardens and other ever green trees near by water sources showed an increase (5.2%).

Table 2. Confusion matrix of land use land cover by area in percent during 1994 – 2002 in targeted area in Ennuhud locality, West Kordofan State

Land use classes		1	2	3	4	5	Total 1994 area/ha (Occupancy rate %)
1		7843.14	10302.3	4703.13	1234.44	5007.69	29090.7
	%	31.7	33.1	22.6	11.1	32.0	28.1
2		6675.66	8813.07	5837.13	2211.03	4282.83	27819.72
	%	27.0	28.3	28.0	19.9	27.4	26.9
3		6118.02	5936.22	8226.81	1157.31	4194	25632.36
	%	24.7	19.0	39.5	10.4	26.8	24.8
4		782.64	1172.52	242.64	3273.21	265.95	5736.96
	%	3.2	3.8	1.2	29.5	1.7	5.5
5		3346.29	4945.59	1822.32	3237.48	1907.1	15258.78
	%	13.5	15.9	8.7	29.1	12.2	14.7
Total 2002 area/ha		24765.75	31169.7	20832.03	11113.47	15657.57	103538.5
Occupancy rate %		24.0	30.0	20.1	10.7	15.1	100.0

1= Hashab trees, 2= Grass/Bushland, 3= Mixed woody trees, 4= Baobab trees and gardens, 5= Bareland/ agriculture

Table 3. Land use land cover confusion matrix during 2002 – 2014 in targeted area, Ennuhud locality

Land use classes		1	2	3	4	5	Total 2002 area/ha (occupancy rate %)
1		9419.602	8935.762	2054.482	1521.542	3506.132	25437.52
	%	26.7	27.5	15.4	18.5	24.6	24.6
2		10473.3	10433.5	3667.592	1836.562	4806.432	31217.39
	%	29.7	32.1	27.6	22.3	33.7	30.2
3		10634	7583.002	770.522	1461.002	1607.602	22056.13
	%	30.1	23.4	5.8	17.7	11.3	21.3
4		1445.222	1286.192	5045.942	2034.412	1725.912	11537.68
	%	4.1	4.0	37.9	24.7	12.1	11.1
5		3300.802	4217.092	1770.862	1382.312	2618.732	13289.8
	%	9.4	13.0	13.3	16.8	18.4	12.8
Total 2014 occupancy rate area/ha	%	35272.93 34.1	32455.55 31.3	13309.4 12.9	8235.83 8.0	14264.81 13.8	103538.5 100

1= Hashab trees, 2= Grass/Bushland, 3= Mixed woody trees, 4= Baobab trees and gardens, 5= Bareland/ agriculture

When the transformation of land use/land cover is concerned over the whole period of the study (1994 – 2014), Table 4 showed that the area of Acacia senegal trees (Hashab trees class) is considerably increased by 6.6%, grassland class showed increased by 6%, mixed woody trees class rather than Hashab trees is increased by 6.8 %. These classes were increased in

the expenses in of mainly baobab trees, gardens and evergreen trees class - which showed a sharp decreased of about 15.9% and the class of Bareland/agriculture which decreased by 3%.

Accuracy assessment. Classification accuracy of images 2014, 2002 and 1994 was carried out in terms of Error matrix and

accuracy total tables and the corresponding overall accuracy for the three classified imageries as well. Error matrix for the reference points which were randomly taken for the landsat8 satellite image 2014 was performed and the producers', users' and overall accuracies are presented in Table 5. The overall accuracy was 92.4%.

Table 4. Land use land cover conversion matrix during 1994 – 2014 in targeted area, Ennuhud locality

Land use classes	1	2	3	4	5	Total 1994 area/ha (occupancy rate)
1	10424.08	11749.02	1651.652	1369.722	4059.062	29253.54
%	28.9	35.7	13.1	17.7	28.5	28.3
2	10135.52	8546.862	3209.792	1072.952	3872.152	26837.28
%	28.1	26.0	25.5	13.9	27.2	25.9
3	11160.57	8006.522	402.9416	3012.002	1624.532	24206.57
%	30.9	24.3	3.2	38.9	11.4	23.4
4	442.5216	306.9316	3701.352	240.9416	917.9716	5609.718
%	1.2	0.9	29.4	3.1	6.5	5.4
5	3932.812	4273.952	3624.762	2045.102	3754.792	17631.42
%	10.9	13.0	28.8	26.4	26.4	17.0
Total 2014	36095.51	32883.29	12590.5	7740.718	14228.51	103538.5
occupancy rate %	34.93	1.8	12.2	7.5	13.7	100.0

1= Hashab trees, 2= Grass/Bush land, 3= Mixed woody trees, 4= Baobab trees and gardens, 5= Bare land/ agriculture

Table 5. Accuracy total for reference values of the landsat8 image 2014

Class name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Hashab trees	68	73	65	0.95	0.89
Bushland	70	65	64	0.91	0.98
Mixed woody trees	26	24	23	0.88	0.96
Baobab trees and gardens	11	13	10	0.90	0.77
Residential areas	26	25	23	0.88	0.92
Bareland /Agric	26	23	21	0.95	0.91
Totals	223	223	206		

Overall Classification Accuracy = 92.4%

Error matrix for the reference points which were randomly taken for the landsat7 satellite image 2002. Accuracy assessment for the classification of image in year 2002, producers' accuracy and users' accuracy for the classes were summarized in Table (6) with overall classification accuracy of 88.70%.

Total accuracy assessment for the land sat5 classified image for the year 1994 is shown in Table 7 for the part concerned error matrix. Producer's accuracy and user's accuracy for the classes of classified image 1994 are also presented in Table (7) and the overall classification accuracy was found to be 84.80%.

Table 6. Accuracy total for reference values of landsat7 image 2002

Class name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy (%)	Users Accuracy (%)
Hashab trees	44	46	36	0.82	0.78
Grass/Bushland	72	66	63	0.88	0.95
Mixed woody trees	25	25	24	0.96	0.96
Baobab trees and Gardens	29	35	27	0.93	0.77
Residential areas	25	25	23	0.92	0.92
Bare land/agriculture	28	26	25	0.89	0.96
Totals	223	223	198		

Overall Classification Accuracy = 88.7%

Table 7. Accuracy total for reference values of landsat5 image 1994

Class name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy (%)	Users Accuracy (%)
Hashab trees	69	70	61	0.884058	0.871429
Grass/Bushland	55	45	38	0.690909	0.844444
Mixed woody trees	15	13	12	0.8	0.923077
Baobab trees and Gardens	54	55	51	0.944444	0.927273
Residential areas	30	40	27	0.90	0.675
Bare land/agriculture	223	223	189	0.847534	
Totals					

Overall Classification Accuracy = 84.80%

Kappa statistics ($K^{\wedge}$). The kappa-statistic measure of agreement is scaled to be 0 when the amount of agreement is what would be expected to be observed by chance and 1 when there is perfect agreement. For intermediate values, Landis and Koch (1977a) suggest the following interpretations: 0.0 Poor, 0.00 – 0.20 Slight, 0.21 – 0.40 Fair, 0.41 – 0.60, Moderate 0.61 – 0.80 Substantial, and 0.81 – 1.00 Almost perfect. So beside the accuracy assessment of the classification, kappa statistics ($K^{\wedge}$) was performed for the three imagery dated 2014, 2002 and 1994; the results revealed overall Kappa statistics of 0.90, 0.85 and 0.80, respectively as showed in Table 8. So the classification of the images is almost perfect for 2014 and 2002 while the classification of the image in 1994 reveals substantial. Therefore, the classification of the three images is accurate.

Table 8. Conditional Kappa for each Category of land use land cover in 1994, 2002 and 2014

	Kappa	Kappa	Kappa
Class Name	2014	2002	1994
Hashab stands	0.86	0.73	0.81
Bare land/Agriculture	0.94	0.94	0.65
Grass/Bush land	0.96	0.86	0.83
Mixed woody trees	0.83	0.74	0.82
Baobab trees, even green trees and gardens	0.92	0.96	0.87
Overall Kappa Statistics	0.90	0.85	0.80

Discussion

The temporal analyses of the land sat satellite images reveal that six classes for land uses in the study area were Mixed wood trees, Grass/bush land, Baobab trees, evergreen trees and gardens, Hashab trees and Bareland/agriculture. The study findings further reveal that the area of *Acacia senegal* (Hashab trees) decreased by 3% during the period 1994-2002 but increased by 10% during 2002-2014, the overall increase during the twenty years from 1994-2014 being 7%. This increase might be attributed to two reasons. Firstly, there was revitalization of Gum Arabic Production and Marketing Project which was funded by World Bank (WB) and executed by the First National Corporation in the area. It promoted the Gum arabic associations and producers to increase the area of Hashab trees. Secondly the better prices for gum arabic commodity encourage the producers to look after their Hashab tree to increase their income from this produce as stated by CBS (2013). These results to some extent concur with the findings of Adam (2011) who observed five classes in the area of path/row of 175/5: bare/farm, bush land, forest dominated by Hashab and mixed woody trees. The only difference is that this study resulted in a class for big and mixed trees within the path/row of 176/51 and the other classes were the same as Adam (2011). The study of Adam (2011) found that the area covered by Hashab trees in 1985 was 41631.1 ha (27.09%) and decreased to 32724.8 ha (21.29%) in 1999 then increased to 37221.3 ha (24.21%) in 2007 due to the starting of Revitalization of Gum Arabic Production and Marketing Project in the area. Mey *et al.* (2013) reported that the annual rate of deforestation is close to 504 ha and Sudan's loss of soil fertility and physical loss of soil due to erosion and desertification are critical issues throughout the country.

Moreover, Almost 30% of Sudan is classified as desert. An estimated 50 to 200 km southward shift of the boundary between semi-desert and desert occurred since the 1930s. Most of the remaining semi-arid and low rainfall savannah, representing approximately 25% of Sudan's agricultural land, is at considerable risk of further desertification. Desertification is projected to continue to move southwards due to climate change and changing rainfall patterns causing an estimated 20% drop in food production. Overgrazing, inappropriate agricultural practices and deforestation mainly cause land degradation. The rapid population growth and growth in livestock has led to a marked increased demand for lands for grazing and agriculture.

Conclusion

The sustainable development in Sudan needs to optimize use of remote sensing techniques for better understanding of processes of land use land cover changes. This paper concludes that remote sensing plays an effective role in desertification and land degradation monitoring in arid lands in Sudan since some of the free satellite data became available e.g Landsat data. Hence international cooperation can strongly support the adoption of multidisciplinary use of remote sensing in Sudan. This study concluded that the reduction in forest land and the increase in bare land/agriculture is a sign of desertification. The different transformation in land use systems resulted in an instability of the resource use. Although there is some sort of deterioration in the forest resource in the gum belt in the target area, there was on-going effort through the revitalization of gum arabic production and marketing project which had been implemented by FNC. Therefore it is recommended to conduct remote sensing for more detailed studies focusing on the spatial dimensions of impacts due to human activities on water resources management, on monitoring of rangeland and agricultural land and on food security and desertification monitoring.

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