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ASSESSMENT OF LAND USE AND LAND COVER CHANGES IN *ERRAHAD* LOCALITY, SUDAN, USING REMOTE SENSING AND GIS

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study aimed to identify, assess and mapping of land use and land cover in the period of 1985 to 2015 in Errahad Locality in North Kordofan State, Sudan. In addition, to investigate the impacts of socio-economic activities on land use and land cover. Three landsat images with multi-temporal dates (TM 1985, TM 1995 and Landsat8 OLI 2015) were acquired in dry season. The images were geo-referenced and radiometrically corrected. Image classifications using supervised classification system by maximum likelihood were applied. A total number of 200 control points were registered using GPS. In the social survey, 50 respondents representing household were randomly interviewed using structured questionnaire with sampling percentage of 6% of the household in five villages. Remotely sensed data were processed and analyzed using ERDAS 9.1 and ArcGIS10.0 software, while social survey data were analyzed using Excel and SPSS. version18.0. Results showed that land use and land cover in Errahad Locality were identified and classified into six classes; bare lands, range lands, forests, agricultural lands, shrub lands and water bodies. The change of land use and land cover during the period 1985, 1995 and 2015 is indicated by the increase of agricultural lands as 14.34%, 23.08 and 28.87%, respectively. Also the range lands were increased from 23.46% (1995) to 26.04% (2015). However, during the same periods, forests and shrubs classes are decreasing from 14.61% to 11.56% and from 27.42% to 12.43%, respectively. The overall accuracy assessment of classified imagery from TM (1985), ETM+ (1995) and landsat8 LOI (2015) revealed 81%, 84% and 91% in Kappa statistics, respectively. The results of social survey revealed that 90% of the respondents owned a piece of the land in term of personal and tribal basis. The results confirmed that 50% of the respondents stated that overcutting of the trees (50%) climate change (10%) are most factors affecting the vegetation cover and land use. The study concluded with a witnessed degradation processes mainly in vegetation cover as a consequence of agricultural land expansion. The study recommended adoption of appropriate conservation and rehabilitation measures in forest and rangelands.

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1. INTRODUCTION

"Sudan's forests are important sources of food, timber, firewood, and habitat. fuel wood and charcoal supply amount to more than 75% of the country's energy needs. Forests also provide fodder for livestock, marketable non-wood products such as honey, gum Arabic, tubers and roots. Forests contribute to watershed quality by stabilizing off-site soil, reducing off-site sedimentation, reducing flood peaks on streams in small watersheds and replenishing groundwater and watercourses" [1]. "Forests and woodlands are estimated by the Forest National Corporation (FNC) as 21826166.62 hectares, equivalent to 11.60% of the area of Sudan" [2]. The importance of forests and natural resources is indisputable, when considering the developing countries especially areas situated in the arid and semi-arid climatic zones. The scarcity of forests resources in Sudan is further aggravated by a high deforestation rate. FAO [3] ranked "Sudan as the third country following by Brazil and Indonesia in terms of net forest loss per year between 2000 and 2005. Many factors are attributed to the deforestation in Sudan such as agricultural expansion, fires, overgrazing and illicit felling of trees for fuel wood". "Land use and land cover (LULC) changes have a significant influence on the ecosystem with impact on biotic diversity, soil degradation, ability of biological systems to support human needs and the vulnerability of places and people to climatic, economic and socio-political perturbation. Understanding these surface processes and predicting the impact on the environment and food production system is necessary for militating against the continuous negative impact of these changes" [4]. The Sudan Central Bureau of Statistics, in 2013 estimates the population of Sudan as 33,419,625 growing at 2.8%, with more than 30 million people living in rural areas, over 80% of Sudan's employment takes place in the agricultural sub-sector of the economy, the majority of the population are farmers and pastoralists living on subsistence farming and livestock herding in a nomadic way of life.

"Land Use and Land Cover applications involve both baseline mapping and subsequent monitoring, since timely information is required to know which current quantity of land and which type of use and to identify the land use and land cover changes from year to year" [5]. "This knowledge helps to develop strategies to balance conservation, conflicting uses, and developmental pressures. Remote sensing techniques have now become the single most effective method for land use and land cover data acquisition. Monitoring of vegetation by remote sensing techniques is an accepted and effective technique of resource assessment and is commonly used in the quantitative description of vegetative growth. Remote sensing uses the knowledge that radiation intensity within different wavelengths is often typically emitted by different objects, thus giving different objects different spectral signatures" [6].

"Land use and land cover are essential parameters to determine the situation of the land. Land Cover is a geographic feature, which may form reference base for many applications including forest management, rangeland planning to biodiversity and desertification" (FAO, 1995). "The increasing impact of land use and cover changes on the environment has been an issue of concern in the developed and the developing countries with consequential effects on sustainable development and long term impact on the other sectors of the economy. Hence information about LULC is essential for planning and management of natural resources. Analysis of the recent history of LULC offers a present-day baseline for assessing future landscape patterns and their consequences" [7]. "Desertification and land degradation are major problems in Sudan. As adverse physical and socio-economic consequence of persist leading to deterioration of land productivity and deterioration of livelihood. Remote sensing techniques are important in acquiring useful data of the earth or its surface by mean of sensors. These remotely collected data will be analyzed to obtain information about the objects, areas or phenomena being investigated" [8].

"The increasing impact of land use and land cover changes on the sustainability of the environment and agricultural production in North Kordofan State has been of concern for sustainable development process in the country. Increasing of population and rising of demand for food coupled with the fragile nature of the environment in the country, the consequential negative impact of land use and land cover for agricultural production and resource mining must be reduced for the long term sustainability of the environment and livelihood security of the citizens. Different research studies have tried to identify the impact of the different agricultural practices including crop and livestock production on the environment in the country and land use and land cover sustainability" [9]. However, there is need to carry out identifications and analysis of land use and land cover changes in localities of North Kordofan State. Therefore the study aims to identify, assess and map the land use land cover in Errahad Locality in North

Kordofan State during the last three decade. In addition, to investigate the impacts of socio-economic activities on the land use and land cover.

2. MATERIALS AND METHODS

2.1 Study Area

The study area covers Errahad locality with an area of about 8060.5 km^2 in the South East part of North Kordofan State between latitudes 12º 25' and 13º 45' N and longitude 29º 35' and 30º 30' E (Fig. 1). The mean annual temperature varies between 28° and 30°C but during summer the temperature can rise as high as 45°C during the daytime. The study area falls in the semi-desert zone with a single rainy season. In the northern parts of the study area, the dominant trees are: *Acacia senegal* (*Hashab), Acacia tortilis (Seyal), Leptadaenia pyrotechnica (Merikh), Calatorpis procera* (*Usher)* and scattered trees such as *Balanites aegyptiaca* (Higlig) , *Faidherbia albida* (*Haraz*).

2.2 Methodology

Primary data was collected from remote sensing, field survey questionnaire. Satellite imagery covering the study area were downloaded covering scene 174/51 (path/row), including Landsat5 Thematic Mapper (TM 1985 and TM 1995) and Landsat8 OLI (Operational Land Imager). The images were downloaded free of cost from the Global Land Cover Facility (GLCF) archive of Maryland University, USA and United States Geological Survey (USGS) web sites covering an area of (639538 ha). All of them are false colour composite (FCC). Image radiometric and geometric corrections for the three images were applied.

Field survey for land use and land cover classification was conducted in February 2015. A total number of 200 Ground Control Points (GCP) were randomly registered using Garmin Global Positioning System (GPS). Half of these points were used for supervised classification while the rest were used for accuracy assessment of the classified images. Supervised classification (maximum likelihood classification) based on the notion that a priori (known) information is used to classify image pixels by specifying various training areas representing LULC in the a scene [10]. Supervised classification is preferred by most researchers because it generally gives more accurate class definitions and higher accuracy than unsupervised approaches [1]. Accordingly, the classification process carried out using the Parallelepiped decision rule for the nonparametric signatures, the Maximum Likelihood parametric rule was used for the unclassified pixels; while the overlap pixels were been classified by order. The social data regarding the LULC was collected via a questionnaire which was designed and distributed randomly among 75 respondents from six villages with sampling percentage of 5% representing the households.

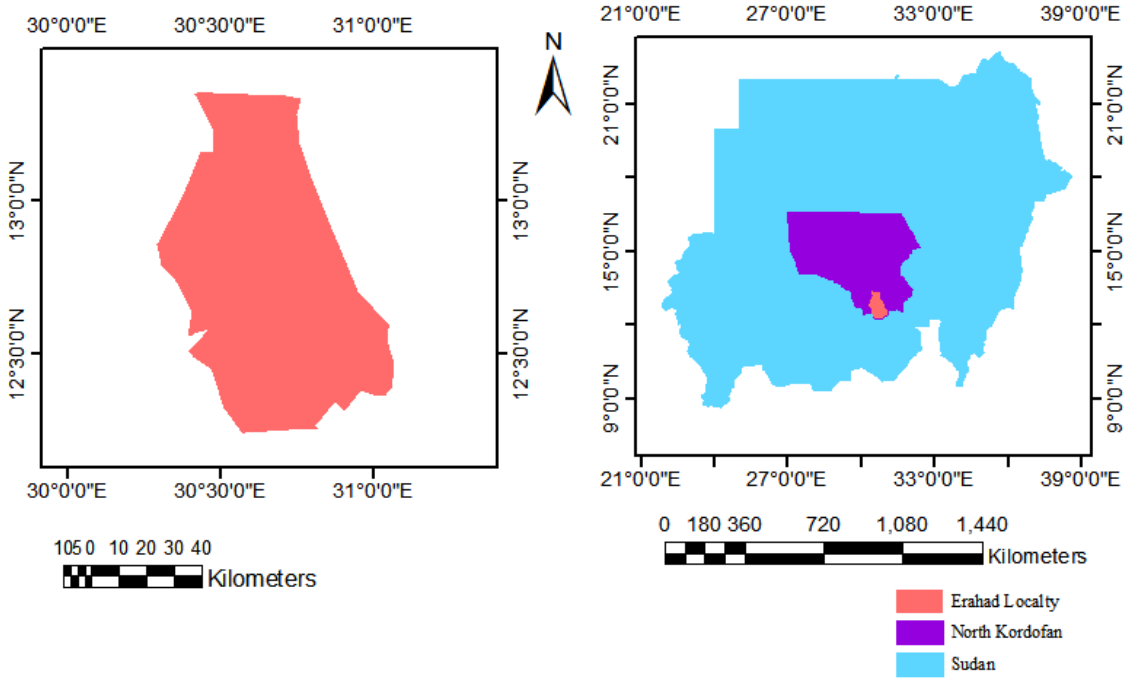

Fig. 1. Location of the study area

2.3 Data Analysis

The remotely sensed data was processed and analyzed by Earth Resources Data Analysis System (ERDAS) Imagine version 9.1 and ArcGIS version 10.0. The social data gathered from the questionnaires was analyzed Statistical Package for Social Sciences (SPSS) version 18 and Microsoft Excel 2007.

3. RESULTS AND DISCUSSION

The results of image classification identified and classified the LULC in Errahad Locality into six categories; bare lands, range lands, forests, agricultural lands, shrub lands and water bodies. The result goes in some classes in line with LULC results obtained from study conducted by Elamin (2016) in Ennuhud locality in West Kordofan State, which included: mixed wood trees, grass/bush land, Baobab and citrus gardens, Hashab trees, bare land/agriculture and residential areas. Other study of LULC also conducted in Elnuhud and Elkhawi localities in West Kordofan State by Adam [1] showed five classes namely: bare/farm, bush land, forest dominated by Hashab and mixed woody trees.

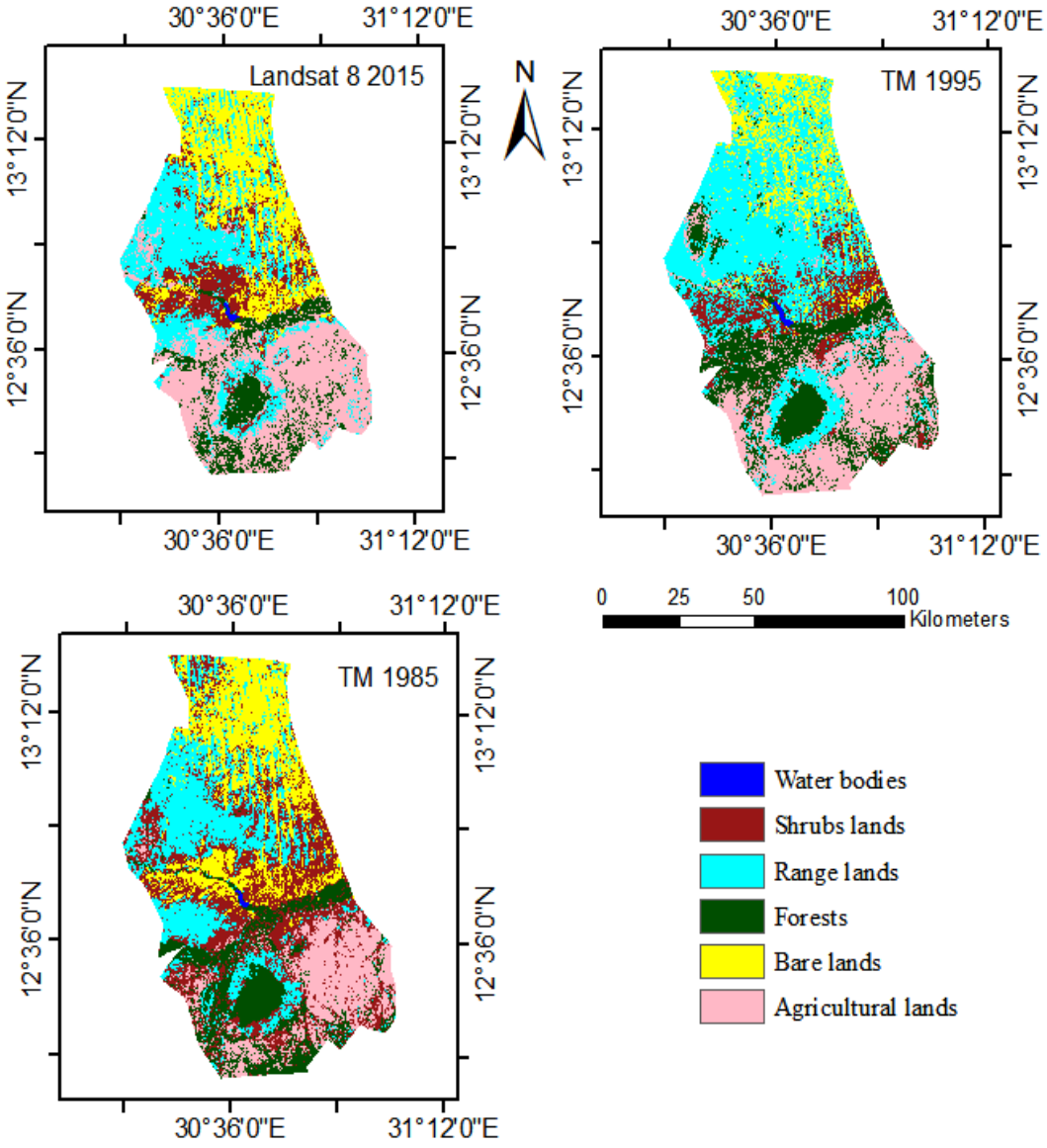

Fig. 2. Maps of LULC classes in Errahad Locality (2015, 1995 and 1985)

Table 1. Classification of LULC of landsat images (2015, 1995 and 1985)

No.	Class type	2015		1995		1985	
		area (ha)	%	area (ha)	%	area (ha)	%
1	Bare lands	133967	20.95	71305.5	11.15	128215	20.05
2	Range lands	166536	26.04	234933	36.73	150056	23.46
3	Forests	73911.2	11.56	122511	19.16	93415.9	14.61
4	Agricultural lands	184615	28.87	147610	23.08	91702.7	14.34
5	Shrub land	79495.2	12.43	61912.3	9.68	175369	27.42
6	Water bodies	1013.49	0.16	1266.66	0.20	779.76	0.12
	total	639538	100	639538	100	639538	100

Classification of the first dataset landast8 (2015) showed that the most dominant LULC was agriculture lands 184615 ha (28.87%) and range lands 166536 ha (26.04%), which collectively covered about 54.87% of the total area. Forest and shrubs lands represent the lowest coverage as 73911.2 (11.56%) and 79495.2 (12.43), respectively. While, bare land covers about 21% (133967) of the area. Also the most dominant classes in classified image in 1995 were presented by agriculture lands 147610 ha (23.08%) and range lands 234933 ha (36.73%) (Table 1) and (Fig. 2). The presented result in 2015 indicated that the extension in agricultural lands and increase of range lands areas were resulting in the reduction of the vegetation cover in the study area.

The collective of the woody vegetation (Forests and shrub lands) in 1995 covered 28.68%, which were decreased to 23.99% in 2015, while in 1985 it covered 42.03% (Table 1). The drastic reduction in woody vegetation the period from 1985 to 2015 is clearly due to the over cutting of trees, overgrazing, agricultural expansion, which agreed with results of Mohamedain [9] and Adam [1]. The range lands were increased from 23.46% to 36.73% in the period 1985 to 1995, respectively, which resulted in the reduction of the vegetation cover in the study area. Also, 80% of the respondents stated that the vegetation cover was the last three decades in Errahad Locality. The traditional rain-fed agriculture class constituted the most coverage of area in the studied years (1985,1995 and 2015), because it is categorized as main land use practised by local communities in the area. The *Acacia senegal* bush-fallow system as traditional practice, is the most practical way of sustaining crop production on the light sandy soils of Kordofan [11, 1]. The concept of customary tribal homeland is the most important constituent of traditional land tenure in Sudan, which has a direct effect on ways and spatial distribution of land use in North Kordofan State. Increasing in traditional agriculture areas is due to increase in population that resulted in a corresponding increase in human needs (cultivable land and wood fuel). This is in line with the general trend of increase of farm lands at the expense of forest to meet the increase demand of crops [12-14]. Moreover, climatic variation, mainly fluctuation in amount and distribution of rainfall (both spatially and temporally) and low soil fertility, in addition to the use of mechanized agricultural [15].

The results of accuracy assessment is presented Table 2 by overall accuracy assessment and Kappa coefficient which is a common and typical method as stated by Congalton and Green [16]. The overall accuracy assessment of classified imagery from TM (1985), ETM+ (1995) and landsat8 LOI (2015) is 81%,84% and 91%, while the Kappa statistics is 0.76, 0.79 and 0.89, respectively. This proves that the classification was within the very good range which was indicated by Pontius [17].

Table 2. Accuracy assessment of land use and land cover classification in Errahad locality

Class name	Landsat5 TM 1985		Landsat7 ETM+1995		Landsat8 2015	
	Producers' accuracy (%)	Users' accuracy (%)	Producers' accuracy (%)	Users' accuracy (%)	Producers' accuracy (%)	Users' accuracy (%)
1	80.00%	80.00%	85.71%	75.00%	77.78%	100.00%
2	75.00%	85.71%	88.24%	88.24%	100.00%	87.50%
3	50.00%	80.00%	60.00%	85.71%	80.00%	100.00%
4	100.00%	85.71%	100.00%	87.50%	92.86%	92.86%
5	100.00%	78.57%	100.00%	80.00%	100.00%	85.71%
Overall Accuracy	81.58%		84.44%		91.67%	
Kappa Statistics	0.7640		0.7947		0.8908	

1= Bare lands, 2= Range lands, 3= Forests, 4= Agricultural lands 5= Shrub lands

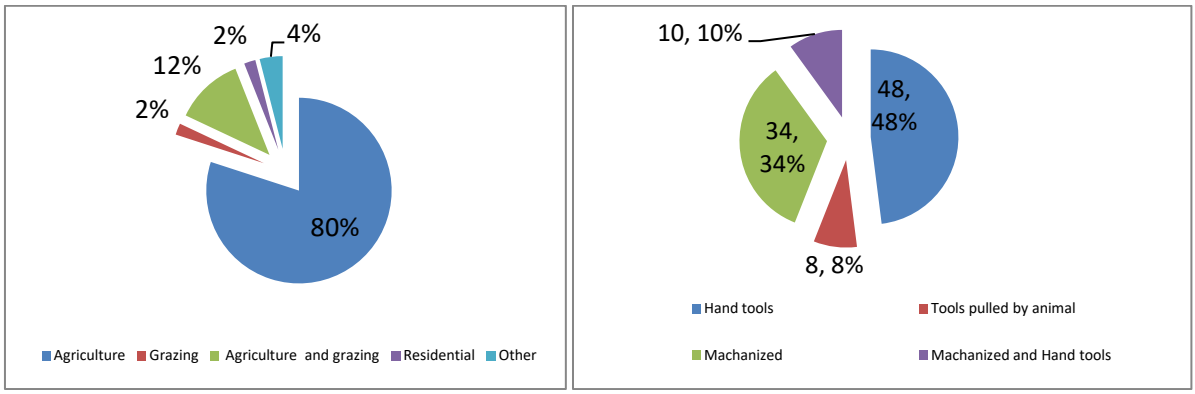

Fig. 3. Types of land use (left) and types of machine used in agricultural in Errahad locality (right)

The results of social data analysis revealed that 90% of the respondent owned a piece of the land indicating that most of the land in Errahad Locality is owned by the local community in term of personal and tribal basis. Also, the results showed that 80% of these owned lands are used land for agriculture practices because the main of the local people in North Kordofan is agriculture. While, 12% of the respondents indicating the use of their land for agriculture and grazing purposes (Fig. 2). It is noticed from the study area that a mechanized farming is recently known and introduced to Errahad Locality in the last years, which used in land preparation, sowing and harvesting activities by using hands tools (48%) and machines (34%) (Fig. 3). This information was also stated from analysis of the images (1985 to 2015) indicating the increase of agriculture and rangelands and decrease of woody vegetation

Practicing of agricultural operations (planting and weeding) by farmers is 52%, while 48% of them are doing weeding for the crops as mentioned by the respondents (Table 2).

Table 3. The distribution of agricultural operations in Errahad locality

Operation	Frequency	Percent
Planting and harvesting	26	52.0
Weeding	24	48.0
Total	50	100.0

According to the view of the respondent, 48% of the land cover in Errahad locality is agriculture lands and 30% is forest lands, while the range lands is constituted only 10% (Table 3). These results is coincide with the satellite image that indicated the agricultural lands is covering most area in the locality in the three studies years.

Table 4. Types of land cover according the view of respondents in Errahad locality

Land cover type	Frequency	Percent
Forest lands	15	30.0
Rand lands	5	10.0
Agriculture lands	24	48.0
Residential	3	6.0
Other	3	6.0
Total	50	100.0

Many activities and programmes have been conducted in the area to increase green coverage. The communities who contributed in these afforestation programmes and panting of trees is about 72% as indicated by the respondents (Table 4). Many factors affecting on these programmes to increase vegetation cover in Errahad area, from which overcutting of the trees (50%) and climate change (20%) and are the most influencing factor as indicated by the respondents (Table 5)

Table 5. Participation of the local community in the afforestation programme in Errahad locality

Participated	Frequency	Percent
Yes	36	72.0
No	14	28.0
Total	50	100.0

Table 6. Some factors affecting the vegetation cover in Errahad locality

Factors	Frequency	Percent
Climate change	10	20.0
Overgrazing	6	12.0
Overcutting	25	50.0
Over cutting and grazing	9	18.0
Total	50	100.0

The study come out with many non-biotic factors that affected change of land use and land use in Errahad Locality, from which the government planning representing 26% of the causes as stated by the respondents. While the residential, displacement of the people and the local disputes are representing 10% for each (Table 6). The displacement and migration of people from their lands are considered as factors cause the increase of vegetation cover, as Oslsson et al. [18] stated that migration consequence is often abandoned fields and reduced grazing pressure.

Table 7. Some causes of land use changes in Errahad locality

Factor	Frequency	Percent
Government planning	13	26.0
Residential	10	20.0
Displacement	10	20.0
Disputes	10	20.0
Migration	7	14.0
Others	50	100.0

4. CONCLUSION AND RECOMMENDATIONS

The study demonstrated that land use land cover change is a very serious environmental concern in the Errahad locality. A significant change has been observed in the patterns of land use and land cover types; this change is characterized mainly by decreasing of forest and shrub lands and increasing of rain-fed agriculture and rang lands. The study witnessed degradation processes mainly in vegetation cover as a consequence of agricultural land expansion. The study recommends adoption of appropriate conservation and rehabilitation measures in forest and range lands to reverse the adverse effects of land degradation and desertification. Improvement of environmental awareness and strengthening of policies and legislation should be promoted and implemented. Finally, conduction of plantation programmes in the locality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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