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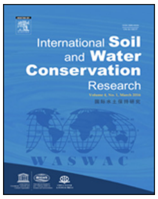

Original Research Article

Land use and land cover changes and Soil erosion in Yezat Watershed, North Western Ethiopia

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ABSTRACT

Soil erosion affects land qualities and water resources. This problem is severe in Ethiopia due to its topographic features. The present research was aimed to estimate spatiotemporal changes in land-use/land-cover pattern and soil erosion in the Yezat watershed in Ethiopia. This study was carried out by using landsat imageries of 2001, 2010 and 2015. Images were classified into categories using supervised classification by maximum likelihood algorithm. They were also classified into different biomass levels by using Normalized Difference Vegetation Index (NDVI) analysis. Revised Universal Soil Loss Equation modeling was applied in a GIS environment to quantify the potential soil erosion risk. The area under grassland, woodland and homesteads have increased by 610.69 (4%), 101.69 (0.67%) and 126.6 ha (0.83%) during 2001–2015. The extent of cultivated land and shrub/bushland was reduced by 323.43(0.02%) and 515.44 ha (3.41%), respectively, during the same period. The vegetation cover in the watershed decreased by 91% during 2001–2010, and increased by 88% during 2010–2015. Increase of NDVI values indicates better ground cover due to implementation of integrated watershed development program in the region. The estimated annual soil losses were 7.2 t ha^{-1} yr^{-1} in 2001, 7.7 t ha^{-1} yr^{-1}in 2010 and 4.8 t ha^{-1} yr^{-1}in 2015. Management interventions are necessary to improve the status and utilization of watershed resources in response to sustainable land management practices for sustainable livelihood of the local people.

1. Introduction

Environmental problems are alarming humanity all over the world. Its effects on ecosystem services challenge conservation, management and rehabilitation activities (Ayele, Suryabhagavan, & Sathishkumar, 2014; Haregeweyn et al., 2015; Zewdu, Suryabhagavan, & Balakrishnan, 2016). Land degradation and associated decline in the productive potential of agricultural lands are threatening economic and social well-being of the present and future generations (Berhanu & Suryabhagavan, 2014; Haregeweyn, Berhe, & Tsunekawa, 2012; Kouli, Soupios, & Vallianatos, 2009). Land degradation is one of the major and widespread environmental threats that the planet earth has been facing since long (Ganasri & Ramesh, 2016; Krishna Bahadur, 2009; Rawat, Mishra, & Bhattacharyya, 2016; Xu, Xu, & Meng, 2012). Soil erosion negatively affects the soil quality, decreasing agricultural efficiency, water intention properly, flooding, debris flow and habitat destruction as a whole (Kidane & Alemu, 2015; Park, Oh, Jeon, Jung, & Choi, 2011). In order to meet livelihoods, to address economic stress and to accelerate development, people in the developing countries utilize land and soil resources in an unsustainable way as evidenced by overgrazing, destruction of forest for urban expansion and high intensive and unscientific agricultural activities, and the resulted improper land-use/land-cover changes (de Meyer, Poesen, Isabirye, Deckers, & Raes, 2011). According to Hurni (1985b), degradation and loss of soil resulting from soil erosion was estimated to be about 20 t per hectare in Ethiopia, i.e., about 1 mm of soil depth per year. Ethiopia loses about 1.9 billion metric tons of fertile soil from the highlands every year and the degradation of land through soil erosion is increasing at a high rate (Fitsum, Pender, & Nega, 1999; Hurni, 1989). Similarly, as reported by Ethiopian highlands reclamation study, soil erosion was forecasted to cost the country 1.9 billion USD between 1985 and 2010

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(FAO, 1986). According to Phillips (1989, as cited in Maria, Pantelis, & Filippos, 2009), the off-site effects of erosion such as reservoir sedimentation and pollution of water resources are more costly and severe than the on-site effects on land resources. There are two main approaches to study soil erosion depending on spatial and temporal scales (Xu et al., 2012). The other is the off-site measurement through modeling, which can be applied to reveal potential patterns of the soil erosion, to evaluate soil erosion process from time to time on a larger scale.

In order to build a dynamic model, as many as possible criteria, which influence soil erosion, should be taken into consideration. The Universal Soil Loss Equation (USLE) was developed by Wischmeier and Smith (1978). The Revised Universal Soil Loss Equation (RUSLE) is a widely used soil erosion intensity evaluation model, modified and improved from the USLE, developed by Wischmeier (1976). Revised Universal Soil Loss Equation was developed to estimate the annual soil loss per unit area based on erosion factors. It provides an estimate of the severity of erosion and also numerical results that can validate the benefits of planned erosion control measures in areas of soil erosion risk. For the last over twenty years, multi-temporal, high-resolution, remotely sensed data and GIS have been used extensively to monitor environmental changes specifically, to assess soil erosion rate, to map land-cover changes on the local, regional and global scales (Ai, Fang, Zhang, & Shi, 2013; Checkol, 2014; Eweg, Van Lammeren, & Woldu, 1998; Gebreselassie, 1996; Girma, 2005; Ringo, 1999). Geographical information system technology is thus appropriate due to its powerful multi-criteria processing and calculation capability (Chretien, King, Jamagne, & Hardy, 1994). Moreover, highly significant spatio-temporal phenomena or changing patterns are revealed by applying GIS and remote sensing based soil erosion and land degradation modeling (Fistikoglu & Harmancioglu, 2002; Gelagay & Minale, 2016; Hoyos, 2005). Thus, evaluation and prediction are easy and faster to address hazards caused by soil erosion. The present study was aimed to detect the spatiotemporal changes in the status and utilization of watershed resources in response to sustainable land management interventions and to assess the extent and rate of soil erosion, which is a major driving force of land degradation.

2. Materials and methods

2.1. Study area

This study was conducted in Yezat watershed, West Gojam Zone of the Amhara Regional State of Ethiopia. It falls in two districts, *viz.*, Gonji Kolla and Yilmana Densa. This area is situated at 37°31'32"–37°31'32"E longitudes and from 11°08'22"–11°09'45"N latitudes covering a total area of about 15,085 ha (Fig. 1), around 430 km from Addis Ababa and 70 km south of Lake Tana, Bahir Dar Town, the capital of Amhara Regional State. The altitude of the study area ranges between 1485–3207 m. The slope gradient of the watershed ranges from 4 to 66.5°. Higher elevation ranges are located at the southwest and eastern parts of the watershed (MoARD, 2006). According to the 2007 National Population and Housing Census, the two districts have a total population of 321,508 of which 160,709 are men and 160,829 are women. About 91.9% of the area is predominantly used for crop production. The livelihood of the people depends on mixed farming (Checkol, 2014). Based on the agro-climatic classification of Ethiopia (Hurni, 1986), the majority of the study watershed falls in Woina Dega agro-climatic zone (traditional climate classification), which is similar to dry sub-humid. Heavy rainfall causes in the area during June–October. Based on long term climatic data and the average annual rainfall of Adet meteorological station near the study area was 1508 mm and mean maximum and minimum temperatures were 29.6 °C and 12.9 °C, respectively. The highest mean monthly temperature was recorded in March and the lowest during December–January.

2.2. Soil and vegetation

According to the FAO-WRB (2006) soil map unit classification system, vertisols are the predominant soil type with the area coverage of 7166.2 ha in moderately gentle slopes and in very deep soils of the study area. This soil class can be characterized by heavy black clay, mostly water logged during the rainy season. It has high cation exchange capacity and base saturation content both in surface and subsurface horizons. The rest of the physiographic units are dominated by cambisols, regosols, luvisols, and leptosols. Moderately deep to very deep major soil types dominate the study area.

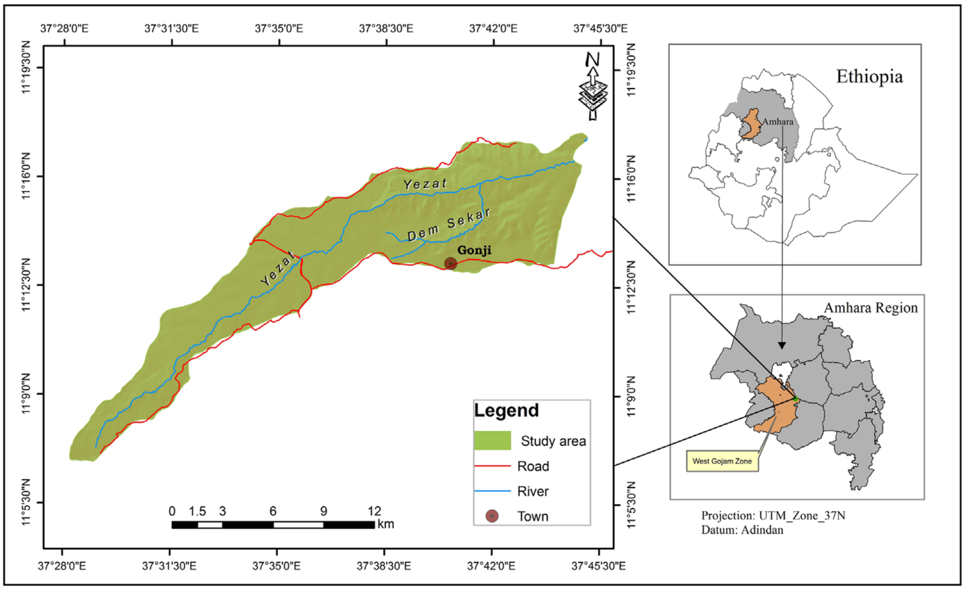


Fig. 1. Location map of the study area.

The main land-covers in the study area are: settlements surrounded by eucalyptus trees, cultivated land, grassland, woodland, and shrub/bushland. The vegetation consists of evergreen and semi-evergreen, small trees and occasionally larger trees. Depending on the landscape and topography of the watershed, there are different types of indigenous vegetation existing in the area. Major crops grown in the area are wheat, barley and sorghum. Few scattered trees such as *Acacia* sp., *Cordia africana* and *Croton* sp. are found in the farmland whereas, *Eucalyptus camaldulensis* in grown around the homestead. According to the information from farmers, the cultivated land has received urea and Diammonium phosphate fertilizers for most crops. They usually use crop residues for livestock feed. In addition, animals are allowed to graze on the cultivated land after harvest.

2.3. Method

2.3.1. Data acquisition and software

Time series landsat (TM, ETM+ and OLI) satellite data of 2001, 2010 and 2015 with path 169 and row 052 were used for developing land-use/land-cover maps of the study area and to determine C and P-factors used in RUSLE model. Field observations were also conducted to fix up training sites, to check ground truth, and to verify the final output of the maps. Shuttle Radar Topographic Mission (SRTM) digital elevation data of 30 m resolution were used in this study. Digital Image data files were downloaded in zipped files from the United State Geological Survey (USGS). All satellite imageries were geometrically rectified with the help of a topographic map (1:50,000) of the study area obtained from the Ethiopian Mapping Authority. This was used to digitize the contours and develop the Digital Elevation Model (DEM), in order to determine S and L-factors in the RUSLE. The soil map of the study area was obtained from the soil database compiled by Food and Agricultural Organization, collected from the Ministry of Agriculture, Federal Government of Ethiopia, and the soil types were classified to obtain K factor values. These were adapted to Ethiopia based on the FAO Soil Classification System (Hurni, 1985a). For determining the amount of soil loss in the study area, the relatively simple RUSLE soil erosion model was used. Remotely sensed data combined with further spatial information in a GIS environment to assess the extent and rate of annual soil loss.

Rainfall data of the study area for the years 1980–2013 obtained from National Meteorological Agency (NMA) of Ethiopia were used to determine the R-factor in RUSLE. All factors in the RUSLE were derived independently. The RUSLE was modified to suit Ethiopian Highlands conditions (Hurni, 1985a) and adapted for the present work to determine values for rainfall erosivity, soil erodibility, slope gradient, slope length, land-cover and conservation practice. Values of the rainfall erosivity factor, slope length factor, slope gradient factor, land cover factor and conservation practice factor were taken empirically by Hurni (1985a) who used trial plots in various parts of the Ethiopian highlands, whereas the quantitative soil erodibility factor was based on FAO Soil Degradation Assessment Methodology adjustments to the RUSLE model.

Remote sensing and GIS software used in this study were ERDAS Imagine®2014 for image classification. Image processing tasks and NDVI analysis were accomplished by using ENVI 5.1. GIS analysis was conducted using ArcGIS®10.2. Stream extraction, fill sinks and flow accumulation generation ware performed using Arc Hydro 10.2 Software plug-in into ArcGIS software. The DEM for the study area was analyzed and processed using ArcGIS®10.2 software and employing RUSLE calculations.

2.3.2. Data processing and analysis

Imageries of bands 4, 3, and 2 of Landsat TM and Landsat ETM+ and bands 5, 4, and 3 of Landsat-8 were used in image enhancement to identify changes in land-use/land-cover features in the study area. All satellite images were in TIFF format. They were exported to img format in ERDAS Imagine®2014 software using layer stack function. These images were georeferenced in to the same map projection of World Geodetic System 1984 Zone 37 N. All satellite images were sub-mapped (subset) for covering only the study area. In order to interpret and discriminate the surface features clearly, all satellite images were composed using Red Green Blue (RGB) color composition. False Color Composites (FCC) of satellite imageries were prepared for the years 2001 and 2010 using band 4 (NIR), band 3 (red), and band 2 (green) and for the year 2015 Landsat 8 using band 5(NIR), band 4(red) and band 3 (green) combination. Descriptions of the land-cover categories of the study watershed are shown in Table 1.

Normalized Difference Vegetation Index (NDVI) was used in this study for gaining information about the seasonal growth of vegetation condition, vegetation dynamics and as one of the input parameters for estimating the potential of erosion using RUSLE model. This index was also used to differentiate vegetation from other land-cover classes. It was estimated by the division of the difference between the near infrared and red reflection (visible wavelength observations) and the sum of these measurements using the formula Eq. (1):

$$NDVI = \frac{(NIR - R)}{(NIR + R)} \tag{1}$$

where, NIR is the reflectance value in near-infrared band; red is the reflectance value in the visible red band,

Landsat TM and ETM+, following the formula Eq. (2):

$$NDVI = \frac{(B4 - B3)}{(B4 + B3)} \tag{2}$$

where, B4 is band 4 (0.76–0.90 μm), which represents infrared band; and B3 is band 3 (0.63–0.69 μm), which represents red band for landsat TM or ETM+ imageries, and Landsat8 (OLI-TIRS), following the formula Eq. (3):

$$NDVI = \frac{(B5 - B4)}{(B5 + B4} \tag{3}$$

where, B5 is band 5 (0.85–0.88 μm), which represents infrared band and B4 is band 4 (0.64–0.67 μm), which represents red band for landsat 8 imagery.

Table 1
Land-use types of the study area.

Sr. no.	Land-use types	Description
1	Crop land	Areas of land ploughed and/or prepared for growing crops. This category includes most flat areas and also some steep slopes where various crops were grown, either on a rain-fed basis or using irrigation.
2	Grassland	Land refers to those land units allocated as a source of animal feed, including privately and communally owned grazing areas with < 10% tree cover.
3	Woodland	Areas covered with relatively tall and dense trees of *Eucalyptus globules* and other remnant trees forming closed canopies.
4	Shrub/bushland	Land that has perennial, woody shrub coverage of different species and bushes with widely varying density from one locality to another, often found in hilly areas.
5	Homesteads	Small rural communities and other man-made structures

2.3.3. Methods of woody biomass estimation

For woody type mapping, land use-/land-cover map of the study area were used. Land use-/land-cover map was prepared from landsat images. During land-use-/land-cover classification, ground truth data and Google earth satellite data were used as reference. Preliminary interpretation of satellite data was done visually on false color composite in order to stratify woody types (IPCC, 2003; Rosenqvist, Milne, Lucas, Inhofe, &, Dobson, 2003). Possible separability of various land-use/land-cover types with special reference to vegetation cover was studied using ground collected data for land-use/land-cover of the study area. Woody biomass available from tress was estimated using the following formula Eq. (4):

$$\begin{aligned}&\text{Growing stock (per ha)}\\&\quad = \text{Area under plantation or canopy (perha)} \times \text{productivity}\\&\qquad (m^3/\text{ha (peryear)}\end{aligned} \tag{4}$$

Productivity estimates made by FAO for indicative forest plantation yields by species and country for hardwood species grown in the tropical and subtropical zone were used (FAO, 1997). Productivity of *Eucalyptus* sp. of Ethiopia is 8.0–12.5 m^3/ha/year. By using this source compiled by FAO, the most dominant species grown in the study area is *Eucalyptus* species. Therefore, an average 10.25 m^3/ha/year was used to compute sustainable yield. Landsat satellite data were used to estimate the size of the woody stands.

2.3.4. Determining the RUSLE model and GIS Parameters

The following five parameters were used in the RUSLE model to estimate soil loss (Renard, Foster, Weesies, McCool, & Yoder, 1997): Rainfall erosivity (R), soil erodibility (K), slope length and steepness factor (LS), cover management factor (C) and conservation practice factor (P). Referring to RUSLE model, the relationship is expressed as Eq. (5):

$$A = R \times K \times LS \times C \times P \tag{5}$$

where, A: computed spatial annual soil loss ($\text{t ha}^{-1}\,\text{y}^{-1}$); R: rainfall erosivity factor ($\text{MJ mm h}^{-1}\,\text{ha}^{-1}\,\text{y}^{-1}$); K: soil erodibility factor ($\text{t ha}^{-1}\,\text{MJ}^{-1}\,\text{mm}^{-1}$); LS: slope length and steepness factor (dimensionless); C: land surface cover management factor (dimensionless); and P: erosion control or conservation practice factor (dimensionless). To identify the spatial pattern of potential soil erosion in the study area, all the above six erosion factors were surveyed and calculated depending on the recommendations of Hurni (1985b). The framework of the study is schematically shown in Fig. 2.

3. Results

3.1. Land-use/land-cover change detection

The land-use/land-cover maps were classified into five classes, such as cultivated land, woodland, grassland, shrub/bushland and homesteads with high classification accuracy (overall classification accuracy $>85\%$ and overall kappa coefficient $>80\%$) for each

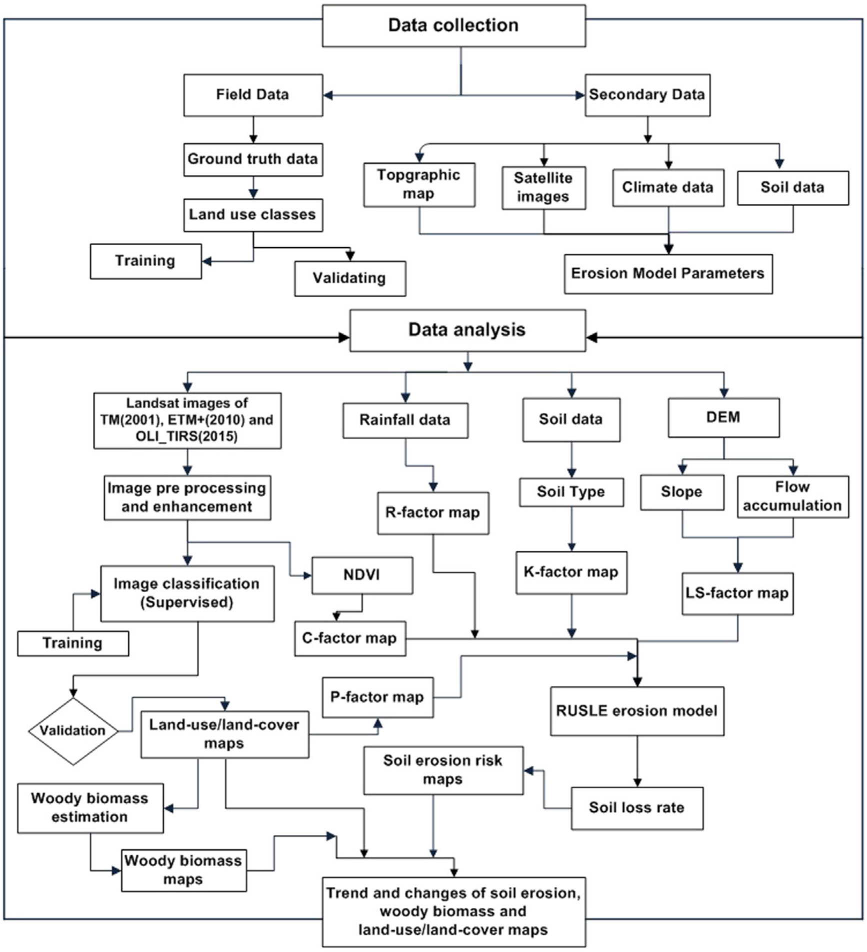


Fig. 2. Methodology framework of the study.

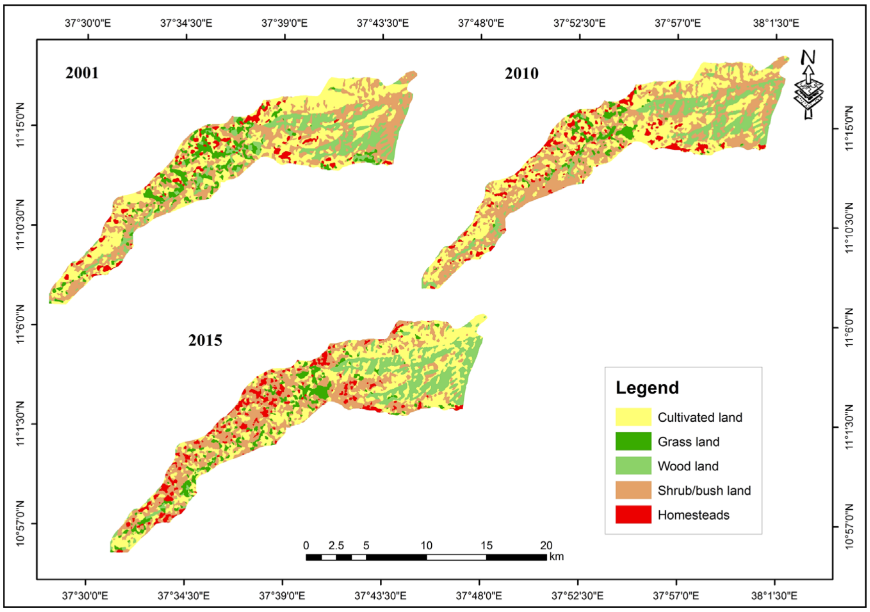


Fig. 3. Land-use/land-cover maps 2001, 2010 and 2015.

Table 2
Comparison of the areas of land-use/land-covers during 2001, 2010 and 2015.

Land-use classes	2001		2010		2015	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Grassland	1509.17	10	643.98	4.3	1254.53	8.3
Woodland	2322.35	15.4	2228.77	14.8	2330.46	15.5
Cultivated land	4886.72	32.4	5589.69	37	5266.26	35
Homesteads	738.63	4.9	1075.65	7.12	1202.25	7.96
Shrub/bush land	5628.11	37.3	5546.85	36.7	5031.46	33.35
Total	15,085	100	15,085	100	15,085	100

periods (2001, 2010 and 2015). Land-use/land-cover classification maps for the years 2001, 2010 and 2015 are given in Fig. 3. The spatial distribution of land-use/land-cover categories of the study area during the period 2001, 2010 and 2015 shows that cultivated land, woodland and homesteads areas have increased, while the extent of shrub/bushland declined continuously from 2001 till 2015. A comparison of different land-use/land-covers during these years is shown in Table 2.

As per the land-use/land-cover classification map of 2001, the watershed was covered with shrub/bushland (37.3%), while cultivated land, woodland, grassland and homesteads covered only 32.4%, 15.4%, 10% and 4.9%, respectively. By the year 2010, the extent of cultivated land and homesteads have increased to 37% and 7.12%, respectively, while that of shrub/bushland, woodland and grassland have decreased to 36.7%, 14.8% and 4.3%, respectively. By the year 2015, the extent of woodland increased by 15.5%, followed by grassland (8.3%) and homesteads (7.96%). The extent of shrub/bushland was decreased to 33.35% by the year 2015.

3.2. *Trends of land-use/land-cover changes*

From the results of classification during the 2001–2010 (Table 1), grassland and woodland areas have decreased. Especially the extent of grassland was decreased by 865.19 ha (−5.73%) during these nine year period. Areas under woodland and shrub/bush land were decreased by −93.58 ha (−0.62%) and −81.26 ha (−0.51%), respectively. Conversely, the extent of cultivated land and homesteads were increased by 702.97 ha (4.66%) and 337 ha (2.23%), respectively. Land-use/land-cover of the study area for the period 2010–2015 showed that extents of grassland, woodland and homesteads have increased by 610.69 ha (4%), 101.69 ha (0.67%) and 126.6 ha (0.83%), while the extents of cultivated land and shrub/bush land have decreased by 323.43 ha (0.02%) and 515.44 ha (3.41%), respectively. The change detection during 2001–2015 showed that the area coverage of cultivated land, woodland and homesteads have increased by 379.54 ha, 8.11 ha (2.51%) and 463.62 ha (0.05%), while grassland and shrub/bushland slightly decreased 255 ha (1.69%) and 596.65 ha (3.4%), respectively. The change of land-use/land-cover areas during 2001, 2010 and 2015 are shown in Table 3 and Fig. 4. The overall accuracy for land-use/land-cover of 2001 image classification was 85%, of 2010 was 91% and of 2015 was 93.2%.

3.3. *Estimation of spatial distribution of woody biomass production*

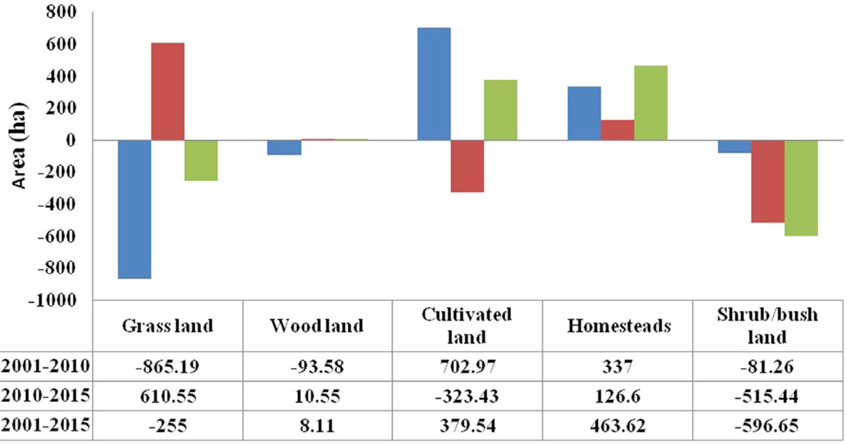
The estimated woody biomass production for 2001, 2010 and 2015 were 5844, 5706 and 5972 t/ha/yr, respectively (Fig. 5). The estimated woody biomass was less during the period 2001–2010. In the year 2015, significant increase in the woody biomass area was observed. This increase may be due to the interventions (transformed of wastelands to plantation, due to adoption of soil and water conservation practices, better utilization of surface and groundwater).

3.4. *Vegetation cover*

The range of NDVI values for 2001, 2010 and 2015 were, 0.025–0.75, −0.028–0.67 and −0.03–0.76, respectively. The NDVI map (Fig. 6) indicates that the vegetation was less during the period

Table 3
Land-cover classes and rates of change in the study area during 2001, 2010 and 2015.

Land-cover class	2001–2010		2010–2015		2001 – 2015	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Grassland	−865.19	−5.73	610.55	4	−255	−1.69
Woodland	−93.58	−0.62	101.69	0.67	8.11	0.05
Cultivated land	702.97	4.66	−323.43	−0.02	379.54	2.51
Homesteads	337	2.23	126.6	0.83	463.62	3.1
Shrub/bush land	−81.26	−0.51	−515.44	−3.41	−596.65	−3.4



	Grass land	Wood land	Cultivated land	Homesteads	Shrub/bush land
🟦 2001-2010	-865.19	-93.58	702.97	337	-81.26
🟥 2010-2015	610.55	10.55	-323.43	126.6	-515.44
🟩 2001-2015	-255	8.11	379.54	463.62	-596.65

Fig. 4. Land-use/land-cover changes in the study area during 2001–2010, 2010–2015 and 2001–2015.

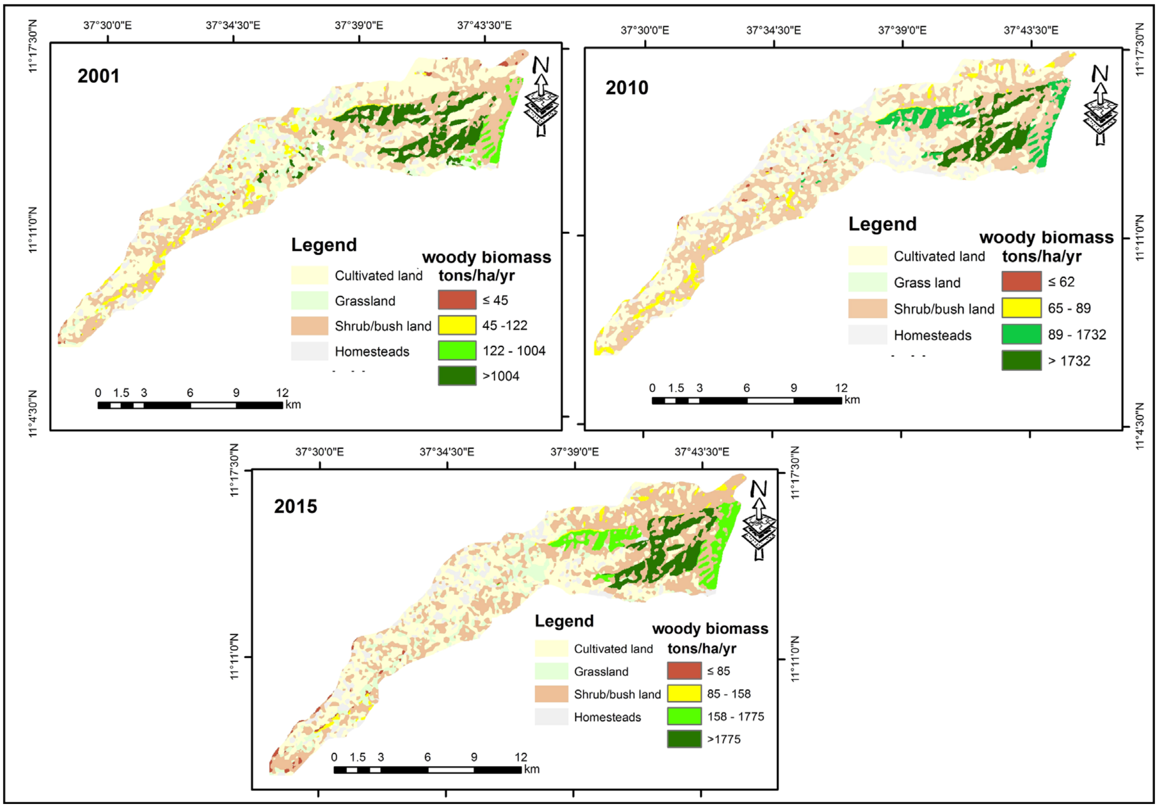


Fig. 5. Spatial distribution of the total above-ground biomass and estimation of woody biomass (2001, 2010 and 2015).

from 2001–2010, whereas during the period 2010–2015, there was significant increase observed. This increase may be due to adoption of soil and water conservation practices, better utilization of surface and ground water. It was also noticed that the NDVI values were higher in the central part of the watershed than the south and east during the study periods. Such indication could be of interest in understanding the hydrology of the area. The value of NDVI indicates the absence or presence of groundwater assuming that vegetation response to presence of water in the soil. Areas with denser vegetation, i.e. higher NDVI, may indicate areas with higher rainfall and presence of ground water, In the northwest and west parts of the watershed, low NDVI values were limited groundwater or low rainfall zones.

3.5. Soil loss rates

The predicted annual soil loss maps of the study area for 2001, 2010 and 2015 are given in Fig. 7. For the year 2001, annual soil loss ranged from 0 in the plain area to 201.4 metric tons ha^{-1} yr^{-1} in much of the steeper slopes of the banks of the tributaries in the watershed. The mean annual soil loss for the entire watershed was estimated at 7.2 metric tons ha^{-1} yr^{-1}.

For the year 2010, annual soil loss ranged from 0 in the plain area of the study watershed to 152.2 metric tons ha^{-1} yr^{-1} in much of the steeper slope banks of tributaries. The mean annual soil loss for the entire watershed was estimated at 7.7 metric tons ha^{-1} yr^{-1} for 2010. For the year 2015, annual soil loss ranged from

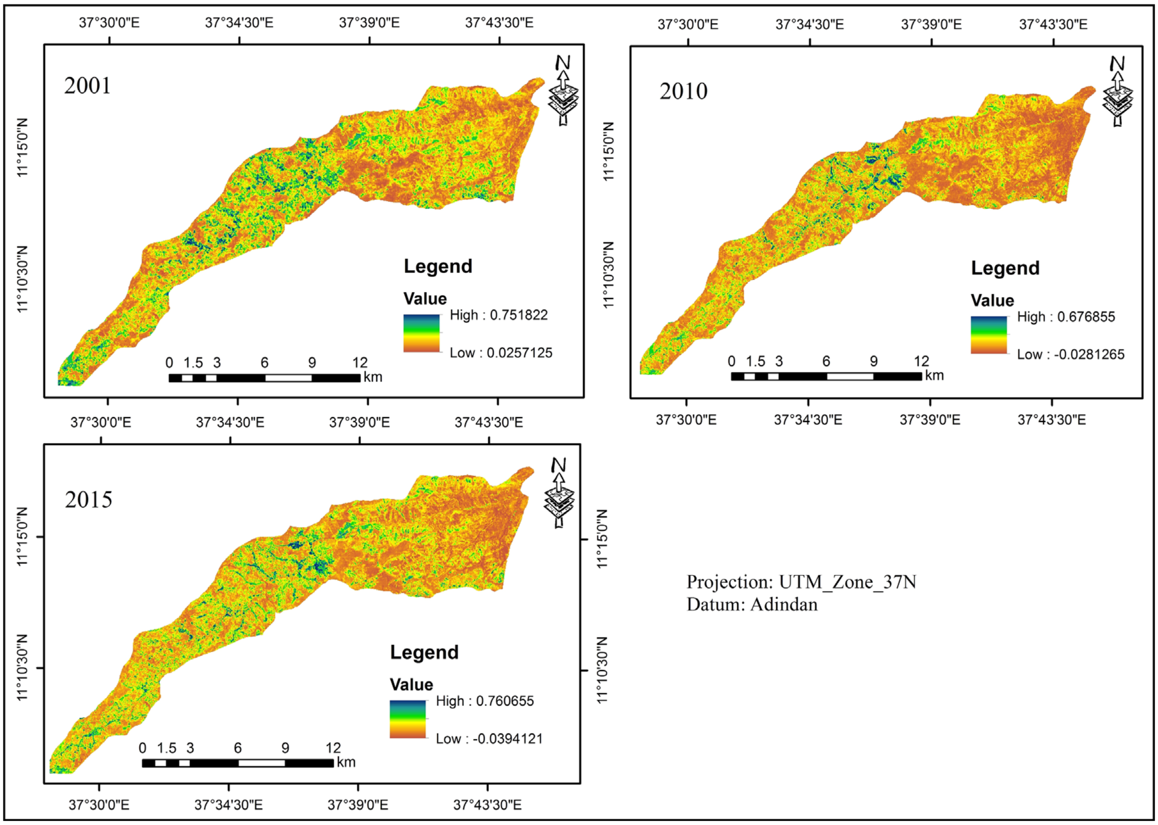


Fig. 6. NDVI index based vegetation cover status (2001, 2010 and 2015).

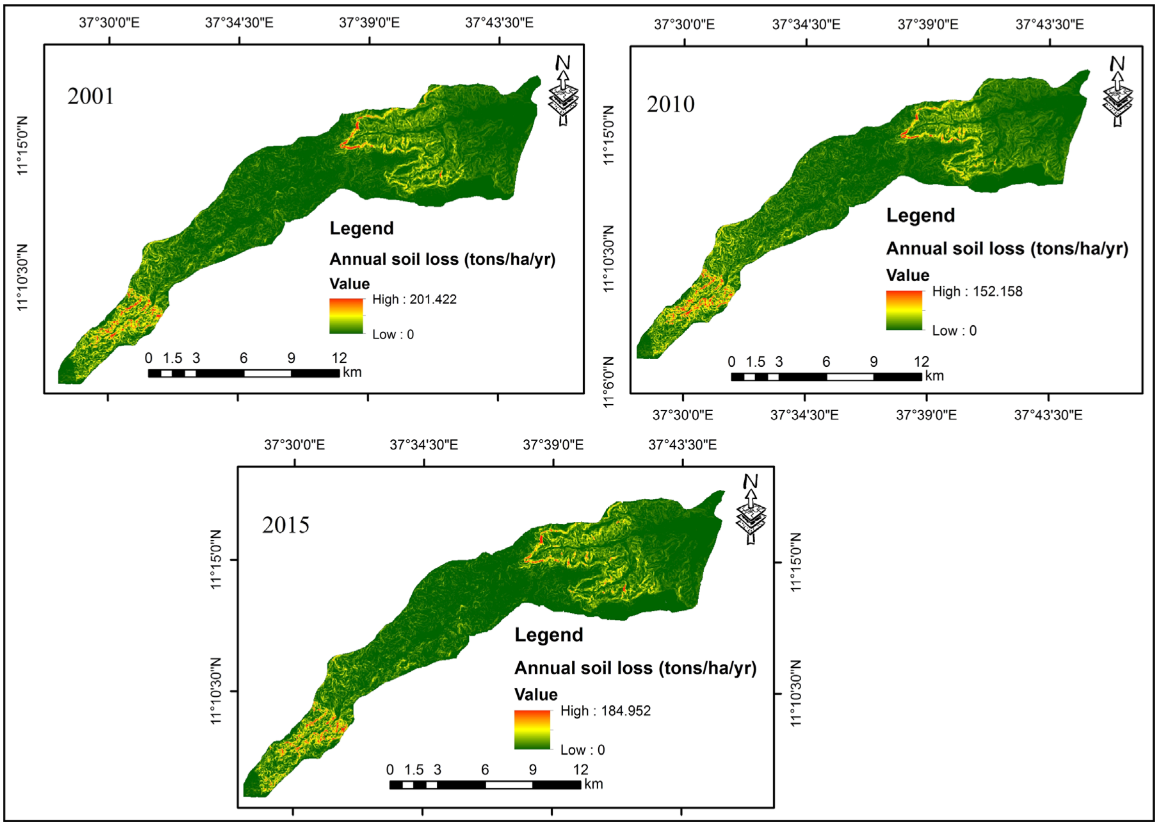


Fig. 7. Predicted annual soil loss maps of 2001, 2010 and 2015.

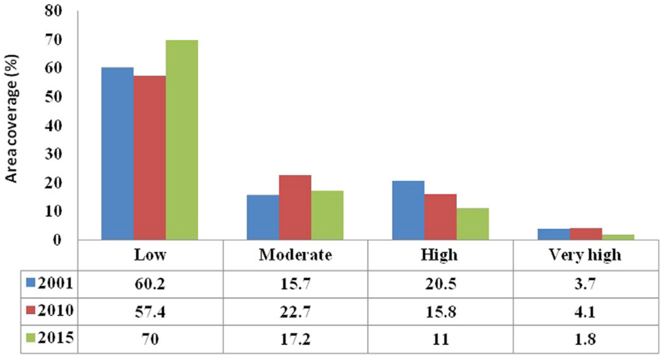


Fig. 8. Area coverage for the erosion risk map 2001, 2010 and 2015.

0 in the plain area to 184.9 metric tons ha^{-1} yr^{-1} in much of the steeper slopes of the banks of the tributaries the study area. The mean annual soil loss for the entire watershed was estimated at 4.8 metric tons ha^{-1} yr^{-1}.

The results for the year 2001 presented in Fig. 8 show that about 60.2% of the study area was of low potential erosion risk, while rest of the area was under moderate to high erosion risk. In terms of actual soil erosion risk, 15.7% of the area was of moderate risk, 20.5% was of high risk and 3.7% was of very high risk. In the year 2010, 57.4% of the area was of low potential for erosion risk, 22.7% was of moderate potential for erosion risk, 15.8% was of high potential for erosion risk and 4.1% area of very high potential for erosion risk. There was an increase of very high and moderate soil erosion risk compared with the year 2001. The result for 2015 showed 70% of the area was under low potential erosion risk, which was much higher than that of 2010 with 17.2% of the area with moderate erosion risk, 11% with high risk and only 1.8% with low risk of soil erosion. The threshold for each of the risk level is presented in Table 4.

3.6. *Soil erosion trends related land-cover changes*

Soil erosion trends in the study area were assessed in terms of NDVI index. As illustrated in Fig. 9, mean NDVI values decreased from 0.25 to 0.15 during the years 2001–2010 and increased from 0.15 to 0.23 during the years 2010–2015. The histogram shows a comparison of the NDVI increase and decrease among the three target years. The increasing NDVI indicates better ground cover vegetation condition.

Vegetation cover 91.1% of the land area in the study area has decreased during the years 2001–2010. Throughout the watershed, only 8.9% increase was observed mainly in the central part of the watershed. From 2010–2015, 88% of the land area was changed to increasing trend. An increase in NDVI was observed across the watershed. However, 12% of the land area has decreasing. Comparing the years 2001 and 2015, 36% of the land area has an increasing trend in vegetation cover. This indicated that most of the central part of the study area has got more vegetation cover during the years 2010–2015.

Soil erosion changes and trends explored are given in Fig. 10. The estimated soil erosion increased during 2001–2010, and decreased during 2010–2015. The NDVI value in the year 2010 was much lower than the year 2001 and 2015. This indicates that soil erosion is more sensitive to changes in vegetation cover. There were an increasing and decreasing trends in the mean annual soil loss during the year 2001, 2010 and 2015 (Fig. 10). From the year 2001–2010, 0.5 metric tons per ha^{-1} yr^{-1} soil loss especially in the southwest and eastern parts of the watershed. From 2010–2015, there was a general decrease in soil erosion risk by 2.9 metric tons ha^{-1} yr^{-1}. Areas with higher soil erosion risk were located in the southwestern and eastern parts of the study area. When comparing the years 2001 and 2015, soil loss through erosion had significantly decreased by 2.4 metric tons ha^{-1} yr^{-1}.

Table 4
Soil erosion severity zones with erosion rate and area covered.

Threshold tons ha^{-1} yr^{-1}	Severity Classes	2001 Area (ha)	2010 Area (ha)	2015 Area (ha)
< 5	Low	9022	8581	10,452
10	Moderate	3052	3401	2558
25	High	2354	2368	1618
> 50	Very high	552	607	269

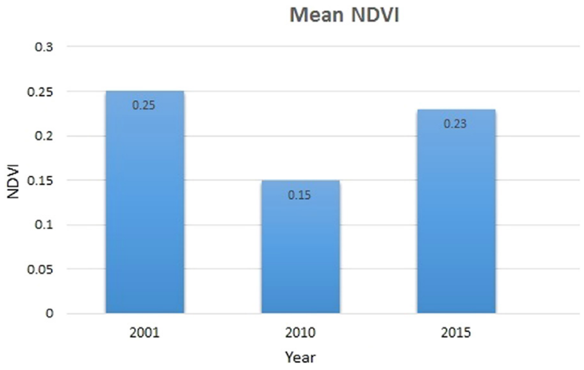


Fig. 9. Vegetation cover trends to the study area during 2001–2015 using NDVI index.

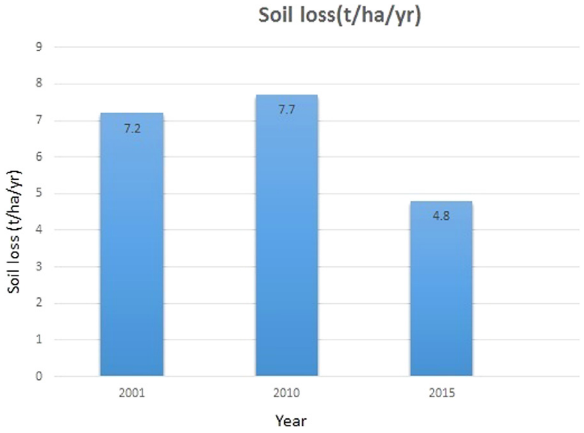


Fig. 10. Mean annual soil loss trend from the period 2001–2015.

4. Discussion

Many studies (Baigorria & Romero, 2007; Hamelmal, 2005; Paul, 1997) revealed that soil erosion estimation using the application of empirical soil erosion model such as RUSLE integrated with GIS to estimate soil erosion potential and the potential zones in Yezat Watershed. Also, an attempt has been made to study the impact of change in land-use and land cover on erosion rate. The Ethiopian government has recognized the serious implications of soil erosion and to mitigate environmental degradation national programs were implemented in the 1970s and 1980s (MoARD, 2005). There was an expansion of the area of cultivated land during the period 2001–2010 in the study area. During this period, sparsely wooded land, grassland and shrub land have vanished. This was due to the human population pressure, which resulted in the expansion of agricultural activities and settlements. Detection of land-use/land-cover changes for the period 2010–2015 has revealed that the extents of grassland, woodland and homesteads have increased. Due to the implementation of watershed management program, considerable amount of shrub/bush lands were transformed to cultivated land and plantation area. These changes led for productive use of the area by adopting suitable treatment measures like changes in the cropping pattern and in soil and water conservation practices. It was also observed that the area under homesteads was increased. This coincides with the increase in human population and construction of new houses (Bajocco, De Angelis, Perini, Ferrara, & Salvati, 2012; di Gregorio, 2005; MoARD, 2005; Zhou, Luukkanen, Tokola, & Nieminen, 2008). A similar land-use/land-cover study made by Abate (1994) in southern Ethiopia indicated that the influence of land-use/land-cover changes depends on the nature of the land and the management techniques used. The rapid change in the land-use/land-cover of the study area has been driven by factors such as population pressure, expansion of rural towns, overgrazing and recurrent droughts. Marked land-use/land-cover dynamics were also observed in dense forest, wetland, shrub-land, and intensively cultivated (irrigation) land (Fitsum et al., 1999).

From the estimation of spatial distribution of woody biomass maps for 2001, 2010 and 2015, the woody biomass considerably decreased during the period 2001–2010. On the other hands in the year 2015, significant increase in the woody biomass was observed. This increase may be due to the interventions (transformation of degraded land to plantation, due to adoption of soil and water conservation practices, better utilization of surface and groundwater). According to Kumar, Gupta, Singh, Patil, and Dhadhwal (2011), a combination of satellite and forest inventory data reduces uncertainties in aboveground biomass estimation. Sheikh, Kumar, Bussman, and Todaria (2011) estimated the carbon storage in India's forest biomass for the years 2003, 2005 and 2007 using secondary data of growing stock data and satellite data and revealed that there was a continuous decrease in the carbon stock in India's forest biomass since 2003, despite a slight increase in forest cover (ISFR, 2003, 2005, 2009). Lu (2005) conducted a study to estimate the above-ground biomass in the Brazilian Amazon using Landsat TM data. This study showed that the use of Landsat TM image for estimating forest above-ground biomass was more successful for succession forests rather than mature forests.

There was an improvement in the vegetation cover owing to implementation of various soil and water conservation measures as reflected in the NDVI images of the present investigation. The rehabilitation of vegetation in many places of the watershed has improved the vegetation cover. Farmers also confirmed during focus group discussions, that the vegetation cover has increased and the changes observed were results of the intervention, i.e. the establishment of enclosures. The major changes in the watershed due to this implementation of watershed development program are having reflected in the development of vegetation cover due to control of soil erosion. Prasannakumar, Vijith, Abinod, and Geetha (2012) proved NDVI to be a useful indicator of land-cover conditions and a reliable input into models of soil dynamics. The estimated rate of soil loss and the spatial patterns are generally realistic and in agreement with results from previous studies. The average annual soil loss estimated by USLE from the entire Medego watershed in northern Ethiopia was 9.63 metric tons per $ha^{-1} yr^{-1}$ (Tripathi & Raghuwanshi, 2003). Therefore, the RUSLE model was critically applied using an integrated remote sensing and GIS approach in a raster environment to obtain maps for each RUSLE factor.

The positive impact of the watershed management in the study area could be explained in terms of reduced soil erosion rates, and increased soil moisture availability, which resulted in the increased crop production, reduced sedimentation and flooding problems in the lower parts of the watershed, stabilized gullies and river banks, rehabilitation of degraded lands and improved ecological balance in the area. Similar studies elsewhere in northern Ethiopia also reported the effectiveness of sustained conservation efforts in catchments in controlling soil erosion and in improving hydrology and land productivity of the area (Bewket, 2003; Liu et al., 2008; Munro et al., 2008; Nyssen, Getachew, & Nurhussen, 2009; Zhang, Drake, & Wainwright, 2002). Improvement of vegetation cover in the watershed decreased the depth to the groundwater, which could be managed and used for irrigation purpose.

5. Conclusion

Assessment of the impacts of watershed development programs using satellite data are paramount importance in order to evaluate the pre and post watershed intervention conditions, and generate baseline information that helps to monitor and evaluate real time situation in the future for different options within the relatively large geographical area and repetitive time scale coverage. Major changes in the watershed due to implementation of integrated watershed development programs an reflected in the development of vegetation cover, agricultural land-use, reduced soil erosion and rehabilitation of degraded lands. The improvement in vegetation cover could be attributed to the better soil and water conservation practices through SLM interventions. It is hoped that the findings of this research will contribute to developing future watershed resources management strategies in response to sustainable land management.

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