Implication of long-term watershed development on land use/land cover change and sediment loss in Maybar Sub-Watershed, South Wello Zone, Ethiopia

Tilahun Taye\textsuperscript{1*} and Awdenegest Moges\textsuperscript{1}

\textbf{Abstract:} Long-term-watershed management in Ethiopia has been assessed in different locations since the 1980s, but there are no adequate studies of its effect on the aspects of natural resources. A boundary map of geographical coordination and Google Earth imagery was created from the ground base survey. This study was conducted to investigate the implications of long-term watershed management on the land use/land cover change and trend of runoff-sediment loss. Data for this study were obtained from- Time-series satellite Landsat images of the years 1986, 1997, 2008, and 2019, and runoff, and sediment load and discharge data from the Maybar watershed station dataset. Analyses of these data show, from 1986 to 2019, forest and settlement land area coverage had been increased from 20.9\% to 39.2\% and from 9.2\% to 22.6\%, respectively. In contrast, cultivation land, open woodland, and grassland coverage was reduced from 26.7\% to 18.4\%, from 32.7\% to 18.9\%, and from 10.6\% to 1.1\%, respectively. The discharge–runoff and runoff–sediment load processes were affected by the watershed development activity which the trend of annual sediment loss and runoff generation slightly reduced through time. Therefore, the long-term growth of watersheds has a beneficial effect.

\textbf{ABOUT THE AUTHORS}

Tilahun Taye is a soil and water conservation researcher at the Agricultural research center in the Amhara region, Ethiopia. His background is a natural resource management and specialized by soil and water conservation engineering at Hawassa university institute of technology in Ethiopia and he published some articles related to soil fertility and productivity.

Awdenegest Moges (PhD) is an Associate Professor at the Hawassa University in Ethiopia. His research interest is in soil conservation and watershed management and published articles related to soil erosion and conservation, landuse dynamics and land management aspects.

\textbf{PUBLIC INTEREST STATEMENT}

In most rural areas of Ethiopia watershed development activities were implemented by different-concerned bodies (governmental or nongovernmental organizations) through capacity building for the Ministry of Natural Resources. In most watershed development programs various physical and biological land rehabilitation activities were implemented. This could contribute a lot of significant roles for natural resource improvement, for example, it gives value to land cover and land-use changeover time. It also affects the runoff and sediment loss processes. Therefore, this study was conducted in order to investigate the implications of long-term-watershed management with a particular focus on land use and land cover and sediment loss situations. It is important to policymakers with regard to natural resource management, and land-use planning. Moreover, it is important to demonstrate the long-term-watershed impacts for the beneficiary (local communities).
on changes in on-site natural resources, such as improving vegetation coverage and reducing the generation of runoff.

Subjects: Agriculture & Environmental Sciences; Soil Conservation Technology; Vegetation; Earth Sciences; Environmental Management; Environment & Resources; Remote Sensing; Statistical & Mathematical Analysis; Geography; Topography

Keywords: watershed development; land use; land cover; soil loss; Maybar

1. Introduction
Watersheds are not only hydrological units but also biophysical and socio-political units that contribute an essential role in determining food, social, habitat, and economic services that provide life support attributes for the people (Bekele-Tesemma, 1997; Bewket, 2003; Worku & Tripathi, 2015). Watershed management in sustainable conditions is protecting and improving natural resources such as soil, water, and vegetation environmentally and ecologically suitable manner (Worku & Tripathi, 2015). Sustainable watershed management can alter any physical, biological, or chemical attribute of the watershed by limiting any negative human activities on the environment (Quentin et al., 2006) and specifically it affects the land-use land-cover systems (Anchan et al., 2018; Pandian, 2014). Therefore, watershed management can be the cause of altering land-use land-cover systems over long periods of time.

Land-use land-cover changes coming about from different characteristic and human components inside social, financial, and political settings. Any exercises that conducted by the nearby community derivers may be assessed by the rate and sorts of changes and by their analysis of other pertinent informations such as family characteristics and approaches related to arrive asset organization (Ebanyat et al., 2010; Kosmas et al., 2019). The transition in land-use cover to land loss has resulted in increased surface runoff and sediment yield, but if it changes the coverage of vegetation, the yield of runoff and sediment can be decreased. (Bekele, 2019; Munoth & Goyal, 2019).

Most anthropogenic activities can be the cause of land-cover changes. Normal occasions such as climate, flooding, fire, climate vacillations, and environmental elements may moreover start adjustments upon the land cover (Cui & Graf, 2009). Currently, land-use land cover is mostly changed by direct human interference. Hence, the expansion of livestock production, deforestation, and the development of urbanization is the basic factors. Similarly, other incidental impacts also affect the land-cover system by various factors such as forest and lakes injured by acid rain from fossil fuel combustion and crop area damaged by tropospheric ozone (Meyer, 1995).

The physiographic condition of Ethiopia, highly impacted the problem of land degradation. It also the reason for watershed degradation that is aggravated by the natural and manmade activities (Gete et al., 2006). In most rural areas of the country watershed development activities were implemented by different governmental or nongovernmental organizations through the leading role of the Ministry of Natural Resources/Agriculture (Bewket, 2003), with significant contribution in the effort to combat soil degradation and overall natural resource improvements (Gashaw, 2015).

Watershed development could contribute a significant role in the land-cover change of an area as it affects the attributes of the earth’s land surface in the distribution of vegetation, soil, topography, surface, and groundwater (Chrysoulakis et al., 2004). It also affects the land-use system, the service, and management strategy placed on the land cover through human exploitation like industrial and residential areas, agricultural fields, grazing, logging, and mining among many others (Zeleke & Hurni, 2001; Zubair, 2006). Most studies in Ethiopia indicated that land-use land-cover changes were shown during the second half of 20th century. The cause for this change was driven by different factors such as economical, institutional, and biophysical factors (Gebresamuel et al., 2010; Gessesse & Bewket, 2014).
On the other hand, watershed development also contributes to soil and water resource conservation (Osman & Sauerborn, 2001). In order to manage the watershed sustainably, different soil and water conservation structures could have been implemented to reduce the detachment and movement of soil particles by running water. Soil loss and sedimentation are natural processes that could be accelerated as a result of human activities. Eroded soil particle deposit in an area or deposit in drainage systems or waterbodies (Duball, 2017). The effect of watershed development is thus both on land-use changes and sediment and soil loss in a catchment. Therefore, this study was carried out in order to investigate land-use land-cover change at the catchment level and evaluate sediment loss and runoff generation over the past two decades.

2. Material and methods

2.1. Study site description

Maybar is located in the north-eastern part of the central Ethiopian highlands in the Southern Wello Zone. It was the Soil Conservation Research Project’s (SCRP) first research site that was established in 1981. The watershed outlet is located at 39°40’ E and 11°00’ N and it is characterized by highly rugged topography with steep slopes ranging between 2500 and 2860 m above sea level within a topographical catchment of 116.19 ha (Bosshart, 1997). Slopes range from over 64% to less than 6% (Figure 1). Rainfall is characterized by a bimodal pattern with an erratic distribution, the mean annual rainfall is 1325 mm/yr (Mitiku et al., 2006). The annual mean minimum and mean maximum temperatures for the periods from 1999 to 2006 were 11.43°C and 21.6°C, respectively.

The soil is dominated by sandy clay loam covering 80% of the watershed, and the rest is clay loam (SCRP, 2000). A mixed farming system such as livestock husbandry and crop production is the farming system in the Maybar catchment with rain-fed agriculture. Soil conservation interventions such as level soil and stone bunds were introduced in the catchment in 1983 through a Food-for-Work campaign conducted by the Ministry of Agriculture (SCRP, 2000). The Maybar watershed research unit is representative of the moist Weyna Dega/Moist Dega climatic belt. Approximately 60% of the total catchment area is cultivated whereas 20% is woodland and 20% is The grassland is mainly located on the lower and flatter slopes. The croplands are generally at mid-slope and the grass and woodlands are near the divide of the watershed and on the shallowest soils (Hurni et al., 2005; SCRP, 1982).

2.2. Methods of data collection and analysis

2.2.1. Satellite data source and processing

Path 168 and row 52 were acquired from the USGS Earth Explorer website using Landsat 4–5, Landsat 7, and Landsat 8 with TM, ETM+, and OLI/TIRS imagery sensors (Table 1). Due to their strong spectral and temporal resolution and modest spatial resolution image data with the least cloud cover (<10%) and sunlight cover, changes in vegetation patterns were observed. Therefore, the use of time-series analysis of Landsat images for the period 1986–2019 with equal year interval partitioning follows (1986, 1997, 2008, and 2019). The imagery was downloaded on the http://www.earthexplorer.usgs.gov website, and the following data sets are provided.

The program ArcGIS 10.3.1 was used to manipulate, document, and evaluate the effect of watershed growth on the dynamics of land-use land-cover change from 1986 to 2019 based on the 11-year interval. The area boundary map was carefully manually delineated on the topographic maps provided by Google Earth Base Maps 1:10,000 ratio.

2.2.2. Composite bands and training site generation

The ground truth data were taken by GPS to develop the training sites. A signature generation was initially developed from those collected ground truth points. These points were overlaid onto true color composite images for the delineation of the training areas. Each training area was digitized
on-screen at a specified distance from its pixel. Each training area contained at least one pixel that was no more than two pixels away from the original ground truth point. It must be stressed to the original ground truth pixels.

Other composites of various band combinations were used to assist in the allocation of training regions for specific features. For instance, forest training sites were digitized over a (RGB) 4, 3, 2 bands combination because forest vegetation appeared red to bright red in the false-color composite image and green to dark green in the true-color composite and (RGB) 4,5,3 (RGB) 7,4,2 and (RGB) 5,4,1 also used which its better suited in visualizing agricultural vegetation lands (Http://gif. berkeley.edu., 2003).
Table 1. The satellite image description used for this study

| Satellite data (image) | Path and row | Date of acquisition | Sensor | Number of bands | Spatial resolution (meter) |
|------------------------|--------------|---------------------|--------|-----------------|---------------------------|
| Landsat 8              | P168r52      | January, 16,2019    | Operational Land Imager/thermal infrared sensor (OLI/TIRS) | 11               | 30                        |
| Landsat 7              | P168r52      | February, 11, 2008  | Enhanced Thematic Mapper plus image (ETM+) | 8                | 30                        |
| Landsat 4–5            | P168r52      | February, 20, 1997  | Thematic Mapper (TM) | 7                | 30                        |
| Landsat 4–5            | P168r52      | March, 26, 1986     | Thematic Mapper (TM) | 7                | 30                        |

2.2.3. Image classification methods

The images were first rectified, geometrically corrected, and geo-referenced to WGS 1984 UTM projection. For land-cover classification the supervised classification method of ArcGIS 10.3.1 software using the decision rule of maximum likelihood classifier algorithm was used. Supervised classification was done making use of ground checkpoints and satellite images of the study area.

Training pixels of each category were selected for digital-automated classification. Training area selection was an important step in the classification which could be homogeneous and represent LU/LC classes was determined. Training data were collected from field information (ground survey) for 2019 image data, and for image 2008 data, collected from Google earth pro. Google earth is freely available and accurate for land-use land-cover analysis which represents a powerful and attractive source of positional data that can be used for investigation and preliminary studies with suitable accuracy and low cost (Tilahun & Teferie, 2017). The year 1986 and 1997 images of training data were also supplemented by the elder local people. With the assessment of the main land uses identified in the watershed were Cultivated land, grassland, open forest/woodlands, forest/dense, and homestead. These land uses are defined as described in Table 2.

2.2.4. Accuracy assessment and change detection

Accuracy assessment is the mandatory evaluation step during the image classification process, as the user of land-cover output needs to determine how accurate the result is used the procedure

Table 2. Land use/land cover classes’ description (Adopted from Tesfaye et al., 2017)

| Land use/Land cover type          | Description                                                                 |
|-----------------------------------|-----------------------------------------------------------------------------|
| Cultivated land                   | This unit includes areas used for rained and irrigated cultivation, including nearly fallowed areas |
| Grassland                         | Areas with permanent grass cover, used for grazing; usually communal         |
| Homestead                         | Areas with the settlement, garden around the home and organizational office |
| Open-forest/woodlands             | Areas covered with scrap scattered trees and sparsely planted woody plant mixed with short bush open areas |
| Forest/Dense                      | Areas covered with trees forming a closed canopy or relatively closed canopy. This unit also includes dense bushlands mixed with closed wood trees |
data correctly (Manandhar et al., 2009). In this study, the overall accuracy range in the classification process was 80% which has been recommended by Thomlinson et al. (1999).

A confusion matrix (or error matrix) were developed, expressing the number of sample units assigned to a particular category relative to the actual category, as verified on the ground (Lu & Weng, 2007). It considers, in aspect, the meanings and calculation methods for overall accuracy (OA), producer's accuracy (PA), user's accuracy (UA), and kappa coefficient (Thomlinson et al., 1999). In land use and cover classification system, kappa values of more than 0.80 indicate a good classification performance. Kappa values between 0.40 and 0.80 indicate moderate classification performance and Kappa values of less than 0.40 indicate poor classification performance (Jensen, 2005; Lillesand et al., 2004).

Therefore, the classification accuracy can be defined as the number of pixels that is correctly classified to the sum of all pixels. It is predicted by evaluating overall accuracy along with the kappa coefficient. These values are calculated by using the confusion matrix (Lillesand et al., 2004). The kappa coefficient can be estimated based on the following mathematical equations:

\[
\text{Overall accuracy} = \frac{\text{total number of correctly classified pixels(diagonal)}}{\text{total number of the reference pixel}} \times 100
\]

\[
\text{User accuracy} = \frac{\text{number of correctly classified pixels in each category}}{\text{Total number of classified row pixels in that category}} \times 100
\]

\[
\text{Producer accuracy} = \frac{\text{number of correctly classified pixels in each category}}{\text{Number of reference pixels in that category}} \times 100
\]

\[
\text{Kappa coefficient(K)} = \frac{(TS - TCS) - \sum (\text{Column total-Row Total})}{TS^2 - \sum (\text{Column total-Row Total})} \times 100
\]

In order to capture qualitative and quantitative information that helps to explain and interpret the land use and land-cover change, a field survey was conducted. In this case, the historical land use and land-cover trend have been collected through interviews, focus group discussions, and 15 key informants. The sampling technique was purposive sampling which is the development agents and the catchment’s hydrological observers, based on their subject knowledge and the study area.

Therefore, for each season and class, 50–75 points for classification and 75–100 points for accuracy assessment were collected based on a random sampling technique. Since the first two seasons ground truth samples were collected from the interview of key informants with supporting GPS tools and the last two periods were also collected from Google Earth historical imagery.

The change detection of each consecutive image is also determined in terms of the difference between the final and the initial year’s image. The total land-use land-cover change of each class was calculated as:

\[
\text{Change detection} = \text{Area of final year} - \text{Area of initial year}
\]

\[
\text{Change detection\%} = \frac{\text{Area final year} - \text{Area initial year}}{\text{Area initial year}} \times 100
\]

2.2.5. Rainfall, discharge and sediment loss data collection, and analysis

The annual rainfall, discharge, and sediment loss data for the periods of 1981 up to 2018 were obtained from the Maybar station database. The rainfall characteristics, amount, and erosivity have been analyzed. Discharge values were calculated from stage measurements at outlet weirs during storms and at daily intervals in the absence of storm rainfall. At runoff, events occurred stage-discharge and suspended sediment had been measured. The measuring interval was at 10-min intervals and
continued until the flowing water cleared (Bosshart, 1996). Otto Halimedeh’s and Otto EcoLog500 pressure gauges were used in May 2013. Rainfall erosivity is the product of total storm energy and the maximum-sustained intensity over 30 min, EI30. Based on Krauer (1988) determination of erosion indices under Ethiopian conditions, however, Wischmeier’s index (EI30) seems to be the most appropriate rainfall-erosivity index. The energy value for each rainfall interval (storm) is thus calculated by,

\[ E = (11.89 + 8.73 \log_{10} I)P \]  

(7)

where \( E \) = storm energy \((\text{J/m}^2)\), \( I \) = storm intensity \((\text{mm/h})\), and \( P \) = precipitation amount during the storm interval \((\text{mm})\).

The term “sediment loss” refers to the suspended sediment passing the gauging station at the outlet of the catchment to determine total sediment loss during a storm. One-liter grab samples were taken from the river at the gauging station. Sampling starts once the color of the water at the gauging station changes to brown, and the sampling continues at 10-min intervals. Gradually, when the runoff becomes clearer, the sampling interval increased to 30 min and continue until the water becomes sediment-free and visible. The collected water samples were filtered using filter paper; then, oven-dried and finally weighed to calculate the net dry soil loss of the sample.

Therefore, in order to calculate each event discharge and sediment load Equation (8) was adopted that was developed specifically for Maybar catchment (Bosshart, 1997);

\[
\begin{align*}
Q \ (\text{m}^3) & = Q(H \leq 21) = 2.016H^{2.211} \\
Q(21 < H \leq 49) & = 0.003H^{3.356} \quad (8) \\
Q(49 < H \leq 180) & = 1.023H^{1.862} \\
H & = \text{Stage (cm)}, \ Q = \text{Discharge (l/s)}
\end{align*}
\]

The data collected were analyzed using TESTMAIN software program. The relationships between runoff-sediment loss and rainfall-runoff in different periods have been analyzed by the double mass curve. On the other hand, the impact of land-use land-cover dynamics and efforts of watershed development activities on sediment load; interaction of runoff-sediment and the rainfall-runoff trend was evaluated by the simple linear regression analysis technique.

3. Results and discussion

3.1. Land-use land-cover change from 1986 to 2019

The area coverage and proportion of LULCC for the years 1986, 1997, 2008, and 2019 are presented in Tables 3–5, and Figures 2–5. The results indicated that land-use land cover of the area was changed either from one land-use type to the other following increasing or decreasing pattern. Both the homestead area and dense forest were increased from 9.2% in 1986% to 22.6% in 2019 and from 24.3% to 39.2%, respectively. This very high change may be explained by different factors. The drivers could be changes in agricultural practices, which themselves are influenced by institutional and economic factors, public policy, and infrastructure growth (Counties et al., 2014). In the study area, it has been observed that the involvement of different governmental and nongovernmental organizations in the integrated watershed development was high. Moreover, improvement of infrastructure (electricity, road, and school), plantation forest, and house building were increased. In contrast, open forest/bushland and common pool grazing land/grassland relative ratio were gradually decreased from 32.7% to 18.9% and from 10.6% to 1.1%, respectively.

According to the interview of key informants, most grassland and bushland areas were planted with Eucalyptus globules and juniper trees in the late 1980s. This happened as farmers have found these plantations to benefit more than the grassland. Similarly, the study also conducted on land-use a land cover that resulted in a slight increase in the proportion of forestland, while grassland
and open woodland have decreased (Assefa et al., 2017; Tesfaye et al., 2017; Mohajane et al., 2018). This investigation has supported most of the integrated water management and land-use land-cover change studies.

Watershed interventions could increase the vegetative index or greenery and income thus reduce poverty. Moreover, interventions of improved technologies provide a good opportunity for

| Table 3. Land use and land-cover change of area coverage in percentages and hectare |
|---------------------------------|------|------|------|------|------|
| LULCC                          | 1986 | 1997 | 2008 | 2019 |
| Culivation                     |      |      |      |      |
| Area (ha)                      | 10.62| 16.92| 23.67| 26.19|
| %                              | 9.2  | 14.6 | 20.4 | 22.6 |
| Home stead                     | 12.33| 6.03 | 21.51| 18.5 |
| Grass land                     |      |      |      |      |
| Area (ha)                      | 37.98| 32.49| 31.4 | 39.2 |
| %                              | 20.9 | 26.3 | 36.45| 45.45|
| Open forest                    | 24.3 | 30.6 | 36.45| 45.45|
| Dense forest                   | 30.96| 25.9 | 26.5 | 18.4 |
| Total                          | 116.19| 100 | 100 | 100 |

| Table 4. Land use and land-cover change detection |
|---------------------------------|------|------|------|------|------|
| LULCC                          | 1986–1997 | 1997–2008 | 2008–2019 |
| Culivation                     |      |      |      |
| Area (ha)                      | 6.30 | 6.75 | 2.52 |
| %                              | 58.70| 39.73| 10.78|
| Home stead                     | −6.30| −2.25 | −2.52|
| Grass land                     |      |      |      |
| Area (ha)                      | −5.49| −10.98| −0.45|
| %                              | −14.37| −33.93| 2.16 |
| Open forest                    | 6.30 | 5.85 | 9.00 |
| Dense forest                   |      |      |      |
| Cultivation                    | −0.81| 0.63 | 9.00 |
| Area (ha)                      | −50.94| −36.54| −66.67|
| %                              | −36.54| −33.93| 2.16 |
| Overall accuracy               | 83.91| 91.67| 92.66|

| Table 5. Accuracy assessment in percent (%) of LULC maps of each year |
|---------------------------------|------|------|------|------|------|
| LULC class                      | 1986 | 1997 | 2008 | 2019 |
| Culivation                     |      |      |      |      |
| Producer                       | 92.31| 90.90| 90.90| 90.91|
| User                           | 80   | 90.90| 90.47| 90.91|
| Home stead                     | 66.67| 88.88| 86.67| 92.66|
| Grass land                     |      |      |      |      |
| Producer                       | 78.94| 88.46| 91.67| 93.75|
| User                           | 75   | 88.46| 95.65| 88.24|
| Wood land                      |      |      |      |      |
| Forest                         |      |      |      |      |
| Producer                       | 94.44| 95.83| 95.24| 93.10|
| User                           | 94.44| 95.83| 95.24| 93.10|
| Overall accuracy               | 83.91| 91.67| 92.66| 90.91|
| Kappa statistic                | 80.47| 85.17| 89.69| 90.91|
employment and reduction of migration from the watershed to other areas, mostly to urban areas (Pathak et al., 2013). Therefore, reduction of migration and improving livelihood strategy is the means of increasing the settlement area.
Figure 4. Land use/cover map of the year 2019.

Figure 5. Land use/cover map of the year 2008.
The increase in forest and homestead land has resulted a gradual decrease in cultivated area, from 26.7% in 1986% to 18.4% in 2019. Such land-use dynamics are not common. During the field visit, at the time of land-use classification, it has been observed that most forest areas were covered by Eucalyptus globules and most previous cultivation land also changed to a plantation forest. This might be due to the benefits of eucalyptus in the area for its multiple uses including cash income. In Kenya, a study in land-use land-cover changes over a period of 30 years reported that agricultural land reduced from 39.7% to 15.8% (Odera, 2015).

3.2. Land-use land-cover change detection
The changes in land use/cover percentage over a decadal period indicated that homestead and dense forest positively changed (Table 4). While grassland showed negative change throughout the whole study period. On the other hand, some fluctuation on the open forest in 1997–2008 and cultivation land in 2008–2019 land use/cover classes have appeared; however, its general trend shows negatively changed.

According to Sewnet (2015), in the northwestern Ethiopia, in treated watershed bushlands were lost and occupied by cultivated lands and forest covers and due to the population growth, the settlement area also increased. Contrary to this there are reports of decreased forest area in untreated watersheds. A case in point is a study in Wallecha Watershed in the Bilate River Basin in Wolayita Zone, the general trend was a decrease in forest lands and shrub-grasslands while cultivated lands were increasing (Babiso et al., 2016).

3.3. Land-use land-cover change accuracy assessment result
Accuracy assessment was performed for the years 1986, 1997, 2008, and 2019, based on Land-use land-cover change maps, Google earth pro at different times of the year, and knowledge of the local community. The classified results of 80% are acceptable, this accuracy is within specified as minimum accuracy standards by the USGS. The minimum overall accuracy for this study was 83.91% in 1986 and 92.66% in 2019 (Table 5) which is a satisfactory accuracy standard for such assessment (Hosseini & Rahimzadegan, 2017).

The results from accuracy assessment showed an overall accuracy in acceptable ranges which are 83.91%, 87.83%, 89.69%, 90.91%, and 92.66% with corresponding kappa statistics of 80.47%, 85.17%, 89.69%, and 90.91% for the year 1986, 1997, 2008, and 2019 (Table 5). Several studies have proven the effectiveness of remote Sensing imagery for monitoring LU/LC changes and evaluated the impact of watershed management programs (Abd EI-Kway, 2011; Alemayehu, 2009) and the overall accuracy results of these study was accurate.

3.4. Rainfall, runoff and sediment loss
Mean annual rainfall for 1982–2016 was 1289.99 mm ranging from as low as 635.9 mm in 2011 to as high as 1620.9 mm in 1998 (Figure 6). The trend indicates a slightly increasing \((R^2 = 0.0022)\) pattern of the annual rainfall over the considered period. This result also validated the previous reports of the station (rainfall analysis from 1982 to 2005) with \(R^2 = 0.308\) (Hurni et al., 2006). Similarly, the rainfall erosivity slightly increased with \(R^2 = 0.0116\) but the general runoff trend decreased. It indicated that the probability of runoff occurrence has been decreased. It might be the result of watershed development activities such as soil and water conservation structures were effectively retained the dropped rain rather than released in the form of runoff.

The general temporal trend in sediment loads were decreasing, with the exception of the sediment loads in 1985 being the largest (Figure 7). This may be explained by a large gully formation in 1985 according to the Albko wereda agricultural office (2000) report, which could have caused the generation of a large amount of sediment in that year. This year was the initiation of the watershed monitoring and management program (physical and biological soil and water conservation practices) but not fully effective in controlling soil erosion in the catchment. Moreover, at the time, it has been reported that there was inappropriate construction of cutoff
drains that have resulted in large gully was the formation in the area. The situation also enhanced by the severe drought that occurred in the area (Wello drought). Increased sediment yield in an area can be caused by the prevalence of severe drought, the soil particles can be fine by the prolonged temperature and easily detach during the coming rainfall, then washed to the runoff channels (Trnka et al., 2016).
Sediment loss is mostly affected by the land use/land cover type and the management practice of the drainage area (Kosmas et al., 2019). Hence, the proper land management such as the implementation of soil and water conservation practices strongly reduces runoff production and soil loss (Adimassu et al., 2014). In addition soil and water conservation measure and hydroclimatic conditions also contribute to sediment load generations (Lemann et al., 2016; Walling, 2008).

In general, the variability of rainfall erosivity and rainfall amount has occurred. Even though the erosivity of rainfall was slightly increased the runoff and sediment load was reduced, the same for discharge. This indicates that even if the runoff factor erosivity was increased, due to improved land cover and management practice as well as soil and water conservation interventions, the amount of discharge generated from the catchment was reduced. An estimated average annual soil loss from agricultural land is 137 tons ha⁻¹ yr⁻¹, which corresponds to an annual soil depth loss of approximately 10 mm (Zelleke Gete et al., 2010). Different studies have ensured that the estimation of sediment load has been reduced if agricultural land has been converted to forest and vegetation land. Since over-cultivation practices in erosion-prone areas were the major factors relative to nonerosion-prone areas in case of increasing soil erosion potential under the catchment level (Sharma et al., 2011).

Suspended sediment is closely connected to the events of discharge or flood (Wudneh et al., 2014). It is a direct comparison of the measurements of stream discharge and suspended load transport volume (Angelis et al., 2012). On the basis of SCRP 1980s plot-level data, run-off, and soil loss reduced in Maybar catchment (Bantider, 2007).

The simple linear regression was applied to evaluate the runoff-sediment load and runoff rainfall relations. The cumulative plot of the mass of annual runoff and sediment yield has a strongly positive relationship ($R^2 = 0.98$) (Figure 9); similarly, the amount of rainfall strongly correlated with the amount of runoff generated from the catchment ($R^2 = 0.99\%$) (Figure 8).

The regression coefficient between annual runoff and sediment load is 0.98, indicating that runoff has a relatively high correlation with sediment load, and it has strong effects on sediment load in the catchment.

This result is in-line with the Chena Woreda, Kaffa Zone, Southwestern Ethiopia watershed management where intervention brought a reduction in soil erosion and sedimentation thereby
improving quality and water availability, and the development of plantation forests in its intervention area (Meshesha & Birhanu, 2015).

3.5. Effect of land-use land-cover change on runoff–sediment loss

According to the land-use analysis result, from 1986 to 2019 forest coverage has increased by 14.9%. Similarly, the homestead area also increased by 13.4% which is negatively affecting factors to sediment load. In contrast, grassland, open forest/woodland, and cultivation land which are positively affecting soil loss were decreased by 9.5%, 13.8%, and 8.3%, respectively.

The rainfall erosivity and mean annual rainfall trend indicates a slightly increasing but with decreasing general trend of runoff and sediment yield. Higher vegetation cover could perhaps contribute a great deal to reduced sediment loss in the catchment.

Rainfall and soil surface characteristics are important factors for the erodibility of soil and intensity in raindrop erosion. Because of the role of direct raindrop impact, vegetation cover can also provide mechanical protection to the soil against erosion by absorbing the energy of the falling drops and generally reducing the drop sizes that reach the ground (Guzha, 2018; Haj-ElTahir et al., 2010). This study also confirmed the truth which the vegetation coverage of the watershed increased with decreasing the runoff. According to correlation analyses of rainfall–erosivity research, there was a strong positive correlation between soil loss and runoff (Oguz, 2019).

Human activities are the main cause of land-use land-cover change which affects the soil erosion impact either positively or negatively. It depends on the type and nature of interference of each activity on the land. If the interaction of human activity growth centered on the pattern of runoff can be minimized, but the interaction of human activity dependent on natural resource depletion, the runoff can be aggravated (Bhadoria, 2010).
4. Conclusion

Land-use land cover of the Maybar watershed in the last two decades changed considerably from sparse to the dense and higher cover of the soil surface. This implies better protection of the ground surface and hence control of erosion. Five major land-use land-cover types identified; namely, settlement land, dense forestland, grazing land, cultivation land, and open-forest land. The coverage of forestland and settlement areas was significantly extended, but grassland and open shrubland were shirked. These changes are attributed to the intervention done in the watershed for the last more than two decades.

Therefore, long-term watershed development had influenced the dynamic of land use and land-cover proportion. From 1986 to 2019 the portion of forest area changed from 20.9% to 39.2% and settlement land also from 9.2% to 22.6%, respectively. On the other hand, cultivation land, open woodland, and grassland coverage was reduced from 26.7% to 18.4%, from 32.7% to 18.9%, and from 10.6% to 1.1%, respectively.

Likewise, it has led to soil erosion and runoff patterns, suggesting a decline in the general temporal trend in sediment loads. It could come from improving vegetation coverage, which results in decreased soil particle detach and increased infiltration capability. Therefore, long-term monitoring of watersheds has had a significant impact on the land coverage of vegetation and also leads to reducing soil erosion and producing runoff.

Acknowledgements

We would like to thank colleagues from the soil and water management research directorate, Sirinka Agricultural Research Center for the support in data collection and encoding. Special thanks to Amhara Agricultural research institute and Sirinka Agricultural research center, for providing funds for field works. Water and Land Resource Center (WLRC) is gratefully acknowledged for providing the necessary data and financial support, particular thanks goes to Dr. Gete Zeleke, Director General of WLRC.

Funding

The authors received no direct funding for this research.

Author details

Tilahun Taye
E-mail: sarztilahun3@gmail.com
Awdenegest Moges
E-mail: awde_moges@yahoo.co.uk
1 Agricultural Research Center, Hawassa University, Awasa, Ethiopia.

Citation information

Cite this article as: Implication of long-term watershed development on land use/land cover change and sediment loss in Maybar Sub-Watershed, South Wello Zone, Ethiopia, Tilahun Taye & Awdenegest Moges, Cogent Food & Agriculture (2020), 7: 1863596.

References

Abd El-Kway, E. (2011). Land use land cover change detection in western Nile delta of Egypt using remote sensing data. Applied Geography, 31, 483–494.
Adimassu, Z., Kindu, M., Chilot, Y., & Kessler, A. (2014). Effect of soil bunds on runoff, soil and nutrient losses, and crop yield in the central highlands of Ethiopia. Land Degradation & Development, 25(6), 554–564.
Alemayehu, F. (2009). The impacts of watershed management on land use and land cover dynamics in eastern Tigray (Ethiopia). Resources, Conservation & Recycling, 53.
Anchan, S. S., Shetty, A., Bhat, H. G., & Chadda, M. (2016). Land use and land cover change detection through spatial approach: A case study of Mangaluru Taluk, Karnataka. Journal of Geomatics, 12(11), 167–173.
Angelis, I., Metallinos, A., & Hriissanthou, V. (2012). Regression analysis between sediment transport rates and stream discharge for the Nestos river, Greece. 14(3), 362–370.
Assefo, D., Rewold, B., Sandén, H., Rosinger, C., Abiyu, A., Yilateru, B., & Godbold, D. L. (2017). Deforestation and land use strongly effect soil organic carbon and nitrogen stock in Northwest Ethiopia. Catena, 153, 89–99. https://doi.org/10.1016/j.catena.2017.02.003
Babiso, B., Toma, S., & Bajigo, A. (2016). Land use/Land Cover Dynamics and Its Implication on Sustainable Land Management in Wallecha Watershed, Southern Ethiopia. 16(4).
Bantider, A. (2007). Landscape Transformation and Opportunities for Sustainable Land Management along the Eastern Escarpment of Wello (EEW). University of Bern.
Bekele, T. (2019). Effect of Land Use and Land Cover Changes on Soil Erosion in Ethiopia. International Journal of Agricultural Science and Food Technology, 5, 026–034. https://doi.org/10.17352/2455-815x.000038
Bekele-Tesemma, A. (1997). A participatory agroforestry approach for soil and water conservation in Ethiopia. Bewket, W. (2003). Towards integrated watershed management in highland Ethiopia: TheChemoga watershed case study. Wageningen University and Research Centre, No. 44.
Bhadoria, P. B. S. (2010, March). Effect of land use land cover change on soil erosion potential in an agricultural watershed. https://doi.org/10.1007/s10661-010-1423-6.
Bosshart, U. (1996). Measurement of river discharge for the SCRP research catchments. Methodology and theoretical background. SCRP Research Report. Methodology and theoretical background. Bern-Addis Abeba.
Bosshart, U. (1997). Measurement of river discharge for the SCRP research catchments. Switzerland-Addis Abeba.
Chrysoulakis, N., Kamarianakis, Y., Farsari, Y., Diamandakis, M., & Prastacos, P. (2004). combining satellite and socioeconomic data for land use models estimation. (proc. of 3r: R. (In goossens, Ed.)
Counties, S., Province, Y., Diallo, Y., Hu, G., & Wen, X. (2014). Applications of remote sensing in land use/land cover change detection in applications of remote sensing in land use/land cover change detection in Puer and Simao Counties, Yunnan Province.

Cui, X., & Graf, H. F. (2009). Recent land cover changes on the Tibetan Plateau: A review. Climatic Change, 94(1–2), 47–61. https://doi.org/10.1007/s10584-009-9556-8

Duball, C. E. (2017). Environmental impacts of Oyster aquaculture on the coastal Lagoons of Southern Rhode Island.

Ebanyat, P., de Ridder, N., & de Jager, A. (2010). Drivers of land use change and household determinants of sustainability in smallholder farming systems of Eastern Uganda. 674–506. https://doi.org/10.1007/s11111-010-0104-2

Gashow, T. (2015). The implications of watershed management for reversing land degradation in ethiopia. Research Journal of Agriculture and Environmental Management.

Gebresamuel, G., Bol, R. S., & Øystein, D. (2010). Land-use changes and their impacts on soil degradation and surface runoff of two catchments of Northern Ethiopia. Acta Agriculturae Scandinavica Section B: Soil and Plant Science, 60(3), 211–226. https://doi.org/10.1080/09064710902821741

Gessesse, B., & Bewket, W. (2014). Drivers and implications of land use and land cover change in the central highlands of ethiopia: Evidence from remote sensing and socio-demographic data integration. Ethiopian Journal of the Social Sciences and Humanities, 10(2), 1–23–23.

Gete, Z., Kassie, M., Pender, J., & Yesuf, M. (2006, January). Second draft Stakeholder Analysis for Sustainable Land Management (SLM) in Ethiopia: Assessment of opportunities, strategic constraints, information needs, and knowledge gaps (pp. 96). Environmental Economics Policy Forum for Ethiopia (EEPFE).

Gete, Z., Agegnehu, G., & Dejene Abera, S. R. (2013). Fertilizer and soil fertility potential in Ethiopian: Constraints and opportunities for enhancing the system. IFPRI.

Guzho, A. C. (2018). Impacts of land use and land cover change on surface runo ff, discharge and low fl ow s: Evidence from East Africa. Journal of Hydrology: Regional Studies, 15(December 2017), 49–67. https://doi.org/10.1016/j.ejrh.2017.11.005

Hej-Elfarrou, A. K., Kibb, A., & Xu, C. Y. (2010). Identification and mapping of soil erosion areas in the Blue Nile-Eastern Sudan using multispectral ASTER and MODIS satellite data and the SRTM elevation model. Hydrology and Earth System Sciences, 7, 130–179.

Hosseini, S., & Rahimzadeh, S. M. (2017). Detection of land use changes in northeastern Iran by landsat satellite data. 15(3), 1443–1454.

http://gis.berkeley.edu. (2003). Landsat Spectral Band Information. RS/GIS Quick Start Guides Collaborative Training Materials Available from the Biodiversity Informatics & Geospatial Innovation Facilities, & (http://biodiversityinformatics.amnh.org), 6–7.

Hurni, H., Armare, B., & Debele, B. (2005). Area of Moybar, Wello, Ethiopia: Long-term monitoring of the agricultural environment, volume 2 climate, land use, soil erosion and runoff database. 2, 1995–2006.

Hurni, H., Tato, K., & Zeleke, G. (2005). The implications of changes in population Landuse on NileBasin.pdf. 25 (2), 147–154.

Jensen, J. R. (2005). Introductory digital image processing: A remote sensing perspective (John R. Jensen, Ed.) (3rd ed.). Pearson Education Inc.

Kosmas, C., Donalatos, N., & Cammeraat, E. L. H. (2019, February). The effect of landuse on runoff and soil erosion under Mediterranean conditions The effect of land use on runoff and soil erosion rates under Mediterranean conditions. 8162. https://doi.org/10.1007/978-3-030-53411-8(2020).1863956

Krauer, J. (1988). Rainfall, Erosivity and Isoredant Map of Ethiopia. SCRP, Research Report 15. University of Bern, Switzerland in Association with MOA.

Lernon, T., Zeleke, G., Amsler, C., Giavanoli, L., Suter, H., & Roth, V. (2016). Modelling the effect of soil and water conservation on discharge and sediment yield in the upper Blue Nile basin. Ethiopian Applied Geography, 73, 89–101. https://doi.org/10.1016/j.ajgeog.2016.06.008

Lillesand, T. M., Kiefer, R. W., & Chip Man, J. (2006). Remote sensing and image interpretation (J. Wiley, Ed.) (5th ed.).

Lu, D., & Weng, Q. A. (2007). Survey of image classification methods and techniques for improving classification performance. International Journal of Remote Sensing, 28, 823–870.

Manandhar, R., Odeh, I. O., & Anceu, T. (2009). Improving the accuracy of land use and land cover classification of Latsdata using post-classification enhancement. Remote Sensing, 1, 330–344.

Meshesha, Y. B., & Birhanu, B. S. (2015, October). Assessment of the Effectiveness of Watersheds Management Intervention in Chenia Woreda, Kaffa Zone, Southwest Ethiopia. 1257–1269.

Meyer, W. B. (1995). Post and present land-use and land-cover in the U.S.A. Consequences, 24–33.

Mitiku, H., Herweg, K., & Stillhardt, B. (2006). Sustainable land management – a new approach to soil and water conservation in ethiopia. Mekelle University.

Mojahane, M., Essahalaou, A., Oudija, F., Hafayani, M. E., Hmaidi, A. E., Ouali, A. E., Randazza, G., & Teodoro, A. C. (2018). Land Use/Land Cover (LULC) Using Landsat Data Series (MSS, TM, ETM + and OLI) in Azrou Forest, in the Central Middle Atlas of Morocco. p. 1–16. https://doi.org/10.3390/Environments5120131

Munoth, P., & Goyal, R. (2019). Impacts of land use land cover change on runoff and sediment yield of Upper Tapi River Sub-Basin. International Journal of River Basin Management, 1–13. https://doi.org/10.1080/15715124.2019.1613413

Odero, P. A. (2015, December). Land use land cover change and their effects on agricultural land : A case study of Kiambu County -Kenya.

Oguz, (2019). Rainfall erosivity in north-central anatolia in Turkey. 17 (2), 2719–2731.

Osman, M., & Sauernborn, P. (2001). Soil and water conservation in Ethiopia experiences and lessons. Soils & Sediments, 1(2), 117–123.

Pandian, M. (2014). Land Use and Land Cover Change Detection Using Remote Sensing and GIS in Parts of. (September). www.iirsg.com

Pathak, P., Chourasia, A. K., Wani, S. P., & Sudri, R. (2013, January). Multiple impact of integrated watershed management in low rainfall semi-arid region : A case study from eastern Rajasthan, India. 23–36. https://doi.org/10.4236/jwarp.2013.31004

Quentin, F. B., Jim, C., Julia, C., Carole, H., & Andrew, S. (2006). Drivers of land use change, latest report: Matching opportunities to motivations. Department of Sustainability and Environment and Primary Industries, Royal Melbourne Institute of Technology (esri project 05116).

SCRP. (1982) . Soil and Water conservation project, second progress report. University of Bern, Switzerland in Association with MOA.
SCRP. (2000). Area of maybar, wello, Ethiopia: Long-term monitoring of the agricultural environment 1981 – 1994.

Sewnet, A. (2015). Land use/cover change at infraz watershed, northwestern ethiopia. Journal of Landscape Ecology, 8(1).

Sharma, A., Tiwari, K. N., & Bhadoria, P. B. S. (2011). Effect of land use land cover change on soil erosion potential in an agricultural watershed. Environmental Monitoring and Assessment, 173 (1–4), 789–801. https://doi.org/10.1007/s10661-010-1623-6

Soil conservation Research project. (2000). Area of Maybar, Wello, Ethiopia: Long-term monitoring of the agricultural environment 1981 – 1994.

Tesfaye, G., Assefa, A., & Kidane, D. (2017, September). Runoff, sediment load and land use/cover change relationship: The case of Maybar sub-watershed, South Wollo, Ethiopia. 89–101. https://doi.org/10.1080/15715124.2016.1239625

Thomlinson, J. R., Bolstad, P. V., & Cohen, W. (1999). Coordinating methodologies for scaling land cover classifications from site-specific to global: Steps toward validating global map products. Remote Sensing of Environment, 70, 16–28.

Tilahun, A., & Tefere, B. (2017, June). Accuracy assessment of land use land cover classification using google earth. https://doi.org/10.11648/j.ojep.20150404.14.

Trnka, M.,Semeradová, D., Novotný, I., & Dumbrovský, M. (2016, October). Assessing the combined hazards of drought, soil erosion and local flooding on agricultural land: A Czech case study. https://doi.org/10.3354/cr01421.

Walling, D. E. (2008). The changing sediment loads of the world’s rivers. IAHS-AISH Publication, 325, 323–338. https://doi.org/10.2478/v10060-008-0001-x

Worku, T., & Tripathi, S. K. (2015). Watershed management in highlands of Ethiopia: A review. OALib, 02(6), 1–11. https://doi.org/10.4236/oalib.1101481

Wudneh, A., Erkossa, T., & Devi, P. (2014). Sediment and nutrient lost by runoff from two watersheds, Digga district in Blue Nile basin, Ethiopia. 8(9), 498–510. https://doi.org/10.5897/AJEST2014.1747

Zeleke, G., & Hurni, H. (2001). Implications of land use and land cover dynamics for mountain resource degradation in the Northwestern Ethiopian Highlands. Mountain Research and Development, 21(2), 184–191. https://doi.org/10.1659/0276-4741(2001)021[0184:ilolua]2.0.co;2

Zubair, A. O. (2009). Change detection in land use and land cover using remote sensing data and gis (a case study of ilorin and its environs in kwara state). University of Ibadan.