Evaluating Ecosystems Services Values due to Land use Transformation in the Gojeb Sub-basin, Southwest Ethiopia

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Research

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Abstract

Background

Land use land cover (LULC) transformation and ecosystems service valuation (ESVs) play important roles for vegetation restoration and payment for ecosystems service (PES) programs. The objective of this work was to quantify LULC transformations and associated ESVs in the Gojeb sub-basin by analyzing LULC between 1986 and 2016 using satellite images, field observations and ancillary datasets.

Results

The summarized LULC classes are: bareland, cropland, grassland, forest, plantation, settlement, shrub, water-body and woodland. The ESVs were evaluated for each LULC based on these LULC classes. Forests had the highest cover (>423,000ha ~60%) in 1986 but it reduced to 317,000ha (~45%) in 2016. About >56,000ha of forests were changed to cultivated land, and >105,000ha to different classes. Cultivated land increased from >258,000ha (~37%) in 2016 compared to 150,000ha (~21.5%) in 1986. The sub-basin had ESVs of US$2.52 billion in 1986 but decreased to US$1.97 billion in 2016; losing about US$0.551 billion within the last 30 years (annual loss rate of US$18.4 million). Potential drivers would be agricultural expansion, land degradation/erosion, landslide and deforestation, indicating that requires concerted effort to restore and manage landscapes for sustainable socio-ecological and economic uses.

Conclusion

This study is meaningful for management of natural resources in the catchment, improvement of hydropower production and lifespan of the hydropower reservoir on one hand and productivity of small holder farmers and inhabitants in the basin on the other besides to the lesson learned to other similar basins. Hence, payment for ecosystems service scheme is recommended as a win-win approach to be implemented between upper and downstream users for sustainable use of resources. This study assist policy makers in designing evidence-based solutions for PES programs in the study area and elsewhere.

Highlights

- Forest area had the highest cover (>423,000 ha ~ 60%) in 1986 but it was reduced to 317,000 ha (~45%) of the watershed in 2016.
- About >105,000 ha of forest were changed to different land use types. Of which, more than 56,000 ha of high forest area were changed to cultivated land such as agroforestry and cropland with and without trees.
- Cultivated area covered the second largest areas (>258,000 ha ~37%) in 2016 as compared to 150,000 ha (~21.5%) in 1986.
- The sub-basin had ESVs of US$ 2.52 billion in 1986 but it has been decreased to US$ 97 billion in 2016.
- The sub-basin lost about US$ 551 billion within the last 30 years, with annual loss rate of US$ 18.4 million.
- This will assist policy makers in designing evidence-based solutions for payment for ecosystem service (PES) schemes in the study area.

Background

An increasing demand for agricultural, industrial or urban areas compromises the ability of natural forests, waterbodies and grasslands to support mankind (Nelson et al., 2009; Goldman-Benner et al., 2012), which cause land use/cover changes either permanently or temporally. In recent decades, a substantial area of LULC has been observed due to different socio-economic and biophysical drivers.

In sub-Saharan Africa, some studies have been conducted on mapping and valuation of ES in the context of LULC changes (Arowolo et al., 2018; Hulme et al., 2013; Leh et al., 2013; Kindu et al., 2016; Tolessa et al., 2017; Silvestri et al., 2013). Almost all studies indicate that this region is under severe pressure of degradation with significant consequences for rural livelihoods (Scholes et al., 2018). For example, Sutton et al. (2016) estimated for Ethiopia a loss of 17.7% in ESVs due to land degradation, which is also reflected in studies
conducted in different parts of Ethiopia (Gashaw et al., 2018; Kindu et al., 2016; Tolessa et al., 2017). Drivers of land degradation in sub-Saharan Africa include the expansion of crop production, unsustainable grazing and forestry practices and climate change (Scholes et al., 2018).

Species-rich ecosystems are able to simultaneously provide multiple ES (Lefcheck et al., 2015). If LULC changes negatively affect biodiversity and the provisioning of these ES or promote ecosystems disservices (EDS), they also reduce the overall value of the land. According to TEEB (2010), recognizing value in ecosystems, landscapes, species and other aspects of biodiversity is a feature of all human societies, communities and sometimes sufficient to ensure conservation and sustainable use Over the last 20 years, many ecosystem service values (ESVs) studies have been carried out at global, national or subnational levels (Schmidt et al., 2016), and some of which integrating spatially explicit approaches (Kremer et al., 2016; Liu et al., 2009).

Quantification of ESVs based on the ES database (Van der Ploeg et al., 2010) is commonly undertaken by integrating LULC data of biomes present in a region of interest (Costanza et al., 2014; Van der Ploeg et al., 2010). Although these biomes are not exactly similar in their characteristics and functions with the LULC types used in different studies, average values per unit area derived from valuation studies for a particular biome can be used as proxies for estimating the ESVs of the corresponding LULC types (Tolessa et al., 2017).

This study aimed at assessing ESVs values by analyzing LULC changes in the Gojeb sub-basin of Omo-Gibe basin, southwest Ethiopia, and quantifying the consequences on ESVs. Landsat satellite data of two periods: 1986 and 2016 were used to quantify changes in LULC over the last 30 years. Moreover, the specific objectives were to: i) assess LULC dynamics, calculate its gains, losses and net changes in area of the different LULC types, ii) estimate the ESV changes caused by LULC dynamics in the study area in order to assist policy makers in designing evidence-based solutions for the ‘payment for ecosystem service (PES)’ schemes.

Materials And Methods

Study area

This study was conducted at Gojeb sub-basin of Omo-Gibe Basin in the southwest Ethiopia (Fig. 1). The Gojeb River catchment (a tributary of the Omo River) is covering an area of about 700000 ha. Geographically, the catchment is located between 36.16 & 37.492 East and 07.12 & 08.13 North with altitudinal range of 806 to 3348 m.a.s.l. The catchment lies in two regional states, i.e., the Southern Nations and Nationality Peoples Region (SNNPR) and Oromia Region. Climate of the study area is generally classified as tropical cool humid. The agroecology of the catchment consists of cold moist-Dega (around the upper catchment of Gojeb River), hot moist - Kola (the middle portion of the southern part of the catchment) and wet moist - Woina Dega (the remaining substantial part of the catchment). Annual rainfall varies from about 1000 mm in the extreme south to over 1850 mm in the highland northern parts of the catchment with the average being over 1450 mm (Yilkal, 2019).

The study area covers about 700000 ha in the Gojeb sub-basin in the Omo-Gibe-Basin (Fig. 1). Gojeb River is partly bordering Oromia and SNNP regions. The detailed analysis of land transformation of the watershed was identified more than 25 land use/land cover types (Table 1) as small as 0.03 ha and as large as 269499 ha of land with 30 m spatial resolution and within 30 years’ time span. These detailed land use land cover classes were also summarized into commonly used corresponding land use land cover types.

Land use datasets and approaches

Landsat 30 m satellite images analyses were conducted between 1986 and 2016 to monitor 30 years land transformation using the advantages of remote sensing and geographic information system. They provide wide ranges of opportunity to produce LULC data at various scales. However, generating complete and comprehensive LULC information via remotely sensed data that fill the wide range of the need still faces difficulties (Jensen, 1996; Renison et al., 2004). In Ethiopia, two major categories of challenges limit the potential of remote sensing techniques to produce the required scale and accuracy of LULC information: (1) landscape complexity (topographic and farming system) and (2) accessibility of better resolution remotely sensed data and suitable classification approach (Kassawmar et al., 2016a). Experiences shows that a stratified mapping approach can potentially address the challenges encounter when mapping heterogeneous and large areas (Homer et al. 2000; Lu et al., 2015).

Deriving Homogenous Image Classification Units (HICUs) was used that subdivided each Landsat image into smaller units where similar land cover mosaics occur was found to be a suitable classification approach. HICU development was done using multiple information sources such as altitude, terrain, farming system, rainfall pattern and soil. This approach resulted in a varying amount of
HICUs within a Landsat image, depending on the location and landscapes types, followed by identifying the dominant and subordinate land cover features for each HICU, or majority and detailed classes. These land features into were grouped detailed and majority classes based on the occurrence, dominance and distribution of the land features. This requires disaggregation of classes at multiple steps of classification, which could allow capturing smaller classes that are commonly ignored in large and complex landscape mapping. For example, the class forest generated from church forests and protected high forests, which are found either in high moist area or dryland forest. Finally, manual digitizing, edge enhancement and NDVI thresholding were used to extract the majority and/or detailed classes from the imagery. The extracted classes were combined and areas of their occurrence masked within each Landsat image so that they would not distort the further classification process (Table 1).

Different approach has shown a considerable improvement on the accuracy of classification in complex landscapes. However, accuracy of classification could be more improved based on the number and precision of segments developed for every scene and local knowledge of the area (Kassawmar et al., 2016). In complex landscapes traditional classification techniques that apply full scene as unit of analysis have shown limitations due to spectral variability of features related to bio-physical complexity observed in a scene (Kassawmar et al., 2016b). Then major classes were generated from the detailed (Level II) classification result carried out from Landsat image with corresponding ground truth and ancillary data with an accuracy assessment obtained > 85% (Kassawmar et al., 2016).

Table 1
Descriptions of detailed LULC class names (Level II) and corresponding LULC names (Level I)

<table>
<thead>
<tr>
<th>Class name</th>
<th>Description</th>
<th>LULC name</th>
<th>Class name</th>
<th>Description</th>
<th>LULC name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afcf</td>
<td>Agroforestry dominated by coffee</td>
<td>Cropland</td>
<td>Hghf</td>
<td>High forest</td>
<td>Forest</td>
</tr>
<tr>
<td>Afec</td>
<td>Agroforestry enset &amp; coffee</td>
<td>Cropland</td>
<td>Homp</td>
<td>Home garden planation</td>
<td>Plantation</td>
</tr>
<tr>
<td>Afen</td>
<td>Agroforestry dominated by enset</td>
<td>Cropland</td>
<td>Mixf</td>
<td>Mixed forest</td>
<td>Forest</td>
</tr>
<tr>
<td>Agrf</td>
<td>Agroforestry</td>
<td>Cropland</td>
<td>Pfor</td>
<td>Plantation forest</td>
<td>Plantation</td>
</tr>
<tr>
<td>Bare</td>
<td>Bareland</td>
<td>Bareland</td>
<td>Rivc</td>
<td>River courses</td>
<td>Forest</td>
</tr>
<tr>
<td>Chril</td>
<td>Crop in the hillside</td>
<td>Cropland</td>
<td>Rivf</td>
<td>Riverine forest</td>
<td>Forest</td>
</tr>
<tr>
<td>Crwt</td>
<td>Crop with trees</td>
<td>Cropland</td>
<td>SBdn</td>
<td>shrub-bush dense</td>
<td>shrubland</td>
</tr>
<tr>
<td>Csht</td>
<td>Cultivated with shifting</td>
<td>Cropland</td>
<td>SBop</td>
<td>Shrub-bush open</td>
<td>Shrubland</td>
</tr>
<tr>
<td>Cwot</td>
<td>Crop without trees</td>
<td>Cropland</td>
<td>SeTT</td>
<td>Settlement</td>
<td>Settlement</td>
</tr>
<tr>
<td>Dghi</td>
<td>Degraded hills</td>
<td>Shrub</td>
<td>Swmp</td>
<td>Swamp Waterbody</td>
<td>Waterbody</td>
</tr>
<tr>
<td>Dryf</td>
<td>Dry forest</td>
<td>Forest</td>
<td>Wate</td>
<td>Waterbodies</td>
<td>Waterbody</td>
</tr>
<tr>
<td>Gdry</td>
<td>Grassland drained</td>
<td>Grassland</td>
<td>Wldn</td>
<td>Woodland dense</td>
<td>Woodland</td>
</tr>
<tr>
<td>Gsvn</td>
<td>Grassland savanna</td>
<td>Grassland</td>
<td>Wlop</td>
<td>Woodland open</td>
<td>Woodland</td>
</tr>
<tr>
<td>Gwet</td>
<td>Grassland wet</td>
<td>Grassland</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LULC changes were calculated for two different time periods: for 1986 and for 2016, and the change between 1986 and 2016 using cross-tabulation (Kindu et al., 2016; Shiferaw et al., 2019) and calculating percent changes for each LULC type over time (Gashaw et al., 2018; Temesgen et al., 2018). Furthermore, class-specific gains, losses and stable areas, as well as total change area and net changes of the total area analyzed were calculated (Alo and Pontius, 2008; Zewdie and Csaplovics, 2015). Finally, annual change rates were calculated for each LULC type following Puyravaud (2003) and Tilahun et al. (2014), i.e. the rate of change for a specific class was calculated by dividing the class-specific changes between two time intervals by the number of years between these two observed points in time. LULC changes were calculated for two different time periods between 1986–2017 as methods applied by different studies (Eckert et al., 2017; Kindu et al., 2016; Shiferaw et al., 2019) and calculating percent changes for each LULC type over time (Gashaw et al., 2018; Kindu et al., 2016; Temesgen et al., 2018) (Eq. 1).

\[
\text{Percent of change} = \frac{A_2 - A_1}{A_1} \times 100
\]
Where, $A_1$ is area of land use and land cover type (ha) in year 1, $A_2$ is area of land use and land cover type (ha) in year 2.

Furthermore, class-specific gains, losses, and stable areas, as well as total change area and net changes of the total area analyzed were calculated (Alo and Pontius, 2008; Zewdie and Csaplovics, 2015). Finally, annual change rates were calculated for each LULC type following Puyravaud (2003) and Tilahun et al. (2014), i.e. the rate of change for a specific class was calculated by dividing the class-specific changes between two time intervals by the number of years between these two observed points in time (Eq. 2).

\[
\text{Rate of change} = \frac{A_2 - A_1}{Z}
\]  

where, $A_1$ is area of land use and land cover type (ha) in year 1, $A_2$ is area of land use and land cover type (ha) in year 2, $Z$ is the time interval between $A_1$ and $A_2$ in years.

**Ecosystem serving values**

In this study, the benefit transfer approach was used to estimate ecosystems service values (ESVs) of different LULC types and their changes (Costanza et al., 1997, 2014; Niquisse et al., 2017). The benefit transfer approach refers to the process of using existing values and other information from the original study site to estimate ESVs of other similar locations in the absence of site specific valuation information (Bagstad et al., 2013; Niquisse et al., 2017). We calculated the ESVs of the LULC types in Gojeb catchment by adapting the coefficients of tropical areas on regional estimates of ESVs using data provided by Kindu et al. (2016), who conducted a study on LULC and ESVs in Ethiopia using conservative estimates of ESV coefficients, which were based on values from studies conducted in areas similar to the geographical setting of our study area. These ESVs include the main three ES: supply, regulation/monitoring and provision (Kindu et al., 2016) and also using the updated global coefficients provided by Costanza et al. (2014). Land use types such as bare land and settlement did not have a coefficient in some studies (Costanza et al., 1997; Kindu et al., 2016; Tolessa et al., 2017). Hence, the ESVs for all LULC types were calculated for each period using the following Equation (Costanza et al., 1997, 2014) and that for woodland/shrub land provided by Temesgen et al. (2018) (Eq. 3):

\[
\text{ESV} = \sum_{k=0}^{n} A_k (V C_k)
\]  

Where, $ESV$ is estimated ecosystem service value, $A_k$ is the area (ha) of LULC type $k$, and $V C_k$ is the value coefficient (US$ ha^{-1} yr^{-1}$) for LULC type $k$.

**Results**

**Land use land cover transformation**

Land transformation analysis of Gojeb watershed within the last 30 years indicated that shrub-bush land and woodland were mainly changed to croplands of different uses. Of the 700000 ha of the watershed, still 292052 ha (41.7%) of land is covered with high forest by 2016 although high forest area was 346388 ha (49.5%) in 1986. About 56013 ha of high forest area were changed to different cultivated land such as agroforestry, cropland and cropland with and without trees. Cultivated area covers the second largest areas 258395 ha (37%) in 2016 as compared to 150144 ha (21.5%) in 1986 (Fig. 2). On the other hand, bare-land also increased from 14.5 ha in 1986 to more than 1400 ha in 2016 indicating that there is a great de-vegetated activities carried out in the watershed for the last 30 years.

About 161 ha of land was occupied with settlements in 1986 while this becomes more than double (383 ha) in 2016. Swamped and water-bodies were covered more than 755 ha in 1986 but were significantly reduced in 2016. Agroforestry groups were covered about 39682 ha in 1986 and these increased to 53956 ha in 2016 with the expenses of shrub-bushland, woodland and high forest. Cropland (hillside cultivation crop with trees and without trees) has gained double coverage that accounted for 204438 ha in 2016 while it was 110462 ha in 1986 with the expenses of dry grassland, shrub-bush land and woodland.
The forest in general and the dry forest cover in particular was lost more than 105000 ha in the eastern part of the watershed, which has very important role in soil conservation and harbors for biodiversity hotspot. It is significantly reduced in 2016, and replaced by cultivation and open woodland areas. Of the 41000 ha of dry forest in 1986, ca. 4700 ha was changed to cultivation, 15000 ha to shrub-bush, 14000 ha to woodland and the rest changed into different land use types (Table 2). Forest lost about 15% of its cover in 2016 (45%) as compared to 1986 (60%). Woodland lost half of its area in 2016. The annual rates of reduction were about −3525 ha, -1262 ha and −21 ha from forest, woodland and grassland, respectively. On the other hand, bare-land, cropland, plantation, settlement, shrubland and water-body increased in their coverage in 2016 by constraining forest and woodland. The highest land transformation or conversion was observed on forest (ca -3525 ha/year) and cropland (+3608 ha/year).

<table>
<thead>
<tr>
<th>Major Land use cover types</th>
<th>1986</th>
<th>2016</th>
<th>Change between 1986 &amp; 2016</th>
<th>Annual change rate (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bareland</td>
<td>14.5</td>
<td>0.002</td>
<td>1,412</td>
<td>0.2</td>
</tr>
<tr>
<td>Cropland</td>
<td>150,144</td>
<td>21.4</td>
<td>258,394</td>
<td>36.8</td>
</tr>
<tr>
<td>Grassland</td>
<td>23,149</td>
<td>3.3</td>
<td>22,518</td>
<td>3.2</td>
</tr>
<tr>
<td>Forest</td>
<td>423,055</td>
<td>60.3</td>
<td>317,308</td>
<td>45.23</td>
</tr>
<tr>
<td>Plantation</td>
<td>969</td>
<td>0.14</td>
<td>4,670</td>
<td>0.67</td>
</tr>
<tr>
<td>Settlement</td>
<td>161</td>
<td>0.023</td>
<td>383</td>
<td>0.06</td>
</tr>
<tr>
<td>Shrub</td>
<td>20,491</td>
<td>2.9</td>
<td>51,011</td>
<td>7.3</td>
</tr>
<tr>
<td>Swamp</td>
<td>971</td>
<td>0.12</td>
<td>822</td>
<td>-0.14</td>
</tr>
<tr>
<td>Woodland</td>
<td>82,791</td>
<td>11.8</td>
<td>44,929</td>
<td>6.4</td>
</tr>
<tr>
<td>Total</td>
<td>701,595</td>
<td>100</td>
<td>701,595</td>
<td>100</td>
</tr>
</tbody>
</table>

There were very dynamics in the land use changes of the Gojeb watershed. Looking at the details of deforestation processes, high forest and dry forest of the sub-basin were cleared dramatically (Fig. 3). Mainly dry forest (dry area/lowland forest) are totally disappeared in 2016, and woodland decreased by half. These have been happened mainly around the middle and eastern part of the basin. On the other hand, LULC transformation matrix from which to which (Table 3) indicates that bareland was accounted about 2 ha in 1986 but grown more than 600 ha in 2016. Similarly, plantation and settlement areas increased five and twice, respectively from the base 1986.
Ecosystem service values

After we summarized the detailed land use land cover types into nine classes, grassland, forest and woodland lost high amount of values in 2016 as compared to 1986 whereas cropland, settlement and shrub/bushland gained. As a watershed, Gojeb watershed gave about US$ 2.52 billion in 1986 but it decreased to US$ 1.97 billion in 2016. The watershed lost about US$ 0.551 billion within the last 30 years (Table 4). The annual loss of US$ 18.4 million was estimated, the major loss was found from forest and woodland reduction, with about US$ of -569 million, and US$ of -37 million, respectively.

### Table 4

<table>
<thead>
<tr>
<th>Land use types</th>
<th>Area (ha)</th>
<th>ESVs (US$)</th>
<th>1986</th>
<th>2016</th>
<th>Net change (2016 – 1986)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bareland</td>
<td>14.5</td>
<td>1,411.8</td>
<td>1,397</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cropland</td>
<td>150,143.6</td>
<td>258,394.4</td>
<td>108,251</td>
<td>33,932,449</td>
<td>58,397,137</td>
</tr>
<tr>
<td>Grassland</td>
<td>23,148.6</td>
<td>22,517.7</td>
<td>- 631</td>
<td>96,437,193</td>
<td>93,808,863</td>
</tr>
<tr>
<td>Forest</td>
<td>423,055.2</td>
<td>317,308.1</td>
<td>-105,747</td>
<td>2,276,882,925</td>
<td>1,707,751,925</td>
</tr>
<tr>
<td>Plantation</td>
<td>968.9</td>
<td>4,669.5</td>
<td>3,701</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Settlement</td>
<td>160.6</td>
<td>383.4</td>
<td>223</td>
<td>1,069,490</td>
<td>2,553,827</td>
</tr>
<tr>
<td>Shrub</td>
<td>20,490.5</td>
<td>51,010.5</td>
<td>30,520</td>
<td>20,224,104</td>
<td>50,347,334</td>
</tr>
<tr>
<td>Waterbody</td>
<td>822.1</td>
<td>970.6</td>
<td>149</td>
<td>10,284,489</td>
<td>12,143,647</td>
</tr>
<tr>
<td>Woodland</td>
<td>82,790.8</td>
<td>44,928.7</td>
<td>-37,862</td>
<td>81,714,539</td>
<td>44,344,647</td>
</tr>
<tr>
<td>Total/net</td>
<td>701,594.64</td>
<td>701,594.64</td>
<td>2,520,545,189</td>
<td>1,969,347,380</td>
<td>-551,197,809</td>
</tr>
</tbody>
</table>

|                | Annual ESVs change (US$/year) | -18.4 million |
| Annual rate per ha (US$/ha/year) | -26.2 |
Our assessment of LULC changes in the Gojeb sub-basin revealed a significant degradation of ES over the last 30 years and a high associated loss of ESVs. The most important change in land cover has occurred in reductions of forest and increasing of cropland. Bareland may have historically exhibited low levels of vegetation or may have been degraded already due to anthropogenic effects. Hence, our results provide evidence that agriculture can be a key driver of LULC change and associated losses of ESVs at the study area and elsewhere with similar environmental and socio-economic settings.

**Land use land cover transformation**

Land use land cover (LULC) changes are aspects of global environmental change and affect ecosystem processes and services. For example, an increasing demand for agricultural, industrial or urban areas compromises the ability of natural forests, waterbodies and grasslands to support mankind (Nelson et al., 2009; Goldman-Benner et al., 2012). In recent decades, a large amount of change in LULC has been observed, which was caused by different socio-economic and biophysical drivers, such as population growth, agricultural expansion and intensification (Shiferaw et al., 2019), accessibility to infrastructure/markets and water availability or climate.

The LULC change analysis revealed that LULC types particularly important for the ecosystem as well as peoples' livelihoods in the sub-basin, namely natural forest, woodland and grasslands, have substantially decreased in the last 30 years. This reflects a general trend found in studies conducted in similar biomes in different parts of the world, e.g. in Australia (Cleugh et al., 2012), China (Li et al., 2007), Mozambique (Niquisse et al., 2017), as well as in different parts of Ethiopia (Gashaw et al., 2018; Hurni et al., 2005; Kindu et al., 2016; Shiferaw et al., 2019; Tolessa et al., 2017; Tsegaye et al., 2010), but also at the global level (Costanza et al., 1997, 2014).

A shift of grassland to bareland, however, is likely to be a combination of overexploitation of forests and climate change. An ever increasing deforestation resulted in high erosion and sediment load of 20.7 ton/ha/year over the catchment, which is equivalent with an annual sediment influx of 14.5 million tons/year for the sub-basin (Yilkal, 2019) that enters to Gibe III hydroelectric dam at the downstream.

Between 1960 and 2010, the population in Ethiopia has increased by 268% (Pricope et al., 2013), and this has translated into higher livestock stocking rates. In recent years, trends in livestock numbers have become more variable but grazers have decreased and browsers increased (Yosef et al., 2013). Due to climate change, spring and summer rains in parts of Ethiopia have declined by 15–20% since the mid-1970s; and the observed warming across the entire country has further contributed to the increasing dryness (Funk et al., 2012).

Several 'anthropogenic' classes, such as cropland, settlements and bareland have also increased at the expense of natural vegetation cover. Similar trends of LULC changes towards more anthropogenic land use categories were found in other studies conducted in Eastern Africa, with cropland and settlements increasing at the expense of forests, shrubland and grasslands (Eckert et al., 2017; Shiferaw et al., 2019; Tolessa et al., 2017; Zewdie and Csaplovics, 2015). In general, these spatial and temporal analyses and control their processes are important to help manage, restore, rehabilitate and protect environmental resources so as to maintain the quality and quantity ecosystem services provisions (Yilkal, 2019).

**Ecosystem service values and implications**

Since all ESV estimates are based on studies from the study area itself or areas from the same biome (Olson et al., 2001), but not necessarily from the same topographic settings, we estimated the ESVs on the present study based on the coefficients used in different studies in the tropical regions (Costanza et al., 2014; Kiundu et al., 2016, Shiferaw et al., 2019). In the present study, the ESVs dropped annually by US$ 18.4 million over 30 years (or 26.2 US$ ha⁻¹ y⁻¹) while Kindu et al. (2016) estimated that in a 10000 ha area in the Ethiopian highlands, ESVs had dropped over the last 40 years by US$ 19.3 million (or 48.3 US$ ha⁻¹ y⁻¹). This indicates that the study area is relatively better in ESVs than the central highlands where there is high population pressure. Hence, restoring the area before it gets worse would cost less unlike other degraded parts of the country.

Several large scale agricultural investments have already been established in recent years in the sub-basin. This development will have a substantial impact on future LULC changes and ESVs. In addition, the expansion of investment programs both in the upper and downstream is expected to consume large areas of seasonal grasslands, forest and shrub/bushland (Shiferaw, personal observation). It is likely that ESVs from cropland will also further increase in the future due to a growing need for food and thus expansion of crop production in order to nourish the increasing population (Niquisse et al., 2017) though cropland has much lower ESVs than forest.
The average annual loss in ESVs in our study area is more than fourfold of the annual budget plan in 2016/17 budget of the whole zone level where the basin is found (BoFED, 2017). This suggests that changes in ESVs should be considered as one of the indicators of stability of socio-ecological systems, human welfare and hence their assessment should be considered as a policy instrument (Niquisse et al., 2017) in the study area as well as elsewhere exhibiting with the same challenges.

Mainstreaming ES and its values into policy and decision making is dependent on the availability of spatially explicit information on the state and trends of ecosystems and their services (Maes et al., 2012). Moreover, there is a need for designing restoration and/or rehabilitation programs to make the area resilient to climate change, frequent drought and also flood impacts so that sustainable ES and functions are maintained. Together with the implementation of sustainable forest, woodland and grassland management practices will be fundamental for preserving or even restoring the remaining ESVs in the study area and other regions in Eastern Africa.

**Conclusion**

The land use land cover transformation was very dynamic within the last 30 years in Gojeb watershed. The major LULC transformations were found from high and dry forest, shrubland and woodland areas to open woodland, cultivated land, settlement agroforestry and bareland. These have been happened mainly around the middle and eastern part of the basin. On the other hand, bareland, cropland, plantation and shrubland areas increased. The major ES providing land use types were decreased in areas as well as in ESVs: grassland, forest and woodland areas. Hence, Gojeb watershed has been lost ESVs of US$ 18.4 million every year.

Potential drivers could be agricultural expansion, land degradation and erosion, landslide and deforestation, indicating that it requires concerted effort to overcome such impacts. Therefore, restoration schemes should account the baseline land use/cover types so that soil seedbank could support rehabilitation or reforestation with some additions of seeds or afforestation. This can enhance economic and ecosystem services from forest including carbon stock. Moreover, hydropower plants in the downstream will also benefit from upper catchment rehabilitation in terms of renewable energy production for domestic use and regional markets. Thus, this study is meaningful for management of natural resources in the catchment, improvement of hydropower production and lifespan of the hydropower reservoir on one hand and productivity of small holder farmers and inhabitants in the basin on the other besides to the lesson learned to other similar basins. Hence, payment for ecosystems service scheme is recommended as a win-win approach to be implemented between upper and downstream users for sustainable use of resources.

**Declarations**

**Ethics and Declaration or Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

We received a consent for waiving of publication processing fee from ENSR

**Availability of data and materials**

Not applicable

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**Conflict of interest**

The authors declare that there is no conflict of interest.
Authors' contributions

HS conceived the idea, collect relevant data, and wrote the draft manuscript, TA supported field work and write the manuscript, TK carried out LULC analysis, and GZ supported the overall progress. All authors contributed in final writing.

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