Full Length Research Paper

Evaluations of Land Use/Land Cover Changes and Land Degradation in Dera District, Ethiopia: GIS and Remote Sensing Based Analysis

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Abstract. Evaluation of land use/land cover changes and land degradation in Dera District, Ethiopia were undertaken using two remotely sensed datasets (Landsat 5 TM of 1985 and Landsat 7 ETM\textsuperscript{+} imagery 2011). Land use/land cover change detection and Normalized Difference Vegetation Index analysis was carried out on the two images. Global positioning system and topographical maps of scale 1:50,000 for ground verification and ERDAS Imagine 9.1 and ArcGIS 9.2 software for satellite image processing and analysis were used for the study. Field observations and focus group discussions were also conducted to obtain addition information. The result of this study showed that cultivated and degraded lands were increased by 25.79\% and 398\% respectively at the expense of forest, shrub and grazing lands. Normalized Difference Vegetation Index analysis has also indicated the increased of land degradation between 1985 and 2011 images which mainly aggravated by land use/land cover changes.

Keywords: land use/land cover change, land degradation, NDVI

1. INTRODUCTION

Land use and land cover (LU/LC) change is a major issue of global environment change (Prakasam, 2010). The terms “land use” and “land cover” are often confused. Land use change is defined as the alteration of land use due to human intervention for various purposes, such as for agriculture, settlement, transportation, infrastructure and manufacturing, park recreation uses, mining and fishery. In contrast, land cover change refers to the conversion of land cover from one category of land cover to another and/ or the modifications of conditions within a category (Meyer and Turner, 1992).

Land use dynamics is one of the major environmental problems in Ethiopia (Berhan, 2010). Studies conducted in different parts of the country reported a significant decrease of vegetation cover due to the expansion of cultivated land (Gete and Hurni, 2001; Belay, 2002; Gessesse and Kleman, 2007; Abate, 2011). Estimates of deforestation in Ethiopia, which is mainly for expansion of rain fed agriculture, vary from 80,000 to 200,000 ha per annum (EPA, 1997). While, some studies conducted in the previously degraded parts of north Ethiopia, revealed improvement of vegetation cover due to plantation and enclosure of the previously degraded hillsides in the period since the 1980s. For example, a study conducted by Woldeamlak (2002) in Chemoga watershed, East Gojjam revealed the increased of forest cover at a rate of 11 ha per annum from 1957-1998, even though it is eucalyptus plantation. Similar study by Amare (2007) and Amare et al. (2011) in Eastern Escarpment of Wello, Ethiopia and Munro et al. (2008) in Tigray highlands disclosed that vegetation cover improved since the 1980s owing to land rehabilitation efforts of the community supported by the government and multilateral donor agencies.

Land degradation includes all process that diminishes the capacity of land resources to perform essential functions and services in ecosystems (Hurni et al., 2010) are caused by two interlocking complex systems: the natural ecosystem and the human social system. Interactions between the two systems determine the success or failure of resource management (Berry, 2003). The major causes of land degradation in Ethiopia are rapid population increase, severe soil loss, deforestation, low vegetative cover and unbalanced crop and livestock production (Girma, 2001). In this case, the Ethiopian highlands are highly affected by land degradation, which have eroded the
natural resource bases of the area (Tilahun et al., 2001).

LU/LC changes and land degradation are interrelated (Gete and Hurni, 2001; Lambin et al., 2003; Kiage et al., 2007; Messay, 2011) because LU/LC changes are associated with deforestation, biodiversity loss and land degradation (Maitima et al., 2009). As rightly noted by Abate (2011) it is taken as a serious problem in changing the environment. Similarly, Desta et al. (2000); Tilahun et al. (2001); Belay (2002) stated that LU/LC changes towards cultivated land aggravates soil erosion problems unless proper management are undertaken. A study by Hurni and Ludi (2000) also reveals that human land use around the Simen Mountains National Park has accelerated the degradation of vegetation and soils. Thus, evaluating the existing LU/LC and its periodic change and land degradation is useful for urban planners, policy makers and natural resource managers (Tahir et al., 2013). In this case, GIS and remote sensing provides an ability to characterize large assessment areas and establish reference conditions (Abate, 2011). However, studies on evaluation of LU/LC dynamics and land degradation and their linkage are rare in Ethiopia in general and in the study area in particular. Thus, this study aims to evaluate the pattern of LU/LC changes and land degradation and to analysis their link.

2. MATERIALS AND METHODS

2.1. Study area

This study was conducted in Dera district, Ethiopia which is located between 12° 92' - 13° 12’ N latitude and 34° 40' - 35° 80’ E longitude and elevation from 1798 m to 2118 m above sea level. Topographically, the area exhibited plateau at the upper limit to plain in the lower limit. The average annual rainfall and temperature is 1250 mm and 19 °C respectively. Agriculture is the major economic activity which is characterized by rain-fed and predominantly subsistence nature. Both crops and livestock productions are equally important at Dega and Woinadega agro-ecological zones of the study area. The main soil types of the study area are Nitisols, Vertisols, Gleysols, Luvisols and Cambisols. The dominant vegetation type includes: Eucalyptus species, Croton macrostachyus, Juniperus procera, Cordia africana and Ficus vasta.

2.2. Data collection

Two years multi-temporal satellite imageries (Landsat 5 TM of 1985 and Landsat 7 ETM+ imagery 2011) were used for the study. Field observations and focus group discussions with farming households (HHs) were also conducted to obtain additional information. Global positioning system and topographical maps of scale 1:50,000 were used for ground verification.

Table 1: Types of landsat and toposheet used in the study

<table>
<thead>
<tr>
<th>Image</th>
<th>Path</th>
<th>Row</th>
<th>Sensor</th>
<th>Resolution or Scale</th>
<th>No of Bands</th>
<th>Date of acquisition</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat5</td>
<td>169</td>
<td>52</td>
<td>TM</td>
<td>30 X 30</td>
<td>7</td>
<td>25/12/1985</td>
<td>GLCF</td>
</tr>
<tr>
<td>Landsat7</td>
<td>169</td>
<td>52</td>
<td>ETM +</td>
<td>30 X 30</td>
<td>8</td>
<td>12/1/2011</td>
<td>GLCF</td>
</tr>
<tr>
<td>Toposheet</td>
<td></td>
<td></td>
<td></td>
<td>1:50,000</td>
<td></td>
<td></td>
<td>EMA</td>
</tr>
</tbody>
</table>

2.3. Image Classification Methods

The overall objective of image classification procedures is to automatically categorize all pixels in an image into LU/LC classes to extract useful thematic information (Boakye et al., 2008). Multi-spectral image classification is one of the most used methods to extract thematic information from satellite images (Sarma et al., 2008). Image preprocessing including band ratio, radiometric correction (haze reduction), Tasseled Cap and post classification comparisons were performed to correct the surface features reflectance characteristics. Then, the LU/LC maps were produced from Landsat5 TM of 1985 and Landsat7 ETM+ of 2011.

Image classification was undertaken using hybrid classification method involving both unsupervised and supervised techniques. The hybrid classification method was chosen because it improves the accuracy and efficiency of the classification which involves feature identification through both spectral and spatial pattern recognition (Lillesand and Kiefer, 2000). Using signature editor of unsupervised classes, supervised categorization of image pixels were made on the basis of their pixel by pixel spectral reflectance and spatial relationships of pixels with pixels surrounding them through geo-linking techniques. Among different classification algorithms, maximum likelihood was used for supervised classification by taking 60 training areas for six major LU/LC class categories (10 training points for each LU/LC class).
The LU/LC classes include forest land, shrub land, grass land, cultivated land, degraded land and water body (Table 2).

ERDAS Imagine 9.1 and ArcGIS 9.2 software were used for satellite image processing and LU/LC change analysis. The rate of change was calculated for each LU/LC following the formula stated by Abate (2011): Rate of change (ha/year) = (A-B)/C

Where: A = Recent area of LU/LC in ha, B = Previous area of LU/LC in ha, C = Time interval between A and B in years.

Fig. 1: Flow chart of LU/LC classification

2.4. Accuracy assessment

The fact that accuracy assessment is so important that it tells us to what extent the truth on the ground is represented on the corresponding classified image. In this study, accuracy assessment was done for the recent satellite image of Landsat7 ETM+ 2011, for which the ground truth data is likely corresponding. An overall accuracy was calculated by summing the number of pixels classified correctly and dividing by the number of pixels. Thus, an overall accuracy of 84% with a Kappa coefficient of 0.82 was achieved.
2.5. Methods of vegetation stress detection

In order to recognize the vegetation trend which is an indicator of both environmental stress and land cover degradation, the TM imagery of 1985 and ETM+ of 2011 acquired on December and January respectively were used to calculate Normalized Difference Vegetation Index (NDVI). NDVI is an empirical formula designed to separate green vegetation from other surfaces based on the vegetation reflectance properties of the area. NDVI value of the result will be between -1 and 1. NDVI values greater than zero indicate the presence of vegetation. The higher the vegetation index value, the higher the probability that the corresponding area on the ground has a dense coverage of green vegetation. Negative values indicating no vegetation and correspond to the presence of water bodies (Kiage et al., 2007). The final NDVI map of the study area were categorized into four parts that is water bodies (NDVI value < 0), highly stressed (0 < NDVI value ≤ 0.2), moderately stressed (NDVI value 0.2 < NDVI value ≤ 0.4) and low stressed areas (NDVI value > 0.4). Thus, it is possible to know the vegetation trend of the area from 1985 and 2011. ERDAS Imagine 9.1 for calculating NDVI values and ArcGIS 9.2 for NDVI mapping were used.

By using the NDVI result of two different years image (1985 and 2011) vegetation changes were detected which is calculated as NDVI = (NIR-RED)/(NIR+RED)

Where NIR is the near infrared band response for a given pixel and RED is the red response

3. RESULTS AND DISCUSSIONS

3.1. Land use/Land cover change analysis

The result of this study showed that cultivated and degraded land had increased at a rate of 38.29 ha/year and 15.2 ha/year respectively in the last 26 years (1985-2011). These changes were at the expense of forest, shrub and grass land (Table 3). In addition, farmers in the area are encroaching and cultivating sloppy and marginal areas, which aggravate land degradation. LU/LC changes are complex and interrelated that is the expansion of one land use type is at the expense of others (Belay, 2002; Abate, 2011). In relation to this finding, recent watershed based land use studies has showed that land use change is brutal and there has been agricultural land size expansion at the expense of natural vegetation cover lands and marginal areas without any appropriate conservation measures (Woldeamlak, 2002; Amsalu et al., 2006; Gessesse and Kleman, 2007). Similarly, Gete and Hurni (2001) have also documented the expansion of cultivated land at the expense of forestland between 1957 and 1982 in Dembecha area, northwestern Ethiopia.
Table 3: LU/LC changes of the study area between 1985 and 2011

<table>
<thead>
<tr>
<th>LU/LC class</th>
<th>1985 Area (ha)</th>
<th>%</th>
<th>2011 Area (ha)</th>
<th>%</th>
<th>Change in ha (1985-2011)</th>
<th>Rate of change in ha/year (1985-2011)</th>
<th>Percentage change (1985-2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water body</td>
<td>38.79</td>
<td>0.53</td>
<td>35.64</td>
<td>0.48</td>
<td>-3.15</td>
<td>-0.12</td>
<td>-8.12%</td>
</tr>
<tr>
<td>Forest</td>
<td>706.41</td>
<td>9.6</td>
<td>310.14</td>
<td>4.22</td>
<td>-396.27</td>
<td>-15.24</td>
<td>-56.09%</td>
</tr>
<tr>
<td>Shrub</td>
<td>1408.32</td>
<td>19.14</td>
<td>464.4</td>
<td>6.31</td>
<td>-943.92</td>
<td>-36.3</td>
<td>-67.07%</td>
</tr>
<tr>
<td>Grass</td>
<td>1243.98</td>
<td>16.91</td>
<td>1196.46</td>
<td>16.26</td>
<td>-47.52</td>
<td>-1.83</td>
<td>-3.81%</td>
</tr>
<tr>
<td>Cultivated</td>
<td>3859.74</td>
<td>52.47</td>
<td>4855.23</td>
<td>66</td>
<td>+995.49</td>
<td>+38.29</td>
<td>+25.79%</td>
</tr>
<tr>
<td>Degraded</td>
<td>99.36</td>
<td>1.35</td>
<td>494.73</td>
<td>6.72</td>
<td>+395.37</td>
<td>+15.2</td>
<td>+398%</td>
</tr>
<tr>
<td>Total area</td>
<td>7356.60</td>
<td>100</td>
<td>7356.60</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2: LU/LC map of the study area (1985 and 2011)

3.2. Land degradation assessment

The statistics and visual observation of the NDVI images over the subsequent periods were an evidence for land cover changes that may well indicate increased deforestation and land degradation in the study area. As it can be visually compared, the amount of green vegetation is falling. Taking the maximum value, it dramatically decreases from 0.83 in 1985 to 0.58 in 2011. To this effect, the standard deviation value decreases in certain value in 2011 image as compared to 1985 because of the change in vegetation cover (Table 4). Overall, there was an increase in the size of the land cover class classified as severely stressed area. Similar study conducted by Kiage et al. (2007) the Lake Baringo catchment, Kenya, East Africa and Brhane (2010) in Dendi district case study, Ethiopia reported the decline of total vegetation cover and the increase of land degradation in the study periods. Similarly, a study by Ochego (2003) in Aberdares (Kenya) is also in agreement with the findings of this study, who stated that a positive mean of stressed area in the period 1987-2000. NDVI differencing is an indication of reduction in biomass within this period of study which implies a decline in vegetation.
Table 4: NDVI result of the study area

<table>
<thead>
<tr>
<th>Statistics</th>
<th>1985</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>-0.91</td>
<td>-0.09</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.83</td>
<td>0.58</td>
</tr>
<tr>
<td>Mean</td>
<td>0.108</td>
<td>0.05</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.125</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Fig. 3: NDVI map of 1985

3.3. LU/LC changes and land degradation in the study area

Change in LU/LC doesn’t always give necessary result in land degradation. But if LU/LC change is towards cultivated and degraded land, the soil is easily susceptible to erosion than forest, shrub and grass land (Gete and Hurni, 2001; Belay, 2002; Woldeamlak, 2002; Maitima et al., 2009).

The change detected in the study area in accordance with the classified classes between 1985 and 2011 revealed that forest, shrub and grass land cover were transformed into cultivated and degraded land. This showed how changes in LU/LC aggravate land degradation. In addition, NDVI analysis has also proved that there had been change in land use and land cover and increase of land degradation between 1985 and 2011 images. Conversion of forest, shrub and grazing land into cultivated land on steep slopes is one of the causes for soil erosion and degraded land (i.e. land out of cultivation). Thus, the study reveals the existed LU/LC changes aggravated land degradation. Similarly, Belay (1995) illustrated that the expansion of agriculture towards the steeper slopes has accelerated soil erosion in Ethiopia. Tilahun et al. (2001) also accounted that declining vegetative cover and increased farming on steep slopes in Ethiopian highlands have eroded and depleted soils in situ, so that soil degradation is now a widespread environmental problem. Some impacts of land degradation which are caused by LU/LC changes include: increase of poverty and migration, land productivity decline, loss of biodiversity, decline of ground water recharge and carbon storage capacity, change in population size, and spatial distribution (Abate, 2011). As stated by Abbas et al. (2010), more recent significant effects of land use change include urban sprawl, soil erosion, soil and land degradation, salinization and desertification. As discussed above, the present research has shown complex linkages of land use and land cover change with land degradation (Fig 5).
4. CONCLUSIONS

Evaluation of LU/LC changes and land degradation using GIS and remote sensing applications in the study area verified that forest, shrub and grazing land were transformed into cultivated land. NDVI analysis has also proved the increased of land degradation between 1985 and 2011 images. These imply the observed LU/LC changes are a cause for the observed land degradation. Thus, creating off-farm job opportunities, increasing family planning activities, appropriate soil and water conservation measures, appropriate use of soil fertility improving mechanisms and also proper management of the land will reduce the problem. Furthermore, the land use policy of the country should be effectively implemented to reverse the trend of LU/LC changes and land degradation and at the same time to enhance the livelihood of farming households.

REFERENCES


Hurni H, Ludi E (2000). Reconciling Conservation with Sustainable Development: a Participatory Study inside and around the Simen Mountains National Park, Ethiopia. With the assistance of an interdisciplinary group of contributors, University of Berne, Switzerland.


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