

Modeling the Implication of Land Use Land Cover Change on Soil Erosion by Using Remote Sensing Data and GIS Based MCE Techniques in the Highlands of Ethiopia

Asirat Teshome Tolosa

Department of Hydraulic and Water Resources Engineering, Debre Tabor University, Debre Tabor, Ethiopia

Email address:

tesheasirat@gmail.com

To cite this article:

Asirat Teshome Tolosa. Modeling the Implication of Land Use Land Cover Change on Soil Erosion by Using Remote Sensing Data and GIS Based MCE Techniques in the Highlands of Ethiopia. *International Journal of Environmental Monitoring and Analysis*.

Vol. 6, No. 6, 2018, pp. 152-166. doi: 10.11648/j.ijema.20180606.12

Received: November 30, 2018; **Accepted:** December 11, 2018; **Published:** January 2, 2018

Abstract: Soil erosion is one of the natural resources which can be influenced by Land use land cover change (LCC). The main influencing factor for land use land cover change is the increase of population, which in turn resulted in land degradation. This study aimed at modeling and analyzing LCC and its effect on soil erosion. The study was conducted in the highlands of, Blue Nile Basin, Ethiopia. Three Landsat images (1986, 2000 and 2016) were used to analyze the LCC. Supervised classification using maximum likelihood algorithm was used to analyze the LCC. Four land cover types (LCTs) cropland, forest, and grassland and shrubland were defined. Multi-criteria decision analysis (MCE) using the Analytic Hierarchy Process (AHP) was used to prioritize the most influencing factor for soil erosion. Five major factors; land use, slope, soil types, Topographic Wetness Index (TWI) and altitude were considered to analyze the erosion hotspot area. The result showed that cropland and grassland increased from 41.6% and 15.4% in 1986 to 58.8% and 28.3% in 2016, respectively. However, shrubland and forest decline from 32.3% and 10.6% in 1986 to 5.6% and 7.3% in 2016, respectively. The AHP analysis showed that LCT is the most contributors for erosion. It is observed that free grazing in the area is the common practice which is the main contributor to erosion. Hence, 50% of the gully erosion is influenced by LCT. The resultant erosion risk map shows that 1.12% of the area lies under the low-risk zone, whereas 19.02%, 72.67% and 7.2% of the total area fall in medium, high and very high-risk categories respectively. The results verified by field data collected and the judgment of the experts.

Keywords: GIS, Landsat, Remote Sensing, Analytic Hierarchy Process, MCE, Supervised Classification

1. Introduction

Land cover change is the central driver and the most dynamic phenomenon that is caused by the interface between human and ecological system [1]. Human beings have deliberately managed and converted the landscape to utilize natural resources in order to obtain basic needs such as food, shelter, water, and other products [2]. The human activities in general and agriculture, in particular, modify or change the environment of the given landscape. With particular to Ethiopia, different studies, particularly in the highlands of Ethiopia, indicated considerable LCC is a continuous process

due to an increase in human and livestock population [3-6]. The major land cover conversions are from forests into other land cover types (LCTs) such as into cultivated land, settlement, and grassland [4, 6, 7, 8, 9]. These changes and modification of a landscape can be described using field data or remote sensing approach to support the agriculture-related decision and policy-making process. Land cover mapping, modeling, and monitoring of the environment are extracted from remote sensing data. Nowadays, the use of remote sensing data and GIS is increasing over time for mapping land cover change detection and monitoring of different ecosystems since 1972 [8, 10].

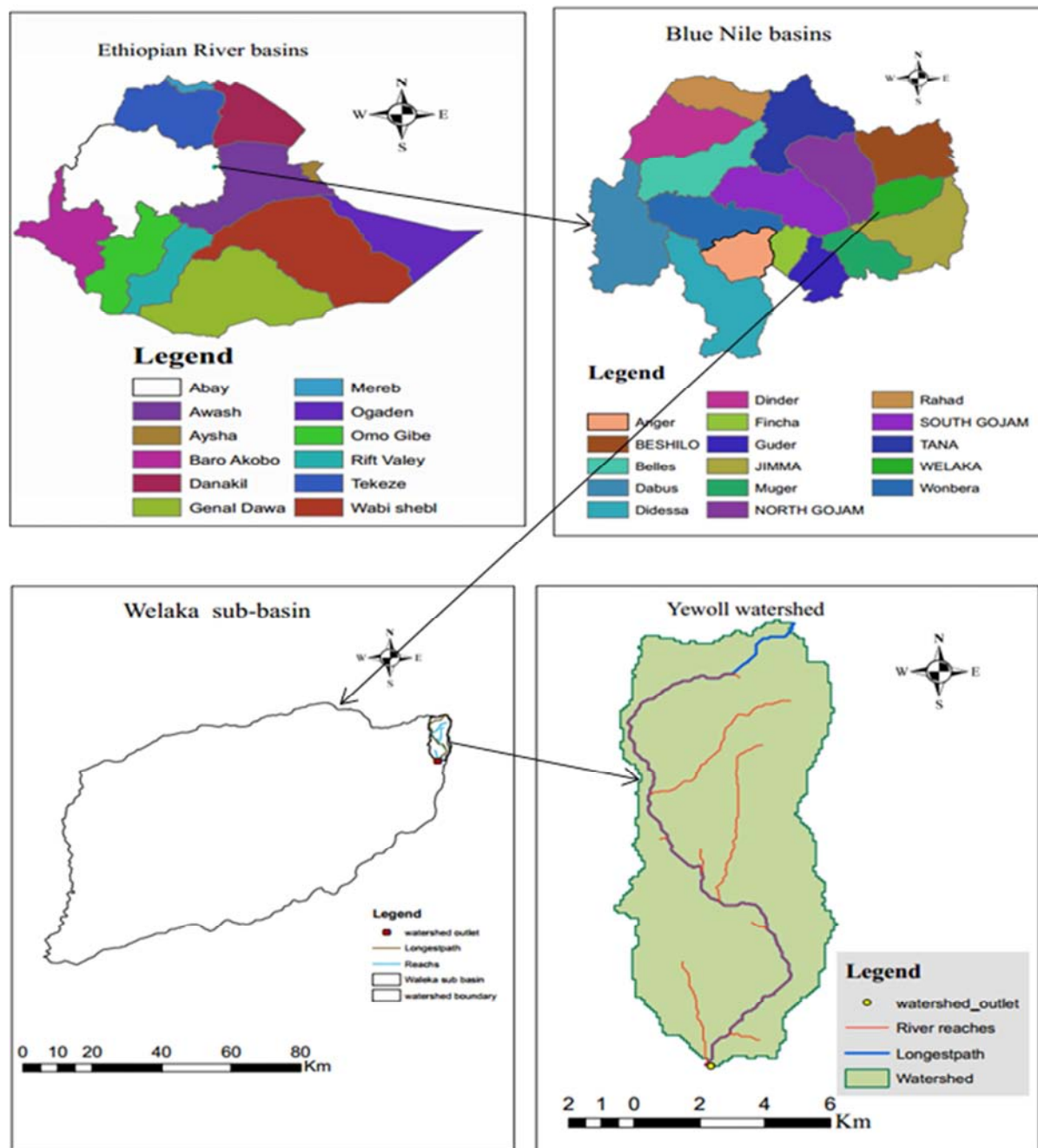


Figure 1. Location of the study area.

Erosion is one of the outcomes of landscape modification and/or change due to mismanagement of land resource [11]. It is a result of a combination of factors such as topography, soil characteristics, and climate and land use land cover change [12]. Soil erosion is caused by land cover change, topographic variables, socioeconomic activities and other biophysical factors [13]. The contribution of different variables for soil erosion and formation of gully has to be weighted and prioritized to further design the mitigation methods. Identifying the most influencing factor for soil erosion helps to choose the best practices to improve the livelihood and environmental situation [14, 15]. The use of remote sensing and geographical information system (GIS)

techniques provide quantitative soil erosion estimation and its spatial distribution with reasonable costs, time and accuracy in larger areas. The soil quality degradation due to erosion resulting from human activities and natural conditions threatens the sustainability of agriculture. Agricultural land degradation by soil erosion is a worldwide phenomenon [16]. Soil erosion is a major problem in the highlands of Blue Nile Basin, Ethiopia [17, 18, 19]. Yewoll watershed is part of Blue Nile basin situated in the highlands of Eastern Amhara and characterized by soil erosion similar to other highlands. Soil erosion is directly affected by land use change. Therefore, the modeling of land use change is important with respect to the prediction of soil erosion and

degradation. Specifically, this study was designed to answer the following research questions:

- (1) What is the impact of LULC change of study watershed on soil erosion potential within the watershed?
- (2) Can we identify the soil erosion vulnerable areas in the study watershed?
- (3) What are the important factors considered for soil erosion in the study area?

Generally, the consequences of both anthropogenic activities and natural processes in the area aggravates land degradation by soil erosion, as a result of this land cover change was detected, the rate of change quantified and soil erosion susceptible area mapped using GIS and Remote sensing.

2. Materials and Methods

2.1. Description of the Study Area

The study area is situated approximately between the Geographic coordinate system of $10^{\circ}46'29.83''$ and $10^{\circ}55'11.21''$ N, and between $39^{\circ}24'35.38''$ and $39^{\circ}28'20.60''$ 'E. The nearest town is Dessie in the South Wollo zone of Amhara region. It is about 460 km north-east

of Addis Ababa. The study area comprises three districts namely; Werraeilu, Leg ambo, and Dessie zuria. Topographical location of study area ranges with an elevation difference from 2731 m a.s.l just at the outlet of Selgi River to 3847 m a.s.l at the top of the Yewoll Mountain. The main River Selgi and the tributaries Aba Tisha river and Abale river drain the upper parts of Yewoll watershed. The total area of the watershed is about 8203ha. The study watershed is characterized by different landforms which range from high mountains too steep lands to flat slope at the outlet. The watershed is drained to Selgi river which is emanated from spring of Yewoll Mountain. The study area is situated in the upper part of Blue Nile basin and particularly located in Welaka sub-basin of the Blue Nile basin. The location of the study area was presented (figure 1)

2.2. Acquisition of Digital Elevation Model

A DEM supplied from SRTM (Shuttle Radar Topography Mission) data were used to obtain slope and altitude information. The SRTM DEM with a spatial resolution of 30mx30m and the location of study site was downloaded from website <http://earthexplorer.usgs.gov/> (Figure 2).

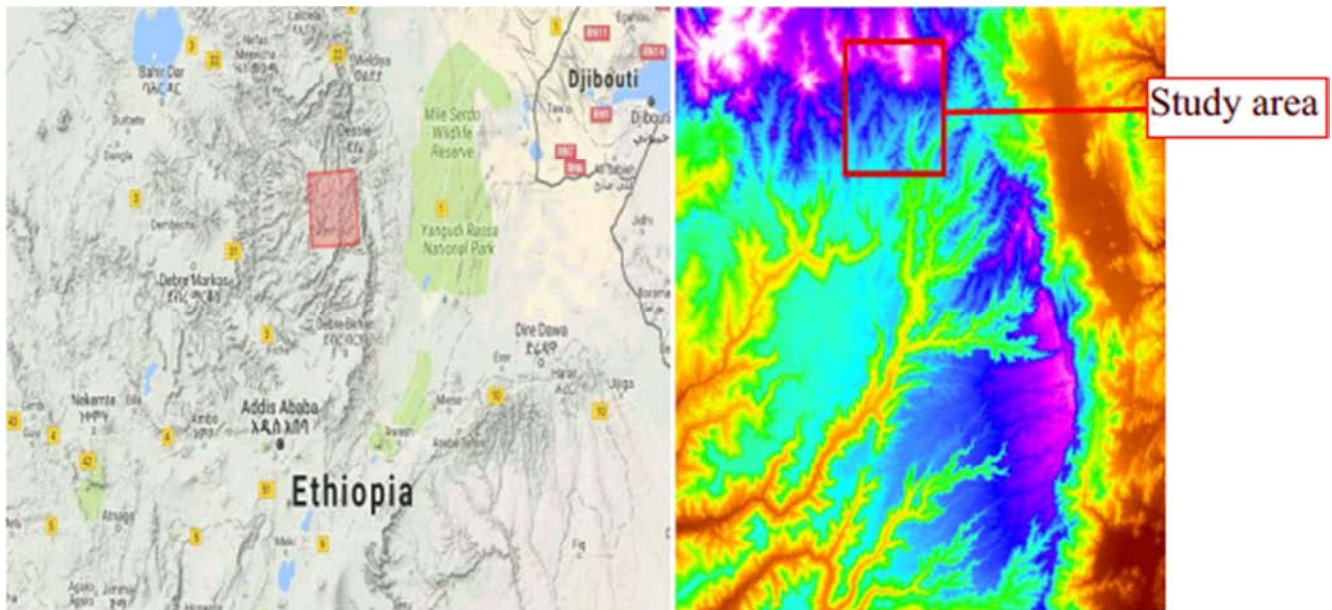


Figure 1. Location of the study site in a scene (source: <http://earthexplorer.usgs.gov/>).

2.3. Methods

The methods used in this study are field data collection includes reference information and socioeconomic data, and satellite image analysis. Three satellite images (Landsat8 OLI, L7 ETM+, and L5 TM) were acquired from USGS website <http://earthexplorer.usgs.gov>. These data were used

to analyze the status and changes of LC in the different time span. The field data collection conducted during the study period was used to validate the image classification and understanding the different features of the study area. The methodology applied for this study was consolidated according to the following flowchart (figure 3).

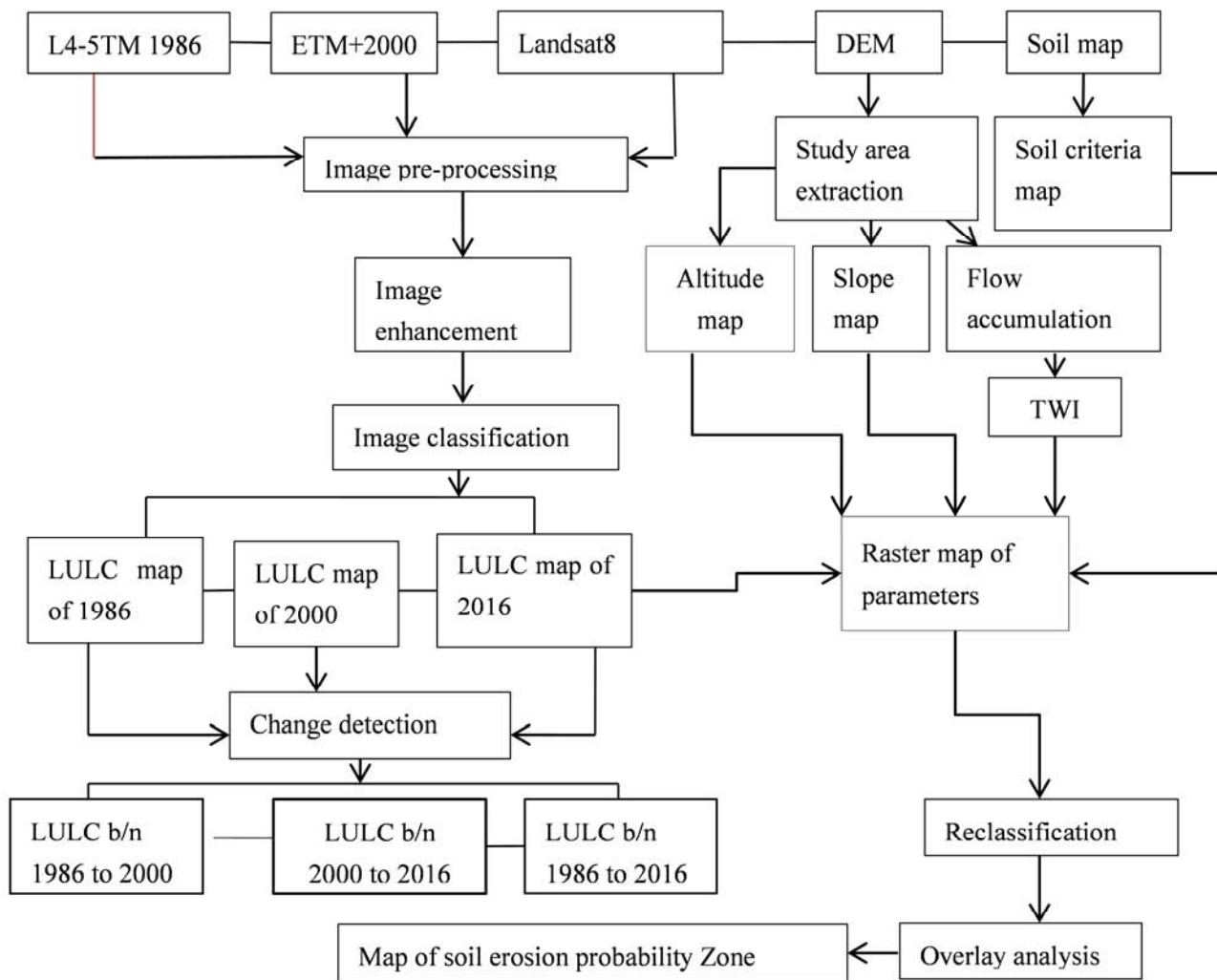


Figure 3. Workflow of the analysis method.

2.4. Data Collection

A DEM supplied from SRTM (Shuttle Radar Topography Mission) data was used to obtain slope and altitude information. The SRTM DEM with a spatial resolution of 30m was downloaded from website <http://earthexplorer.usgs.gov/>. Field data collection were carried out to obtain ground control points (GCPs) using GPS and to collect biophysical data. The GCPs were used to understand the features of the different LCTs, to support the visual interpretation of the images and to select reference areas (area of interest) and accuracy assessment. All reference areas were localized using GERMIN76 GPS. Representative samples were taken from Cropland, Forest land, Grassland, Shrubland, and Gully sites as training

samples to start image analysis. In addition, the samples were used for accuracy assessment. The numbers of representative training samples for Cropland, Forest, Grassland, Shrubland, and Gully sites were 38, 34, 39, 11 and 15, respectively. As it was said earlier GPS readings were taken for each sample point with an accuracy varying from 3 to 7.5 meters. Physical description of the land cover types was carried out to support image analysis. The local development agencies and the farmers residing in the watershed assisted to describe different LCTs and the biophysical condition of the area. A local expert provided detailed information about the land cover types. The land cover categorization scheme was set following the methods of [6, 20]. As indicated in Table 1.

Table 1. Land covers categories for change detection.

Cover class	Characterization, features
Cropland	Cultivated and fallow land has a characteristic pattern, for example, sharp edges between fields. Dark to grey color in the Landsat image (4, 3, 2 color composition), unless the land lies fallow.
Forest-land	This category comprised of planted junipers, eucalyptus trees, Acacia and natural forest or areas covered by trees planted around homesteads and some public institution areas.
Grassland	Land allocated as a source of animal feed. Land under permanent pasture and grassland [21].
Shrubland	The areas covered with different species of shrubs, bushes and young tree species with widely varying density from one locality to another [22].

2.5. Data Analysis

Image preprocessing such as layer stacking and contrast stretching were carried out using ERDAS Imagine 2014. Contrast stretching using a linear method was conducted to enhance the image so that to improve the visual interpretability of the image. The method used to classify the Landsat images was supervised classification. The decision rule used in supervised classification was the maximum likelihood classifier algorithm. Area of interests (AOIs) was selected and collected as training areas for classification of the pre-defined LCTs. Pixels were clustered into the categories of Cropland, Forest land, Grassland, and Shrubland. Variable numbers of AOIs were used to classify the images of the three dates (1986, 2000 and 2016). In addition, size and distribution of individual training polygons (AOIs) were variable within and between LCTs depending on the location and availability. The AOIs were distributed in the area of each LCT. The AOIs were selected based on the knowledge of the area obtained from field work and visual interpretation of the images. During selection of AOIs, cropland was differentiated from grassland based on differences in pattern and texture. After classification, feature space was developed to understand the separation. AOIs for Cropland, Forest, Grassland and Shrub-land in 1986 was 36, 47, 26 and 31, in 2000 was 46, 40, 22 and 23, and also in 2016 was 48, 40, 30 and 17 respectively. The results of supervised classification satellite images were evaluated using overall accuracy assessment and kappa coefficient.

2.6. Land Cover Change Detection Analysis

Post classification comparison was carried out for independent images (thematic maps) which are the most proven technique to deal with change detection. Before LCC detection, consistency of classification and approach was checked to reduce human-induced misclassification. ERDAS modeler was used to detecting the change between the two datasets

2.7. Multi-Criteria Decision Analysis

The integration of MCE techniques within GIS context is important to support spatially explicit information to support

decision-making processes. The AHP has been implemented in various fields of studies viz. natural, economic and social sciences. The first important component is the pair-wise comparison matrix, then computing the eigenvalue and eigenvector of the pair-wise comparison matrix. Five parameters (land use/cover, soil, slope, Topographic Wetness Index and Altitude) were chosen to analyze the soil erosion risk mainly the formation of the gully in Yewoll Watershed. These parameters were derived from different data sources such as DEM, FAO soil, and remotely sensed data.

A Multi-Criteria Decision Analysis (MCE) called Analytic hierarchy process (AHP) was used to compare the five parameters with regard to their effect on soil erosion risk assessment. The major focus of erosion hotspot area assessment was gully formation. AHP was used to rank factors affecting soil erosion using scoring and weighting i.e. changing the qualitative description into quantitative information [23]. AHP is a method used to convert subjective assessments of relative importance to a set of overall scores or weights. This study involved five steps to make MCE. These were the identification of the problem i.e. soil erosion risk assessment using different parameters, selection of the factors influencing soil erosion mainly gully formation, comparison and weighting factors, a ranking of the factors and finally delivering MCE evaluation results. Group discussions, interviews, and document analysis were used in combination to support the decision of identifying, choosing and ranking to obtain the most hotspot erosion risk areas to design sustainable land management practices. After identification of the potential gully site in the study area by using remote sensing data the result was validated by ground control point collected from gully site on the field. Soil erosion risk was rated as low, medium, high and very high using the method.

2.8. Problem Identification

Soil erosion is one of the contributors to land degradation and thereby for food insecurity. The AHP was suggested as MCE tool in order to use a hierarchical structure to effectively frame a problem. It decomposes complex multi-criteria decision problems into a simplified analysis process.

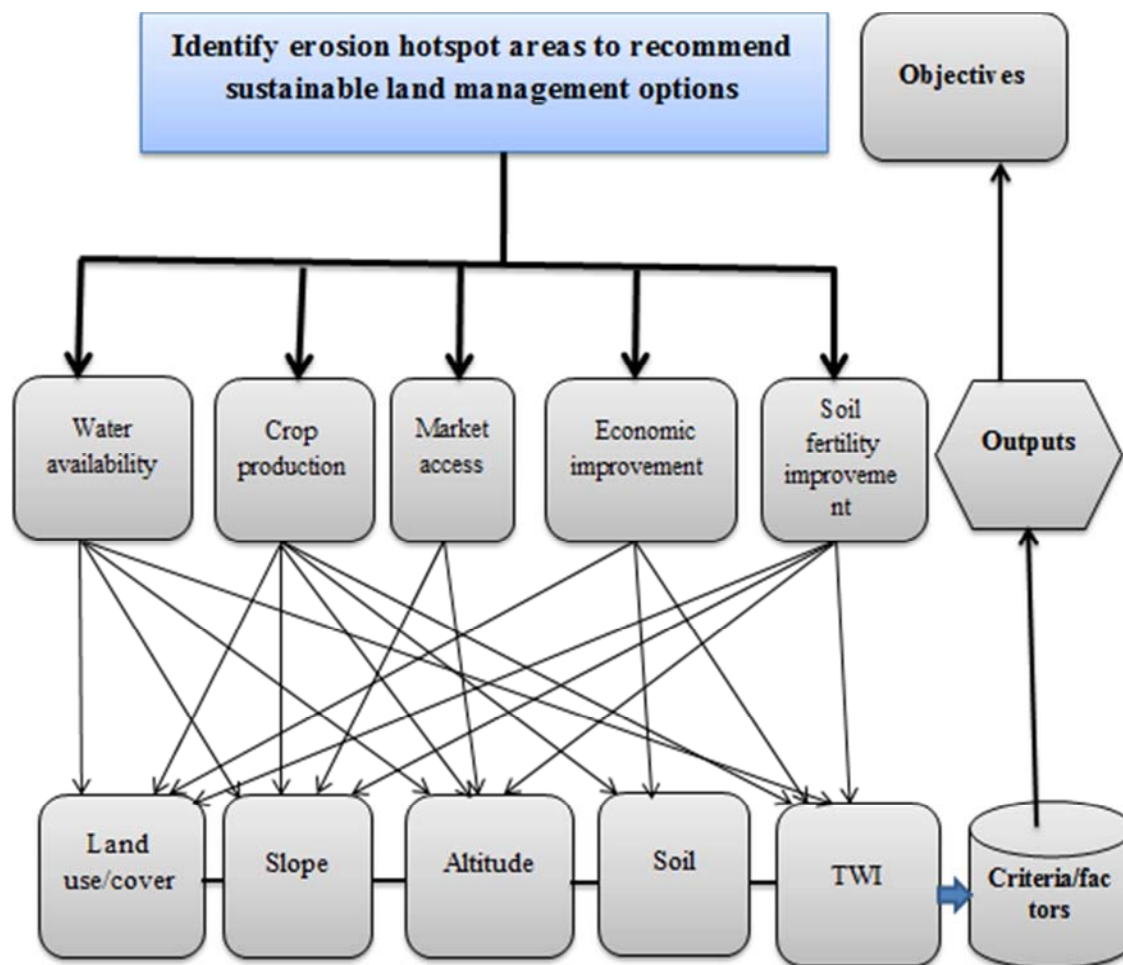


Figure 4. Major phases involved in MCE.

The first level is the risk of soil erosion, the second level represents the development or improvement if the parameters are well-managed and controlled, and the third level of the hierarchy represents the parameters used to assess soil erosion risk areas (Figure 4 above).

2.9. Selection of Soil Erosion Affecting Parameters

2.9.1. Parameter 1: Land cover

The economic source of the people residing in a watershed relied on land use practices. The improvement of the household income is obtained from these uses. Different land use practices also contribute to soil erosion differently. For example, unmanaged grazing land affected soil erosion more than the other uses. The land cover data was obtained by analyzing the Landsat image of the current year.

2.9.2. Parameter 2: Altitude

Land management options and agricultural practices with the existing farming system varied due to elevation differences. The land use and land management practice in the upper part of the watershed is different from the lower part of the watershed [24]. Altitude information was obtained from DEM. According to [25], reveals that organic matter content of soil and bulk density of soils decrease as altitude increases.

2.9.3. Parameter 3: Soil

Soil determines the capacity and type of crop be produced including water holding capacity. Soil also affects the choice of land management and land use to be practiced in a specific area. For example, Vertisols are more liable to erosion than Cambisols due to its inherent characteristics [26].

2.9.4. Parameter 4: Topographic Wetness Index (TWI)

It is an important element in soil erosion, distributed hydrological modeling and describes the effect of topography based on saturated excess runoff generation mechanism in a watershed. It is also useful for mapping soil type, drainage, chemical, and physical properties of soil, soil infiltration and crop or vegetation distribution. In addition, it is important for soil/land evaluation for sustainable use [27], land use planning and management, hydrologic modeling and watershed management [28]. The TWI was calculated using the formula [29].

$TWI = \ln(a/\tan\beta)$, where a is the contributing area and β is the slope in degree calculated from the DEM. The TWI was calculated using raster calculator from Arc GIS 10.3 version.

2.9.5. Parameter 5: Slope

The slope is one of the most important topographical feature responsible for affecting degradation and production.

DEM was used to generate slope map using Arc GIS 10.1 version. It is necessary to make comparisons to establish the full set of pairwise judgments for n criteria. For instance, if the numbers of criteria or judgments are five then the comparisons will be:

$$\text{Comparisons} = \frac{1}{2}n(n-1) = \frac{1}{2} * 5(5-1) = 10$$

The overall pairwise comparison process was summarized as indicated by (figure 5).

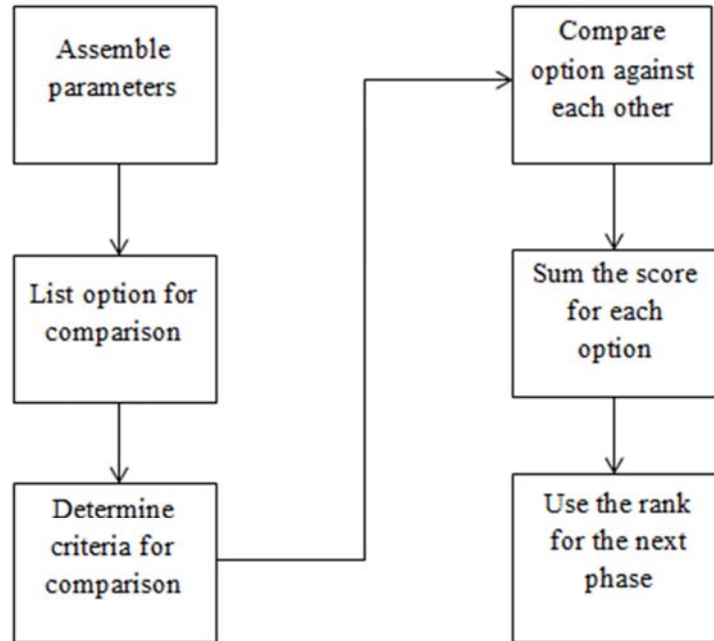


Figure 5. The process of pairwise comparison.

The following workflow developed to identify the erosion hotspot area. After deciding several factors that contribute to soil erosion in the study area the GIS-based model was used according to this procedures.

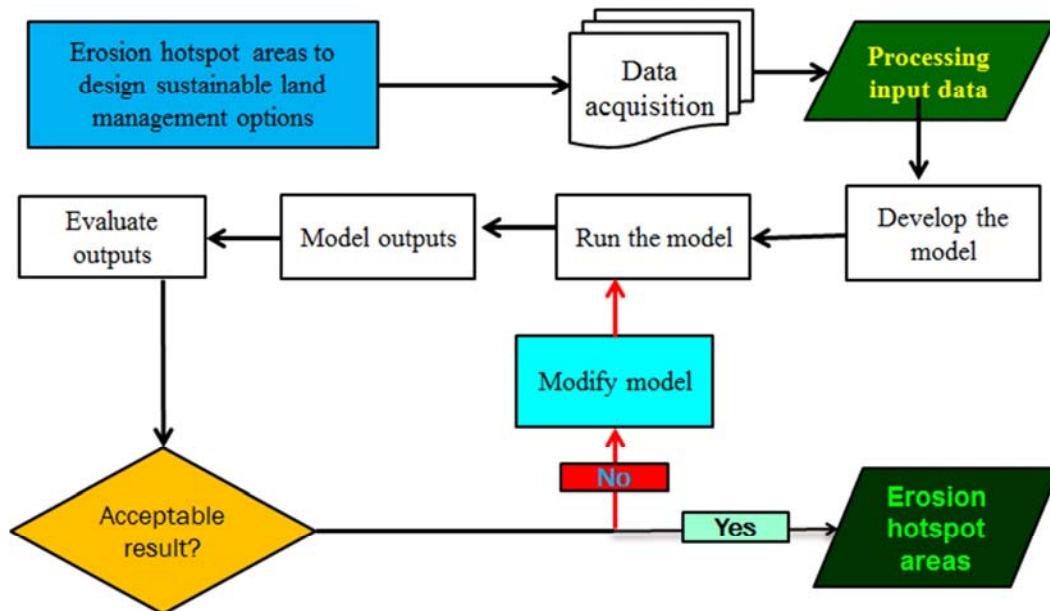


Figure 6. Workflow to locate erosion hotspot areas.

2.10. Multi-criteria Decision Analysis Model

The five major parameters; slope, land use, altitude, TWI, and soils were analyzed in the ArcGIS environment. The criteria maps of each parameter were generated in raster format for the model. Then the model would proceed as follow in order to identify erosion hotspot area (figure 7).

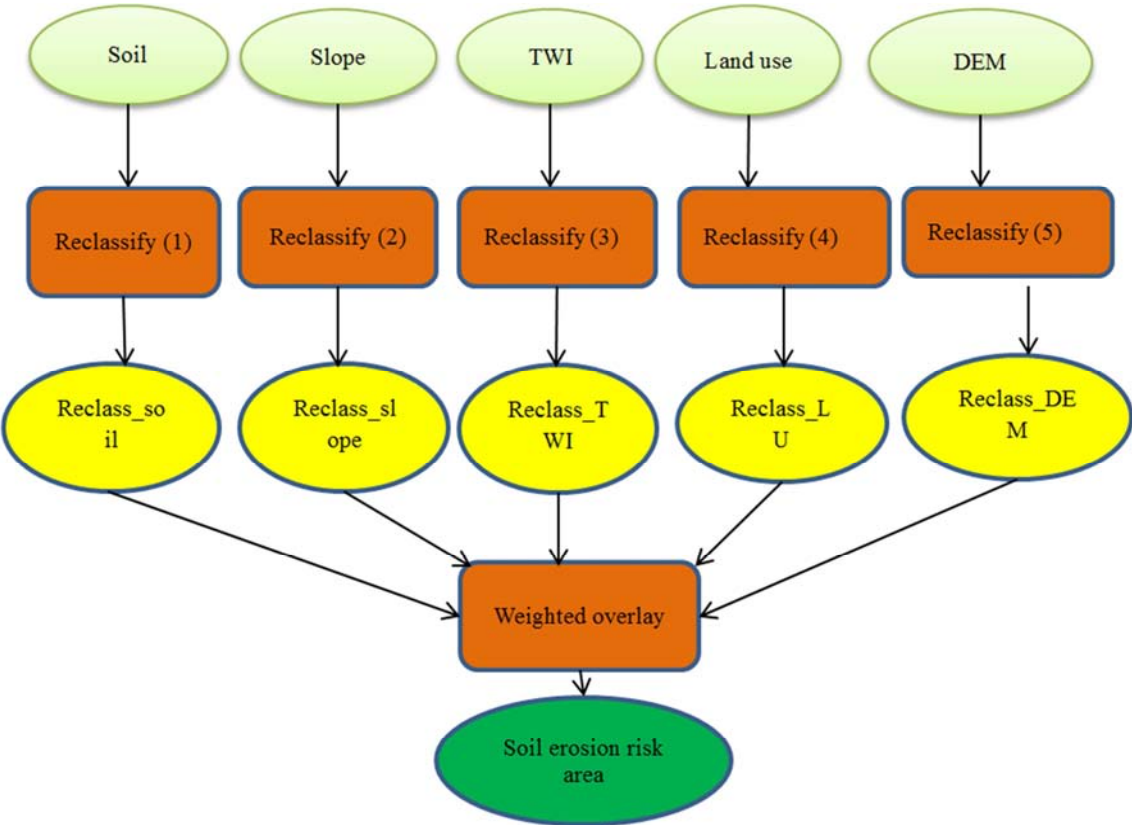


Figure 7. Workflow of the criteria weighting using MCE in Arc GIS.

3. Results

3.1. Land Cover Change Detection

Major LCTs in the study area in the year 1986 to 2016 include cropland, forestland, and grassland and shrubland. As indicated by the following table and figure 8. For each classified image, the area of each land use/cover class was computed (Table 2) and compared statistically if there are differences between the images.

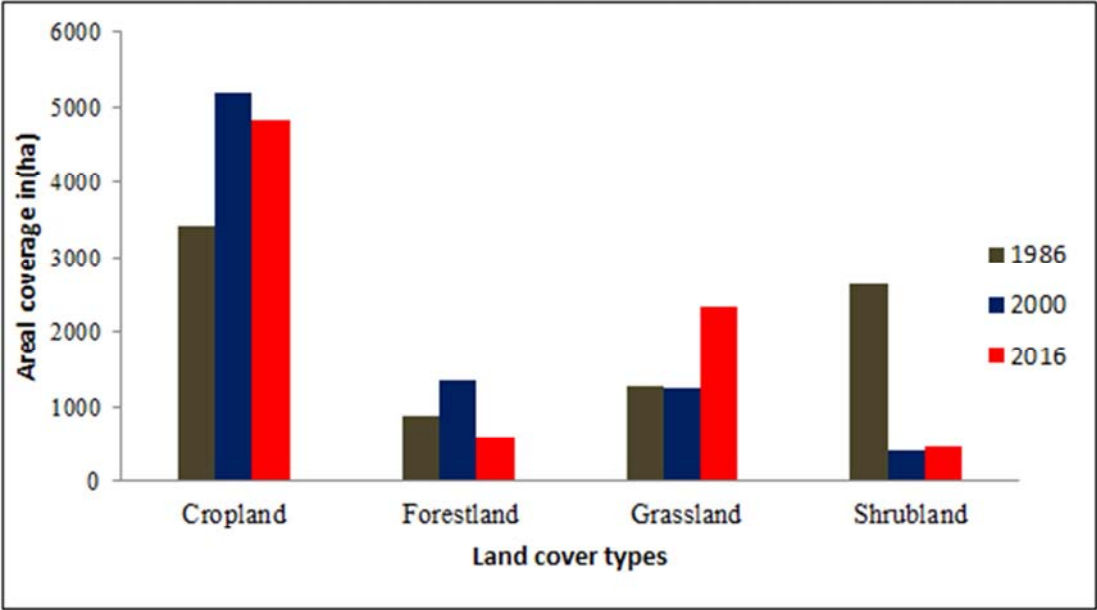
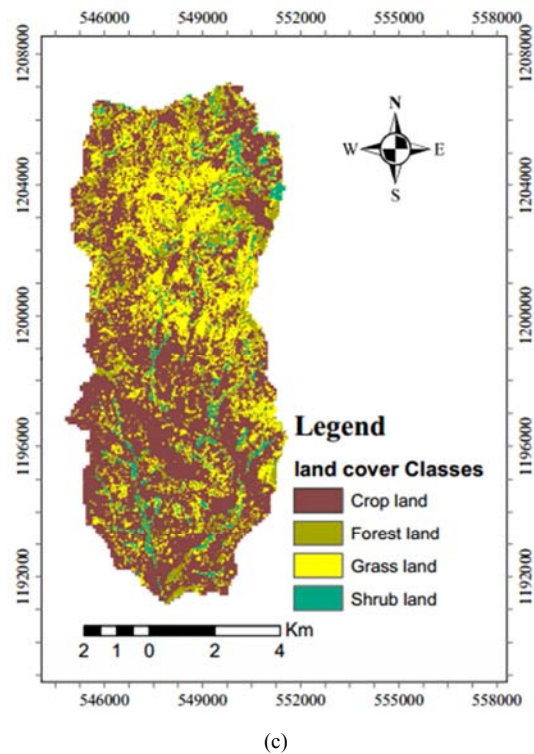
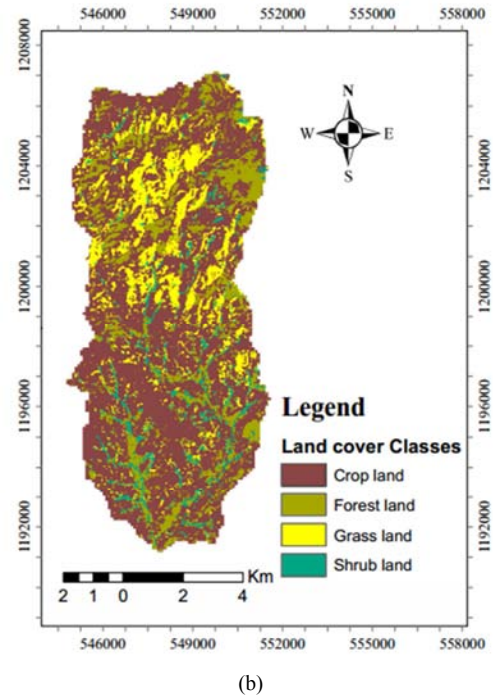
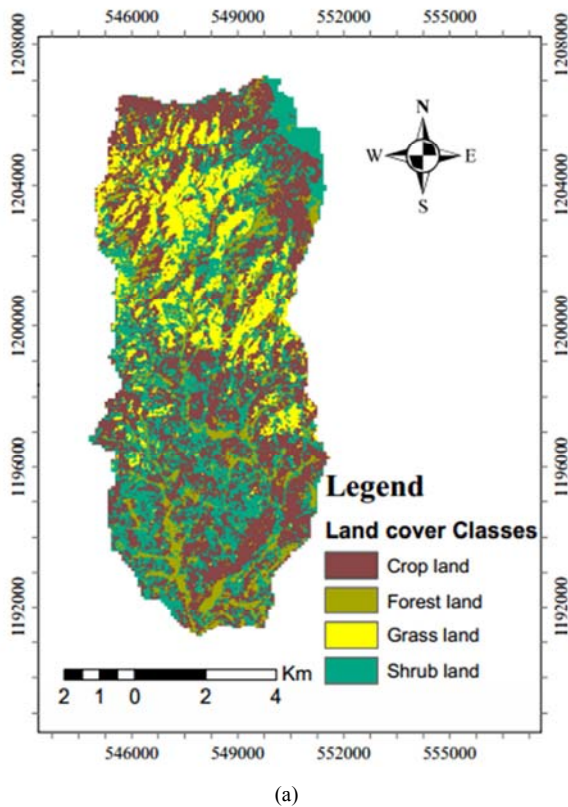


Figure 8. Areal coverage of different categories (1986, 2000 & 2016).

Table 2. Area coverage of each LCT from 1986-2016.

LCT	1986		2000		2016	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Cropland	3414.78	41.6	5196.6	63.3	4825.26	58.8
Forestland	873	10.6	1348.56	16.4	596.25	7.27
Grassland	1261.62	15.4	1241.19	15.13	2323.98	28.33
Shrub-land	2653.65	32.3	416.7	5.08	457.56	5.58
Total	8203.05	100	8203.05	100	8203.05	100

Between 1986 and 2016, forest declined from 10.6% to 7.27% (Table 2). Cropland and Forestland in the study area during observation from 1986 to 2000 have increased by 1781.82 ha and 475.56 ha respectively. But Grassland and Shrubland have decreased by 20.43 ha and 2237 ha respectively. As indicated by Table 2 and figure 8 above. The impact of decreased in grassland and shrubland in the study area between 1986 and 2000 have resulted in land degradation particularly soil erosion. Because if the grassland and shrubland are decreased on the surface of the soil then infiltration capacity of the soil was decreased this, in turn, increases the surface runoff.

**Figure 9.** Land cover map of the (a) 1986, (b) 2000 and (c) 2016.

Cropland and Forestland in the study area during observation from 1986 to 2000 have increased by 1781.82 ha and 475.56 ha respectively. But Grassland and Shrubland have decreased by 20.43 ha and 2237 ha respectively. As indicated by table 2 and figure 9 above. The impact of decreased in grassland and shrubland in the study area between 1986 and 2000 have resulted in land degradation particularly soil erosion. Because if the grassland and shrubland are decreased on the surface of the soil then infiltration capacity of the soil was decreased this, in turn, increases the surface runoff.

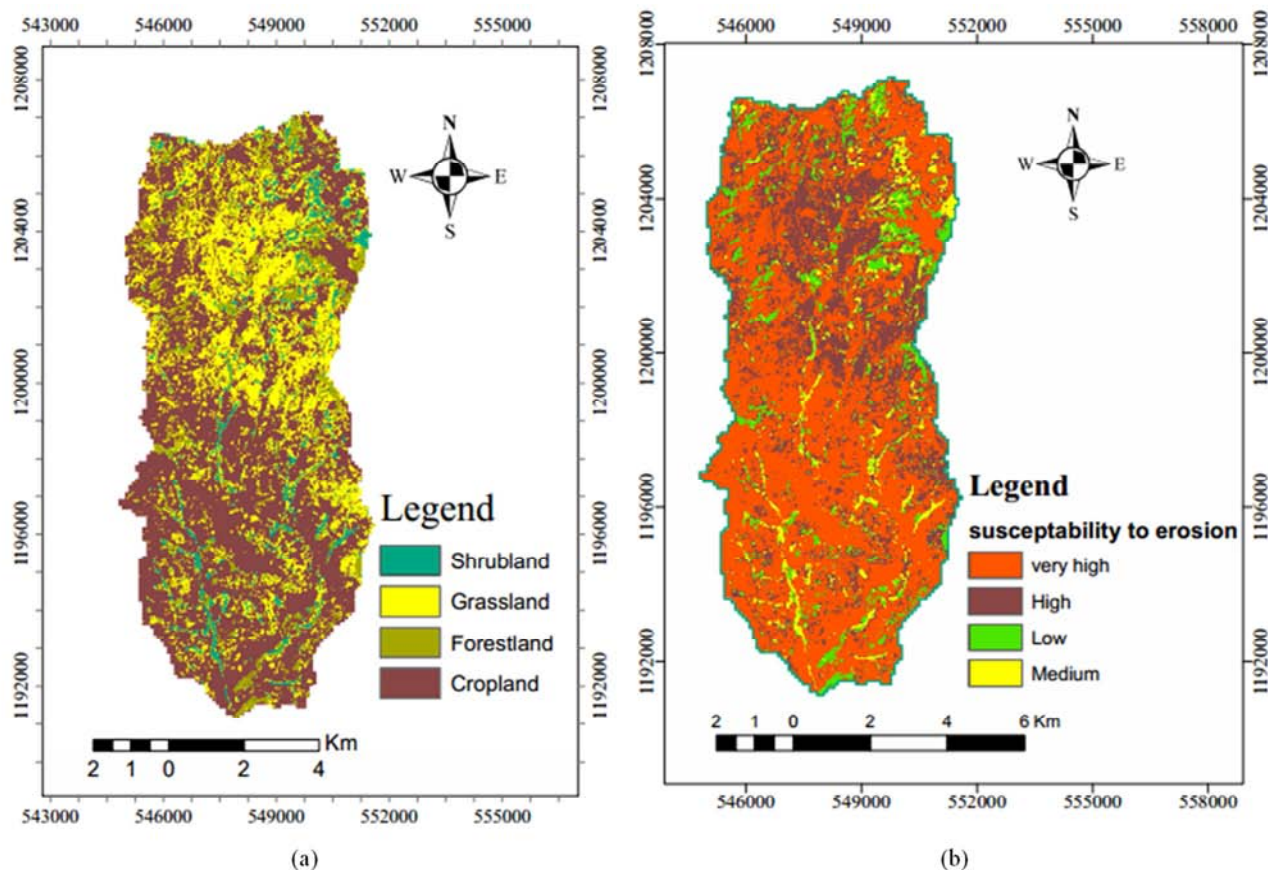
All the four LCTs generated a total of 16 possible combinations or transformations including the four “no change”. From the total area of the watershed, 46.5% of the area remained unchanged and 53.5% of the area changed from one land cover to another category within 30 years.

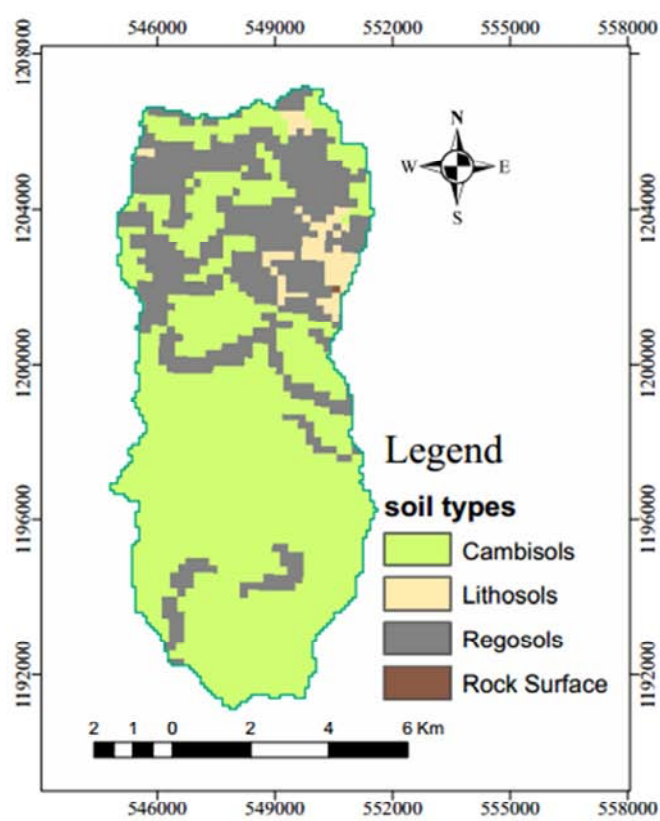
As indicated by the figure above all the land cover classes have gains and losses. The cropland is increased by 17.2%, whereas shrub land declined by 26.72% in 30 years period (1986 - 2016).

3.2. Multi-criteria Evaluation Technique Analysis

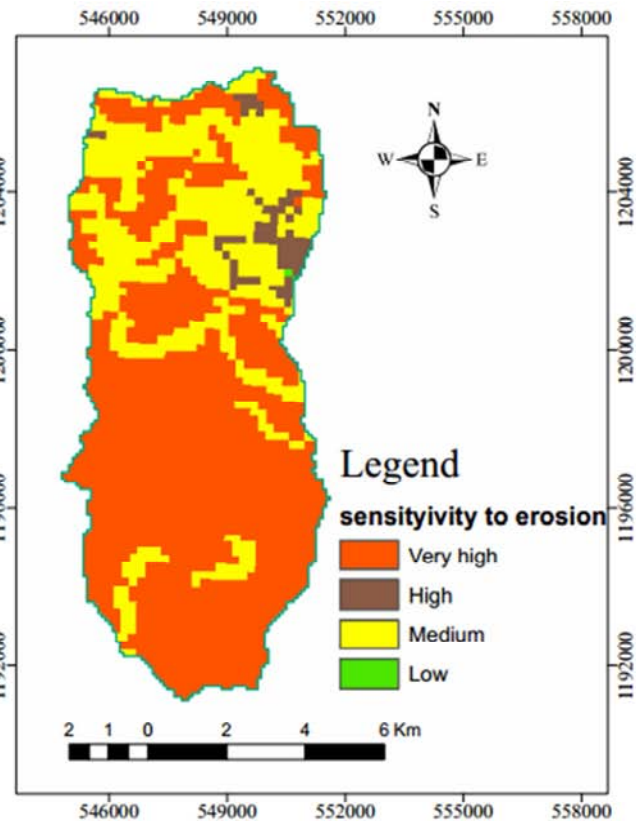
The results indicated that land cover type is the highest contributor to erosion mainly gully formation. As it was checked by field data collected specifically ground truth from gully site. Soil erosion risk map was generated using five erosion controlling factors, namely; land use, altitude, slope, soil type and topographic wetness index (TWI). The maps were indicated below (figure 10).

The re-classified land use map (Figure 10b) indicated that the area under forest cover is low risk to erosion which covers the area of 7.3% of the total area. Very high erosion risk categories occupy 28.3% of the total area covered under grassland whereas high and medium risk categories occupy 58.8% and 5.6% covered under cropland and shrub land respectively. As seen from (Figure 10 a&b) Cambisols (67.1%), Lithosols (3.4%), Regosols (29.5%) and Rock surface (0.08%) were sensitive to soil erosion Very high, high, medium and low respectively. The reclassified TWI map (Figure 10f) shows that about 0.06% is Very high, 1.7% is High, 10% is Medium and 88% is Low soil erosion risk area.

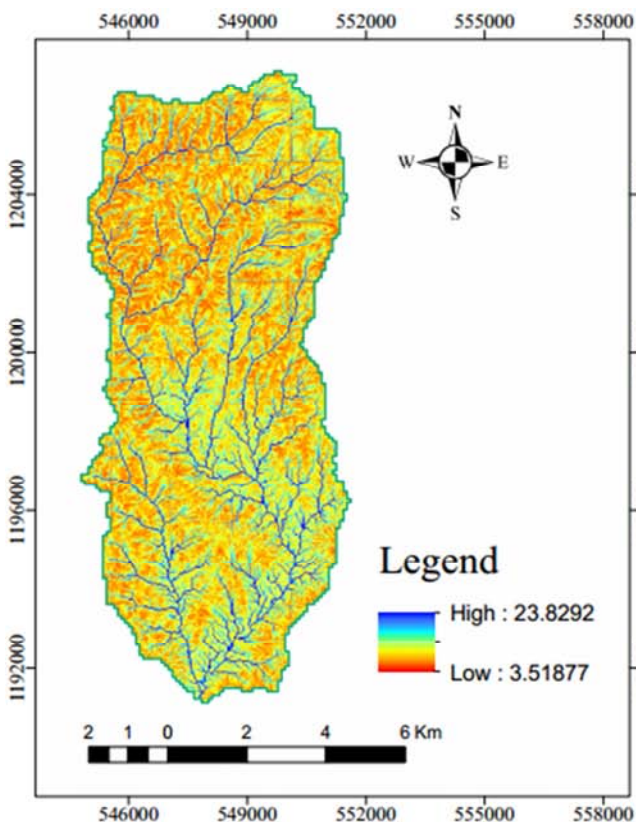




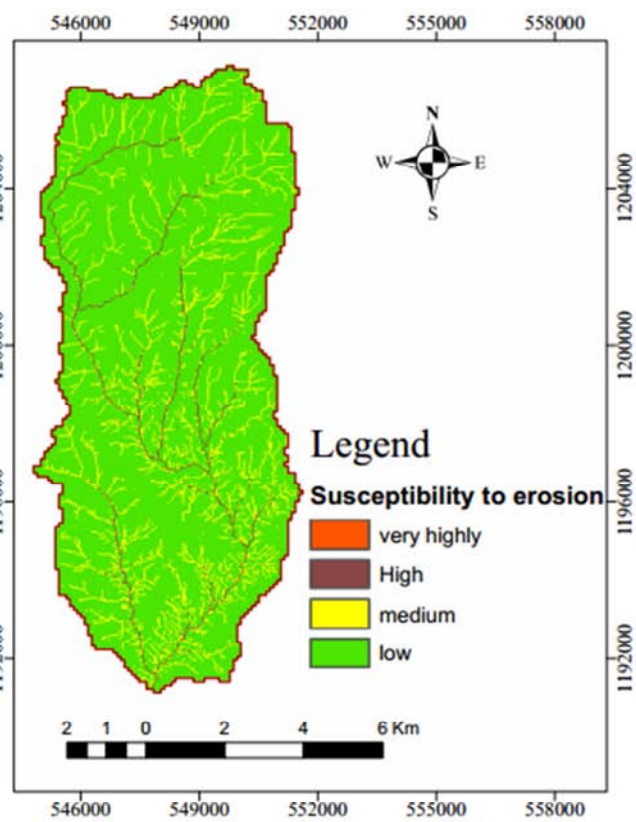
(c)



(d)



(e)



(f)

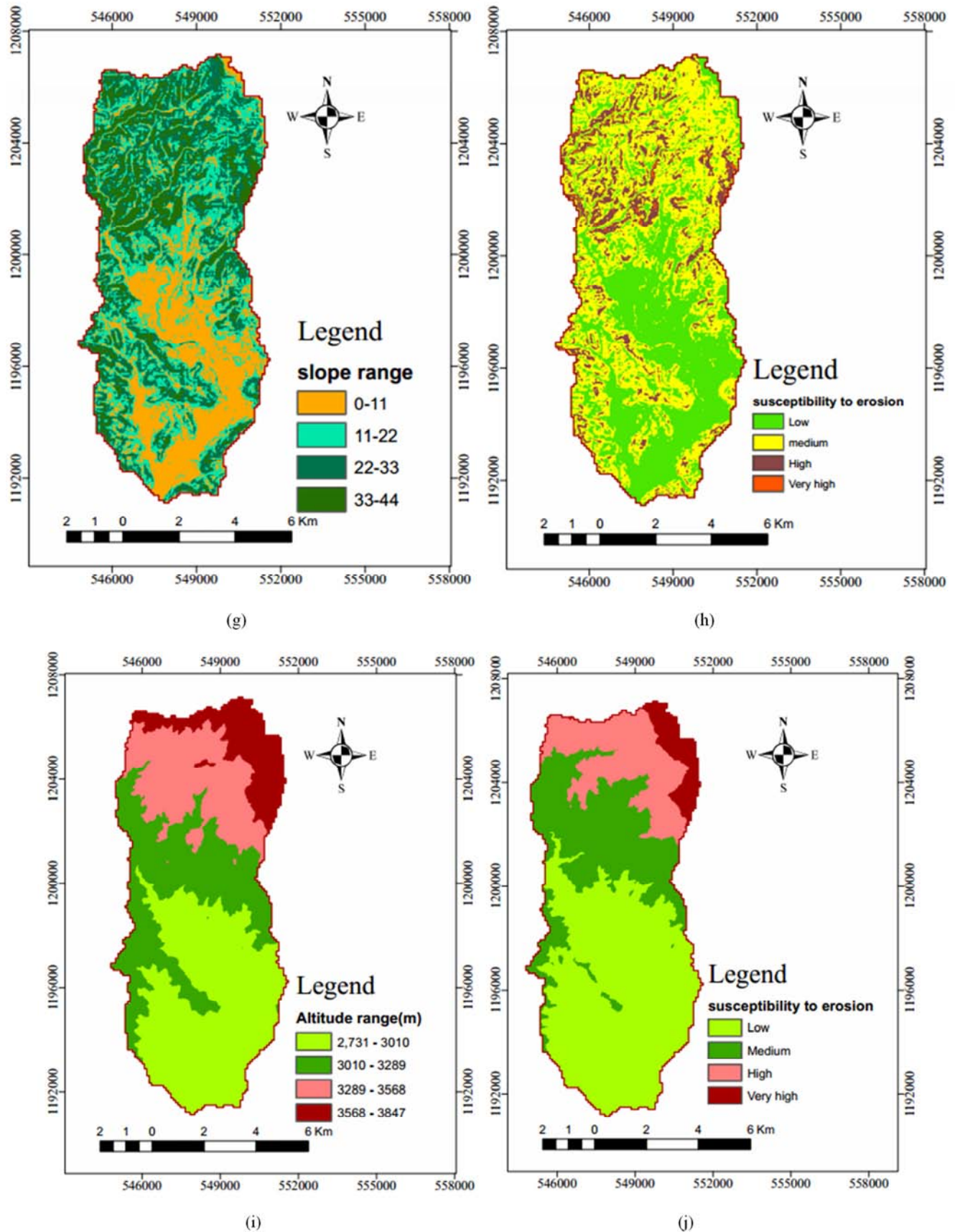
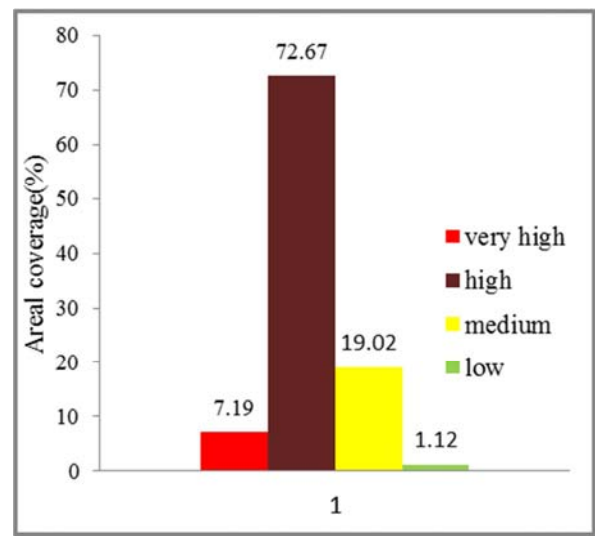


Figure 10. Spatially delineated erosion susceptible areas in Yewoll watershed using multi-criteria evaluation (MCE) - (a) Land use map, (b) Reclassified land use map, (c) soil map, (d) Reclassified soil map, (e) TWI map, (f) Reclassified TWI map, (g) slope map, (h) Reclassified slope map, (i) Altitude map and (j) Reclassified altitude map.

The slope is one of the major factors that play important role in enhancing the susceptibility level of the area to erosion. The slope of the study area was range from 0 to 44 degrees. The steeper slope is highly affected by soil erosion than gentler slope. The higher the value represents the steeper slope while the lower represents for gentler (Figure 10g). The reclassified slope map (Figure 10h) indicated that 0.4% is Very high, 11.4% High, 45% Medium and 43% Low soil erosion of the entire area. The altitude of the study area which derived from DEM was ranged between 2731 to 3847m. It is one of the variables which determine the distributions of land cover classes. In the study area, the land management practice is different from the highest altitude to the lowest altitude. The highest altitude is affected by soil erosion than the lowest altitude. The higher the value represented to the highest altitude while the lower represents for the lowest altitude (Figure 10 i & j above).

3.3. Erosion Hazard Map

The result revealed that over a period of 30 years, a decrease has taken place in forest and shrubland at a change rate of -3.40% and -26.80% respectively. The resultant erosion risk map shows that 1.12% of the area lies under the low-risk zone, whereas 19.02%, 72.67% and 7.19% of the total area fall in medium, high and very high-risk categories respectively. These are from lower potential to higher potential to soil erosion susceptible, respectively (figure 11 a & b). This result was verified by field data collection such as questionnaires from local people and ground truth collected from different land cover types in the study area.

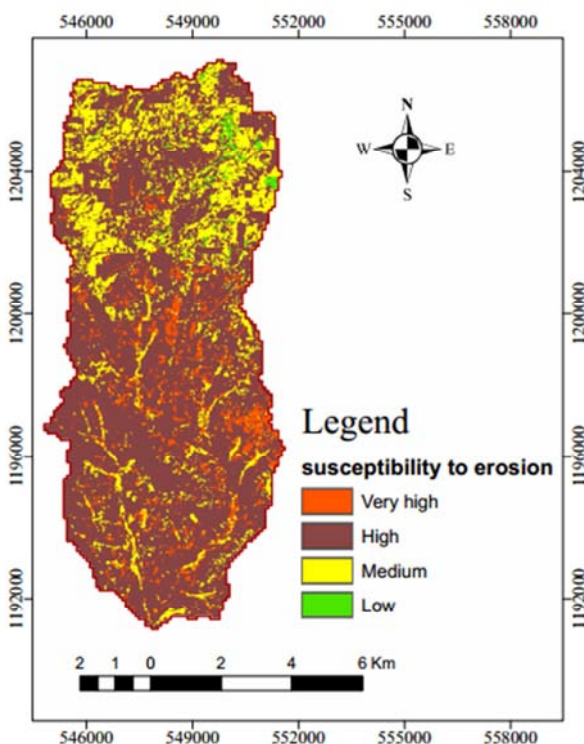


(b)

Figure 11. (a) Soil erosion risk map, (b) % age coverage of relative susceptibility of soil erosion.

3.4. Validation of the Result

As shown on (figure 12), gully site indicates that area under very high and high susceptible to soil erosion. The rate of soil erosion expansion in this area is higher than the rest. Therefore, to protect the land from soil erosion, priority is to be given for the area of very high and high potential to soil erosion. A comprehensive plan addressing soil erosion hazard management is, therefore, necessary.



(a)

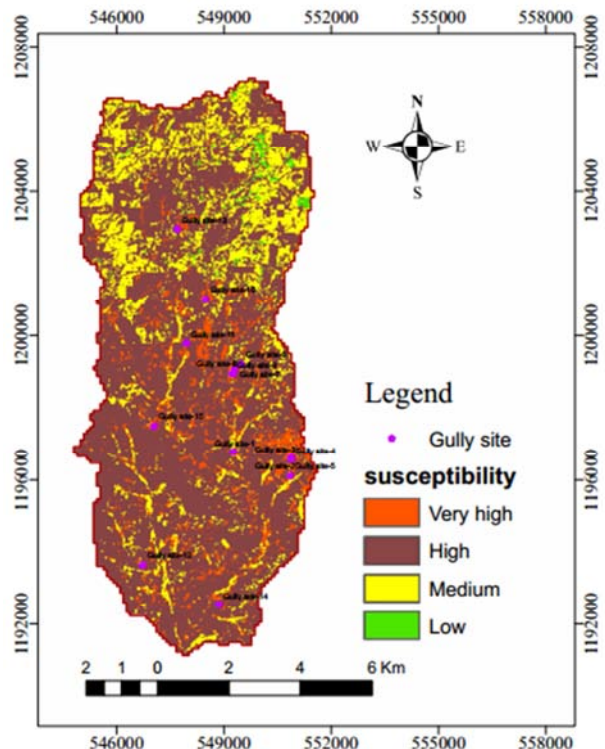


Figure 12. Location of severe gully site (source: GCPs data from the field).

4. Conclusion

By analyzing remote sensing data from a period of 30 years (1986 - 2016), the quantitative evidence of land use land cover change shows that cropland and grassland showed 17.2% and 13% increase in areal coverage between 1986 and 2016, respectively. On the other hand, forestland and shrub land showed 3.4% and 26.8% decrease in their areal extent respectively. This was due to the transformation of forestland and shrubland into other land use/land cover types. As revealed from the socio-economic survey and confirmed by GIS and RS analysis of satellite images the land use change dominantly from forestland to cropland. Erosion hotspot area has been identified in this study by using MCE model with the purpose of detecting the spatial extent of soil erosion in the watershed, as a result of this producing erosion risk map. The erosion risk map has been generated by considering five important parameters; land use, soil, altitude, slope and topographic wetness index (TWI). The AHP was used to compare parameters with regard to their effect on soil erosion risk assessment focusing on gully formation. As concluded from the result of the study soil erosion risk were rated as low, medium, high and very high. The result obtained from the MCE model showed that 1.2%, 19%, 72% and 7.2% of the total area fall under low, medium, high and very high erosion risk zone respectively. The output of this study can be used as a basis for sustainable development of the study area. The information obtained from the classification of Landsat imagery is crucial for decision making. It quantitatively describes the state of the landscape and the base of the economic activity of the watershed, which is necessary for long-term planning, and for utilizing and managing land resources. The results of this study can provide information useful for designing land use planning to regulate the effect of land cover change. The modeling and analysis of land use land cover change with consideration of major factors causing soil erosion help to identify erosion hotspot and might also help to plan future development in the study area. Finally, it could be concluded that soil erosion hazard maps can be effectively used to formulate appropriate management strategies and planning for the protection and conservation of soil erosion.

Acknowledgements

I would like to acknowledge the reviewers for their constructive review and fruitful comments on the manuscript, I am grateful to express my deepest gratitude to Dr. Seifu Admasu and Dr. Menale Wondie for their unreserved assistance, technical support, and guidance in remote sensing part of the study. My thanks go to Bahir Dar University Institute of Technology for logistic and office facility support to accomplish this research. I'm very grateful to farmers of the study area for their hospitality during fieldwork.

References

- [1] Manson, S. M., 2005. Agent-based modeling and genetic programming for modeling land change in the Southern Yucatan Peninsular Region of Mexico. *Agriculture, Ecosystems and Environment*, 111, pp. 47-62.
- [2] Goldewijk, K. K. & Ramankutty, N., 2004. Land cover change over the last three centuries due to human activities: The availability of new global data sets., 61, pp. 335-344.
- [3] Zeleke, G. & Hurni, H., 2001. Implications of Land Use and Land Cover Dynamics for Mountain Resource Degradation in the Northwestern Ethiopian Highlands Implications of Land Use and Land Cover Dynamics for Mountain Resource Degradation in the Northwestern Ethiopian Highlands., 21 (2), pp. 184-191.
- [4] Wondie, M. et al., 2011. Spatial and temporal land cover changes in the semen mountains national park, a world heritage Site in northwestern Ethiopia. *Remote Sensing*, 3 (4), pp. 752-766.
- [5] Alemu, B., 2015. The Effect of Land Use Land Cover Change on Land Degradation in the Highlands of Ethiopia. *Journal of Environment and Earth Science*, 5 (1), pp. 1-13.
- [6] Wondie, M. et al., 2016. Modeling the dynamics of landscape transformations and population growth in the highlands of Ethiopia using remote-sensing data. *International Journal of Remote Sensing*, 37 (23), pp. 5647-5667.
- [7] Fisseha, G. et al., 2011. Analysis of land use/land cover changes in the Debre-Mewi watershed at the upper catchment of the Blue Nile Basin, Northwest Ethiopia., 1 (6), pp. 184-198.
- [8] Lunetta, R., Ediriwickrema, J. & Johnson, D., 2002. Impacts of vegetation dynamics on the identification of land-cover change in a biologically complex community in North Carolina, USA. *Remote Sensing of*, 82, pp. 258-270.
- [9] Molla, M., 2015. Land Use/Land Cover Dynamics in the Central Rift Valley Region of Ethiopia: Case of Arsi Negele District. *African Journal of Agricultural Research*, 10, pp. 434-449.
- [10] Lunetta, R. & Elvidge, C., 1999. Remote sensing change detection.
- [11] Hurni, H., Tato, K. & Zeleke, G., 2005. The implications of changes in population, land use, and land management for surface runoff in the upper Nile basin area of Ethiopia. *Mountain Research and Development*.
- [12] Chang, T. & Bayes, T., 2013. Development of erosion hotspots for a watershed. *Journal of Irrigation and Drainage*.
- [13] Lambin, E., Geist, H. & Lepers, E., 2003. Dynamics of land-use and land-cover change in tropical regions. *Annual review of the environment*.
- [14] Vrieling, A., Sterk, G. & Beaulieu, N., 2002. Erosion risk mapping: a methodological case study in the Colombian Eastern Plains. *Journal of Soil and Water*.
- [15] Conforti, M. et al., 2011. Geomorphology and GIS analysis for mapping gully erosion susceptibility in the Turbolo stream catchment (Northern Calabria, Italy). *Natural hazards*, 56, p.: 881-898.

- [16] Ganasri, B. & Ramesh, H., 2015. Assessment of soil erosion by RUSLE model using remote sensing and GIS: A case study of Nethravathi Basin. *Geoscience Frontiers*.
- [17] Bewket, W. & Teferi, E., 2009. Assessment of soil erosion hazard and prioritization for treatment at the watershed level: case study in the Chemoga watershed, Blue Nile basin, Ethiopia. *Land Degradation & Development*, 20, pp. 609-622.
- [18] Bewket, W. & Sterk, G., 2002. Farmers' participation in soil and water conservation activities in the Chemoga watershed, Blue Nile basin, Ethiopia. *Land Degradation & Development*, 13, pp. 189-200.
- [19] Assefa, et al., Identification of Erosion Hotspot Area using GIS and MCE Technique for Koga Watershed in the Upper Blue Nile Basin, Ethiopia.
- [20] Amsalu, A., Stroosnijder, L. & Graaff, J. De, 2007. Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia. *Journal of Environmental Management*, 83, pp. 448-459.
- [21] Hurni, H. & Ludi, E., 2000. Reconciling conservation with sustainable development: a participatory study inside and around the Simen Mountains National Park, Ethiopia.
- [22] Ahmad, P. & Prasad, M., 2011. Environmental adaptations and stress tolerance of plants in the era of climate change.
- [23] Satty, T., 1980. The analytical hierarchy process: planning, priority setting, resource allocation. RWS publication, Pittsburg.
- [24] Mottet, A. et al., 2006. Agricultural land-use change and its drivers in mountain landscapes: A case study in the Pyrenees. *Agriculture, ecosystems*.
- [25] Saeed, S. et al., 2014. Impact of Altitude on Soil Physical and Chemical Properties in Sra Ghurgai (Takatu mountain range) Quetta, Balochistan., 5 (3), pp. 730-735.
- [26] Dejene, A., 2003. Integrated Natural Resources Management to Enhance Food Security.
- [27] Fu, B. & Chen, L., 2000. Agricultural landscape spatial pattern analysis in the semi-arid hill area of the Loess Plateau, China. *Journal of Arid Environments*, 44, pp. 291-303.
- [28] Western, A. & Grayson, R., 1998. The Tarrawarra dataset: Soil moisture patterns, soil characteristics, and hydrological flux measurements. *Water Resources Research*.
- [29] Beven, K. & Kirkby, M., 1979. A physically based, variable contributing area model of basin hydrology/Un modèle à base physique de zone d'appel variable del'hydrologie du bassin versant. *Hydrological Sciences Journal*, 24, pp. 43-69.