Erosion Source Area Identification Using Rusle and Multi-criteria Decision Analysis, Acase of Andassa Watershed, Upper Blue Nile Basin

Moges Animut Tegegne (mogianimutt@gmail.com)
Debre Tabor University
Yibeltal Zewudu
Debre Tabor University
Tadele Fentahun
Debre Tabor University

Research Article

Keywords: Soil erosion, Hotspot, MCDA, Andassa watershed

Posted Date: August 3rd, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1718698/v2

Abstract

The Main objective of this study was to identify source areas of soil erosion and quantify rate of soil erosion and sediment yield in Andassa watershed, Blue Nile Basin. In this study, Multi Criteria Decision analysis (MCDA) technique integrated with GIS and Remote sensing was applied to estimate soil erosion source areas, identify major soil erosion factor (s), prioritize and map the most sensitive soil erosion sources of the watershed for soil and water conservation practice. From soil erosion factors, Topographic wetness index followed by land use land cover have been found to have significant effect on soil erosion in the watershed.

The result shows in qualitative Sensitivity map investigates that the more than half of the watershed was under moderately sensitive risk of soil erosion (68.12%) about 400.861km^2. Next 17.56% (103.35km^2) of the watershed was under slightly sensitive and the remaining 14.27% (83.999 km^2) of the watershed was under highly sensitive risk of soil erosions. From the overall combined map of Multicriteria decision analysis (MCDA) map showing the areas of increased risk erosion represented by highly sensitive (S1), moderately sensitive(S2), less sensitive(S3), and constraint areas so the governmental or non-governmental organizations or any concerned organization should refer this important severity map of soil erosion for watershed management and priority of the watershed. Even though measured values of sediment yield at the catchment are hardly available the hotspot areas can be identified by multicriteria decision analysis and significant amount of soil loses are sourced from Gully sites.

1. Introduction

1.1 Background

Soil erosion is the dominant one among the most significant environmental degradation processes that affect the landforms(Assefa, et al., 2018).Soil erosion is a natural process that causes mobilization, transport and off-site sedimentation of mineral and organic soil particles, as well as associated chemicals and non-sustainable soil erosion rates(Dagnew,et al., 2018).Deforestation, urbanization and agricultural intensification are the major factors which influence the rate of erosion and sedimentation(Bhattarai, 2010).Soil erosion is the detachment, movement, and deposition of soil by water, wind or landslides. Modelling of the processes governing erosion and sedimentation can further help our understanding of the basin-wide issues in terms of the critical factors controlling erosion and associated sediment transport (Peden et al., 2013).Strategic watershed management interventions should focus on erosion sensitive portion of the catchment to prevent further land degradation(Assefa, 2015).

In Ethiopia highlands, considerable amount of soil is being lost by water erosion every year particularly in Andassa watershed is tremendous. Rates of soil erosion documented in Ethiopia ranges from 16 to 300 tons/ha/year. Water induced soil erosion is the most prevailing form of land resources deterioration in the highlands of Ethiopia, where huge amount of fertile soil is being lost annually (Yesuph, 2019).Sediment in the Nile is mainly originating from the Ethiopian Highlands with large quantities of eroded soil (Ahmed, 2008). The Nile Basin watershed is undergoing severe soil erosion that has led to a deterioration of soil and water resources mainly due to a loss of soil fertility on the hill slopes and an excessive transport of sediment in the river. Modeling and identifying soil erosion source areas represent as powerful tool in order to predict the effect of induced and natural environmental changes on sediment dynamics and to evaluate scenarios of changing land use management. Estimating soil erosion rates using geospatial data have a great role in the decision making and to recommend soil and water conservation measures for hot spot area (Tadele et al., 2020).

GIS is capable of efficiently storing, retrieving, transforming, displaying and analyzing spatial data(Assefa, 2015). It provide the decision-maker with a powerful set of tools for the manipulation and analysis of spatial information (Carver, 2007).It is important for processing, manipulating, and storing geodatabases when integrated with Multi-Criteria Decision Analysis (MCDA)which could help users to improve their decision-making processes. Soil erosion assessment using remotely sensed data and GIS is less time, labor and capital intensive and effective in generating essential quantitative information on soil erosion (Assefa, et al., 2018).The rate of soil erosion in a particular catchment depends on particular factors on a catchment such as intensity of rainfall, topography, vegetative cover, soil type, and land-use practices and catchment shape. GIS combines this different soil lose factors as impacts that contribute to the development of soil erosion qualitatively and RUSLE as quantitatively. With integration of GIS RUSLE model has the potential to estimate rate of soil erosion while the multi criteria evaluation with integration of GIS have the ability to rank or rate alternatives and analyze spatial information based on selected criteria or factors that would affect soil erosion. Areas of application of MCDA models are identified in water resources management; catchment management; ground water management; infrastructure selection; project appraisal; water allocation; water policy and the planning of supply; water quality management; and marine protected area management (Odu, 2019).

A number of researchers who have conducted erosion hotspot analysis by implementing geospatial methods provides basic information about erosion prone areas and characteristics of watershed in terms of qualitative and quantitative models(Mekonnen, 2011).In qualitative model a problem needs a hierarchic or a network structure to represent that problem and pairwise comparisons to establish relations within the structure (Saaty, 1987). Quantitative and qualitative analysis of water induced soil erosion and its spatial variation plays a decisive role for better evidence and priority-based implementation. Thus, this study aimed to estimate potential soil loss and identify hotspot areas, and prioritize for conservation measures in Andassa watershed using RUSLE, GIS and remote sensing techniques. Water induced erosion has been continued to threaten the land resources in highlands of Ethiopia (Tsegaye, 2019).

The main objective of this study was the identification of vulnerable erosion areas by RUSLE and MCDA in Andassa watershed by GIS extension tool. MCDA are important in solving complex problems based on the various criteria considered. This technique within GIS environment uses to identify the actual source of erosion and map sensitive areas based on spatial dataset analysis this study can serve as a reconnaissance input for soil and water conservation related planning activities. Weight of decision factors are assigned based on their relative effect to erosion process which would be very important for downstream dams like Great Ethiopian Renascence dam and other downstream projects which need up stream management for prevention of sediment loading risks.

2. Materials And Methods

2.1 Description of the area

The study area Andassa Watershed is located in the western part of Gojjam and the outlet is found 12 km far from Bahirdar city along Tiss Abay Bahir Dar weathered road. The altitude varies between 1701 and 3216m above sea level and the watershed is located in the northern highlands of the country with Geographical coordinate 11°30'51.71" N and 37°29'26.61" E. The main river Andassa is drained to Blue Nile Basin. The outlet of the Catchment was identified with the direct taking GPS coordinates. The total area of Andassa watershed is 583. 9km^2.The topography of the watershed can be divided into two main part most of the northern part of the watershed is mountainous and steep and the lower part is relatively flat and gentle.

2.1.1Topography and slope

The elevation of the area ranges from 1701 to 3216m above sea level. Some part of the study area is flat and water over flow from the river and accumulates on a flat ground during the rainy season, whereas, during the dry months, the area dries up and serves as grazing lan

2.1.3: LULC type

Land use land cover significantly affects soil erosion spatially. The land use land cover types identified from USGS land sat 8 satellite imagery using ERDAS IMAGINE and GIS 10.1 of Andassa watershed were classified under seven classes (table 3.2). The dominant land use land covers were Agriculture and grass land which covers (61.64 %) and (19.21 %) of total watershed area respectively.

2.2 Materials

Under this research the materials and software used for the application of remote sensing and ARC- GIS are listed below (Table 3.4).

2.3 Methodology

The flow chart/ methodology for this specific study includes data collection from different sources. Ground truth points were collected from selected field and other primary and secondary data are collected from different organizations and offices. After the data collection the following flow charts were used for the analysis and estimation of the soil loss and sediment yield as well as hotspots and gully erosion locations. Finally soil loss severity areas by using MCDA have been mapped by weighted overlay method to get the erosion hotspot areas.

2.4 Data collection

2.4.1. Primary data collection

The primary data collection involves sample survey of geographic features by using GPS. Satellite data, cloud free Landsat8 image of August 2020G.C of the study area was downloaded from USGS Earth explorer for supervised land use land cover classification. From Shuttle Radar Topographic Mission (SRTM), 30x 30 m resolution Digital Elevation Model (DEM) was used for watershed delineation, slope and flow accumulation generation of the study area. In addition to this, random sample of gully area polygons were generated from Google earth and GPS survey for verification of gully potential location map. For verification of classified image and accuracy assessment field data were collected randomly within the study area.

2.4.2 Secondary data

Rainfall data was collected from National Meteorological Agency (NMA)Bahir Dar district. Since, there was only one metrological station available at the outlet of the catchment which is not sufficient for rainfall erosivity map preparations. The meteorological station found nearby stations namely; Bahirdar, TisAbay, Meshenti, Merawi, Adet and Andassa were used to find the mean annual rainfall. The areal rainfall was computed using interpolation IDW method and used as an input factor for RUSLE mode land soil data was collected from Ministry of Water Irrigation and Electricity(Pandey & Mal, 2007)

2.5 Data Analysis

Some data like Sediment and rainfall are not available for the current situation but previous measured rainfall data were used for the analysis of rainfall map. There were few missed value for rainfall on the Andassa station in April and September 2003G.C and arithmetic method of filling missed data used in order to get continuous data for the intended purposes. The sediment data are hardly available at the outlet of the catchment so rating curve developed by the available data and used to predict the sediment data to get consistent and complete measured values. The analysis of RUSLE and MCE factors in ArcGIS 10.1, and ERDAS Imagine software were used. The watershed (study area) which was 583.9 km^2 was delineated from 30m resolution DEM of Amhara region using Spatial Analyst Tools of ArcGIS. The parameters were identified (RUSLE and MCE) and classified in to sub classes to get the relative weights using pairwise comparison method and the soil erosion factors are weighted overlay to produce final soil erosion source area mapping order to create integrated analysis for the diverse inputs. Weighted values are overlayed for each overlying cell and to get spatial representation of the output layer were mapped in the watershed.

2.5.1 Multi Criteria Decision Analysis (MCDA) factors

Multi Criteria Decision Analysis (MCDA) is numerical algorithms that define the suitability of a particular solution based on the input factors and weights together with some mathematical or logical means(Zhang et al., 2017). In this technique “weight” was assigned to the thematic layers to reflect their relative importance. The process of soil erosion is complex, consideration of many factors both natural and anthropogenic is required in a geologically complex terrain(Shiferaw, 2018). It is essential to understand how these factors affect soil erosion of any area for conservation planning and management. Factors that controlling soil erosion by water must treated and integrated by assigning different rank and weight to give a clear picture of the situation. Based on this, the present study aims at overlay analysis using MCE technique in GIS environment for decision making problems concerning to soil erosion.

Boolean overlay is the first procedure where all factor was evaluated by thresholds of suitability to produce Boolean maps, which are then combined by logical operators such as intersection (AND) and union (OR)(Lin, and Changsheng et al.,2014).The second was weighted linear combination, when there are more than one factors considered to find the most suitable location, each of them are assigned a weight based on its importance. The results were multi attribute spatial features with final scores, the higher the score the more suitable the area. For multi criteria decision analysis of factor generation, the main types of data inputs were used. Those includes land use, DEM and soil type which used to generate soil erosion factor maps such as land use land cover map, soil map, topographic wetness index map and potential gully location map of Andassa watershed. Finally, those factors were reclassified and sensitivity analysis selected and prioritized. From DEM gully and slope and TWI will be derived.

2.5.1.1 LULC map

The LULC classification was made by ERDAS EMAGIN 2014 integrated with google by collecting 170 ground truth points for selected and known sites and GIS10.1 also used supervised classification. The ground truth points are very important for classification of LULC by GIS but for more quality ERDAS EMAGINE software was the best. Accuracy assessment is important and mandatory for validation of image classification process by evaluating how effectively pixels were correctly grouped. Error matrix is the basic for accuracy assessment. The matrix gives a cross tabulation of the class label predicted against the ground truth GPS data. The error matrixes give very important information on image classification to both map user and producer’s community.

Kappa coefficient measures the accuracy between the remote sensing derived classification map and the reference data indicated by the major diagonals and the chance agreement, which is indicated by the row and column totals (Jensen,2005).

Overall accuracy is often the only accuracy statistic reported with predictive landscape models(Zhang et al., 2017) but the error matrix provides a means to calculate numerous additional metrics describing model performance. The overall accuracy of the model is simply total number of correct classifications divided by the total number of sample points.

Kappa coefficient = $\frac{\text{Observedaccuracy} - Expectedaccuray}{1 - \text{Expectedaccuracy}}$ (3.8)

$Overallaccura$cy = $\frac{\text{numberofpixelscorrectlyclassified}}{\text{totalnumberofpixels}}$ (3.9)

Where: - Observed accuracy = Diagonal observation/total observations(N)

Expected accuracy = Row X Column/total observation squared(N^2)

2.5.1.2 Slope

The steepness and length of the slope are important factors for runoff and soil erosion(Orman, 2016). Different erosion and runoff characteristics exist in different slopes which can be classified as uniform, concave, convex and complex shape(Orman, 2016); but under this study only the effect of degree of steepens considered for the sake of qualitative and quantitative evaluation of erosion severity under this study. Catchments with steep slope greater than 30 degree has significant contribution to soil erosions (Ganasri & Ramesh, 2015).The slope of the catchmen were dominated by gentle slopes

2.5.1.3 Topographic wetness index (TWI)

The topographic wetness index (TWI), which combines local upslope contributing area and slope, is commonly used to quantify topographic control on hydrological processes(Sørensen et al., 2006). TWI is a physically based index or indicator of the effect of local topography on runoff flow direction and accumulation and affects spatial distribution of the soil erosion(Counties & Ballerine, 2017)

Topographic witness index (TWI) defines the effect of topography based on saturated excess runoff mechanism which characterizes spatial distribution of surface saturation and surface runoff that were very important parameter for soil erosion analysis.Topographic wetness index and soil moisture increases as contributing area increases and slope gradient decreases (Zhang et al., 2017).

2.5.2 Saaty’s AHP and Fundamental scale

The Analytic Hierarchy Process (AHP) rules carefully defines the possibility of the problems. It is based on the well-defined mathematical structure of consistence matrices and their associated eigenvector in order to generate exact or approximate weights for the criteria(Zhang et al., 2017). The principle of the mathematics of AHP and the calculation technique are to construct a matrix expressing the relative values of a set of attributes. Pairwise comparison method is important to reduce the complexity of decision-making process. In Pairwise comparison method comparison matrix was developed by computation weights for each element finally consistency was checked to minimize subjectivity of the factors rating(Zhang et al., 2017). In the comparison process a scale of numbers are required to indicate how many times more important or dominant one factor over another with respect to the compared factor(Zhang et al., 2017). In addition, expert questionary with natural resource management experts who works or directly or indirectly knows Andassa watershed was undertaken and used as input for pair wise comparison in GIS environment. For the judgments applied to compare homogeneous factors fundamental scale set because judgments are first given verbally and then a corresponding number is associated with that judgment (White,1987). These judgments are used to estimate the supremacy in making comparisons between various factors, particularly when the criterion of the comparisons is an intangible.(Pandey & Mal, 2007)

For qualitative data such as preference, ranking and subjective opinions, it is suggested to use scale 1 to 9 as indicated in table below. The scale is derived from basic principles involving the generalization of comparisons to the continuous case, obtaining a functional equation as a necessary condition and then solving that equation in the real and complex domains (Zhang et al., 2017).

2.5.3 Steps for AHP

Multicriteria decision analysis (MCDA) is inclusive, reasonable and important outline process for decision-making, processes which consists of steps by decomposing complex decisions making to feasible one in order to resolve the complex structures.

A. Defining problems and setting Goal

The aim/goal of this study was to identify and map soil erosion source areas of Andassa watershed.

B. Determining significant factors

The main significant factors that can potentially affect soil erosion in the Andassa watershed are land use land cover, topographic wetness index, Soil type, Slop and potential gully locations.

C. Weighting factors

Analytical hierarchy process (AHP) weight calculator generates weight for each factor by experts surveyed data assigned based relative importance to selected factors. The priority scales can be also derive by calculating the eigenvector associated with the principal eigenvalue of each comparison matrix by excel (Saaty, 2008).After estimation of final weight, from Satty analytical hierarchy calculator; the final priority could be determined using normalization and their corresponding weights obtained from Saaty’s AHP based multi-criteria decision analysis (MCDA) and classified in different categories the priorities.

D. Consistency Checking

Checking the overall consistency of hierarchy by summing for all levels, with weighted consistency index (CI) in the nominator and weighted random consistency index (RI) in the denominator. To overcome subjectivity of the judgment or to increase reliability; consistency could be checked by estimating the consistency ratio. The consistency ratio (CR) less than or equal to 10% is acceptable (Odu,2019).

$CR(\%) = \frac{\mathrm{CI}}{RI}$ *100) where, CI is the consistency index and RI is the random consistency index as shown in the table below (CR < 0.1).

$CI = \frac{\lambda max - 1}{n-1}$ where, λmax is the principal eigenvalue obtained from priority matrix and n is size of comparison matrix. After consistency is checked and pair wise comparison was done, then final weight could overlay to produce map of soil erosion source areas and identify risk areas of the Andassa watershed.

2.5.4 Weighted overlay

Soil erosion factor maps are prepared for each factor (land use land cover map, Topographic wetness index map, potential locations of gully, soil map, and slope map) were reclassified based on sensitivity classes. Expert based weights were assigned for all factor depending on the level of importance given by regional and woreda level agricultural experts. The different level of importance was assigned to each factor based on pair wise comparison criteria using ARCGIS, excel and AHP calculator software. Pair wise comparison method was used to generate the final weight of each factor. Based on factors final weight, the reclassified map was overlaid to obtain the combined effect of all factors and produce the final soil erosion map. The sensitivity of the factors was classified based on FAO 1979(Table 3.7).

The selection of criteria was conducted based on available relevant literatures, and expert opinions also integrated in factor selection procedure in assigning weights for each factor. This is an iterative process where experts and experienced individuals in the field interviewed independently to identify relevant factor for soil erosion problems. These results are then discussed together and the experts can revise their choice in a second round. This process is continued until a consensus is achieved about a common set of factors/criteria.

3. Result And Discussion

3.1 Multi Criteria Evaluation (MCE) factors

3.1.1 Gully location map generation

Gully erosion is a key issue in erosion source area mapping often has severe environmental, economic, and social consequences. Gully erosion is a major contributor to soil erosion and sediment and cannot be estimated by RUSLE models. Gully survey was done by using GPs for some accessible parts of the watershed. Threshold values of SPI and TWI are overlaid to map accurate location of gully and ground truth values are mapped in the Watershed and used as validations gullies. The stream power index is a measure of the erosive power of a flowing water which calculated based on slope and contributing area.

Gully potential sites were collected at selected and known sites by using GPS material for the purpose of exporting to ARC-GIS and validation of potential zones of the threshold values. 46 ground truth points were collected by GPS at different gully affected areas. overlaying gully potential zone to watershed boundary and, Gully potential zones will show the exact location of gullies by overlapping collected or surveyed points to mapped sever potential zones. The investigation will show how much gully sites were mapped correctly with comparison of the collected one so validation will be done. For the analysis of potential zones by GIS first stream power index must be generated and overlaid with topographic power index so that the the gully potential locations will be mapped correctly.

From figure(4.18) the SPI values are blow the treshold value adopted by(Mekonnen & Melesse ,2011),but small gully potential areas were found along the streams of catchment blow the threshold values adopted which shows where gullies might be more likely to form on the watershed. The threshold values are less than the adopted by Mekonnen and Melese potential locations of gullies were predicted where the two thresholds were satisfied that is Stream Power Index > 18 and Topographic Wetness > 6.8(Mekonnen & Melesse, 2015)

The topographic witness index threshold values are 63.63% safe from gully and the remaining 36.37% indicates for gully potential areas combining stream power index. This result shows there were gully potentials of 212.5 km^2 area. The reclassified gully potential sensitivity map of Andassa watershed (Fig. 20) indicated that 22.4% were high potentials to gully and 77.6% were not potential to gullies. From the total area of Andassa watershed 132.03 km^2 indicated gully potential areas from moderate to high and 457.37 km^2 of the watershed areas with less gully potentials. Based on the result, gullies were found along the rout of streams. Gully polygons were captured from GPS near to the outlets and the rest from google earth to validate gully potential locations.

During site observation and collection of ground truth points gully and stream bank erosions were affecting the land resources significantly along the stream and small tributary streams of Andassa watershed (Fig. 4.21). These deep channels (Gullies) are formed due to the removal of subsoil and top soil during heavy rainfall. Ground truth points collected at some parts for LULC classification by GPS and most parts are collected by integration of ERDASIMAGINE 2014 and Google earth. Site investigation of the selected catchment parts were very vital for easily understanding the nature of the catchment specially to know the different land use classes and ephemeral gully locations.

To validate gully potential sites overlaying gully potential zone, watershed boundary and, ground truth points as shown in figure (28), and this shows gully sites were mapped correctly. The validation for Gully sites were 91.3% accurate (Table 12). The surveyed ground truth points collected from field are shown in appendix(D).

3.1.2 Topographic wetness index (TWI) factor Severity map

TWI is the most important factor considered for identification of erosion hotspot area; and it uses for soil erosion evaluation for land management priority, watershed management and hydrologic modeling, land use planning and managements. The TWI was calculated using raster calculator from Arc GIS 10.1 version. The criteria layers were obtained from MCDA factor generation and reclassification and multiplied by applicable weight derived from pair wise comparison of criteria.

Based on this map showing the areas of increased risk erosion represented by highly sensitive (S1), moderately sensitive(S2) and less sensitive(S3) so the land planer or land management or any concerned organization can recognize the severity of erosion in terms of topographic witness index (TWI) in this area for priority soil conservation practices. The catchment has significantly affected by moderately sensitive areas which covers 47.16% in terms of TWI.

3.1.3 Soil factor Severity map

The soil types in the study area also considered as a major factor contributing for soil erosion. There were Four major soil types incorporated in the study area. These important soil types were reclassified depending on their sensitivity to soil erosion.

The severity map Pelic vetisols are the dominant one in area coverage which covers 40% of the total area but the severity was(S3) less severity class with the k values of 0.15. Chromic vertisols and Chromic luvisols have K values (0.2) with moderately sensitive class and area coverages for both soil groups cover 36.28% of the area respectively which indicates moderately sensitive to soil erosion(S2). Based on soil erodibility factor(k) values the middle parts of the watershed was relatively less sensitive and covers large parts of the watershed. The lower parts of the watershed near to the outlet was highly sensitive(S1) to soil erosion and covered by Eutric nitosols with k value of 0.25.

3.1.4 Slope factor Severity map

The slope is one of the most significant topographical features that impact degradation and production. Each slope category was given an index for their sensitivity to erosion.

Depending on the result of soil erosivity class mountainous and steep parts of the watershed has high severity class(S1) and covers 13.5km^2 or 2.31% of the watershed and mostly found at the middle and upper part of the watershed. Large areas are covered by less sensitive slope class less than 15 degree and it covers 84.74% of watershed.

4.2.1.5 Land use land cover map.

Based on the specific cover type, the most important land cover types were classified in to different land cover types. These seven classes of cover types were reclassified according to the sensitivity of each cover types and overlaying the similar sensitive parts of the landcover to get the land use land cover sensitive areas of the watershed.

From the total 377.89 km ^{2} of the watershed was covered by highly sensitive(S1) parts in terms of land use land cover classifications. This severity is due to high coverage of Agriculture land in the catchment. The remaining 131.8 km^2 was moderately(S2) sensitive and the last 78.3km^2 less sensitive(S3) parts excluding the constraints(0.25km^2).

4.3 Pairwise comparison

4.3.1 Weights and MCDA Sensitivity map

Having a comparison matrix, compute priority vector, which is the normalized Eigen vector of the matrix. Pairwise comparison matrix was prepared based on the comparison scale 1 to 9(table)based on experts Questionnaire Survey result. Position of the Respondent are: Agriculture Regional and woreda level natural resource experts: five (5), from woreda Agricultural experts and five (5), from regional agricultural experts and five from kebele level experts.

In identifying soil erosion hotspot areas, TWI was the first most influential factor and it come on top of the hierarchy while soil was considered to have the least influential factor based on the level of importance given by the experts. The values in each pixel represent the scale of relative importance for the given paired factors. The diagonal has the value of 1 throughout because the diagonal represents factors being compared to itself and the scale if equally importance factors compared. For the lower diagonal the values of compared scale are in fractions because the factors are being paired in the reverse order and the scale of relative importance was given as the reciprocal of the upper diagonal pairwise comparisons based on the AHP calculator software from Fig. (4.30&4.31). TWI the 1st, land use was ranked 2nd, Gully was the 3rd, slope the 4th and soil the 5th most important parameters in identifying erosion hotspot area in Andassa watershed.

The weighted overlay by result shows in qualitative Sensitivity map investigates that the more than half of the watershed was under moderately sensitive risk of soil erosion (68.12%) about 400.861km^2. Next 17.56% (103.35km^2) of the watershed was under slightly sensitive and the remaining 14.27% (83.999 km^2) of the watershed was under highly sensitive risk of soil erosions.

The analytical hierarchy calculator gives result based on the input level of importance provided by the experts. From the above graph we investigate the most important criteria and the least important criteria based in terms of percentage values. TWI and LULC covers 41.5% and 31.5% of the weight respectively among the selected criteria. The remaining 15.7,7.5, and 3.8 were covered by Gully, Slope and Soil respectively.

Based on the level of importance given by the experts for the criteria matrix, principal eigen value, and consistency index (CI)from the Excel was 5.1299 and 0.032respectively. The random consistency index for n = 5 was 1.12(Seri, 2009)so the corresponding consistency ratio was 0.043 < 0.1(ok).

In order to check the analytical hierarchy calculator, result the graph prepared based on excel results and the answer for both analytical hierarchy process and Excel manual calculation was the same (Fig. 4.30&4.31) based on the input level of importance provided by the experts.

The above graph investigates the most important criteria and the least important criteria and intermediate values in terms of percentage values and both AHP calculator and excel results was the same.

4. Conclusions

This study provides the soil erosion risk assessment in Andassa River Watershed based on a combination MCDA with the application of GIS and RS. Multicriteria decision analysis (MCDA) were applied compare the different parts of the watershed in terms of sensitivity to soil erosion. MCDA identifies sources of soil erosion areas spatially and gully locations in Qualitative measurement and to plan further management priorities for responsible organizations, government officials, and nongovernmental officials. The soil erosion risk of the study area is high compared to some other places of Ethiopia, but the ranges of average soil lose rate was within the range of Ethiopian highlands. The results in combination with proper field validation provide more accurate erosion sensitivity prediction. In general, moderate soil erosion severity classes (most parts of the watershed), high severity classes, and less sensitive should be given the first, second, third priority, respectively.

This study provides information to land planners and decision makers, to take effective soil and water conservation measures, in order to reduce soil loss and to increase amount of water accumulation in the study area.

Declarations

We here submitted the manuscript entitled “EROSION SOURCE AREA IDENTIFICATION USING MULTI-CRITERIA DECISION ANALYSIS, ACASE OF ANDASSA WATERSHED, UPPER BLUE NILE BASIN”to be considered for publication. We declare that this is our original research work.

There is no conflict of interest between the authors.

Funding statement: - There is no funding organization to publish

Author Contribution: The corresponding author Moges Animut has made overall manipulation of the manuscript and the other author Yibeltal Zewudu has reviewed and edited the hole manuscript.

Ethical statement: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants involved in the study.

I understand that journals may be available in both print and on the internet, and will be available to a broader audience through marketing channels and other third parties. Therefore, anyone can read material published in the Journal.

References

1. Academy, H. (2008). *On Saaty ' s and Koczkodaj ' s inconsistencies of pairwise comparison matrices 1. 42*(2), 157–175. https://doi.org/10.1007/s10898-007-9236-z

2. Ahmed, A. A. (2008). Sediment in the Nile River System. *Consultancy Study Requested by UNESCO*, *January*, 93 pp.
3. Assefa, T. T. (2015). Identification of erosion hotspot area using GIS and MCE technique for koga watershed in the upper blue Nile Basin, Ethiopia. *American Journal of Environmental Sciences*, *11*(4), 245–255. https://doi.org/10.3844/ajessp.2015.245.255
4. Bhattarai. (2010). *A comparative analysis of sediment yield simulation by empirical and process-oriented models in Thailand / Une analyse comparative de simulations de l ' exportation sédimentaire en Thaïlande à l ' aide de modèles empiriques et de processus A comparative a*. *6667*. https://doi.org/10.1623/hysj.53.6.1253
5. Carver. (2007). *Integrating multi-criteria evaluation with geographical information systems*. *3798*. https://doi.org/10.1080/02693799108927858
6. Counties, D., & Ballerine, C. (2017). *Topographic Wetness Index Urban Flooding Awareness Act Action Support*. *April*.
7. Efthimiou, N., Lykoudi, E., & Karavitis, C. (2014). *Soil erosion assessment using the RUSLE model and GIS*. *January*.
8. FAO, & UNESCO. (1979). Soil Map of The World: South East Asia. In *Soil Map of The World: Vol. IX*.
9. Ganasri, B. P., & Ramesh, H. (2015). Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin Geoscience Frontiers Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin. *Geoscience Frontiers*, *December*. https://doi.org/10.1016/j.gsf.2015.10.007
10. Hurni, H. (1988). *Degradation and Conservation of the Resources in the Ethiopian Highlands Author (s): Hans Hurni Source : Mountain Research and Development , Vol . 8 , No . 2 / 3 , African Mountains and Published by : International Mountain Society Stable URL : http://w*. *May 1988*. https://doi.org/10.2307/3673438
11. Jaiswal, R. K., Ghosh, N. C., Galkate, R. V, & Thomas, T. (2015). Multi Criteria Decision Analysis (MCDA) for watershed. *Aquatic Procedia*, *4*(Icwrcoe),
12. Lee, G., & Lee, K. (2010). *Determining the Sediment Delivery Ratio Using the Sediment-Rating Curve and a Geographic Information System – Embedded Soil Erosion Model on a Basin Scale*. *15*(October), 834–843. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000254
13. Lin, C., Kou, G., Ergu, D., Lin-, C., Kou, G., & Ergu, D. (2014). *A statistical approach to measure the consistency level of the pairwise comparison matrix A statistical approach to measure the consistency level of the pairwise comparison matrix*. *65*(9), 1380–1386. https://doi.org/10.1057/jors.2013.92
14. Mekonnen, M., & Melesse, A. M. (2011). *Soil Erosion Mapping and Hotspot Area Identification Using GIS and Remote Sensing in Northwest Ethiopian Highlands , Near Lake Tana*. 207–224. https://doi.org/10.1007/978-94-007-0689-7
15. Mhiret, D. A., Dagnew, D. C., Assefa, T. T., Tilahun, S. A., Zaitchik, B. F., & Steenhuis, T. S. (2018). Erosion hotspot identification in the sub-humid Ethiopian highlands. *Ecohydrology and Hydrobiology*,

19(1), 146–154.

16. Nile, B. (2015). *Identification of erosion hotspot area using gis and MCE technique for koga identification of erosion hotspot area using GIS and MCE technique for koga watershed in the upper blue nile basin*. *June*.
17. Odu, G. O. (2019). Journal of Applied Sciences and Environmental Management,. *Ournal of Applied Sciences and Environmental Management.*, *23*(8), 1449. https://doi.org/10.4314/jasem.v23i8.7
18. Olson, J. M. (2003). *Assessing the extent , cost and impact of land degradation at the national level : findings and lessons learned from seven pilot Commissioned by Global Mechanism with support from the World Bank. February*. *February*.
19. Pandey, A., & Mal, V. M. C. B. C. (2007). *Identification of critical erosion prone areas in the small agricultural watershed using USLE , GIS and remote sensing*. 729–746. https://doi.org/10.1007/s11269-006-9061-z
20. Peden, D., Smakhtin, V., & Molden, D. (2013). The Nile river basin: Water, agriculture, governance and livelihoods. In *The Nile River Basin: Water, Agriculture, Governance and Livelihoods* (Vol. 9780203128).
21. Saaty, R. W. (1987). The analytic hierarchy process-what it is and how it is used. *Mathematical Modelling*, *9*(3–5), 161–176. https://doi.org/10.1016/0270-0255(87)90473-8
22. Seri, R. (2009). *The Analytic Hierarchy Process and the Theory of Measurement*. *January*.
23. Shiferaw. (2018). *Soil loss estimation and source areas using RUSLE and MCE technique in chemoga watershed , blue nile basin.*
24. Sørensen, R., Zinko, U., & Seibert, J. (2006). On the calculation of the topographic wetness index: Evaluation of different methods based on field observations. *Hydrology and Earth System Sciences*, *10*(1), 101–112.
25. Tadele, H., Ademe Malede, D., & Befekadu Geleta, F. (2020). Erosion Risk Potential Assessment Using GIS and RS for Soil and Water Resource Conservation Plan: The Case of Yisir Watershed, Northwestern Ethiopia. *Agriculture, Forestry and Fisheries*, *9*(1), 1. https://doi.org/10.11648/j.aff.20200901.11
26. Teshome, & Tsegaye, D. (2019). Potential soil erosion estimation and area prioritization for better conservation planning in Gumara watershed using RUSLE and GIS techniques '. *Environmental Systems Research*.
27. White, G. P. (1987). The implementation of management science in higher education administration. *Omega*, *15*(4), 283–290. https://doi.org/10.1016/0305-0483(87)90016-8
28. Yesuph. (2019). Soil erosion mapping and severity analysis based on RUSLE model and local perception in the Beshillo Catchment of the Blue Nile Basin ,. *Environmental Systems Research*, 1–21.
29. Zhang, B., Mal, V. M. C. B. C., Bilas, G., Misopolinos, N., Silleos, N., & Assfaw, A. T. (2017). soil loss estimation and source areas using rusle and mce technique in chemoga watershed , blue nile basin.

Procedia Environmental Sciences, *19*(April 2016), 912–921. https://doi.org/10.1007/s11269-006-9061-z

Tables

Tables are available in the Supplementary Files section

Figures

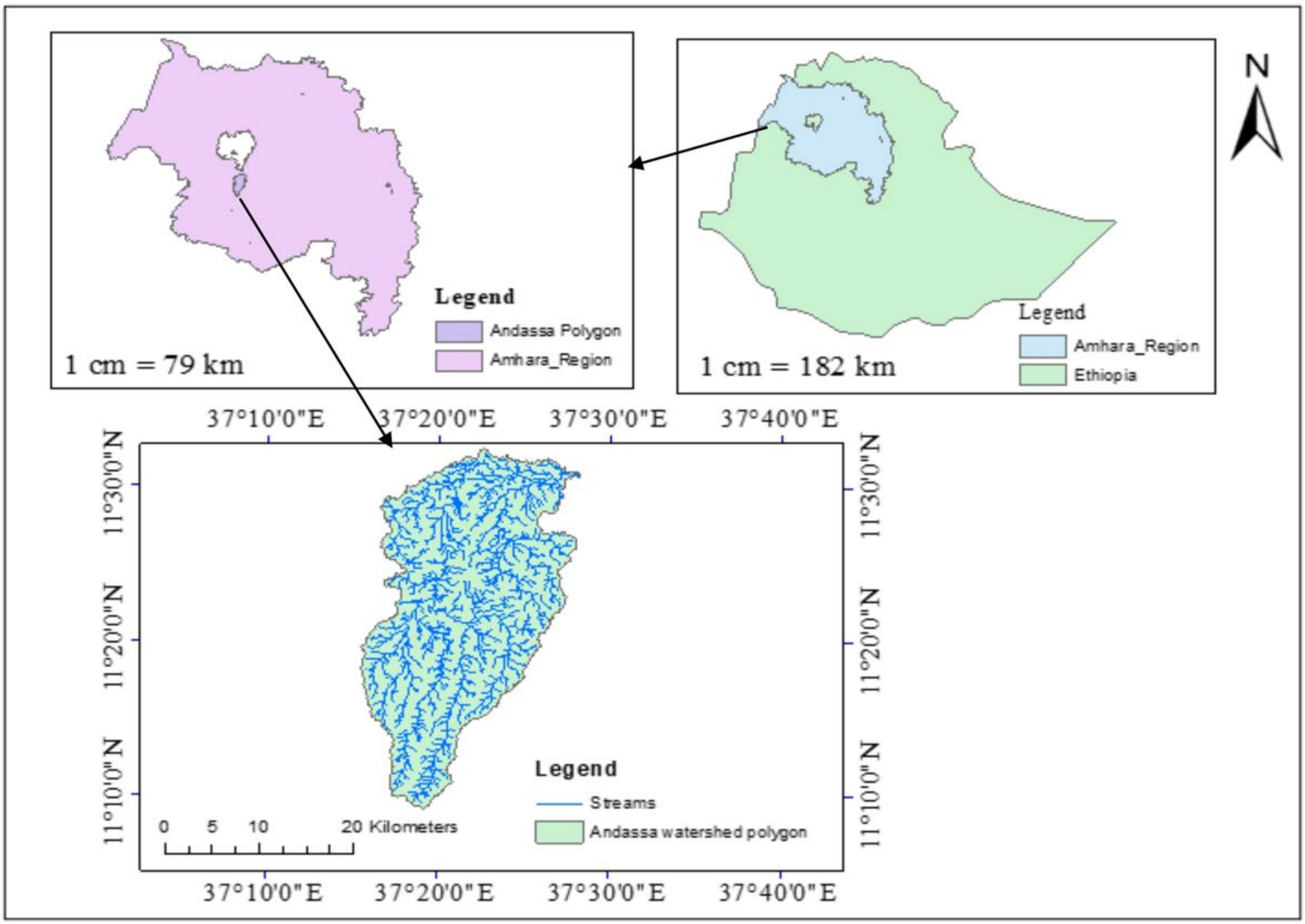

Figure 1

Figure 2.1:Study area description of Andassa Watershed

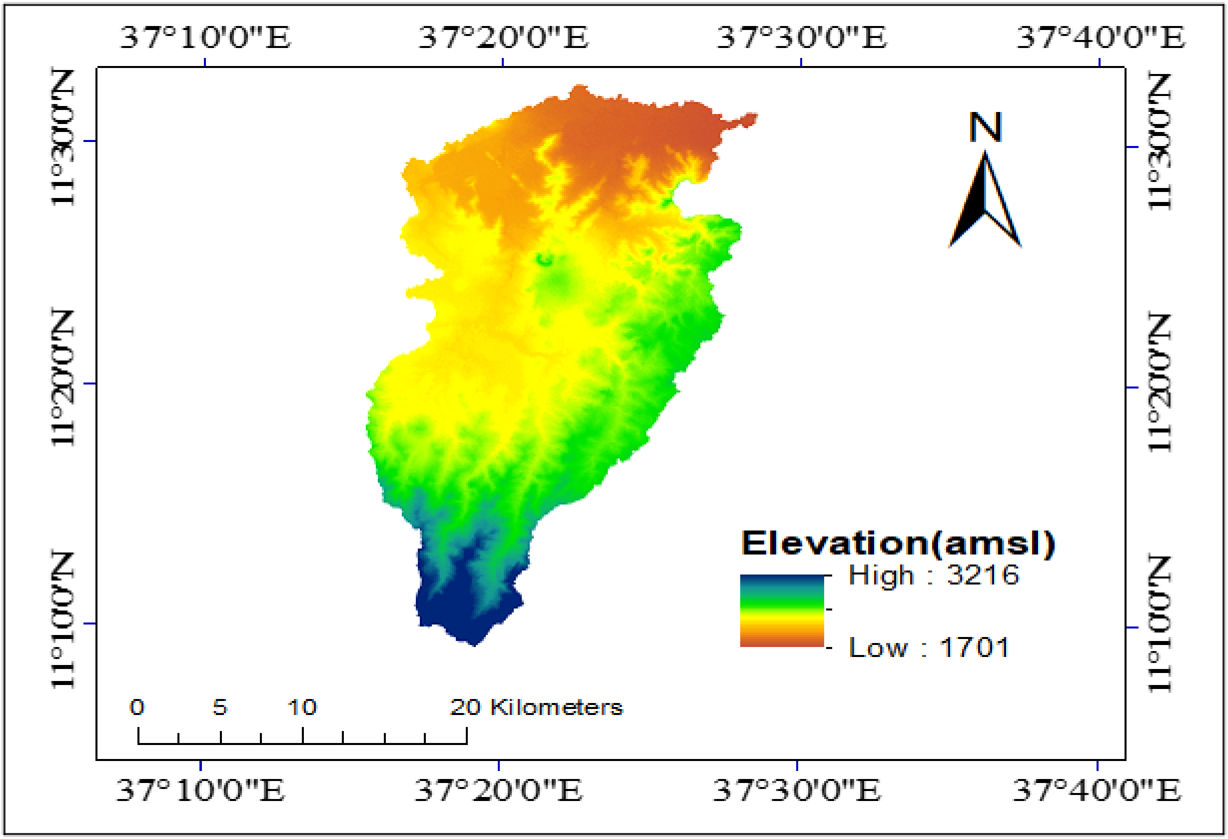

Figure 2

Figure 2.2: Elevation range of Andassa watershed

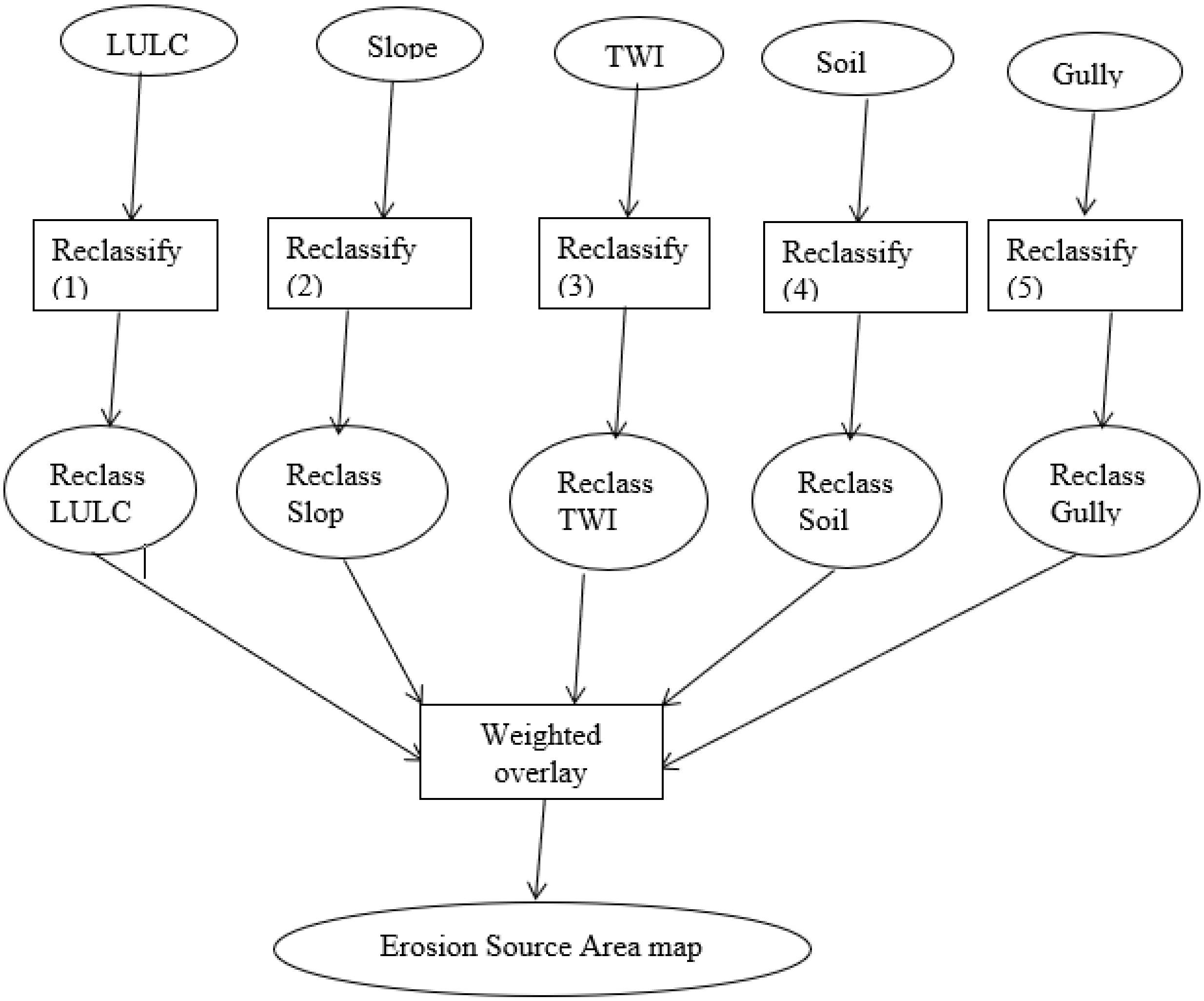

Figure 3

Figure 2.3: Weighting criteria Flowchart for MCDA part in GIS 10.1

Figure 4

Figure 3.1: Ground truth point collection in the catchment (August 2012 EC)

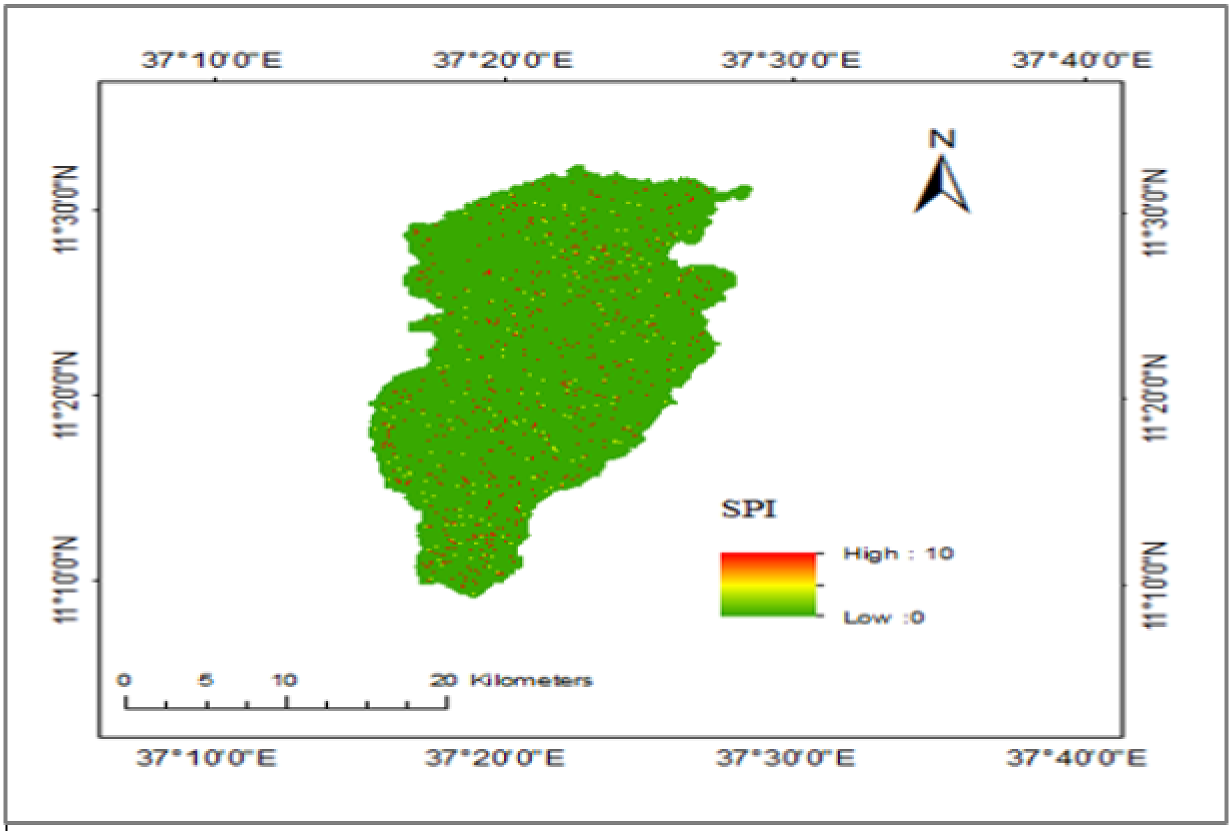

Figure 5

Figure 3.2: Stream power index

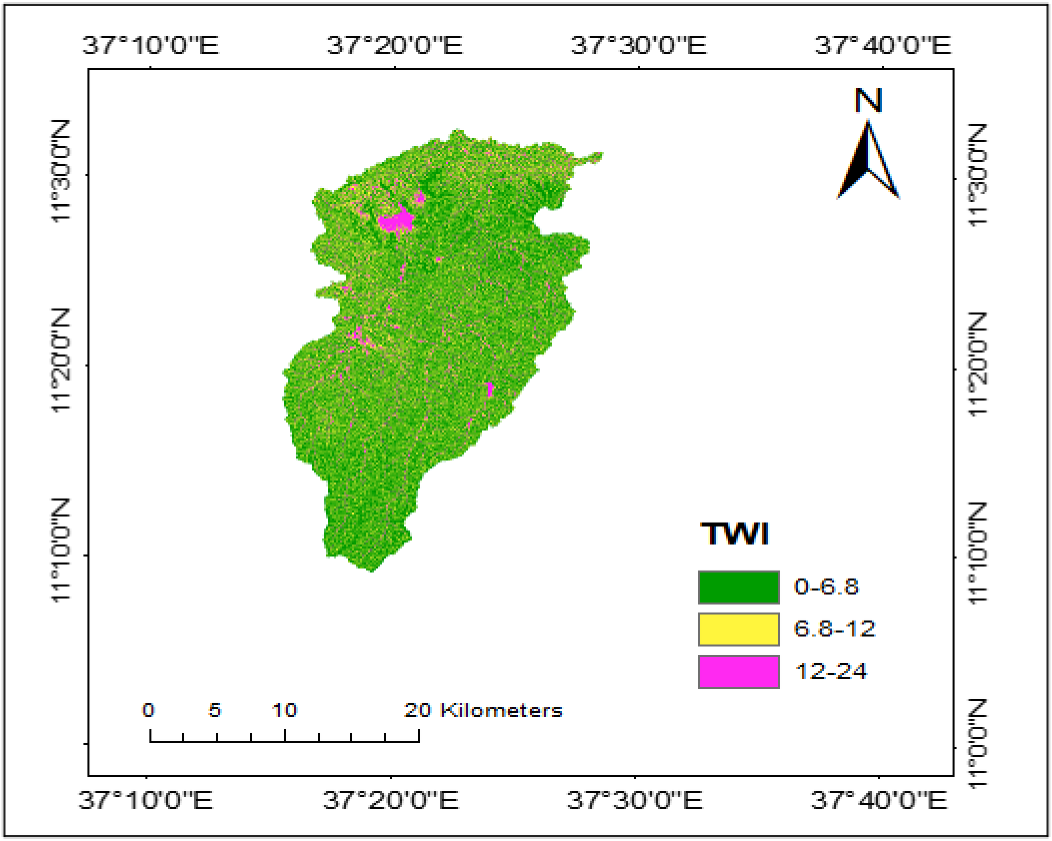

Figure 6

Figure 3.3: Topographic witness index

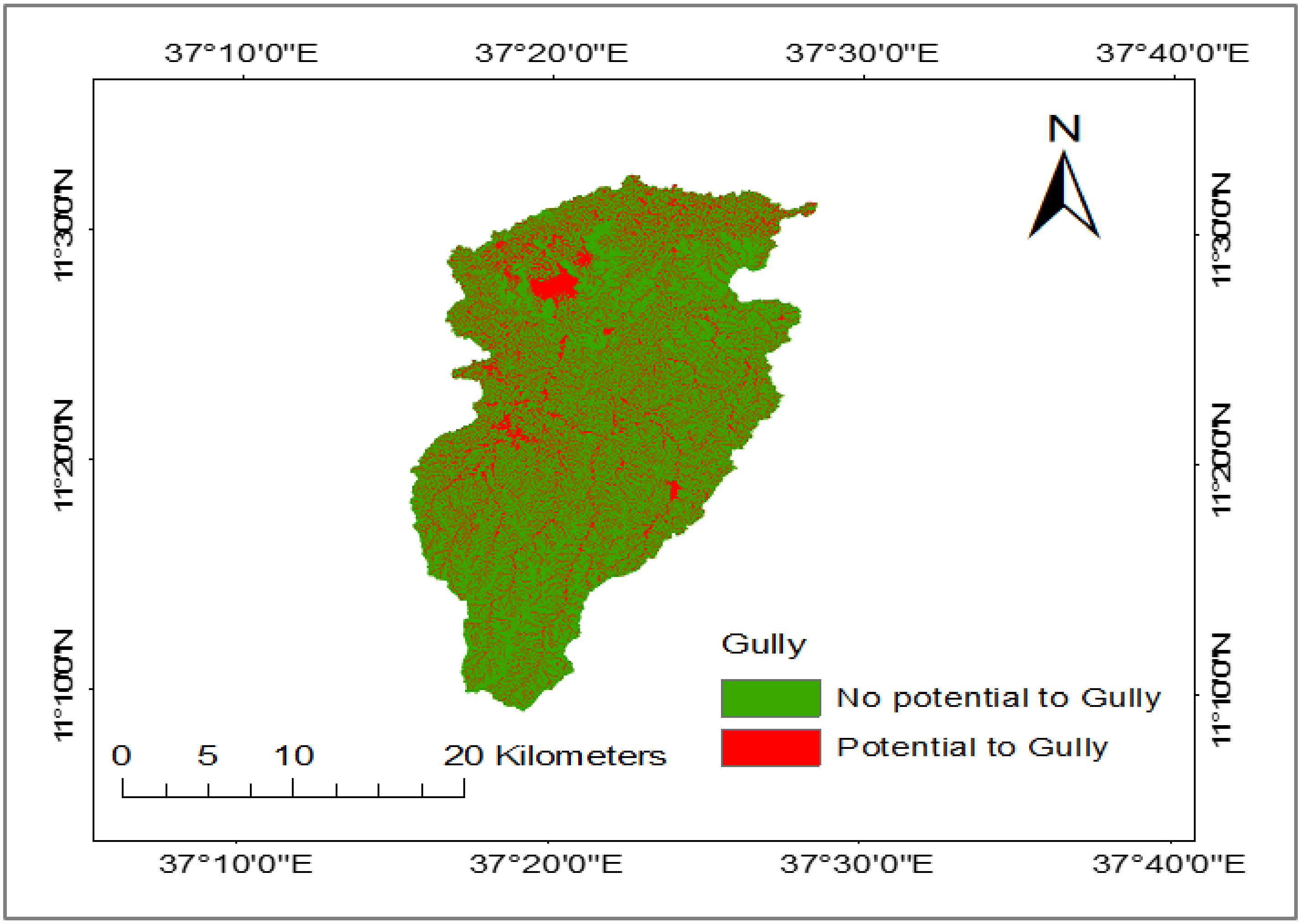

Figure 7

Figure 3.4: Gully location map

Figure 8

Figure 3.5: Gully and stream bank erosion in the watershed August (2012 EC)

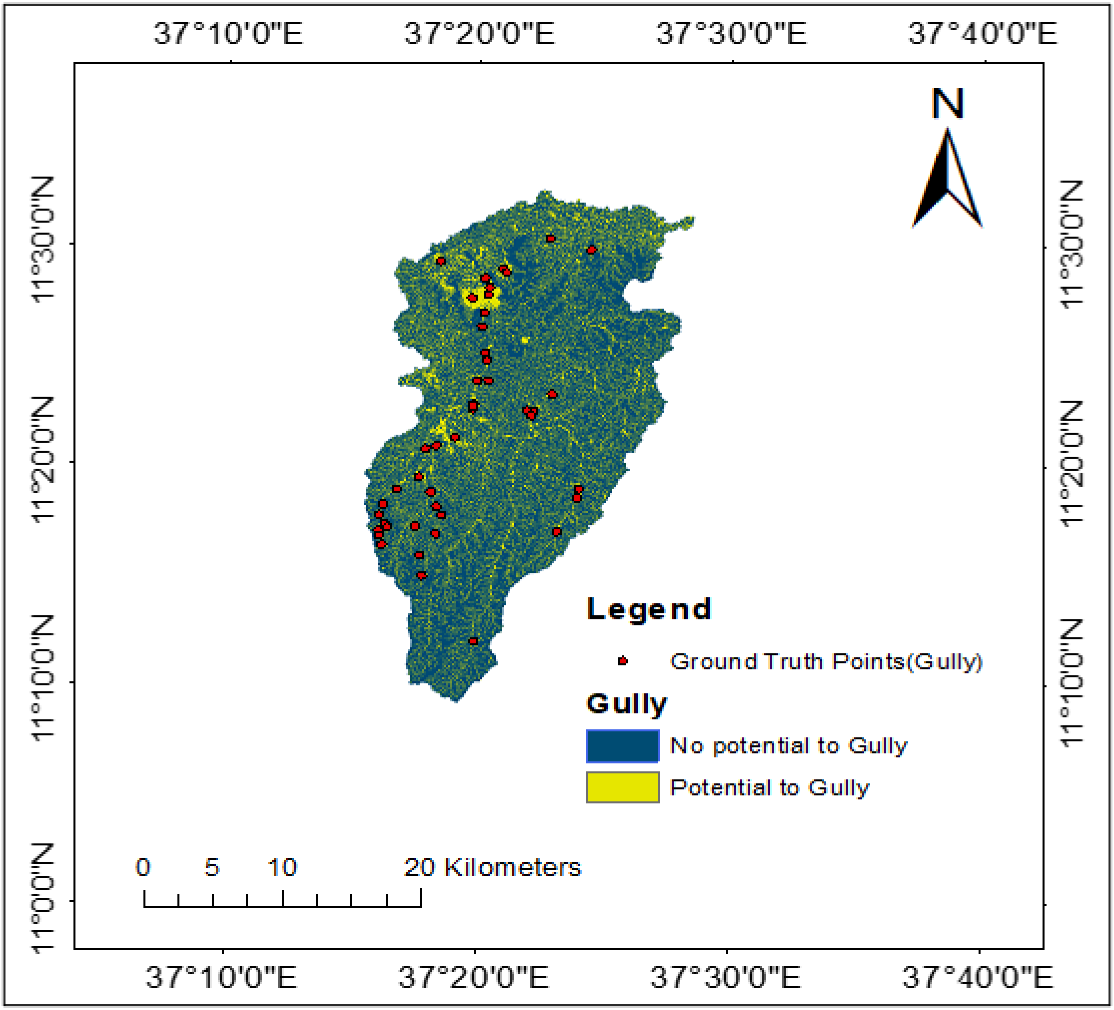

Figure 9

Figure 3.6: Gully ground control points Collected from GPS.

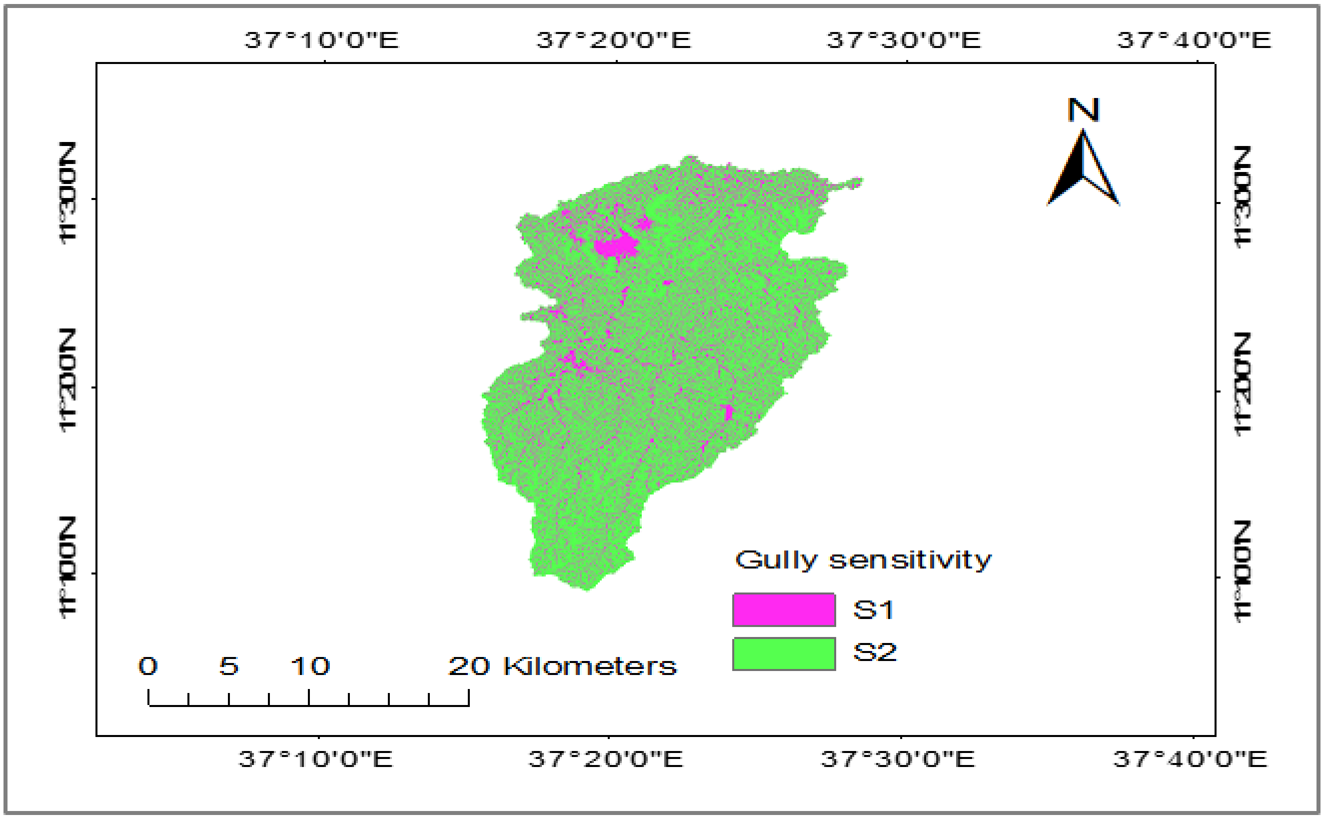

Figure 10

Figure 3.7: Gully factor Sensitive map:

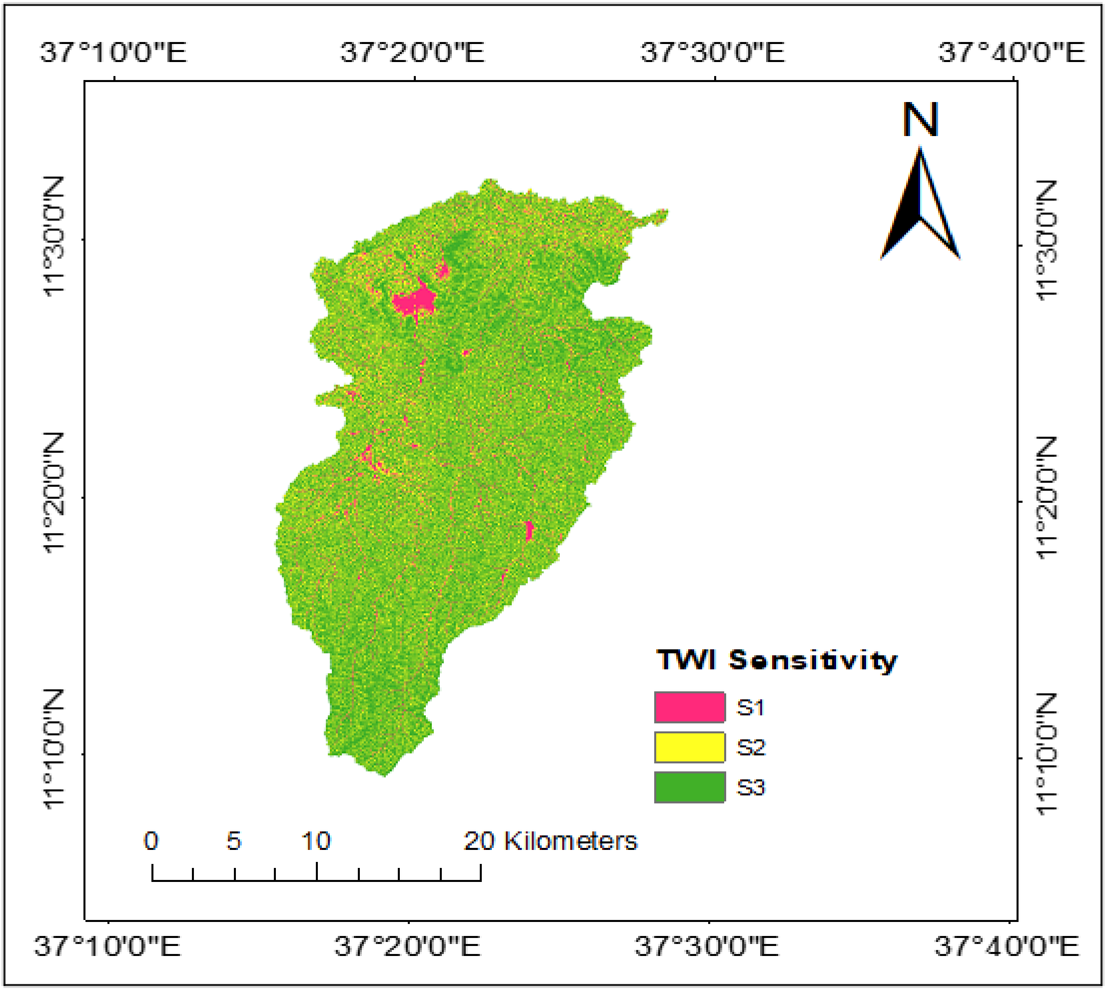

Figure 11

Figure 3.8: TWI factor map

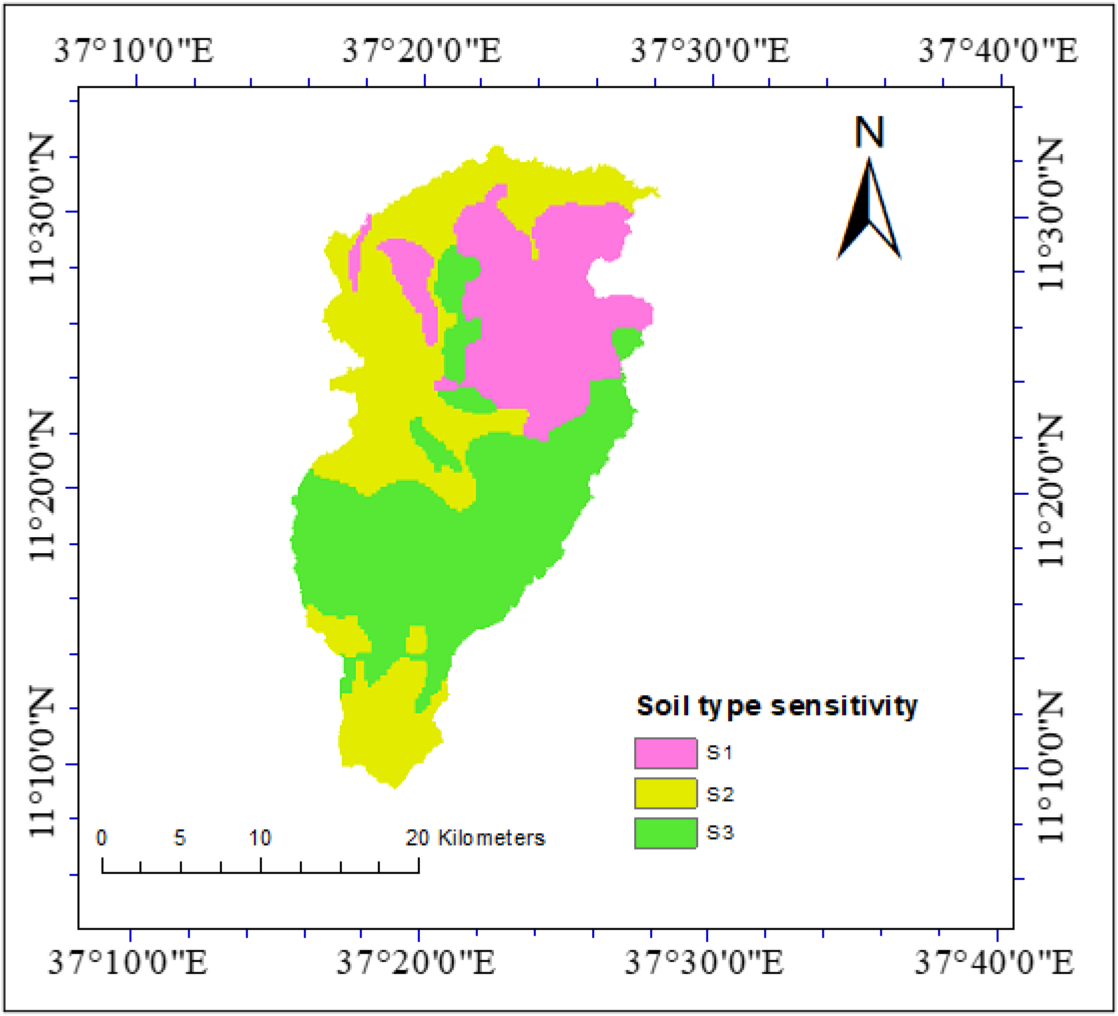

Figure 12

Figure 3.9: Soil Severity map

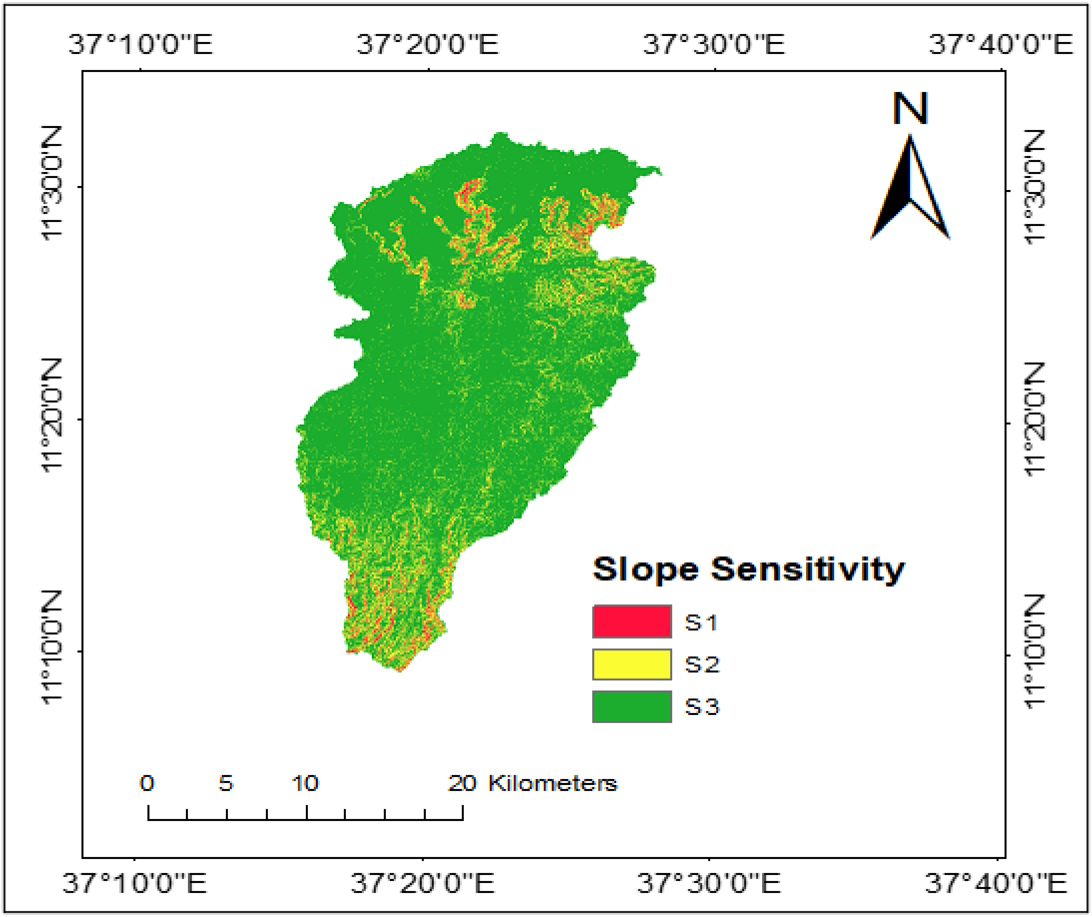

Figure 13

Figure 3.10: Slope factor map

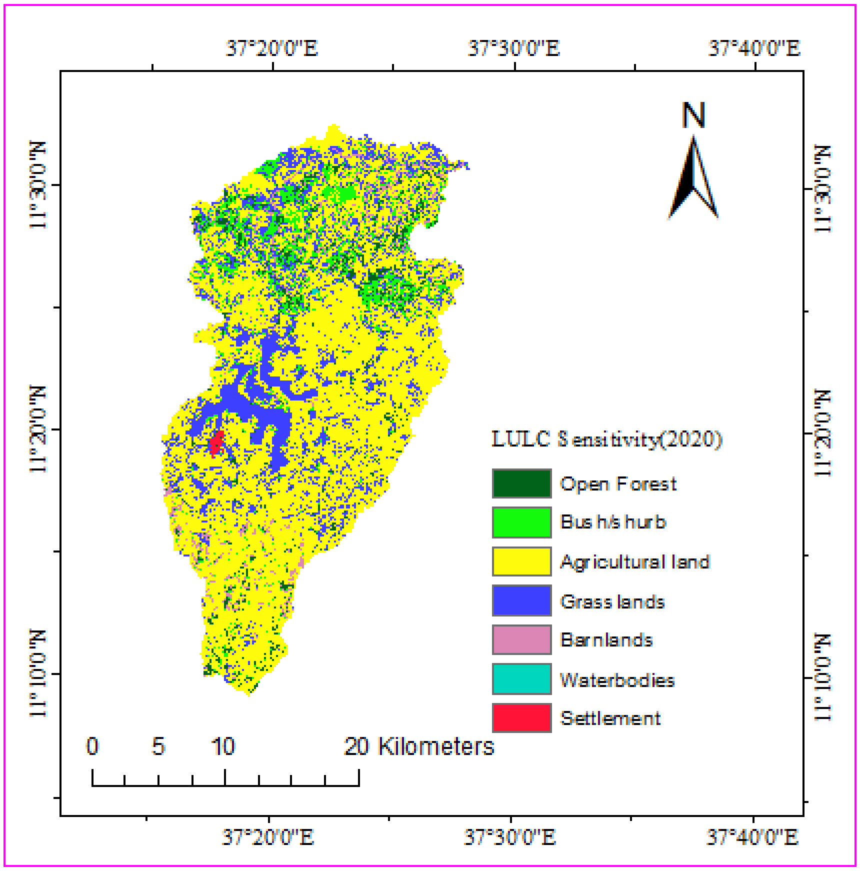

Figure 14

Figure 3.11: LULC severity map

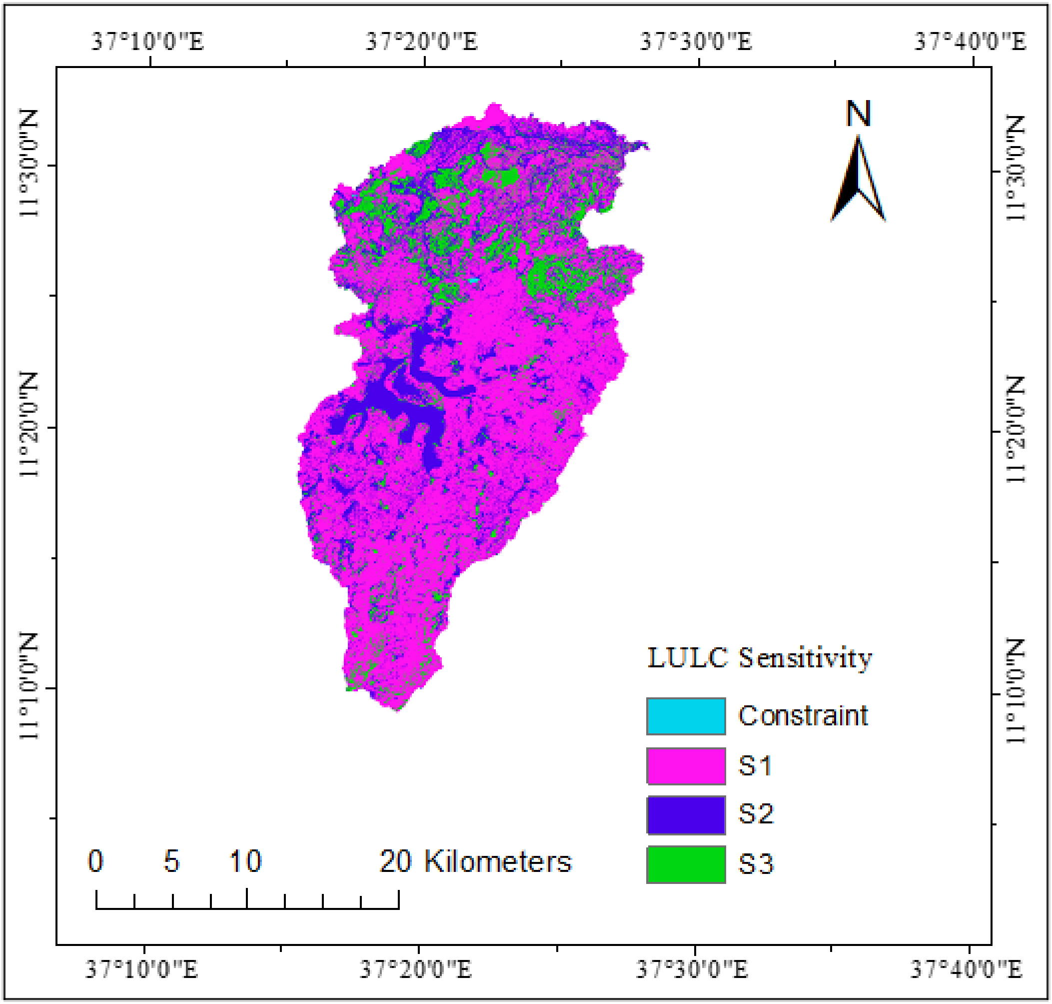

Figure 15

Figure 3.12: LULC severity map

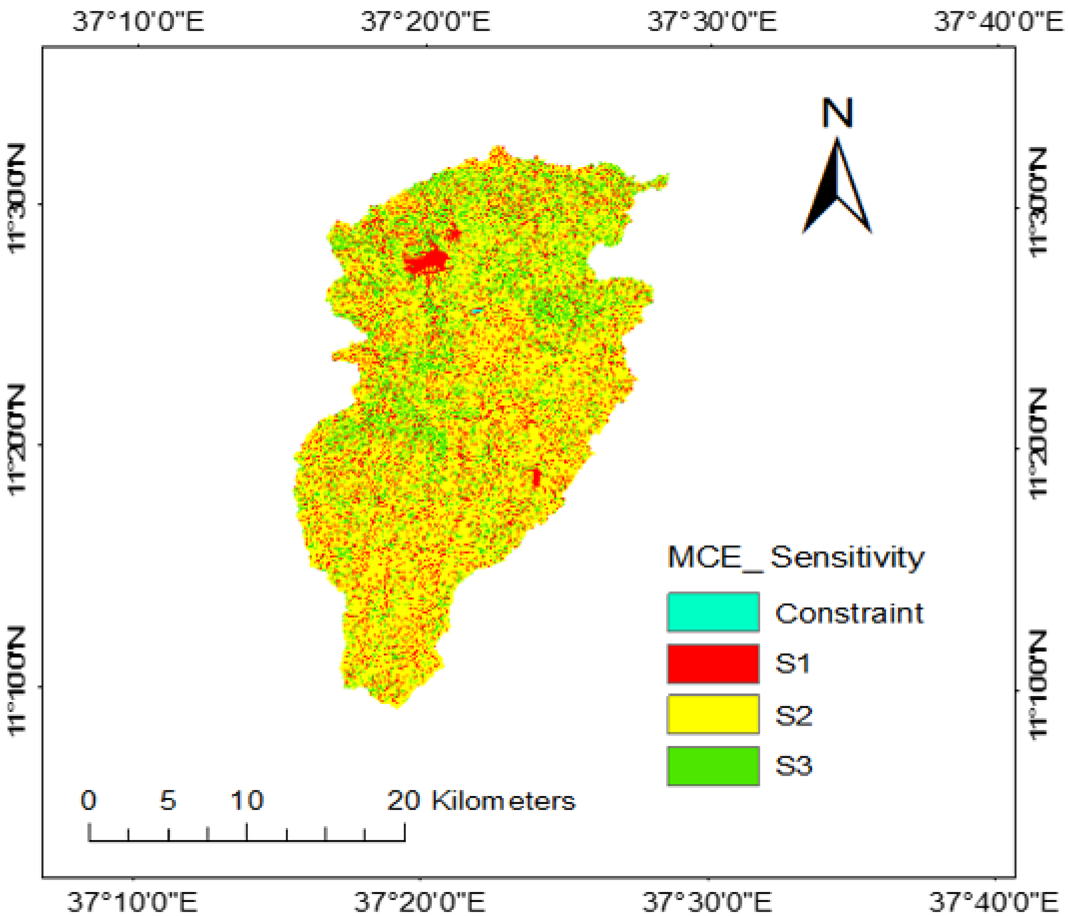

Figure 16

Figure 3.13: MCE Sensitivity map

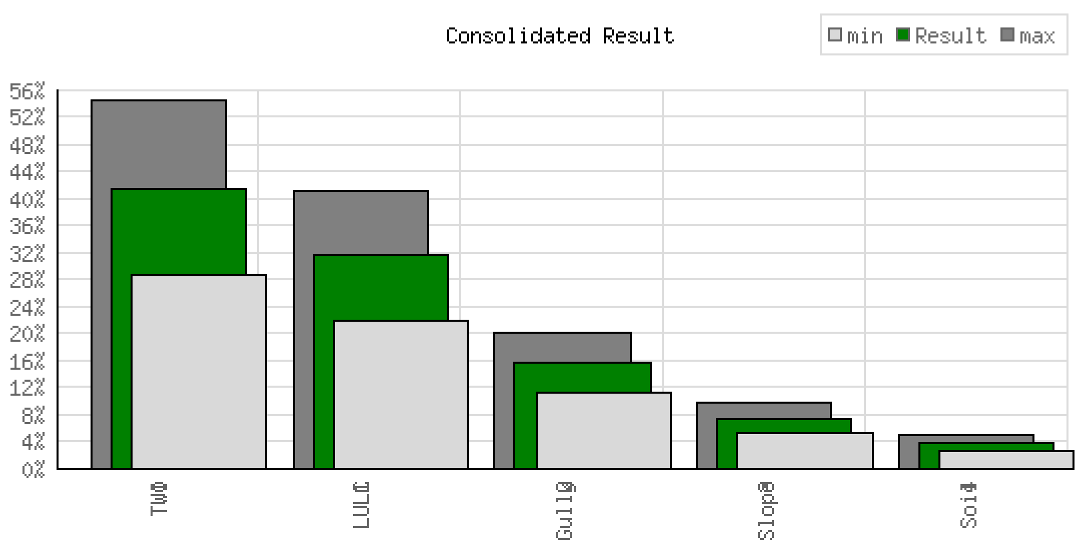

Figure 17

Figure 3.14: Relative Weight graph based on AHP calculator software.

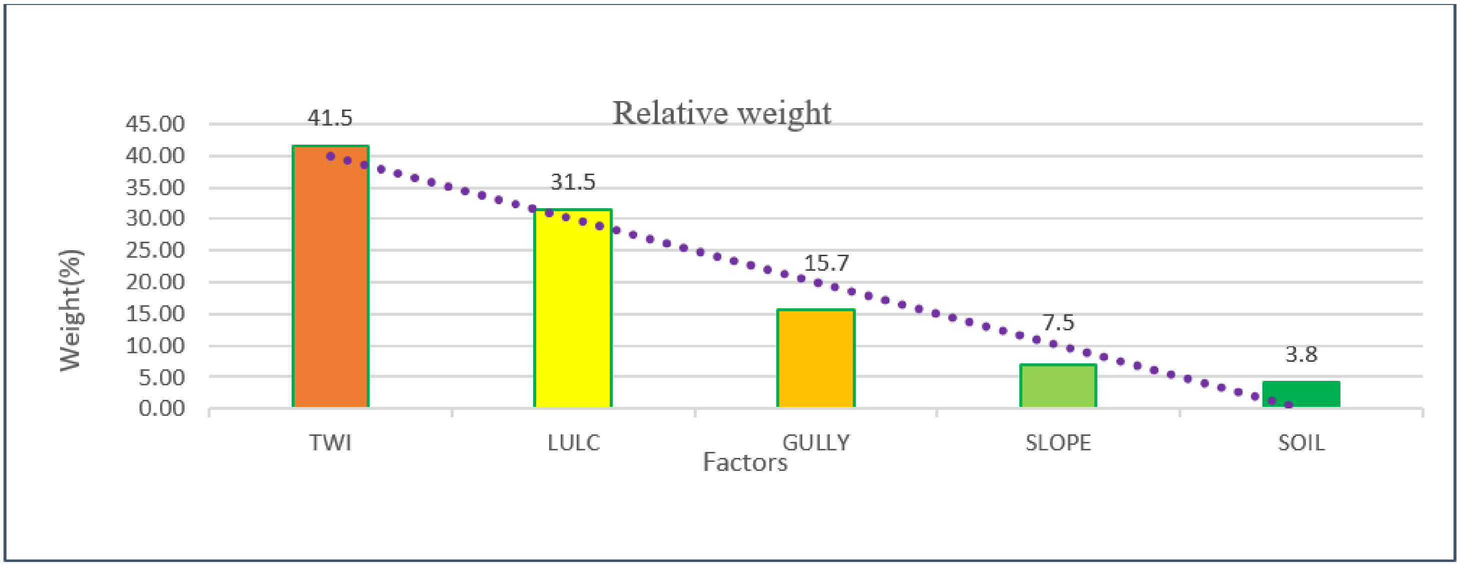

Figure 18

Figure 3.15: Relative Weight graph based On Excel data.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Tables.docx