Multi criteria evaluation for universal soil loss equation based on geographic information system

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Abstract. The purpose of this research were to produce (1) a conceptual, functional model designed and implementation for universal soil loss equation (usle), (2) standard operational procedure for multi criteria evaluation of universal soil loss equation (usle) using geographic information system, (3) overlay land cover, slope, soil and rain fall layers to gain universal soil loss equation (usle) using multi criteria evaluation, (4) thematic map of universal soil loss equation (usle) in watershed, (5) attribute table of universal soil loss equation (usle) in watershed. Descriptive and formal correlation methods are used for this research. Cikapundung Watershed, Bandung, West Java, Indonesia was study location. This research was conducted on January 2016 to May 2016. A spatial analysis is used to superimposed land cover, slope, soil and rain layers become universal soil loss equation (usle). Multi criteria evaluation for universal soil loss equation (usle) using geographic information system could be used for conservation program.

1. Introduction
The integration of Geographic Information System and Multi Criteria Analysis has proved to be an indispensible tool in land suitability evaluation, especially when the spatial problems are characterized by multiple alternatives. Nevertheless, in the execution of the models based on these methods and techniques, little attention has been paid to the evaluation of the final results and to priority of weights. [1].

Agricultural land suitability evaluation for crop production is a process that requires specialized geo-environmental information and the expertise of a computer scientist to analyze and intrepret the information. Agriculture Land Suitability Evaluator (ALSE) is an intelligent system for assessing land suitability for different types of crops in tropical and subtropical regions based on geo-environmental factors that automates the process of evaluation and illustrates the results on an attribute table. Its main features include support of GIS capabilities on the digital map of an area with the FAO-SYS framework model with some necessary modifications to suit the local environmental conditions for land evaluation, and the support of expert knowledge through on spatial tools to derive criteria weights with their relative importance. [2].

Erosion is defined as the movement of soil by water and wind, and it occurs in Kalar watershed under a wide range of land uses. Erosion by water can be dramatic during storm events, resulting in wash-outs and gullies. It can also be insidious, occurring as sheet and rill erosion during heavy rains. Most of the soil lost by water erosion is by the processes of sheet and rill erosion. Land degradation and subsequent soil erosion and sedimentation play a significant role in impairing water resources within sub watersheds, watersheds and basins. Using conventional methods to assess soil erosion risk is expensive
and time consuming. A comprehensive methodology that integrates Remote Sensing and Geographic Information Systems (GIS), coupled with the use of an empirical model (Revised Universal Soil Loss Equation-RUSLE) to assess risk, can identify and assess soil erosion potential and estimate the value of soil loss. GIS data layers including, rainfall erosivity (R), soil erodability (K), slope length and steepness (LS), cover management (C) and conservation practice (P) factors were computed to determine their effects on average annual soil loss in the study area. Based on the result soil erosion was classified in to soil erosion severity map with five classes, very low, low, moderate, high and critical respectively. Further RUSLE factors has been broken into two categories, soil erosion susceptibility (A=RKLS) and soil erosion hazard (A=RKLSGP) have been computed. It is understood that functions of C and P are factors that can be controlled and thus can greatly reduce soil loss through management and conservational measures. [3].

Urban watershed is a discrete and complex system where a diverse number of factors govern its quality and health. The time required for data collection and high cost of research, is the difficulty in identification of area sensitive to water induced soil erosion by conventional methods. However, these problem can be solved by the use of GIS base predictive models both at local and regional scale. The main objective of the study is to assess the sites vulnerable to soil erosion based on multi-criteria evaluation (MCE) in the upper catchment of Markanda River. GIS is used for derivation, integration, and spatial analysis of geographic layers of each theme. Analytical Hierarchy Process (AHP) is used to calculate the weights of soil erosion influencing factors such as rainfall, vegetation, slope, soils, drainage density and land use. The modeling result is validated by field survey and interpretation of high resolution satellite imagery. Ground verification of resulted sites revealed that there are various visual indicators of erosional and depositional geomorphic features like sand point bars, cut bank erosion, abandoned channel and siltation in agriculture fields and the ponds. Thus, the model’s result based on multi-criteria evaluation in GIS proves that identification of sites vulnerable to soil erosion is prerequisite. Such models based soil erosion scenario maps are important in planning conservation and control measures for soil erosion to prioritize the area according to severity of erosion. [6].

Soil erosion affects land qualities and water resources. This problem is severe in Ethiopia due to its topographic features. The present research was aimed to estimate spatiotemporal changes in land-use, land-cover patterns and soil erosion in the Yezat watershed in Ethiopia. This study was carried out by using landsat imageries of 2001, 2010 and 2015. Images were also classified into categories using supervised classification by maximum likelihood algorithms. They were also classified into different biomass levels by using Normalized Difference Vegetation Index (NDVI) analysis. Revised Universal Soil Loss Equation modeling was applied in a GIS environment to quantify the potential soil erosion...
risk. Management intervention are necessary to improve the status and utilization of watershed resources in response to sustainable land management practices for sustainable livelihood of the local people. [7].

Reliable databases are the prime requirement for identifying vulnerable erosion zone in order to execute alleviation measures. Geo-morphometric characterizations of a watershed are commonly used and scientific approach in this connection. A total of 15 (7 relief and 8 drainage) geo-morphometric parameters have been considered for the study with the aid of Remote Sensing (RS) and Geographical Information System (GIS). Principle Component Analysis (PCA) based Average Weighted Composite Score (AWCS) method is used to assimilate the erosion driving variables and thereby to fabricate spatial soil erosion vulnerable map. According to the result, high to severe erosion susceptibility zone counts about 34.85% of the basin area, mainly concentrated in the upper catchment due to excessive drainage conditions, steep slope, high dissection and ruggedness index, surplus drainage density and stream frequency. These erosion hotspot areas of the river basin needs special attention to take up mechanical soil conservation measures, gully control structures and grass erection to protect nutrient rich topsoil loss this agriculturally conquered region. [8].

The high islands of the Pacific are characterised by short and steeply-sloping watersheds, where erosive events can generate large terrigenous material run-off loads that threaten the adjacent reefs. To assess the sediment deposition it is necessary to characterize the erosion process on the watersheds and highlight the areas most affected. The research aims to describe the implementation of the Universal Soil Loss Equation (USLE) for the mapping and quantification of the potential soil erosion in countries. The USLE model, commonly used to calculate average annual soil loss per unit land area resulting from sheet and rill erosion, can be written as $A=R\times E\times L\times S\times C\times P$. $A$ is the soil loss, $R$ is the rainfall-run off erosivity factor, $E$ is a soil erodibility factor, $L$ is a slope length factor, $S$ is a slope steepness factor, $C$ is a cover management factor and $P$ is a supporting practice factor. The spatialization of this model is implemented using the data processing and mapping functionalities of a Geographical Information System (GIS) from input data which included a digital elevation model, a soil map, a land cover map and precipitation data. [9].

The objective of impact of land use change on erosion risk study was to evaluate the impact of rapidly changing land use on erosion and sedimentation in a mixed land use watershed in the Ozark Highlands of the USA. The research combines a geographic information system-based soil erosion modeling approach with land use change detection to quantify the influence of changing land use on erosion risk. Five land use and land cover maps were generated or acquired for a 20-year period (1986 through 2006) at approximately 5-year intervals to assess land use change and to predict a projected (2030) land use scenario for the West Fork White River watershed in Northwest Arkansas. The unit stream power based erosion/deposition model was applied to the observed and predicted land use to assess the impact on erosion. Total erosion from urban areas was predicted to increase by a factor of six between 1986 and 2030 based on the projected 2030 land use. Result support previous reports of increased urbanization leading to increase soil erosion risk. This study highlights the interaction of changes in land use with soil erosion potential. Soil erosion risk on a landscape can be quantified by incorporating commonly available biophysical data with geographic information system and remote sensing, which could serve as a land/watershed management tool for the rapid assessment of the effects of environmental change on erosion risk. [10].

2. Methods
The method used is descriptive for spatial analysis, which presents symptoms in the field significantly. The descriptive method was applied to the analysis of spatial form of presentation of thematic maps that go through stages, namely: 1) Identification of user needs for Universal Soil Loss Equation; 2) The collection of all data (base map, rainfall thematic map, soil type thematic map, slope thematic map, land use thematic map and rainfall data per month); 3) Grouping data by types and levels; 4) Conceptual modeling for input, processing and output of data based on base map and user institution for optimizing data base; 5) Functional Modeling to design data structures and database management based on graphical type (point, line and polygon) and attribute type (numeric, string, boolean, date) for accurating
analyzing and results; 6) Implementation of spatial development system for Universal Soil Loss Equation; 7) Submission of data to convert analog data into digital so that graphical and attribute data becoming integrated in digital computer environment; 8) Programming to build a model of the interaction between the database management systems with the users; 9) Test spatial system to obtain feedback; 10) Revision of the spatial system Universal Soil Loss Equation; 11) The use of a spatial system Universal Soil Loss Equation; 12) Maintenance spatial system Universal Soil Loss Equation.

3. Results and Discussion

Figure 1. Rainfall-run off erosivity factor map in December 2014 at Cikapundung watershed consists of five classes based on USDA-ARS 1954 [11]. First class is 198.187 cm/month, second class is 198.7 – 202.349 cm/month, third class is 202.349 – 210.509 cm/month, fourth class is 210.509 – 225.936 cm/month and fifth class is 225.936 – 302.435 cm/month.

![Rainfall-RUN OFF Erosivity Factor Map in December 2014 at Cikapundung Watershed](image1.png)

Figure 1. Rainfall-Run Off Erosivity Factor Map in December 2014 at Cikapundung watershed.

Figure 2. A soil erodibility factor map in December 2014 at Cikapundung watershed consists of three classes based on USDA-ARS (United States Department of Agricultural-Agricultural Research Service, 1954) [11]. First class is alluvial soil, second class is andosol soil, and third class is latosol soil.

![Soil Erodibility Factor Map in December 2014 at Cikapundung Watershed](image2.png)
Figure 2. A Soil Erodibility Factor Map in December 2014 at Cikapundung watershed.

Figure 3. A slope (length and steepness) factor map in December 2014 at Cikapundung watershed consists of five classes based on USDA-ARS (United States Department of Agricultural-Agricultural Research Service, 1954) [11]. First class is slope less than 8 %, second class is slope bigger than 40 %, third class is slope 16 % to 25 %, fourth class is slope 26 % to 40 %, and fifth class slope 8 % to 15 %.

Figure 4. A land use (cover management and supporting practice) factor map in December 2014 at Cikapundung watershed consists of seven classes based on USDA-ARS (United States Department of Agricultural-Agricultural Research Service, 1954) [11]. First class is forest, second class is plantation, third class is farm field, fourth class is rice fields, fifth class is shrubs, sixth class is river/lake/reservoir, and seventh class is housing settlements.
Figure 4. A Land Use (Cover Management and Supporting Practice) Factor Map in December 2014 at Cikapundung watershed.

Figure 5. Soil erosion (ton/month) map in December 2014 at Cikapundung watershed consists of five classes based on USDA-ARS (United States Department of Agricultural-Agricultural Research Service, 1954) [11]. First class is 547.48 ton/month, second class is 547.48 to 2,414.404 ton/month, third class is 2,414.404 to 6,728.637 ton/month, fourth class is 6,728.637 to 15,411.644 ton/month, and fifth class is 15,411.644 to 23,232.039 ton/month.

Figure 5. Soil Erosion (Ton/Month) Map in December 2014 at Cikapundung watershed.
4. Conclusion
The conclusions of this research are: 1) A biggest landuse is housing settlements at Cikapundung watershed. Housing settlements areas increased from 33.91% in 2010 to 36.9% in 2014; 2) A biggest erosion rate is in December 2010 and 2014. Class of erosion disaster is moderate at Cikapundung watershed; 3) A rainfall-run off erosivity and slope (length and steepness) factors are most influential to erosion rate at Cikapundung watershed.

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