CHAPTER 1: INTRODUCTION

1.1 General

Soil erosion is a primary concern for resource and environmental management as it is a continuing problem that reduces soil quality and field productivity. To support sustainable uses of these resources an appropriate model is required in this area, and to develop such model hydrological and soil erosion modeling is essential. The conventional method requires the input of too many variables making it time-consuming. On the contrary, Geoinformatics and Remote Sensing techniques can simplify the procedure. Geography and earth science increasingly rely on digital spatial data acquired from remotely sensed images analyzed by geographical information systems (GIS) and visualized on paper or the computer screen. The main advantage of the GIS methodology is in providing quick information on the estimated value of soil loss for any part of the investigated area. Therefore, in this work the analysis and modeling are done in a GIS platform.

1.2 Background

A watershed or catchment is an extent of land where surface water from various sources like precipitation, melting snow, or ice converges to a standard outlet point at a lower elevation. The watershed assumes a predominant part of the advancement of landforms, and in this manner, the analysis of drainage basin has profound importance in geomorphic studies. A watershed is a perfect unit for administration of Natural resources like soil and water and for the moderation of the effect of cataclysmic events for accomplishing sustainable advancement (Rahaman et al., 2015)

Interest in developing a different algorithm for prioritizing watershed and identifying the critical soil erosion-prone areas has increased for the last few years. The researchers knowing the dangerous effects of soil erosion on water quality and agricultural production are trying to develop specific measures for mitigating these effects. The real challenge for planning and management of natural resources at a micro-level is due to high precision data requirements. Therefore, micro-level hydrological units (sub-watersheds) are chosen cautiously for improved planning and management (Aher et al., 2014). The watershed management practices cannot be carried out for the full watershed. It should get started from the most sensitive sub-watershed. Welde (2016) has divided the watershed into 47 sub-watershed and then with the help of Soil and Water Assessment Tool (SWAT) 2009 identified and prioritize the most sensitive watershed. Comin et al., (2014) have prioritized watershed for water quality improvement in an agricultural watershed.

Soil erosion assessment has gained attention because it can be used as a base for developing adequate soil and water conservation plans (Ali and Hagos, 2016). Estimation of soil erosion and identification of critical soil erosion prone area for implementation of sediment filtration basins and other Best Management Practices (BMPs) is central to the success of soil conservation program (Ganasri and Ramesh, 2016). The detailed and more accurate information on the statics of soil erosion and surface water discharge is helpful for the watershed managers, for the better management and conservation of the natural resources like soil and water and sustainable development.

Presently various procedures have been produced for hydrological modeling utilizing precipitation, land use and soil characteristics information. Some of them are Water Evaluation and Planning system (WEAP), Agricultural Non-Point Source Pollution Model

(AGNPS), Areal Nonpoint Source Watershed Environment Response Simulation (ANSWERS), Soil and Water Assessment Tool (SWAT), Systeme Hydrologique European (SHE) and Water Erosion Prediction Project (WEPP) and so forth. Among these strategies, the Soil and Water Assessment Tool (SWAT) is one such process-based hydrological model, made by the United States Department of Agriculture (USDA), Agricultural Research Service (ARS), which can be used effortlessly for hydrological modeling (Kumar et al., 2015). On the other hand, a couple of algorithms have been created to reduce parameters vulnerability and achieve the best estimate of parameters in the hydrological modeling.

SWAT is widely used for hydrological and sediment yield modeling. It is a time-consistent, and spatially appropriated test model developed to assist watershed managers in anticipating the effects of land use management activities on runoff, soil erosion, and agricultural chemical yields (Khalid et al., 2016). Specialists have effectively used SWAT for runoff assessments (Salimi et al., 2016, Noori et al., 2016), water quality modeling (Qiu and Wang 2014, Pisinaras et al., 2010), hydrological and river basin modeling (Omani et al., 2000, Fukunaga et al 2015, Shi et al., 2013), sediment yield modeling (Briak et al., 2016, Jeong et al., 2012, Yesuf et al., 2015, Vigiak et al., 2017), and managing of erosion-prone areas (Sardar et al., 2014, Kumar et al., 2015). Psomas et al., (2016) utilized SWAT and WEAP to develop water efficiency measures in Greece.

Calibration is necessary to modify the elements that influence SWAT yields using observed values and evaluated estimations of runoff, evapotranspiration, and other SWAT outputs. Validation is the method of comparing the results of SWAT to the observed data, without modifying the values of the influencing factors. Calibration of various parameters is necessary for proper hydrological modeling. There are 26 parameters distinguished for runoff, more than 30 for soil disintegration, and 41 for water quality, all of which can be utilized for calibration. The calibration of such a circulated parameterized watershed model entails some significant issues that require thoughtful and mindful attention by investigators, particularly concerning uncertainty (Shi et al., 2013).

Earlier researchers applied deterministic approaches like the trial and error method for uncertainty analysis, calibration, and validation. In such methods, we must continue to alter the parameters until a sensible match between simulation and observation is achieved. However, these approaches are now outdated; scientists have developed many stochastic algorithms for calibration, validation, and uncertainty analysis. Some of the widely used algorithms for calibration are Sequential Uncertainty Fitting version 2 (SUFI-2), Parallel Solution (ParaSol), Particle Swarm Optimization (PSO), Generalized Likelihood Uncertainty Estimation (GLUE), Artificial Neural Network (ANN), and Markov Chain Monte Carlo (MCMC).

Soil erosion depends on many factors like rainfall, runoff, land type, soil type & slope. Researchers have evaluated the impact of rain, slope gradient (Fang et al., 2015), land use (Zhang et al., 2015), wind effect (Schmidt et al., 2017) on soil erosion. It was found that the more amount of rainfall or runoff would be the more be the soil erosion and the area which is mostly covered by wasteland and barren land would be more prone to soil erosion. Scientists also analyzed that increase in the soil gradient would lead to increase the soil erosion (Zhang et al., 2015). However, when these factors combined in different watersheds, it is difficult to find out which element is more dominant and which watershed would have more soil erosion. So for finding out the principal cause of soil erosion, it is imperative to determine the impact of Land Use Land Cover (LULC) dynamics and climate change on soil erosion. Wynn and Mastaghimi (2006) used multiple linear regression analysis to determine the impact of vegetation and soil type on soil erosion.

Before attempting to model the remedies of soil erosion, a researcher needs to study the topographic characteristics of the study area and nearby surrounding. Also, the study of the land uses land cover dynamics needed to be done. The location of all the water bodies, the reservoir is needed to be known, and the climate of the study area needed to be observed. The preliminary work which is required to be done before analysis and modeling are:

1) Identifying the land use land cover and the slope of the study area.

2) Planning and mapping of naturally occurring geological formation of soil types which may be potentially responsible for soil erosion.

The most commonly used soil erosion control measure is the plantation. Plants reduce runoff that is helpful in protecting soil from getting eroded (Rey 2003, Duran et al., 2006). The plant produces the energy of rain with the canopy, and their roots bind the soil (Baets et al., 2007). Also, vegetation stops the flow of soil by acting as a barrier. The distribution of vegetation along the slope is an essential factor for decreasing soil erosion (Francia et al., 2006). Apart from this prevention, prevention techniques of soil erosion are divided into two types:

1) Reducing runoff amount.

2) Reducing runoff velocity.

The amount of runoff can be reduced by increasing infiltration of soil or by preventing runoff using diversion channels or interception ditches directly. The velocity of runoff can be decreased by using hydraulic structures.

The purpose of this research is to study the part of Ganga watershed present in the southern part of Uttar Pradesh, for analyzing and prioritizing soil erosion-prone areas using remote sensing and GIS techniques, after estimating the soil erosion-prone areas the hydrological and sediment yield modeling is done using Arc-SWAT. The calibration and validation part was done by using the Sufi-2 algorithm. The Impact of Land use land cover dynamics is analyzed for soil erosion, and the principal causes of soil erosion were determined using Multivariate regression technique. Moreover, after that, the preventing measures were proposed to reduce the water and soil problems of the watershed.

1.3 Definition of Problem

The process of soil degradation is as old as agriculture itself, its effect on human nourishment and the Earth becoming more genuine than any time due to its degree and intensity. The main reason for soil degradation is soil erosion. It is a standard procedure in which wind and water moved particles of soil and uprooted to another area. Initially, when erosion used to occur naturally the soil is driven at about the same rate as it is made, so no harm is done to the earth. However, now due to anthropogenic activities, urbanization, and human interference, the rate of soil erosion is 13 to 40 times faster than the rate of creation (Zuazo and Pleguezuelo, 2008). Erosion is one of the most significant worries of Earth's property surface. It affects the rural generation and furthermore in all building and development enterprises.

Every year around 75 million tons of soil is degraded from the world global logical community. Around 6.6 billion tons of soil is lost in India per year (Lal, 1990). Agricultural land occupies around 36.5% of earth's land surface; most of the soil erosion takes place on the surface of the agricultural land only. The circumstances and result should be studied and considered to control soil erosion. Erosion regardless of whether it is by water, wind or culturing includes three particular steps that are soil separation, movement, and deposition. In every step, the soil may get decomposed resulting in the emission of some gases due to the reaction of Carbon present in the soil with the microbes and oxygen. This emission of gases may harm the environment. So it is essential to analyze the impact of soil erosion on climate change and the environment in each step of soil erosion. Four fundamental elements of soil that are soil properties, plant cover, topography, and climate are the deciding factors for erosion potential of any surface. Soil erosion control strategies are hypothetically straightforward, however inherently extreme, tedious, relentless and exorbitant. All soil erosion strategies are mainly site particular.

1.4 Research Objectives

The primary objectives of this research work are to estimate the soil erosion-prone areas, to do the hydrological and sediment yield modeling of the watershed, then to assess the impact of land use dynamics on soil erosion, to determine the principal cause of soil erosion, to analyze the impact of soil erosion on environment and global warming, and finally to propose the deterrence techniques. The results of this study would be further utilized for soil and water conservation purposes in the Ganga basin in the Varanasi, Mirzapur, Balia, Babatpur and Gazipur region.

The specific objectives of the study are:

1. To analyze the morphometric parameters of the study area and to identify the erosion-prone areas by prioritizing the sub-watershed using Morphometric analysis, LULC analysis, and USLE analysis.
2. To test the execution and applicability of the SWAT model in anticipating runoff and sediment yield.
3. To compare and determine the best calibration algorithm among three popular algorithms that are SUFI-2, GLUE, and ParaSol, for calibrating and validating the SWAT results using best techniques among the three.
4. To model the impact of LULC dynamics on sediment yield and to determine the principal cause of soil degradation using Multivariate Linear Regression.
5. To analyze the impact of Soil erosion on Climate change and Global warming and to propose the deterrence techniques as the prevention measures for reducing soil erosion for the Watersheds.

To achieve above objectives various tools and techniques are applied, such as remote sensing and GIS for data preparation, field analysis for soil mapping and validation of obtained results and hydrological modeling for controlling soil erosion and sediment transport within the watershed.

1.5 Outline of the Present Work

Chapter I is an introductory chapter which sketched the broader context and the growing relevance of studying the soil erosion-prone areas of the Ganga watershed. Finally, the research problems and the objectives of the research were formulated. In the following chapters, the targets listed above are achieved by incorporating material and methodology to each of the specific objects.

Chapter II gives an overview of the relevant literature regarding the estimation of soil erosion-prone areas and modeling techniques. It begins with a brief literature review of the prioritization of watershed and ends with modeling of soil erosion prevention measure .

In Chapter III, the complete details of the study area and the data used for the modeling and analysis are described. It explains the pre-processing of raw data; the processed data can be then used in the model as inputs. In this chapter, I also described the techniques utilized for completing this work.

In Chapter IV, the methodology for morphometric analysis is explained. This chapter gives us all the information about the parameters of the watershed like stream length and order, bifurcation ratio, watershed shape and other linear and nonlinear morphometric parameters.

In Chapter V, the estimation of soil erosion-prone areas and prioritization of watershed is done using Morphometric analysis, LULC analysis, and USLE analysis.

In Chapter VI, the hydrological and sediment yield modeling is explained which was performed utilizing 20 years of meteorological data and SWAT 2012.

In Chapter VII, three of the most popular calibration and validation techniques (GLUE, SUFI-2, and ParaSol) were compared, and the calibration of the SWAT results was performed using the best algorithm, i.e., the SUFI-2 algorithm.

In Chapter VIII, the impact of LULC dynamics on soil erosion is analyzed using image processing and Geoinformatics techniques and the principal causes of soil erosion were determined using Multivariate Regression Technique and MATLAB.

In Chapter IX, the impact of soil erosion on climate change and global warming is analyzed, and the Best Management Practices (BMPs) were proposed as the deterrence techniques to reduce soil erosion, and then the positive impact of these BMPs in future soil and water problems of the watershed are analyzed.

In Chapter X, the summary and conclusions of this research work are provided, in which the technique developed and knowledge acquired from this research are described and evaluated together with some comments. Future scope of the present work is also described.