USE OF GPS AND GIS FOR PREPARATION OF INPUT MAPS FOR AGNPS MODEL BASED ON ELEVATION

By

WONG KOK FOO

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ABSTRACT

Agricultural Non-Point Source (AGNPS) is a distributed parameter model that predicts soil erosion and nutrient transport from agricultural watersheds for real or hypothetical storms. Erosion modeling is built upon the Universal Soil Loss Equation (USLE), which predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. The determination of slope and its corresponding slope length is identified by slope and aspect classes. In the present study, elevations of about 500 well-distributed points were taken by using Global Positioning System (GPS). Root Mean Square Error (RMSE) of these elevations was determined by comparing the elevation interplolated from the contours. By combining the elevation of points and the contour maps, a Digital Elevation Model (DEM) was created by using Geographical Information System (GIS). From the DEM, various parameters such as flow direction, flow accumulation, watershed area, slope, aspect, hillshade and LS factor map was produced. Flow direction is determined by finding the steepest descent from each cell while flow accumulation represent the amount of rain that would flow through each cell, assuming that all rain become runoff. The watershed areas are described as the surface runoff as being the locus of points within an area where runoff produced inside the parameter will move into a single watershed outlet. Slope, aspect and hillshade are useful in determining the LS factor. A detailed analysis for determination of LS factor is carried out using the AGNPS – GIS interface. Results shows that the values of LS factor vary from 0 – 111.

ABSTRAK

Model “Agricultural Non-Point Source (AGNPS)” merupakan suatu model yang dapat menganggar pemindahan tanah daripada suatu kawasan tadahan air, sama ada bagi ribut sebenar atau ribut anggaran. Model untuk menganggar pemindahan tanah ini didirikan berdasarkan konsep “Universal Soil Loss Equation (USLE)” di mana knosep ini menganggarkan kadar pemindahan tanah tahunan berdasarkan bentuk hujan, jenis tanah dan topografi. Penentuan kecerunan dan panjang kecerunan adalah berdasarkan kecerunan dan kelas “aspect”. Dalam projek ini, lebih kurang 500 titik yang mengandungi ketinggian tanah telah diambil dengan menggunakan “Global Positioning System (GPS)”. Kesalahan atau kesisihan data telah ditentukan dengan menggunakan “Root Mean Square Error (RMSE)” dan didapati bahawa keputusan adalah memuaskan. Dengan menggabungkan titik ketinggian dan peta kontour, satu “Digital Elevation Model (DEM)” akan dapat dihasilkan. Dengan menggunakan DEM pula, beberapa parameter seperti arah pengaliran, kapasiti pengaliran, kawasan tadahan air sebenar, kecerunan dan “LS factor” dapat dihasilkan. Arah pengaliran didapati berdasarkan kecerunan yang paling curam manakala kapasiti pengaliran membayangkan kandungan air hujan yang akan mengalir melalui setiap sel. Daripada keputusan yang diperolehi, “LS factor” mempunyai nilai 0 – 111.

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Chapter 1

INTRODUCTION

1.1 Problem statement

Malaysia launched programme to its agricultural sector soon after the independence. This programme is considered as part of the overall efforts to develop the nation. Land is considered as the most important resource of the country. Therefore, it is without doubt that the decision to develop its agricultural sector was the most logical course of action to be undertaken. The main thrust of the development was directed at the conversion of large areas of forestland into agricultural land.

The development of land in Malaysia was concentrated mainly on land with favorable topography in the nineteen sixties and seventies. Steep areas have been opened up to meet ever increasing demand for land in many places in the peninsula. The infringement of the steep areas is expected to rise to a phenomenal level, with topographic suitable land being used up rapidly in all the states in the peninsula. These phenomena can cause alarmingly adverse effects to the environment if left unchecked. It is necessary to examine steep areas and to analyze to what extent such land can be utilized effectively and profitably for food production without causing undesirable damage to the environment, due to the ever increasing alarming adverse effects.

In Malaysia, soil erosion and land slide have been a menace to most agricultural areas on sloping land. Soil erosion becomes serious problems on slopes more than 25°. Removal of ground covers on steep slopes will invariably result in rapid and excessive soil erosion leading to soil degradation. This in turn will lead to siltation of rivers and flood at the lower catchment's areas. On the other hand, the soil conservation and agronomic practices to a smaller amount are not being adopted by the developers/planners in some areas. Considering all the above, the development plan for agricultural on sloping land degradation is being prepared for districts with high percentage of sloping land to assist the planners and developers in identifying the areas that can be developed for agriculture based on elevation and terrain class.

1.2 Background

By using Agricultural Non-Point Source Model (AGNPS), Universal Soil Loss Equation (USLE) method and geographical information system (GIS), the Erosion Risk Map can show an estimation of the total soil loss due to erosion on area without agronomic and protection practices (worst case scenario) at various terrain classes. The erosion risk map is useful to planners in predicting the average rate of the potential soil erosion and to recommend soil conservation measure to reduce soil loss within permissible limits.

The digital elevation model (DEM) is used in estimating the soil erosion. Information about surface topography is important in soil erosion prediction. Surface related applications such as soil mapping, soil suitability assessment, soil conservation practices and other agricultural and non-agricultural applications can be determined from the terrain information as it is an important input in the determination of surface related applications.

Agricultural Non-Point Source (AGNPS) is a distributed parameter model developed by Agricultural Research Service (ARS) scientist and engineers. It predicts soil erosion and nutrient transport/loadings from agricultural watersheds for real or hypothetical storms i.e., it’s an event-based model. Erosion modeling is built upon the Universal Soil Loss Equation (USLE) applied on a storm basis; thus, it uses the EI-index for single storm events. The distributed model design is achieved by subdividing a watershed to be simulated into a grid of square element areas, assumed to have uniform physical characteristics, and then applying three lumped parameter models to each element. Distributed Parameter Model is a type of mathematical model which attempts to account for spatial variability influences of its independent variables (parameters) by applying its governing equations to small elemental areas within which the parameters are assumed to be uniform, e.g., AGNPS and ANSWERS. Outputs (responses) from one element become inputs for adjacent elements. The advantage of a distributed parameter approach is its potential to accurately characterize influences of spatial changes; the disadvantage is their intense data and computational demands.

The Universal Soil Loss Equation (USLE) developed by Wischmeier and smith (1978) predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. USLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. This erosion model was created for use in selected cropping and management systems, but is also applicable to non-agricultural conditions such as construction sites. The USLE can be used to compare soil losses from a particular field with specific crop and management system to 'tolerable soil loss' rates. Alternative management and crop systems may also be evaluated to determine the adequacy of conservation measures in farm planning.

Five major factors are used to calculate the soil loss for a given site. Each factor is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location. The erosion values reflected by these factors can vary considerably due to varying weather conditions. Therefore, the values obtained from the USLE more accurately represent long-term averages.

The Universal Soil Loss Equation (USLE) modified by Renard et al (1997) for estimating average annual soil erosion is **A = RKLSCP**. (1.1)

The terms are as below:

- **A** = average annual soil loss in t/a (tons per area)
- **R** = rainfall erosivity index
- **K** = soil erodibility factor
- **LS** = topographic factor, **L** is slope length, **S** is slope steepness factor
- **C** = cropping factor
- **P** = conservation practice factor

In this project, concentration will be made on topographic factor such as **L** (slope length) and **S** (slope steepness factor). In the Universal Soil Loss Equation, the combined factor is known as LS factor. The topographic factor is an areal unit which is based on the determination of slope and its corresponding slope length, and is identified by slope and aspect classes. Steeper slope produce higher overland flow velocities. Longer slopes accumulate runoff from larger areas and also result in higher flow velocities. Thus, both result in increased erosion potential, but in a non-linear manner.

Slope and aspect map layers are, generated from digital elevation models (DEM). These are, in turn, generated from elevation contours of topographic maps at 1:50,000 scale. Overall operation on the slope and aspect layers yields a polygonal layer, each polygon of which is an area unit used for determination of slope length.

To use AGNPS, the watershed of interest is subdivided into grid of square elements. Each element requires 22 parameters/coefficients to describe its antecedent conditions like physical characteristics (e.g. soil types and slope steepness), the management practices and rainfall. Some of those elements related to this project are as below:

Hydrologic Characterization: SCS curve number, average land slope (%), Slope Shape Factor, Average Field Slope Length, Average Channel Slope (%), Average Channel Side Slope (%)

Some of the parameters, such as average land slope (%), slope shape factor, average field slope length, average channel slope (%) and average channel side slope (%) can be derived from the digital elevation model (DEM). DEM can be created by the contour map and the elevation of the points in the area by using Global Positioning System (GPS).

A digital elevation model (DEM) is a digital representation of a portion of the earth's surface, or any planet's surface, derived from elevation measurements at regularly spaced horizontal intervals (sampling intervals). A DEM is a way of digitally recording the contours of the terrains. DEMs are a 3-dimensional representation of land surface reporting land elevations, of a particular zone, listed in a regular grid. DEMs usually cover zones of medium-big extensions with possibility to contain even millions of points. Because of their size, DEMs are represented through raster images; inside them, according to different modes, each pixel represents the corresponding elevation.

A geographic information system (GIS) is a tool that uses the power of the computer to pose and display data about places on the earth surface in a variety of ways, including maps, charts and tables. The hardware and software allows users to see and interact with data in new ways by blending electronic maps and database to generate color-coded displays. Users can zoom in and out of maps freely; add layers of new data, study details and relationships. According to NASA, GIS is an integrated system of computer hardware, software and trained personnel linking topographic, demographic, utility, facility, image and other resource data that is geographically referenced. For another description from USGS, a GIS is a computer system capable of assembling, storing, manipulating and displaying geographically referenced information, i.e. data identified according to their locations. Practitioners also regard the total GIS as including operating personnel and the data that go into the system.

A geographic information system (GIS) is an integrated suite of computer-based tools which facilities the input, processing, display, and output of spatially referenced data. Benefits of GIS are the ease of data update, data management, and data presentation in forms most suited to user requirements. GIS allows for vast amounts of information on different themes and from different sources to be integrated.

Global Positioning System (GPS) are space-based radio positioning systems that provide 24 hours three-dimensional position, velocity and time information to suitably equipped users anywhere on or near the surface of the earth (and sometimes off the earth). GPS satellite-based technology is being widely used for surveying throughout the world. It offers a relatively inexpensive alternative to conventional surveying for many uses. GIS users in increasing numbers are incorporating GPS into data collection phase of their projects. Interfaces between GIS and GPS are being developed, and experiences gained are leading to increased and integration GIS and GPS.

1.3 Objectives

- Fully make use of the Global Positioning System (GPS) to take elevation of the points in the area of interest.
- From both contours and points elevation, derive the parameters / variables required for AGNPS model, such as average land slope, slope shape factor, aspect number flow direction within cells, flow accumulation, watershed areas, stream network and LS factor.
- Fully make use of the geographical information system (GIS) to produce the maps for each parameters / variables.

1.4 Organization of Project

A good report should consist of many different chapters related to the study. In this report there are five chapters that cover all the information needed in this study.

Chapter 1 is a brief introduction to this study. It explains objective and scope of this study and gives an introduction on the use of AGNPS, GIS, GPS and slope length (LS) factor which is one of the parameter of the RUSLE equation to calculate the soil erosion of an area.

As for chapter 2, it informs us on the development on the same kind of study done many other researches before this. This chapter is divided into several parts which consist of the importance of topographic controls, DEM generation method from contour lines, Use of DEM to obtain topographic index for simulation model, Universal Soil Loss Equation (USLE), ArcView – AGNPS interface and the GPS survey.

Methodology is an important part of a report on a study or research. Chapter 3 in this report is all on the methodology used in this study. It gives some information on the location of the study area as well as the procedures used. The procedures are divided into nine parts which are the collection of elevation data using GPS, procedure involved in getting GPS data, determination of the linear accuracy of GPS data, steps involved in computing RMSE, useful methods for representing elevation data, slope and slope length / terrain factor and finally the removal of sinks.

Chapter 4 in this report is the most important chapter. It consists of all the results and discussion for the study. In this chapter, the linear accuracy of GPS is checked. Elevations of points collected are checked by using root mean square error (RMSE). Results for parameters such as flow direction, flow accumulation, DEM model, stream network, watershed area and the LS factor are shown in this chapter. Histogram of these parameters are plotted to compare the results between 2 sub-watershed areas.

Chapter 5 discusses the overall conclusion from this study. Suggestions are made in this chapter to those that are interested in this kind of study or research. These suggestions may help the researcher to develop better ways in calculating the slope length factor.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

According to Pullar et al (2000), increased activities in agricultural regions together with higher demand for water supplies have resulted in concerns about water quality. Resource managers are faced with managing this vital resource without adequate time and modeling tools to research the full impacts of their decisions. Best management practices for dealing with many environmental issues are seen as offering workable solutions, especially pressing environmental issues like soil erosion and salinity. In cases where the environmental problem is isolated to a point, i.e. point source pollution, the choice of a management option is relatively straightforward. However in cases where there is no clearly identified pollution source and the degradation is dispersed across the land, it is difficult to determine the best location to contain the problem and judge the impact of remedial actions. This is referred to as non-point source pollution because the source of the pollution is diffuse. Environmental models are a possible solution as they provide a means to simulate physical landscape processes over time and give decision makers an indication of the outcome for different options. But all too often predicative models do not examine the problem in a geographical context. This is where a geographical information system (GIS) becomes a valuable tool. A GIS is a tool for the management, query, visualisation and analysis of spatially referenced information (Burrough and McDonnell, 1998). A GIS coupled with an environmental model provides a tool to run a simulation and to interpret the results in a spatial context.

2.2 Importance of Topographic Controls

Much of the environmental variability controlling the spatial patterns of ground cover might be attributed to topographical factors and their influence on soil-water distribution. Landscape positions modify the local hydrology and have a considerable influence on water availability. The effects of landforms on ecosystem patterns and processes have been widely recognized [Forman and Gordon, 1986]. Numerous authors, based on potential topographic redistribution of precipitation in different ecosystems, have shown the relationships between ecosystem structure and composition and topographic features such as elevation, slope angle, aspect and indices of relative moisture.

Much work has been done to demonstrate the influence of topography on the spatial patterns of vegetation [Brown, 1994]. Moreover, the influence of landforms on microclimate and ground-cover patterns is greatest in topographically complex landscapes. Therefore, in badlands, the frequent, abrupt changes in slope facets, often deeply incised landscape and rapid alternations in slope orientation and exposure favour pronounced microtopoclimatic contrasts affecting vegetation cover patterns [Campbell, 1989]. The effects of microtopoclimatic contrasts appear more pronounced in regions where general aridity promotes critical variation in regolith moisture content. Although some papers examined the influence of certain geomorphological features on microhabitat conditions (soil development, stabilization mechanisms or plant cover) very few dealt with the influence of topography on the spatial patterns of ground cover in semiarid badlands. [Canton. Y, 2004]

Information on the "lay of the land" is always needed by peoples involved in topographic matters. One important part of this information is the peaks and valleys of the landscape and the way the land slopes, or in another word, the topography. A variety of coastal issues requires information on topography or topographic change over time, including: water flow, wireless communications, beach volume changes, shoreline changes, subsidence and emergency response [Nelson F. Fernandes et al, 2004]. Topography is considered as a major controlling factor on hydrological processes at the landscape scale and, thus, also soil processes depend on topographic position. In qualitative way this can be described as soil catenas. digital elevation models (DEMs) and topographic indices calculated based on these DEMs allow the study of the relation between topography and soil characteristics in a more quantitative way [Guangxing Wang, 2001].

2.3 DEM Generation Method from Contour Lines

A digital elevation model (DEM) is a digital representation of a portion of the earth's surface. In a DEM, earth's surface is represented as spatially referenced regular grid points where each grid point represents a ground elevation value. It has long been known that DEMs have a potential for solving theoretical and applied problems in earth science. DEMs also have a major role to play in geographic information systems (GIS), hydrological modeling [O'Callaghan and Mark, 1984], analysis of visibility and hazard mapping. Concentration will be made on method to generate DEMs from contour lines. Countour lines continue to be used to generate DEMs although direct DEM generation such as the automatic matching method of aero-photography, SAR, laser-profiling and laser scanning have been developed. Contour lines continue to be used because in most countries, this data covers the whole area in different scales, thus representing a cheap data source [Prima Oky et al, 2002]. DEM generation methods can be classified into two categories, point methods and line methods, according to the interpretation of contour lines. The point methods uses irregular elevation points by extracting only vertices along each contour line, while the line methods uses all elevation points along contour lines to calculate elevation of grid points [Prima Oky et al, 2002].

There are two sub-methods used in point methods, which are global methods and local methods [Burrough, 1986]. Global methods are usually simple to compute and are often based on standard statistical ideas of variance analysis and regression. These methods can generate a smooth surface. However, the structural features and the accuracy of the original data are rather insufficient. There are several methods used in the local methods, two of the most popular methods are the Triangulated Irregular Network (TIN) based method and minimum curvature method. The local methods use information from the nearest data points or within a specified window. In the TIN based method, linear or higher order function can be applied to compute DEMs. This method is very efficient since once the TIN has been constructed, DEMs can be efficiently computed. However, in certain circumstances, pure TIN may conflict with linear constraint. Therefore, the TIN has to be relaxed. Furthermore, the TIN appears as unrealistic relief derived from DEMs. The minimum curvature has advantages to generate smooth DEMs. However, the smoothing process often disedges the V-shape of ravines. A more sophisticated procedure has been proposed [Heitzinger, 1998] by adding important topographic features (ridges, summits, saddles, drainage lines and valleys), and by applying a drainage enforcement method. The line methods are represented by a morphological contour method, and a fitted-function interpolation along straight lines in the direction of the steepest slope [Barret et al., 1994].

The main idea of the morphological method is to create intermediate contour lines using dilation and erosion methods. However, the continuity of surfaces between areas separated by a contour line is not considered. Therefore, generated DEMs need to be smoothed. The fitted-function interpolation along straight lines in the direction of the steepest slope is designed to represent terrain surfaces which have been affected by runoff processes. However, the noise often appears in the DEM generated by this method when the steepest slope cannot be calculated properly.

2.4 Use of Digital Elevation Model to obtain Topographic Index

A digital elevation model (DEM) is defined as any digital representation of the continuous variation of relief over space [Burrough, 1986]. Elevation data can be represented digitally in many ways, including a gridded model where elevation is estimated for each cell in a regular grid, a triangular irregular network, and contours. The DEM is a computer representation of the earth's surface. The DEM provides a base data set from which topographic parameters can be digitally generated. Hydrological features are often extracted from DEM data because the routing of water over a surface is closely tied to surface form [Wood, 1996]. Flow direction can be determined from slope while the upslope area that contributes flow to a cell can be calculated from flow direction. Upslope contributing area can be used to identify ridges and valleys. The upslope area (A) and slope (TanB) grids can be used to obtain a parameter called the topographic index (natural logarithm of the upslope contributing area per unit contour length divided by slope), expressed as ln (A / TanB). This similarity surface indicates where surface saturation is likely to occur. The DEM is therefore a valuable data source for many resource-related GIS applications.

To predict environmental phenomena such as soil erosion and sediment deposition, numerous empirical and process-based models have been developed. Integration between geographic information systems (GIS) and the models is requisite in order for the models to be applied with maximum effectiveness in large areas of complex terrain. Slope steepness is a fundamental parameter in most soil erosion models. The most efficient method to determine slope in a GIS environment is through the use of digital elevation models (DEMs). DEMs represent topography either by a series of regular grid points with assigned elevation values or as a triangulated irregular network (TIN) where each point is stored by its coordinates and the surface is represented by triangular facets. [Z. H. Shi, 2004]

As described before in the Universal Soil Loss Equation (USLE), the slope steepness factor (S) is a function of slope angles measured in degrees and reflects the influence of slope gradient on erosion. The slope length factor (L) is a function of slope length measured in meters. Soil erosion increases as slope length and steepness increase, and it is more sensitive to slope steepness than to slope length. The combination of the slope steepness factor and slope length factor, called the topographic factor LS, represents the topographic effect as the ratio of soil loss on a given slope length and steepness to soil loss from a slope that has a certain length, and a certain steepness where all other conditions are the same. The topographic factor is the most sensitive in the prediction of soil loss [Renard et al, 1997].

Calculation of slope length factor (L) and slope steepness factor (S) in USLE is carried out by using a set of empirical models [Renald et al, 1997]. Spatial prediction and uncertainty analysis of the LS factor derived from the empirical models using geostatistical methods have been carried out with a field sample [Wang et al, 2000]. The empirical models did not differentiate net erosion and those areas experiencing net deposition when soil loss is estimated for large areas as part of geographic information system (GIS) for converging and diverging terrain. A physically based topographical factor LS equation has thus been developed based on a digital elevation model (DEM). However, the precision for predicting the LS factor is related to the DEM accuracy and spacing, and the methods to derive topographical variables are related to LS. For example, [Mitalova et al, 1996] investigated this approach by interpolating DEMs to finer spacing, and suggested that the commonly used 30-m spacing in USGS DEMs are insufficient.

In addition to prediction precision, capturing the spatial variability with an appropriate DEM spacing is necessary to accurately represent the spatial characteristics of the LS factor. Recently, DEMs with different spacings have become readily available and lead to the problem of choosing an appropriate DEM spacing for a given task. Furthermore, the appropriate DEM spacing may be a function of other variables such as the complexity of the terrain, required precision, desired information, etc. Choosing an appropriate DEM spacing thus becomes very important [Guangxing Wang et al, 2001].

Various techniques have been devised to compute slope from DEMs. Significantly different slope values from the same DEM may be produced due to different computational methods. Variation in the computation of slope can, in turn, lead to widely varying estimates of soil erosion. Soil erosion models are especially sensitive to errors in slope because runoff-induced erosion increases as a power function of slope. Most soil erosion models, while operable within GIS, were not developed using DEM-generated slopes. Rather, they were developed based on slopes obtained from field or plot measurements.

Hence, when applying soil erosion models within GIS, it is imperative that DEM-generated slopes are compatible with measurements made in the field. Few studies, however, have compared computed estimates of slope with actual field measurements and none has evaluated this with respect to soil erosion prediction [Warren S.D., 2004].

2.5 Universal Soil Loss Equation (USLE)

Maas et al. (1985) showed that areas of severe soil loss are often the critical areas for agricultural non-point source pollution. Scha¨uble (1999) mentioned that erosion includes not only the transport of sediment particles but also the transport of nutrients and pollutants. Both mechanisms depend on the amount of surface runoff and are therefore linked together. Both processes can only be lessened by reducing the surface runoff in favour of ground water infiltration. Due to this inseparability of both processes, erosion models can be used to find critical areas of non-point source pollution also. For modeling erosion, many models have been developed. Many of the newer models are derived from the basic USLE of Wischmeier and Smith (1978) and revised USLE of Renard et al (1991). This equation is the result of empirical long-term runoff studies on test fields in the USA. It estimates the long-term annual soil loss in [tons/ha]. Some use restrictions have to be noted: The model is only valid for areas that are similar to those areas for which the factors have been developed; for use under other geographical conditions, it has to be adapted. The model is only valid for the erosive part and not for the accumulative part of the slope. The model was developed for straight slopes only; concave or convex slopes have to be sub-divided.

The capture and processing of large amounts of data was the critical part of using the erosion models. With the introduction of fast computers and GIS software with its functionality, the benefit from the existing erosion models rose tremendously. But Schauble (1999) describes some problems during the conversion of the existing erosion models into commercial GIS systems with their limitations. He mentionned that the standard algorithms implemented are not accurate enough or are inapplicable for an exact estimation of the material balance (erosion versus accumulation) because they cannot take into account the real amount of surface water runoff. Thus, the implementations must be simplified and the concrete amount of eroded material and the position of the erosion/accumulation zones are not exactly predictable with simple conversions into standard GIS products. To reach these goals, complicated GIS implementations and our own software were developed. But, as seen in the problem description, an exact computation of the load amount is not always necessary. Often, a simplified model, which just shows possible risk areas without computing the amount of sediment or nutrient load, is enough for the first step of erosion or pollution analysis. The simple first step model can be used for a huge area which requires only a limited amount of data, is relatively easy to implement in commercial GIS software and is therefore relatively cheap. It can be built up by local authorities without too much specialized knowledge. Only where the rough model really finds critical areas is a second step analysis with a more sophisticated expert model or an on-site exploration necessary. This step will be more expensive because special software and more accurate data will be needed. But this step can be reduced to areas that are obviously critical.

2.6 Integration between GIS and Simulation Models

In the analysis of watershed processes and their interactions, and for development and assessment of watershed management scenarios, simulation models are considered as useful tools. However, Implementation of these models often requires integration of geographic information systems (GIS), remote sensing, and multiple databases for development of the model input parameters and for analysis and visualization of the simulation results [Huang et al, 1999]. For example, a software package, real-time interactive basin simulator (RIBS) integrates a radar-based rainfall prediction model, a digital elevation-based rainfall-runoff model, and other multiple databases to forecast real-time flooding. A GIS and a groundwater model (MODFLOW) are combined to model regional groundwater flow [Brodie, 1999], and a conceptual rainfall-runoff model is parameterized using GIS for catchments modeling. Interfaces between GIS and simulation models have also been developed to facilitate such endeavor, e.g. GRASS and water erosion prediction project (WEPP), Arc/Info and HEC-hydrologic modeling system (HMS), and GRASS and a hydrologic model in a computer aided design (CAD) environment.

More recently, researchers have integrated GIS and hydrologic models within the Windows environment for PCs, e.g. better assessment science integrating point and nonpoint sources (BASINS) by US Environmental Protection Agency [Lahlou et al, 1998], and soil and water assessment tool (SWAT) within ArcView GIS. Such interfaces usually address issues of data processing and visualization, tool coordination, and user friendliness, and significantly improve the applicability of hydrologic models. [Xinhao Wang, 2004]. Agricultural Non-Point Source model (AGNPS) is a tool used for evaluating the effect of management decisions impacting a watershed system. The single event model of AGNPS was developed during the 1980s and 1990s [Young et al, 1989]. AnnAGNPS, an annualized AGNPS is an update of the single event AGNPS and is able to simulate hydrology of a watershed continuously over an annual or longer period [Bingner and Theurer, 2001]. Compared to the single event AGNPS, AnnAGNPS consists of a system of modules, such as an input data preparation model, a flow net generator, a synthetic weather generator, a pollutant loading model, and an output processor model, to improve the capability of the program and to automate many of the input data preparation steps for large watershed analysis. While able to automate some model input processing, these modules are not integrated with a GIS and thus do not allow processing, checking, editing, and displaying input and output data in a map format within a GIS directly. For example, the output data can be displayed in table format, but not in map format in the current version of AnnAGNPS, which affects examination and analysis of spatial pattern of hydrologic phenomena throughout a watershed.

There are proof showing that areas of severe soil loss are often the critical areas for agricultural non-point source pollution. It is mentioned that erosion includes not only the transport of sediment particles but also the transport of nutrients and pollutants. Both mechanisms depend on the amount of surface runoff and are therefore linked together. Both processes can only be lessened by reducing the surface runoff in favour of ground water infiltration. Due to this inseparability of both processes, erosion models can be used to find critical areas of non-point source pollution also. For modelling erosion, many models have been developed. A few overview of some of the important models are given : Universal Soil Loss Equation (USLE), Revised USLE (RUSLE), modified USLE

(MUSLE87), areal non-point source watershed environment response system (ANSWERS) and Agricultural Non-Point Source model (AGNPS) [Shi Z.H., 2004].

Many of the newer models are derived from the basic USLE**,** introduced by [Wishmeier and Smith, 1978]. This equation is the result of empirical long-term runoff studies on test fields in the USA. It estimates the long-term annual soil loss in [tons/ha]. The formula consists of multiplied factors and is as follows: The capture and processing of large amounts of data was the critical part of using the erosion models. With the introduction of fast computers and GIS software with its functionality, the benefit from the existing erosion models rose tremendously. To perform such step one rough analyses to reveal critical erosion and non-point source pollution areas using the advantages of a GIS, a modified USLE model has been used [Sivertun et al, 1988]. That model combines four factor maps by simple raster value multiplication to produce a risk map:

$$P = K * S * W * U \tag{2.1}$$

P: product map, showing the risk of erosion and pollution elution

K: soil factor map

S: slope factor map

W: watercourse factor map

U: land use factor map

Determination of necessary classes of the factor maps has been mentioned as the critical part of building the model [Sivertun et al, 1988]. The class values for the soil slope and land use maps were taken. From the original USLE, the values for the watercourse map are derived and it reflects the relative amount of eroded sediment or pollution material that reaches the water body from each distance zone. Due to the limited capability of the GIS, the class values had to be rounded to integer values. A few classes to some factor maps have been added. Slope values have been added that allows a finer differentiation in steep areas. Some new land use classes such as agriculture (perennial), clear felled areas, pits and dump sites and non-urban green have been added due to the availability of more accurate land use maps. All factor maps use the real values of the original USLE model in the new model. They allow a finer gradation than the rounded integer values of the modified model, which was used only because of the limitations of the early GIS software. The values of the soil and land use maps are directly derived, according to [McElroy et al, 1976]. The values of the new classes, which were added to the land use map as integers and not existing in the original USLE, are estimated.

The simplified USLE model only uses a slope steepness factor, compared to the applications of the original USLE and RUSLE which often combine the slope length and the terrain steepness factor into a common slope length factor map. The slope length component is missing. Since the creation of the model in 1988, big strides have been made in the research of modelling water runoff using GIS. This improved version of the LS factor from the RUSLE takes into account not only the steepness but also the slope length and the upstream water contribution area and is suited to modelling the increased erosion in areas of concentrated water flow. The results are computed individually for every cell as real values and fit therefore to the continuous computation of the other factor maps in the new modified USLE model. The elevation model used to derive this new slope length (LS) map is also improved by dense elevation contour lines, which are added using a TIN [Chanseng He, 2003].

2.7 ArcView GIS – AGNPS interface

Analysis of nonpoint source pollution in an agricultural watershed by AGNPS is often a tedious and time consuming task. These analyses involve providing input parameters for each of the cells that represent the entire watershed. AVNPSM, a Windows-based interface was developed to facilitate the implementation of watershed analysis by AGNPS. AVNPSM was developed to integrate the AGNPS with ArcView GIS (Version 3.0a or later versions) Spatial Analyst using Avenue (a programming language for ArcView) scripts [Chanseng He, 2003].

Soil database, digital elevation, land use/cover, hydrography, climate, and crop management information are included as the basic databases required for the AVNPSM. Information on soil texture, hydrologic group, and soil erodibility factor (*K*) are being extracted by using a soil database such as state soil geographic data base (STATSGO). Derivation of slope, slope length, aspect, and other related parameters are is carried out using a digital elevation model (DEM). Land use/cover file and crop management information are used to determine SCS curve number and management factors such as crop management (*C*), fertilization, and support practice (*P*) etc. The hydrograph database is used to help create the watershed coverage and process and edit the flow direction file. Climate data are used to calculate surface runoff and soil erosion in the AGNPS model. Management information includes crop types and rotation, fertilization level, and tillage practices. These files need to be processed to either an Arc/Info coverage or ArcView shape format to be compatible with the format requirement of the AVNPSM interface. The required AGNPS parameters (parameter generator), create an AGNPS input file (input processor), execute AGNPS simulation (model executor), display the simulated AGNPS output (output visualizer), and conduct statistical analysis such as central tendency and analysis of variance (statistical analyzer) can be generated once the input files are ready [Chanseng He].

2.8 GPS Survey

GPS surveys are an efficient and precise means to determine the location of a point and its movement through time. Data may be collected rapidly and at low costs with respect to ground-base topographical methods. Particularly, the relative positioning between points closely located may be obtained with an observation period of a few minutes [Paolo Mora et al, 2003]. Static surveying methods require GPS receivers to be stationary throughout the measurement session and produce the highest possible precision with GPS. Static occupation times depend on network characteristics and may be reduced to about 10 min for baselines shorter than a few kilometers (rapid static method) on condition that at least five GPS satellites per epoch are visible and a sophisticated post-processing using all the GPS observables is applied. The achievable precision is sub-centimeter for the planimetric coordinates, while altimetric values may be strongly influenced by troposphere conditions, giving lower precision on the order of a few centimeters [Paolo Mora et al, 2003].

Conversely, kinematic methods allow data acquisition with a moving receiver and it is possible to collect many data points in a short period of time with reduced precision (a few centimeters in planimetry and several centimeters in altimetry). Two GPS permanent stations (Trimble dual-frequency receivers equipped with L1/L2 antennas) were installed to provide continuous observation of landslide movement: station OLISTO was set up on a decametric block at the head of landslide and station MASTER, the reference station, was installed on a pillar built outside the landslide area, at a distance of about 300 m. The stability of this point has been checked by means of repeated GPS surveys on a local array defined by six stations of the IGM95 National Geodetic Network [Paolo Mora et al, 2003].

GPS offers several advantages: intervisibility between stations is not necessary; anomalous weather conditions do not prevent the observations; distances between points are not critical (in the range of a few kilometers). On the other hand, GPS approach requires the use of a receiver for every monitored point, increasing the cost with respect to ground geodetic techniques. Nevertheless, the present satellite configuration allows reducing observation times also of rapid static approach that can be extensively used in the periodical monitoring of series of critical landslide points [Adam Theiss et al, 2004].

Kinematic surveying may be applied to rapidly describe landslides surface by means of high spatial resolution DEMs. Even if the intrinsic precision of the method is at centimeter-level, the data acquired in a walking mode, with the antenna mounted on a telescopic pole or on the operator's backpack, are affected by greater errors especially due to difficulty in describing the surface roughness. The crossover error analysis indicates a repeatability of the elevation evaluations ranging between 10 and 17 cm. DEMs characterized by precision of the same order of magnitude are also obtainable by means of aerial photogrammetric surveys, but the sequence of operations needed for DEMs production (project management, work planning, fieldwork logistics, data processing) and