DEVELOPMENT OF EROSION RISK MODEL USING GEOGRAPHICAL INFORMATION SYSTEM (GIS)

BY

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HEBRON- WEST BANK

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January - 2008

CERTIFICATION

Palestine Polytechnic University

PPU

Hebron-Palestine

The Senior Project Entitled:

DEVELOPMENT OF EROSION RISK MODEL USING GEOGRAPHICAL INFORMATION SYSTEM (GIS)

Prepared By:

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In accordance with the recommendations of the project supervisors, and the acceptance of all examining committee members, this project has been submitted to the Department of Civil and Architectural Engineering in the College of Engineering and Technology in partial fulfillment of the requirements of Department for the degree of Bachelor of Science in Engineering.

Project Supervisors **Department Chairman**

Mr. Maher Owaiwi 11/2/08

January - 2008

إهـــداء

إلى الزهرة نبع الحنان   إلى أمي

إلى الماس الذي لا ينكسر نبع العطاء   إلى والدي

إلى ملائكة الأرض شقائق النعمان   إلى إخوتي

إلى قناديل الدرب الشموع التي لا تنطفئ   إلى أساتذتي

إلى المربي الفاضل   ماهر العويوي

إلى المربي الفاضل   ماجد أبو شرخ

إلى رفاق الدرب بناة المستقبل   إلى أصدقائي

إلى صناع الكرامة   إلى شهدائنا

إلى من طلبوا العز ومن رفضوا الخضوع   إلى أسرانا

إليكم جميعا أحبتنا نهدي هذا الجهد المتواضع

محمود وهادين   رأفت أبو صايمة

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Finally, we extended our thank to members in the Civil Engineering Department , especially the part of Surveying Engineering, which help us in designing our project.

Work Team
Mahmoud Whadeen & Ra'fat Abu Sayma

ABSTRACT

DEVELOPMENT OF EROSION RISK MODEL USING GEOGRAPHICAL INFORMATION SYSTEM (GIS)

By:

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Palestine Polytechnic University

Supervisors:

Dr. Majed Abu Sharekh

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The purpose of this study is to establish spatial information of soil erosion using the Universal Soil Loss Equation (USLE) and GIS. The study area, Hebron catchments area, covers an area of approximately 295 km^2 of southern West Bank

A set of factors as identified in the USLE will be studied and reviewed. These include rainfall erosivity factor (R-factor), soil erodibility factor (K-factor), slope and slope length factor (LS-factor), vegetative cover factor (C-factor) and conservation practice factor (P-factor). Each factor which consists of a set of logically related geographic features and attributes is used as data input for analysis.

Each of the above mentioned USLE factors, with associated attribute data, will digitally encoded in a GIS database to eventually create five thematic layers. Simultaneous overlay operation on these five layers produces a resultant polygonal layer, each polygon of which is a homogeneous area with respect to each of the five factors.

Analysis of daily rainfall data of 5 years gives the R-factor. Spatial K-factor will be formed from digitized soil map for Hebron, and soil samples. Digital elevation model

(DEM), interpolated from elevation contours, will employed to generate the slope and LS-factor. Land use map is used to determine the spatial C-factor and consequently P-factor.

ABSTRACT IN ARABIC

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الهدف من المشروع هو تحديد مقدار تعريه التربة، من خلال استخدام المعادلة العامة لتآكل التربة، وذلك في منطقه من محافظه الخليل و التي يبلغ مجمل المساحة (295 كم^2).

مجموعة من العوامل هي التي تحدد المعادلة العامة لتآكل التربة، منها معدل تساقط الأمطار في المنطقة، معدل انجراف التربة، مقدار الانحدار وطوله، نوعية الغطاء النباتي في المنطقة و الممارسات التي تحدث في المنطقة ،وكل عامل من هذه العوامل لديه عدد من المعطيات و القراءات التي تستخدم في التحليل.

سوف يتم تحليل هذه العوامل جميعا باستخدام برنامج (GIS) ، وذلك لتكوين خارطة عن كل عامل ، ثم يتم دمج هذه المعلومات لتكوين الخارطة النهائية عن طبيعة تأكل التربة في منطقة الدراسة .

لعمل ذلك نقوم باستخدام معدل تساقط الأمطار لمدة خمس سنوات ماضية ، تحليل لنوعية التربة في منطقة الدراسة، استخدام خارطة كنتورية للمنطقة لتحديد معامل الانحدار وطوله ، بالإضافة إلى استخدام صورة جوية لتحديد نوعية الغطاء النباتي ونوعية الممارسات التي تحدث في المنطقة .

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CHAPTER ONE

INTRODUCTION

This chapter covers the following items:

1.1 GENERAL
1.2 PROBLEM DEFINITION
1.3 PROJECT AREA
1.4 OBJECTIVES AND ADVANTAGES
1.5 METHODOLOGY OF WORK
1.6 LITERATUER STUDY
1.7 ORGANIZATION OF THE REPORT

CHAPTER ONE
INTRODUCTION

1.1 General

Soils play a central role in the life and development of mountainous lands. They provide a vital substratum for men, animals, plants and micro-organisms. They are a key component of the mountainous ecosystems, in particular for water and nutrient cycling. In addition, they constitute a major genetical reservoir and are a place of major regulation and transformation processes. As a central element of the mountainous landscape, soils have always occupied a central position in the cultural and economic life of human communities. In particular, they constitute the basis for agriculture, including forestry and livestock rising, and a major component for recreational and touristy activities. It is therefore essential to promote the conservation and sustainable use of the soil resource, taking into account the specific sensitivity of mountainous soils to degradation and alteration processes.

Soil erosion as , broadly defined group of processes involving the movement of soil and rock. This movement is often the result of flowing agents, whether wind, water, or ice, which sometimes behaves like a fluid in the large mass of a glacier. Gravitational pull may also influence erosion. Thus, erosion, as a concept in the earth sciences, overlaps with mass wasting or mass movement, the transfer of earth material down slopes as a result of gravitational force.

Even more closely related to erosion is weathering, the breakdown of rocks and minerals at or near the surface of Earth owing to physical, chemical, or biological processes. Some definitions of erosion even include weathering as an erosive process. Though most widely known as a by-product of irresponsible land use by humans and for its negative effect on landforms, erosion is neither unnatural or without benefit. Far more erosion occurs naturally than as a result of land development, and a combination of weathering and erosion is responsible for producing the soil from which earth's plants grow.

Soil erosion is the removal of surface material by wind or water, which is very dynamic and spatial phenomenon. In the process of passing a good farmland to the next generation, it is necessary to have sound and sustainable conservation practice not to allow soil erosion at a rate, which depletes soil resources faster than they can be renewed. To achieve this goal, there is demand for modeling the spatial distribution pattern of soil erosion.

The erosion components like soil infiltration characteristics, rainfall intensity are spatially and temporally variable and have strong impact on water erosion process . All the factors of universal soil loss equation (USLE) are geographic in nature, which means they can be referenced to a particular location. The Geographic Information System (GIS) techniques are valuable tools for spatial data analysis and modeling. It is quite obvious as it assumes the use of various data like soil, vegetation, relief, climate data… etc, that can be effectively processed in GIS environment

1.2 Problem definition

Soil erosion may affect agricultural productivity and land use changes, quantitative estimates on the relationship between soil erosion and crop productivity, also its affect pattern and land use.

1.3 Project area

Hebron catchments area , catchments in Hebron district, its located in the southern of West Bank, it mostly hilly, rocks and its slope is toward the south, and the slope gradient is also increase toward the south, figure (1.1) shows its location.

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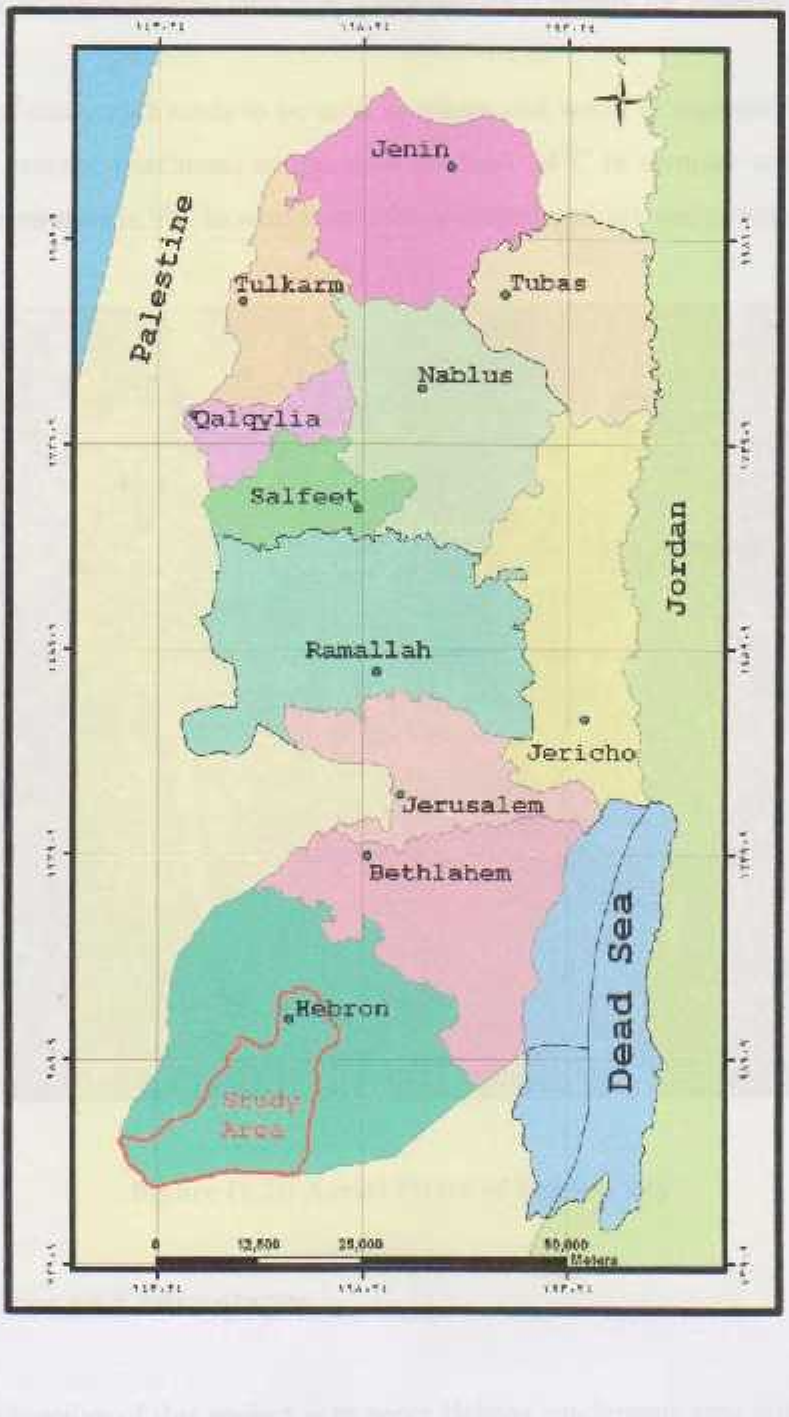

Figure (1.1): Hebron Catchments Area, location map

Out of the total cultivated area, 95% is rain feed, 60% under olives, grapes, almonds, and fruit trees, and 35% under field crops, mainly winter cereals and grain legumes. The remaining 5% of the cultivated land is irrigated and used mainly for vegetable.

The climate of study area tends to be cold in winter and warm in summer and relatively humid. The average maximum temperature is about 34^{0}C in summer and the average minimum temperature is 9^{0}C in winter, and the average humidity varies between 25-80%.

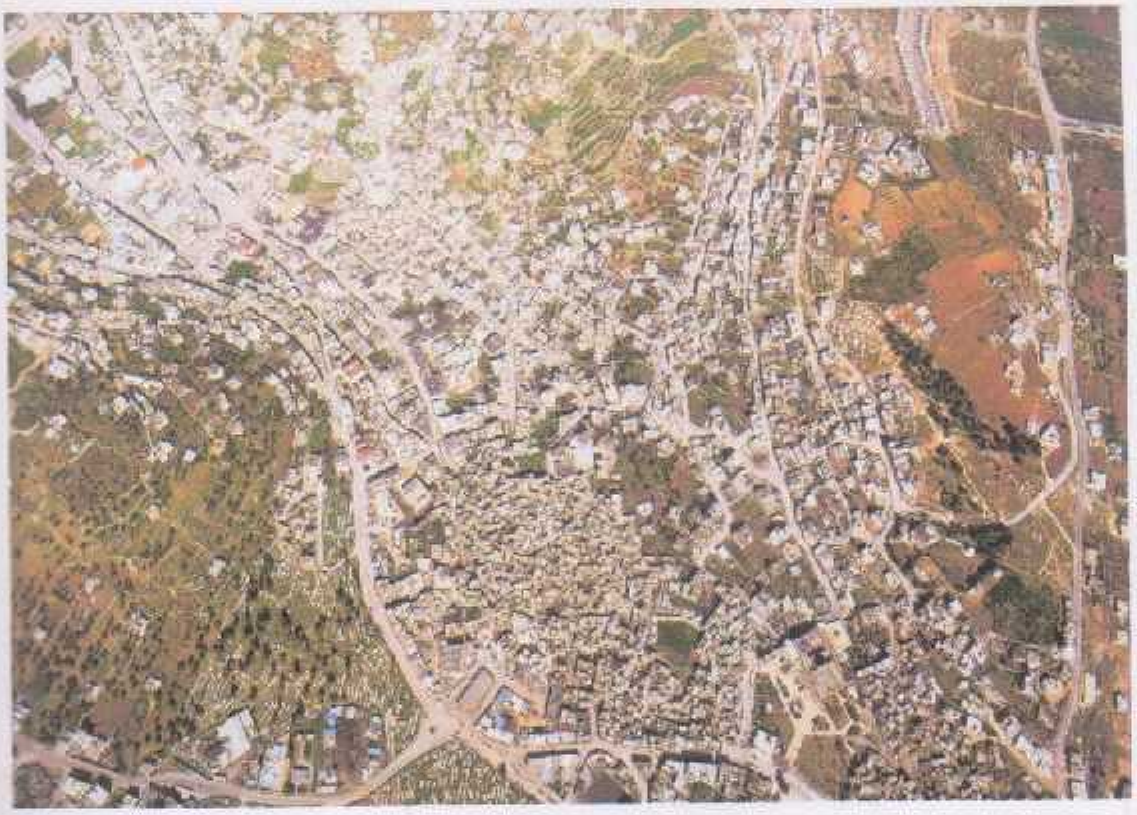

Figure (1.2): Aerial Photo of Hebron city

1.4 Objectives and advantages

The overall objective of this project is to serve Hebron catchments area with erosion risk model using (GIS) to reduce the risk causes by erosion, that's happened, by giving an future overview about the situation of the soil. More specifically the main objectives of this study may be summarized as the follow:

1. Define the study area.
2. Preparing the maps and the necessary information
3. Collect any necessary information from the field
4. Analyses theses data
5. Data processing and map generation
6. Development of a soil erosion intensity map using universal soil loss equation (USLE) with the aid of remotely sensed data in a GIS environment.
7. Development a data base for Hebron catchments area about soil erosion.

After this study we will be able to answer many questions like:

1. How serious is the problem?
2. What does it matter?
3. What major problem or issue is being resolved and how are you resolving it?

1.5 Methodology of the work

The project consists of three phases, which is designed to be completed in according with schedule in table (1.1). The description of each of these three phases of the project tasks involved are listed below:

Table (1.1): Phases of the project with three expected duration

PHASE NO.	TITLE	Duration (2007-2008)							
		2/2007	3/2007	4/2007	5/2007	9/2008	10/2008	11/2008	12/2008
One	Data collection and Survey.	■	■	■	■				
Two	Design of erosion Model.			■	■	■	■	■	
Three	Writing the report and Other related jobs.						■	■	■

1.5.1 First phase: data collection and survey

During this phase, available data and information is collected from different sources. Moreover, many site visits to both project area and the related local organization are conducted. First phase included the following tasks:

1. Collection of aerial topographical maps for the study area.
2. Collection of metrological and hydrological data (temperature, wind speed, rainfall, evaporation ...etc) from different sources.
3. Take sample from the field, that's will be from different places around the projects area.
4. Analyze the sample.

1.5.2 Second phase: design of erosion model

During second phase, the necessary USLE factors are calculated to estimate erosion quantity model. This is including:

1. Preparing any necessary program that's needed in the modeling.
2. Establish the modeling by analyses the data with ArcView.
3. Preparing the final map.
4. Estimate the USLE factors and prepare them to be used.

1.5.3 Third phase: writing the report and other related jobs

After finishing the design modeling map, the research team prepared the specifications map, and model, preliminary, and estimate the amount of erosion in tones per year.
The report of the project is prepared and submitted to the Department of Civil and Architectural Engineering of Palestine University.

1.6 Literature study

Many studies had been conducted about soil erosion because of the serious of the problem but non of these studies related to Hebron catchments area, one of the projects that is near to our project is made by Ahmad Namoura and Ashraf Zaben and Safwat Qwasmah, and is supervised by Dr. Majed Abu Sharkh, and it is about hydrologic study of Wadi Su'd in Dura area using GIS

In other hand, many websites published several studies about erosion and its effect on soil, we study some of them to gain knowledge about how to use USLE and GIS to develop a model for Hebron catchments area.

1.7 Organization of the project

The study report is prepared in according with the objectives, and scope of the work. The report consists of seven chapters as:

Chapter one: Entitled (introduction), outline the problem, projects objective and phases of the projects.

Chapter two: Entitled (GIS Software Overview), how we deal with software to carry out the projects, how does it work, and the importance of these software.

Chapter three: Entitled (Erosion Model and USLE), is contain the erosion definition and relation with GIS, and also the definition of USLE parameters.

Chapter four: Entitled (Data Preparation and Analysis), this chapter describes the field work procedures, soil lab test, and the analysis of these data.

Chapter five: Entitled (Estimation of USLE factor for Hebron catchments area), this chapter illustrates the procedure to estimate the USLE factors, and describes` the soil erosion risk map for the study area.

Chapter six: Entitled (Conclusions and Recommendations)

CHAPTER TWO
GIS SOFTWARE OVERVIEW

This chapter covers how ArcView GIS utilized to carry out the project tasks; the chapters cover the following items:

2.1 GIS BASIC

2.2 ARCVIEW

2.3 ARCVIEW ARCHITETURE

2.4 TRIANGULATED IRRRGULAR NETWORK

2.5 DIGITAL ELEVATION MODEL

2.6 REALATION BETWEEN EROSION, REMOTE SENSING AND GIS

CHAPTER TWO

GIS SOFTWARE OVERVIEW

2.1 GIS basic

GIS (or Geographic Information System) is a computer system capable of assembling, storing, and manipulating geographically referenced information, i.e. data identified according to their locations.

In other words a GIS allows data to be displayed in map format but contains additional information about each map feature through the underlying database and topology. Features contained within a GIS are both visual representations of data as well as actual points of reference for the underlying database.

Types of GIS :

1- Vector based GIS- e.g. Arc-View or Arc-Info. Vector based GIS use points, lines, and polygons to display and reference information about the world.

- A point- has no length or spatial area. It is defined as a single X,Y coordinate. For example, a manhole cover can be displayed as a point that is located at a particular location within a city.

- Lines- represent linear features (even if they have curves). Lines have length but no spatial area. A line can be thought of as a string with a beginning point and end point connected by a line that can vary in shape. The beginning point and end point define the extent of the line (these points are often called nodes).

- Polygons- have length, spatial area, and a perimeter. A polygon can have numerous x,y coordinates that define its shape (these are often called vertices) and always has a single point that defines the beginning and end of the polygon. Examples of polygons are circles, rectangles, or other many sided objects.

2- Raster based GIS- A Raster system uses rows of uniform cells to display and reference information. Each cell is given a value that defines information about the point in space that the cell encompasses. For example, raster cells are often used to represent elevation on the earth's surface. In such a system, a grid of squares, each coded with the average elevation value of the surface that the square covers, is used to represent the distribution of elevation values across a given surface.

2.2 ArcView

ArcView GIS is a desktop geographic information system (GIS) from Environmental Systems Research Institute, Inc. (ESRI). A GIS is a database that links information to location (it connects the what to the where), allowing you to see and analyze data in new and useful ways.

2.2.1 What can ArcView do?

1- Display information which resides locally or over a distributed network.

2- Read spatial and tabular information from a variety of data formats.

3- Use colors and symbols to represent features. For example, rivers can be represented as blue solid lines and roads as black dashed lines.

4-Use colors and symbols to represent features based on their attributes. For example, counties can be shaded based on their population.

5- Connect spatial information to database attributes:

- Select data spatially and retrieve database information.
- Select data from the database and see the spatial representation of the selected features.

2.2.2 Data types used in ArcView

1- Geographic data

Geographic data consists of features represented by points, lines and polygons. ArcView can use

- ArcView shape files
- ARC/INFO coverages (PC or Unix)
- AutoCAD (*.DWG) and Microstation (*.DGN) CAD drawings
- DXF files

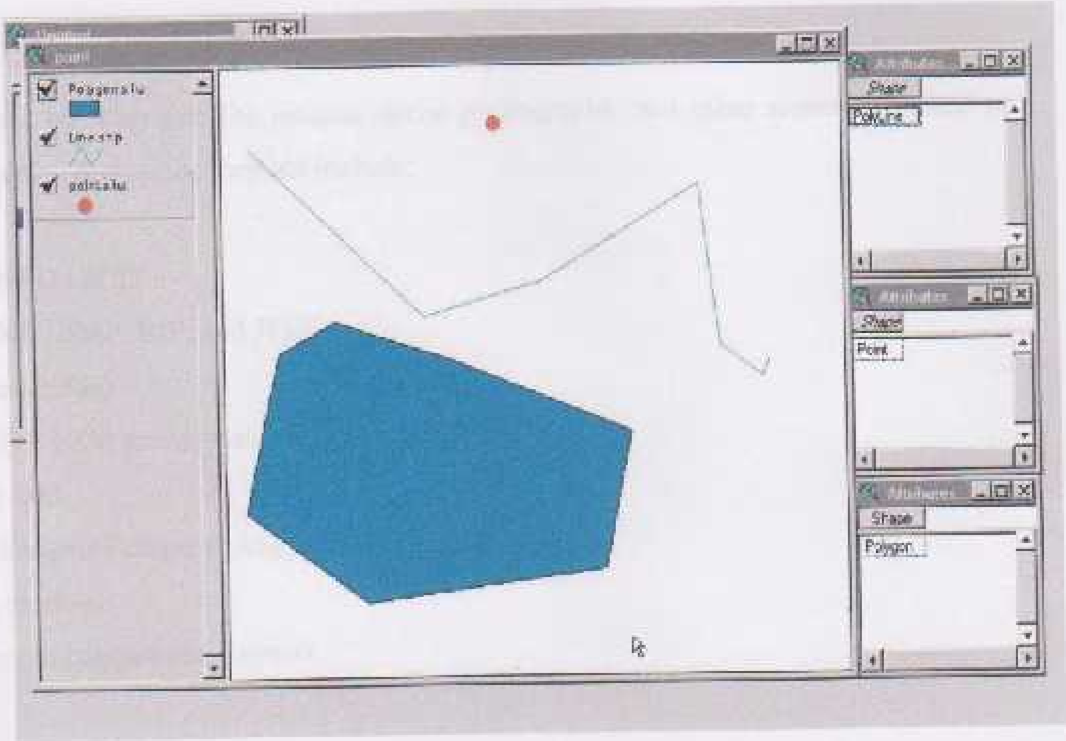

Figure (2.1): Geographic data, ref (3).

2- Attribute data

ArcView can read tabular data from:

- DBASE files
- Database servers such as ORACLE, INGRES, SYBASE, INFORMIX etc.

- INFO tables
- Comma or tab delimited ASCII files.

Figure (2.2): Attribute data, ref (3).

3-Image data

Image data includes satellite images, aerial photographs, and other remotely sensed or scanned data. Supported formats include:

- ARC/INFO GRID
- BSQ, BIL, BMP, BIP, and JPEG
- SUN raster files
- Tiff, TIFF LZW compressed, and GeoTIFF
- Erdas (.lan)
- Erdas Imagine Images (*.img)
- Image catalogs
- Run length compressed formats

4-Grid data

- ARC/INFO GRID
- ASCII raster file format
- Binary raster file format
- USGS DEM format
- US DMA Digital Terrain Elevation Data (DTED)

2.3 ArcView architecture

2.3.1 Project

The Project window contains all of the other documents associated with the project. The document types in a project are: views, tables, charts, layouts and scripts. All of these associated documents are accessed through the active project window.

Projects are text (ASCII) files stored with an ".apr" extension. Projects contain pointers to the physical locations of associated documents as well as user preferences (colors, GUI, window sizes & positions). The user preferences stored with the project affect only the way the data is displayed not the data itself.

Figure (2.3): Project sample, ref (3).

2.3.2 View

A view is the graphic representation of spatial information and can contain any number of "layers" or "themes" of spatial information (points, lines, polygons and images). For example interstate highways, bank locations and soil polygons would be themes in a single view.

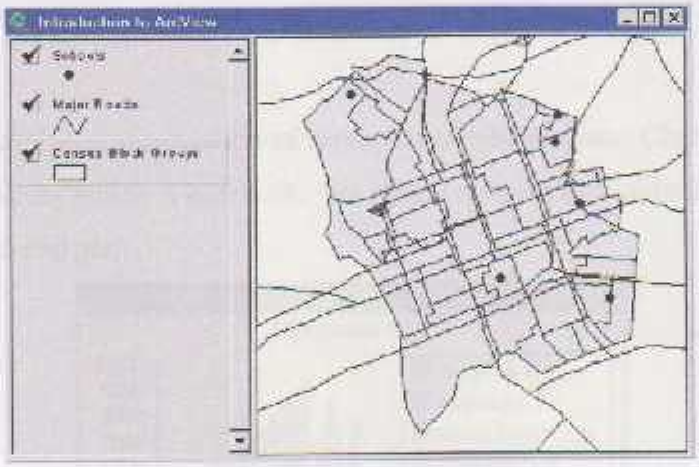

Figure (2.4): ArcView, ref (3).

2.3.3 Table

A table is ArcView's representation of tabular data. Tables contain descriptive information about a specific subject. Each row, or record, defines one entry in the database (e.g., one wetland polygon); each column, or field, defines a single characteristic for the entry (wetland type). Any dBase, INFO or ASCII file can be displayed as an ArcView Table.

Attributes of Census Block Groups

Shape	Area	Perimeter	[illegible]
Polygon	671336.57929	3507.78996	2
Polygon	232891.90629	2844.03737	3
Polygon	1772921.03104	6799.20252	4
Polygon	449398.33308	3924.08006	5
Polygon	501475.69461	4417.11858	6
Polygon	618682.96863	3776.50939	7
Polygon	236462.91467	2244.70510	8
Polygon	372933.76012	2949.34475	9
Polygon	204460.48224	2892.76795	10
Polygon	206413.04353	2202.64536	11
Polygon	363451.92868	2731.78873	12
Polygon	251227.09402	1997.93250	13
Polygon	217260.31483	2354.95561	14

Figure (2.5): Table sample, ref (3).

2.3.4 Chart

Charts provide graphic representation of summarized tabular data. Charts can also query data from the table by which it was built. Six chart types are available: line, bar, column, (x,y) scatter, area, and pie.

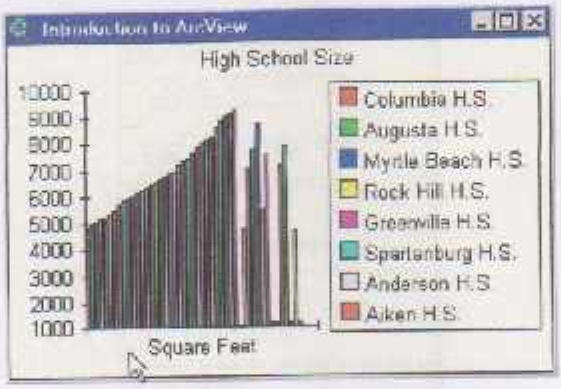

Figure (2.6): The chart, ref (3).

2.3.5 Layout

The layout document is used to combine all other documents (views, tables, and charts) into an output document (usually a hardcopy map). Any previously composed view can be placed into a layout. Within the layout a north arrow, scale bar, legend and other graphics can be added.

Figure (2.7): Layout, ref (13).

2.3.6 Script

Script windows are for writing and displaying Avenue scripts that customize the ArcView user interface or perform user- designed tasks. From the button bar you check syntax, debug and run your script.

Figure (2.8): Script, ref (13).

2.4 Triangulation Irregular Network

A triangulated irregular network (TIN) is a digital data structure used in a geographic information system (GIS) for the representation of a surface. A TIN is a vector based representation of the physical land surface or sea bottom, made up of irregularly distributed nodes and lines with three dimensional coordinates (x,y, and z) that are arranged in a network of no overlapping triangles. TINs are often derived from the elevation data of a rasterized digital elevation model (DEM). An advantage of using a TIN over a DEM in mapping and analysis is that the points of a TIN are distributed variably based on an algorithm that determines which points are most necessary to an accurate representation of the terrain.

Data input is therefore flexible and fewer points need to be stored than in a DEM with regularly distributed points. While a TIN may be less suited than a DEM raster for certain kinds of GIS applications, such as analysis of a surface's slope and aspect, TINs have the advantage of being able to portray terrain in three dimensions.

A TIN comprises a triangular network of points, known as mass points, with associated coordinates in three dimensions connected by edges to form a triangular tessellation. Three-dimensional visualizations are readily created by rendering of the triangular facets. In regions where there is little variation in surface height, the points may be widely spaced whereas in areas of more intense variation in height the point density is increased. A TIN is typically based on a Delaunay triangulation but its utility will be limited by the selection of input data points: well-chosen points will be located so as to capture significant changes in surface form, such as topographical summits, breaks of slope, ridges, valley floors, pits and cols.

2.5 Digital Elevation Model

A Digital Elevation Model (DEM) is a digital earth surface terrain elevations in xyz coordinates which built by converting the contour map of study area to Triangulated Irregular Network (TIN).

The terrain elevations for ground positions are sampled at regularly spaced horizontal intervals. In other countries DEMs are produced by some national institute, e.g. in the USA DEMs are produced by U.S Geological Survey (USGS) as apart of its national mapping program. Cell sizes for United States are available at (30m), (100m), (500m), and for the world at (1 km) cell size. (Maidment, 2002)

A Digital Elevation Model (DEM) consisting of a rectangular mesh of elevation points located over the landscape. Rectangular mesh has a number of cells represents the elevation of the center of the cell as the following figure (2.9).

67	56	55	40	50
49	44	37	38	48
65	55	23	32	24
57	47	21	17	20
53	34	30	11	13

Figure (2.9): Surface terrain represented by a mesh of cells, ref (13).

The highest resolution DEM data is being produced by local mapping efforts with cell sizes of 10 m or smaller.

2.6 Relation between erosion, remote sensing and GIS

The potential utility of remotely sensed data in the form of aerial photographs and satellite sensors data has been well recognized in mapping and assessing landscape attributes controlling soil erosion, such as physiography, soils, land use/land cover, relief, soil erosion pattern. Remote Sensing can facilitate studying the factors enhancing the process, such as soil type, slope gradient, drainage, geology and land cover. Multi-temporal satellite images provide valuable information related to seasonal land use dynamics.

Satellite data can be used for studying erosional features, such as gullies, rainfall interception by vegetation and vegetation cover factor. DEM (Digital Elevation Model) one of the vital inputs required for soil erosion modeling can be created by analysis of stereoscopic optical and microwave (SAR) remote sensing data.

Geographic Information System (GIS) has emerged as a powerful tool for handling spatial and non-spatial geo-referenced data for preparation and visualization of input and output, and for interaction with models. There is considerable potential for the use of GIS technology as an aid to the soil erosion inventory with reference to soil erosion modeling and erosion risk assessment.

The availability of GIS tools and more powerful computing facilities makes it possible to overcome difficulties and limitations and to develop distributed water and wind induced Soil Erosion Assessment and Monitoring.

CHAPTER THREE
EROSION MODEL AND USLE

This chapter describes the erosion definition and relation with GIS, it covers the following items:

3.1 EROSION DEFINITION

3.2 MODELING EROSION PROBLEM WITH GIS

3.3 IMPORTANCE OF ESTIMATING EROSION AMOUNT

3.4 EROSION EQUATION

3.5 EROSION MODEL AND USLE

CHAPTER THREE
EROSION MODEL AND USLE

3.1 Erosion definition

Soil erosion is one form of soil degradation along with soil compaction, low organic matter, and loss of soil structure, poor internal drainage, and soil acidity problems. These forms of soil degradation, serious in themselves, usually contribute to accelerated soil erosion.

Soil erosion is a naturally occurring process on all land. The agents of soil erosion are water and wind, each contributing a significant amount of soil loss each year.

Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks, figure (3.1)

Figure (3.1): Erosion sample, ref (7).

3.1.1 Erosion by water

The rate and magnitude of soil erosion by water is controlled by the following factors:

1. Rainfall intensity and runoff

Both rainfall and runoff factors must be considered in assessing a water erosion problem. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material figure (3.2). Lighter aggregate materials such as very fine sand, silt, clay and organic matter can be easily removed by the raindrop splash and runoff water; greater raindrop energy or runoff amounts might be required to move the larger sand and gravel particles.

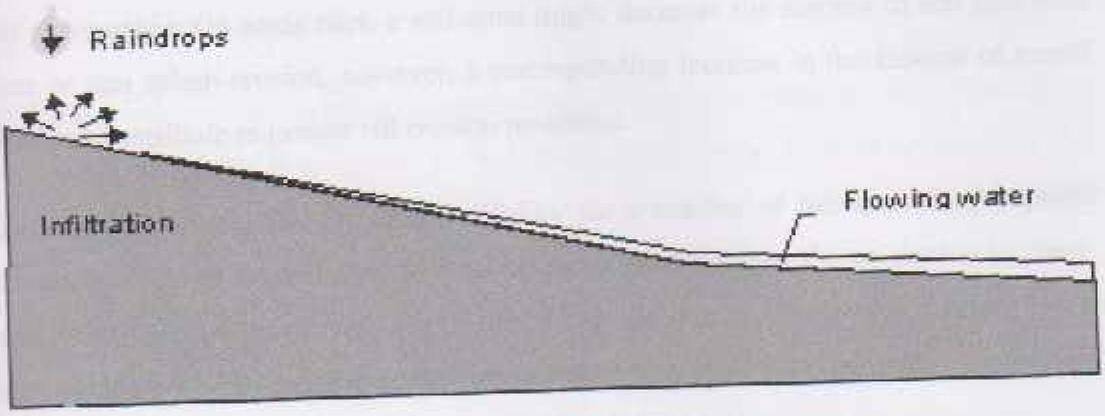

Figure (3.2): Erosion by water, ref (11).

Soil movement by rainfall (raindrop splash) is usually greatest and most noticeable during short-duration, high-intensity thunderstorms. Although the erosion caused by long-lasting and less-intense storms is not as spectacular or noticeable as that produced during thunderstorms, the amount of soil loss can be significant, especially when compounded over time. Runoff can occur whenever there is excess water on a slope that cannot be absorbed into the soil or trapped on the surface. The amount of runoff can be increased if infiltration is reduced due to soil compaction, crusting or freezing. Runoff from the agricultural land may be greatest during spring months when the soils are usually saturated, snow is melting and vegetative cover is minimal.

2. Soil erodibility

Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils.

Tillage and cropping practices which lower soil organic matter levels, cause poor soil structure, and result of compacted contribute to increases in soil erodibility. Decreased infiltration and increased runoff can be a result of compacted subsurface soil layers. A decrease in infiltration can also be caused by a formation of a soil crust, which tends to seal the surface. On some sites, a soil crust might decrease the amount of soil loss from sheet or rain splash erosion, however, a corresponding increase in the amount of runoff water can contribute to greater rill erosion problems.

Past erosion has an effect on soils erodibility for a number of reasons. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils were, because of their poorer structure and lower organic matter. The lower nutrient levels often associated with subsoil's contribute to lower crop yields and generally poorer crop cover, which in turn provides less crop protection for the soil.

3. Slope gradient and length

Naturally, the steeper the slope of a field, the greater the amount of soil loss from erosion by water. Soil erosion by water also increases as the slope length increases due to the greater accumulation of runoff. Consolidation of small fields into larger ones often results in longer slope lengths with increased erosion potential, due to increased velocity of water which permits a greater degree of scouring (carrying capacity for sediment).

4. Vegetation

Soil erosion potential is increased if the soil has no or very little vegetative cover of plants and/or crop residues. Plant and residue cover protects the soil from raindrop impact and splash, tends to slow down the movement of surface runoff and allows excess surface water to infiltrate.

The erosion-reducing effectiveness of plant and/or residue covers depends on the type, extent and quantity of cover. Vegetation and residue combinations that completely cover the soil, and which intercept all falling raindrops at and close to the surface and the most efficient in controlling soil (e.g. forests, permanent grasses). Partially incorporated residues and residual roots are also important as these provide channels that allow surface water to move into the soil.

The effectiveness of any crop, management system or protective cover also depends on how much protection is available at various periods during the year, relative to the amount of erosive rainfall that falls during these periods. In this respect, crops which provide a food, protective cover for a major portion of the year (for example, alfalfa or winter cover crops) can reduce erosion much more than can crops which leave the soil bare for a longer period of time (e.g. row crops) and particularly during periods of high erosive rainfall (spring and summer). However, most of the erosion on annual row crop land can be reduced by leaving a residue cover greater than 30% after harvest and over the winter months, or by inter-seeding a forage crop (e.g. red clover).

Soil erosion potential is affected by tillage operations, depending on the depth, direction and timing of plowing, the type of tillage equipment and the number of passes.

Generally, the less the disturbance of vegetation or residue cover at or near the surface, the more effective the tillage practice in reducing erosion.

5. Conservation measures

Certain conservation measures can reduce soil erosion by both water and wind. Tillage and cropping practices, as well a land management practices, directly affect the overall soil erosion problem and solutions on a farm. When crop rotations or changing tillage practices are not enough to control erosion on a field, a combination of approaches or more extreme measures might be necessary. For example, contour plowing, strip cropping, or terracing may be considered.

3.1.2 Erosion by wind

The rate and magnitude of soil erosion by wind is controlled by the following factors, figure (3.3):

1. Erodibility of soil

Very fine particles can be suspended by the wind and then transported great distances. Fine and medium size particles can be lifted and deposited, while coarse particles can be blown along the surface (commonly known as the saltation effect). The abrasion that results can reduce soil particle size and further increase the soil erodibility.

2. Soil surface roughness

Soil surfaces that are not rough or ridged offer little resistance to the wind. However, over time, ridges can be filled in and the roughness broken down by abrasion to produce a smoother surface susceptible to the wind. Excess tillage can contribute to soil structure breakdown and increased erosion.

3. Climate

The speed and duration of the wind have direct relationship to the extent of soil erosion. Soil moisture levels can be very low at the surface of excessively drained soils or during periods of drought, thus releasing the particles for transport by wind. This effect also occurs in freeze drying of the surface during winter months.

4. Unsheltered distance

The lack of windbreaks (trees, shrubs, residue, etc.) allows the wind to put soil particles into motion for greater distances thus increasing the abrasion and soil erosion. Knolls are usually exposed and suffer the most.

5. Vegetative cover

The lack of permanent vegetation cover in certain locations has resulted in extensive erosion by wind. Loose, dry, bare soil is the most susceptible; however, crops that produce low levels of residue also may not provide enough resistance. As well, crops that produce a lot of residue also may not protect the soil in severe cases.

The most effective vegetative cover for protection should include an adequate network of living windbreaks combined with good tillage, residue management, and crop selection.

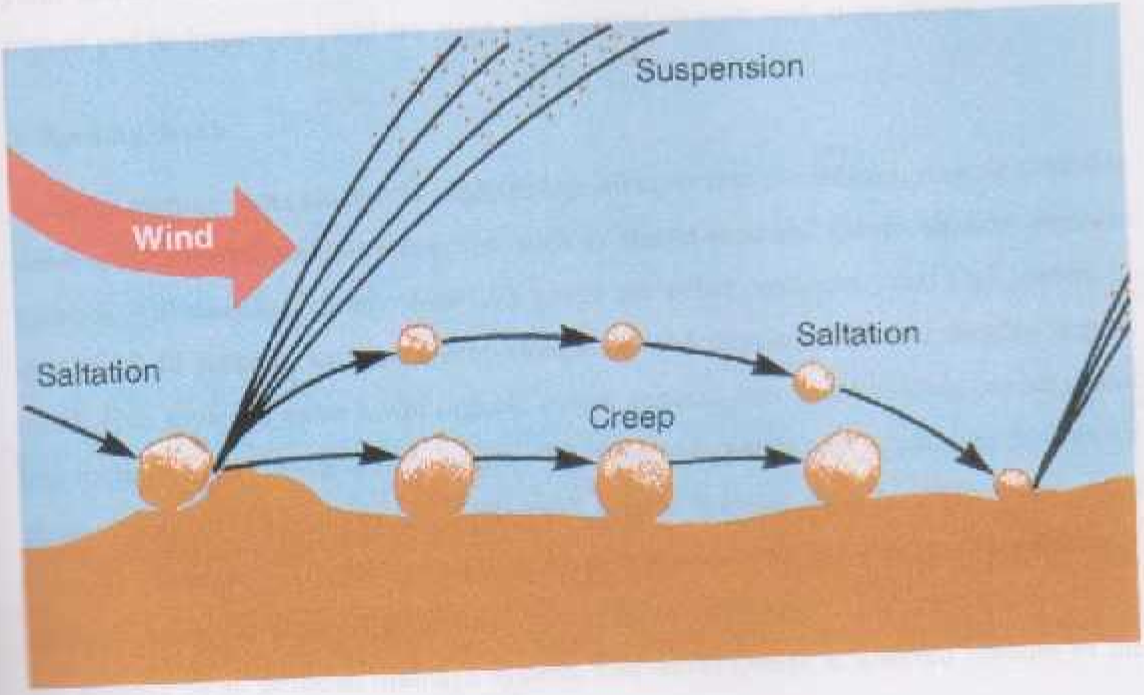

Figure (3.3): Erosion by wind, ref (6).

3.1.3 Soil chrematistics and productivity

To understand the effect of soil characteristics and erosion on soil productivity, producers need to understand soil properties. Long-term effects of soil erosion on productivity can be measured by changes in three soil profile properties:

1. Topsoil thickness;
2. Rooting depth, which relates to plant-available water capacity; and
3. Depth to maximum clay content in the soil profile.

1. Topsoil thickness

The vertical cross section of soil (soil profile) is divided into three parts: topsoil (A-horizon), subsoil (B-horizon), and parent material (C-horizon). Topsoil is generally enriched with organic matter and has granular aggregates that provide larger soil pores, reduce soil density, and enhance water infiltration and aeration. When topsoil is eroded, yield suffers due to nutrient loss and damage to soil physical properties. The loss of topsoil and its impact on yield are more pronounced on soils with steep slopes.

2. Rooting depth

As crops mature, roots extend through the topsoil layer into the subsoil, seeking available water and nutrients. Subsoil properties, such as coarse sand and gravel, shallow depth to bedrock, soil densities greater than 1.65 grams per cubic centimeter, and clay content in excess of 42 percent, can limit root elongation and development and thereby impact yield. Thin topsoil's mean lower organic matter content, low water holding capacity, and less rooting depth. Textural distribution within the soil profile also determines how much plant-available water is present. Soils with coarse textures tend to drain water more quickly, whereas soils with fine textures hold water too tightly for roots. Poor drainage occurs in medium-textured as well as fine-textured soils on concave landforms, and, in the absence of an artificial drainage system, root development is affected because of the lack of oxygen.

3. Depth to maximum clay content in soil the profile

Clay particles tend to accumulate below the topsoil due to the leaching. When topsoil has eroded, the loss of organic matter can alter the soil's physical properties, especially soil density. Higher clay content at the surface can reduce infiltration of topsoil reducing soil recharge, thus reducing water availability to the plants.

3.2 Modeling erosion problem with GIS

Geographic Information Systems (GIS) have become the promising tool for an effective analysis associated with the study of natural hazards. GIS is an ideal tool for erosion modeling owing to its versatility in handling a large set of data, providing an efficient environment for analysis and display of results with its powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data from the real world.

In this project, we will be able to demonstrate the ability of the GIS to incorporate the spatially varying data of ground elevation, soil properties, etc.

3.3 Importance of estimating erosion amount

What's the deep of our problem? What's the effect on our economic activity?. Estimating the amount of erosion can give us the real situation for our soil. Erosion reduces the productivity of many soils by affecting the soil properties and depth.

This reduction is substantial and long-lasting, and can not be reversed over a lifetime, even with conservation management, low intensity use or high fertility amendments. The most important yield-limiting effect of erosion is probably the decrease in plant available water holding capacity.

The soil fertility status may be significantly decreased by erosion but can be replenished by additions of lime and fertilizer, although with greater expense and lower efficiency than for uneroded soil. The overall effect of erosion is an economic loss which accumulates with time as erosion continues.

3.4 Erosion equations

A number of equation have been used to estimate the amount of soil erosion , these can be summarized as :

1-USLE (Universal Soil Loss Equation)

USLE developed by W. Wischmeier and D. Smith, has been the most widely accepted and utilized soil loss equation for over 30 years. Designed as a method to predict average annual soil loss caused by sheet and rill erosion, the USLE is often criticized for its lack of applications. While it can estimate long - term annual soil loss and guide conservationists on proper cropping, management, and conservation practices, it can not be applied to a specific year or a specific storm. The USLE is mature technology and enhancements to it are limited by the simple equation structure.

The USLE for estimating average annual soil erosion is:

$A = RKLSCP$

Where:

A = average annual soil loss in t/a (tons per acre)

R = rainfall erosivity index (mm / year).

K = soil erodibility factor.

LS = topographic factor - L is for slope length & S is for slope (mm).

C = cropping factor.

P = conservation practice factor.

2-CREAMS (A field Scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems)

Is a field scale model for predicting runoff, erosion, and chemical transport from agricultural management systems. It is applicable to field-sized areas. CREAMS can operate on individual storms but can also predict long term averages (2-50 years).

3- EPIC (Erosion/Productivity Impact Calculator)

Is used to determine the relationship between soil erosion and soil productivity. It calculates the loss of crop yield due to soil erosion and other factors. EPIC is a continuous simulation model, and uses a set of modified USLE functions to predict erosion.

4- ANSWERS (Arial Nonpoint Source Watershed Environment Response Simulator)

Simulates the behavior of watersheds on agricultural land. It predicts the erosion caused by specific land uses and management practices and also provides a water quality analysis associated with sediment associated chemicals. ANSWERS is event based - it is primarily limited to a single storm. The erosion component in ANSWERS is very similar to that in the CREAMS model.

5- The AGNPS (Agricultural Nonpoint Source Pollution Model)

Model was developed for the analysis of nonpoint source pollution from agricultural fields. It estimates the quality of surface water runoff and compares it to the expected quality of other land management strategies. AGNPS is a single event based model, though continuous simulated versions are under development. AGNPS uses a set of modified USLE equations in its erosion component.

3.5 Erosion model and USLE

The Universal Soil Loss Equation (USLE) 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 a 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 general formula for Universal Soil Loss Equation (USLE) is :

$A = R \times K \times LS \times C \times P$

Where, (A) represents the potential long term average annual soil loss in tons per acre per year. This is the amount, which is compared to the "tolerable soil loss" limits.

3.5.1 Rainfall Estimation (R)

The rainfall factor, R, accounts for the potential of falling rain drops and flowing water in a particular area to produce erosion. Cumulative effects of all yearly storms above a certain intensity and duration make up this numerical value. As the energy of a storm increases, the potential for more soil particles to detach increases. Runoff also increases with intensity and duration of storms, thereby increasing erosion potential. At present, little can be done to change the amount, distribution, and intensity of rainfall, but measures can be adopted to limit its effect on erosion.
For example, vegetative soil cover can reduce the effect of raindrop impact on the soil and the velocity of runoff.

3.5.2 Soil Erodibility (K)

The soil erodibility factor, K, depends upon soil texture, structure and permeability. Silt and very fine sand are the most easily eroded soil particles so soil textures dominated by these separate classes have the highest erodibility. Aggregated soils are less erodible because soil particles which are bound together resist erosion by virtue of their greater aggregate mass. Highly permeable soils are less subject to soil erosion because a greater proportion of rainfall seeps into the ground and, therefore, less runoff occurs.

3.5.3 Soil Length Gradient Factor (LS)

The topographic factor, LS, is divided into two components: S is the slope grade (drop in elevation/slope length) expressed as a %; and L is the length of the slope. Slope grade affects mainly the speed of runoff. Slope length affects mainly the amount of runoff, since runoff is cumulative. In assessing the effects of slope length it is necessary to take into account the total length of the slope over which runoff occurs, not just the length of the field in question.

3.5.4 Cropping and Management (C)

The cropping management factor, C, represents the ratio of soil loss from land with specific cropping and management to that from tilled and fallow conditions on which the K factor is evaluated. The C factor, also called the cover and management factor, varies between zero and unity (1), and depends on type of vegetation cover, crop season, and other management techniques, ref (7).

3.5.5 Conservation Practices (P)

The conservation practice factor, P. is used to account for the positive impacts of such agricultural management practices as planting on the contour, strip cropping, and use of terraces.

P is the support practice factor, it reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. The P factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. The most commonly used supporting cropland practices are cross slope cultivation, contour farming and strip-cropping.

3.5.6 Soil Loss Tolerance Rate

A tolerable soil loss is the maximum annual amount of soil, which can be removed before the long term natural soil productivity is adversely affected. The impact of erosion on a given soil type, and hence the tolerance level varies, depending on the type and depth of soil. Generally, soils with deep, uniform, stone free topsoil materials and/or not previously eroded have been assumed to have a higher tolerance limit than soils which are shallow or previously eroded. Soil loss tolerance rates are included in Rates.

CHAPTER FOUR
DATA PREPARATION AND ANALYSIS

This chapter describes the field, sampling procedure, soil lab test and preparation of soil, land use and rain full map, it covers the following items:

4.1 FILED Samples
4.2 SOIL TEXTURE (SIEVE ANALYSIS).
4.3 SOIL TEXTURE TRIANGEL
4.4 MEASUERMENT OF INFILTRATION
4.5 SOIL MOISTURE
4.6 ORGANIC MATTER
4.7 CONTOUR MAP
4.8 LAND USE MAP
4.9 SOIL MAP
4.10 RAINFALL MAP

CHAPTER FOUR
DATA PREPARATION AND ANALYSES

4.1 Field samples

30 soil samples have been collected from the field. At least one sample have been collected for each soil association, figure (4.1).

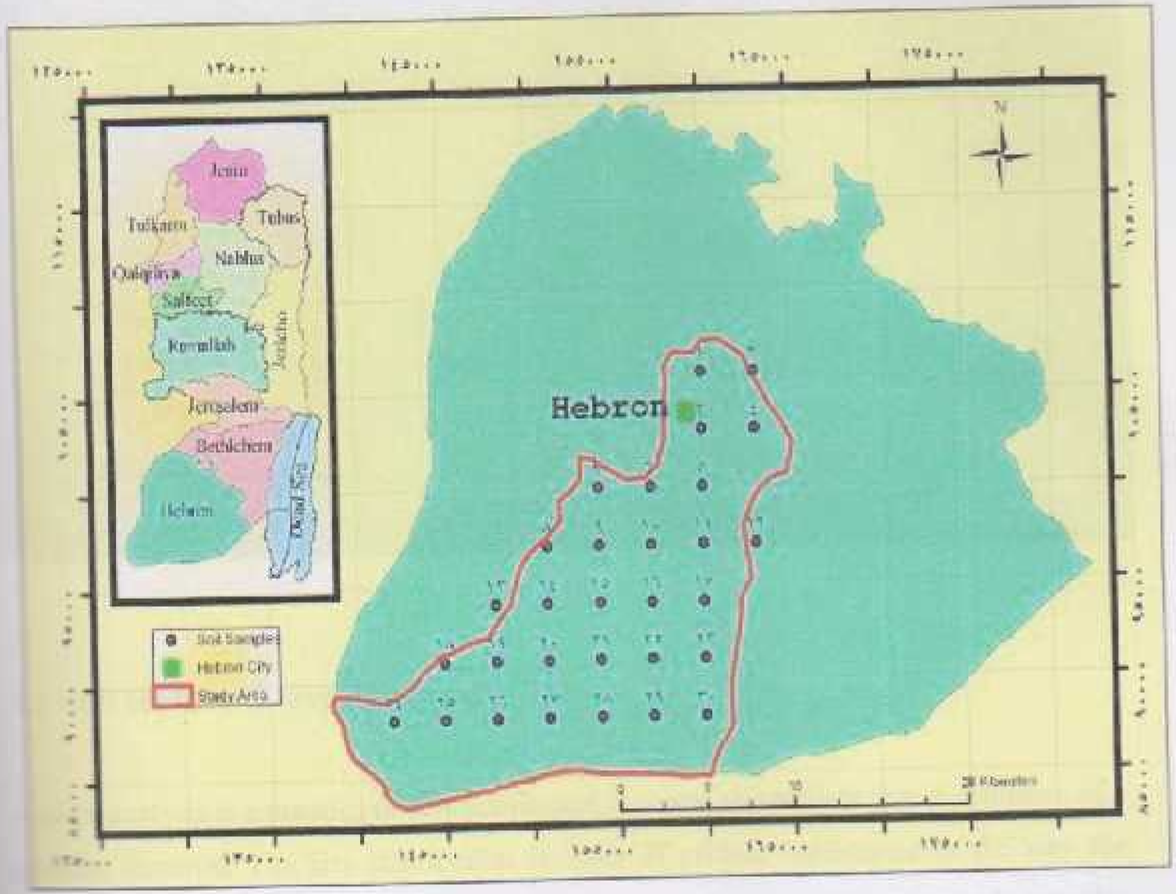

Figure (4.1): location Soil samples

Table (4.1) shows the coordinates of the soil samples:

Table (4.1): Coordinate of soil samples.

No:	Coordinate (x,y)	No:	Coordinate (x,y)
1	(106000,160000)	16	(94000,154000)
2	(106000,163000)	17	(94000,160000)
3	(103000,160000)	18	(91000,145000)
4	(103000,163000)	19	(91000,148000)
5	(100000,160000)	20	(91000,151000)
6	(100000,157000)	21	(91000,154000)
7	(100000,154000)	22	(91000,157000)
8	(97000,151000)	23	(91000,160000)
9	(97000,154000)	24	(88000,142000)
10	(97000,157000)	25	(88000,145000)
11	(97000,160000)	26	(88000,148000)
12	(97000,163000)	27	(88000,151000)
13	(94000,148000)	28	(88000,154000)
14	(94000,151000)	29	(88000,157000)
15	(94000,157000)	30	(88000,160000)

4.2 Soil texture (Sieve analysis).

A sieve analysis is a practice or procedure used to assess the particle size distribution of a granular material. The size distribution is often of critical importance to the way the material performs in use. It can be used for any type of non-organic or organic granular and materials including sands, clays, granite, feldspars, coal, soil, and a wide range of manufactured powders.

Table (4.2) shows the standard sieve sizes:

Table (4.2): Standard sieve sizes

standard sieve sizes	
sieve number	Opening Size (mm)
4	4.750
6	3.350
8	2.360
12	1.70
16	1.180
20	0.850
30	0.600
40	0.425
50	0.300
60	0.250
80	0.180
100	0.150
140	0.106
200	0.075
270	0.053
325	0.045
400	0.038

Table (4.3) shows the calculation for one sample by using sieve analysis.

Table (4.3): Sieve analyses for one sample:

sample coordinate (88000-148000)

sieve number	weight in (g)	percent of wight	total pass
1/2	302.3	30%	697.7
4	308.2	31%	389.5
10	177.4	18%	514.4
20	140.3	14%	682.3
40	42.1	4%	817.6
60	13.4	1%	944.5
140	7.1	1%	979.5
200	4.8	0%	988.1
plat	4.4	0%	990.8
total	1000		

All other calculations are shown in appendix.

4.3 Soil texture triangle.

A soil texture triangle, figure (4.3), is used to classify the texture class of a soil. The sides of the soil texture triangle are scaled for the percentages of sand, silt, and clay. Clay percentages are read from left to right across the triangle (dashed lines). Silt is read from the upper right to lower left (light, dotted lines). Sand from lower right towards the upper left portion of the triangle (bold, solid lines). The boundaries of the soil texture classes are highlighted in blue. The intersection of the three sizes on the triangle gives the texture class. For instance, if you have a soil with 20% clay, 60% silt, and 20% sand it falls in the "silt loam" class, figure (4.3).

Figure (4.2): Soil sample picture.

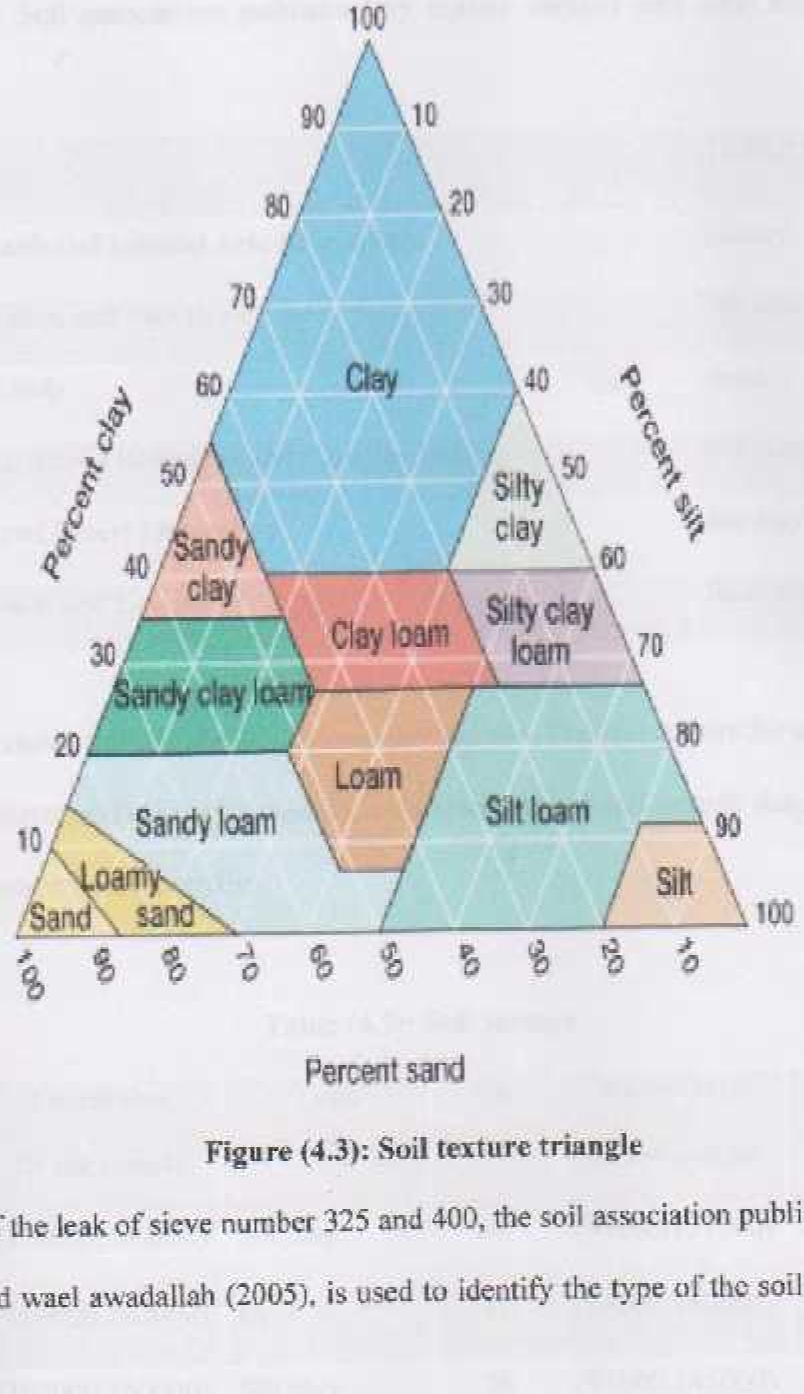

Figure (4.3): Soil texture triangle

Because of the leak of sieve number 325 and 400, the soil association published by maher awaiwi and wael awadallah (2005), is used to identify the type of the soil texture , table (4.4).

Table (4.4): Soil association published by maher owaiwi and wael awadallah, ref (10).

Soil Type	Texture
Brown Lithosols and Loessial Arid Brown Soils	**Loamy**
Brown Rendzinas and Pale Rendzinas	**Silt clay**
Dark Brown Soils	**Sand**
Terra Rossas, Brown Rendzinas and Pale Rendzinas	**Silt clay**
Bare Rocks and Desert Lithosols	**Silt clay**
Brown Lithosols and Loessial Serozems	**Sand clay**

Table (4.5) shows the soil texture for each soil sample, The soil texture for each field sample is determined using GIS overlay technique between soil sample shape file and .the soil as association shapefile.

Table (4.5): Soil texture

No.	Coordinate Of soil sample	Type	No.	Coordinate Of soil sample	Type
1	(106000,160000)	Silt clay	16	(94000,157000)	Silt clay
2	(106000,163000)	sand	17	(94000,160000)	sand
3	(103000,160000)	Silt clay	18	(91000,145000)	sand
4	(103000,163000)	sand	19	(91000,148000)	Silt clay
5	(100000,160000)	Silt clay	20	(91000,151000)	sand
6	(100000,157000)	sand	21	(91000,154000)	sand

7	(100000,154000)	sand	22	(91000,157000)	Silt clay
8	(97000,151000)	sand	23	(91000,160000)	Silt clay
9	(97000,154000)	Silt clay	24	(88000,142000)	Loamy
10	(97000,157000)	sand	25	(88000,145000)	Loamy
11	(97000,160000)	Silt clay	26	(88000,148000)	sand
12	(97000,163000)	Silt clay	27	(88000,151000)	Silt clay
13	(94000,148000)	sand	28	(88000,154000)	sand
14	(94000,151000)	Silt clay	29	(88000,157000)	Silt clay
15	(94000,154000)	Silt clay	30	(88000,160000)	sand

4.4 Measurement of Infiltration

4.4.1 Introduction

One of the most important of catchments characteristics is the infiltration rate which is helped to classify the soil. It is usually measured by the depth in (mm) of the water layer that can be entered the soils in one hour (mm/hr).

Initial infiltration rate described dry soil where the water infiltrates rabidly. At the same time water replaces the air in the pores, and the water infiltrate become slowly and eventually reaches a steady rate which is called the basic infiltration rate. The size of soil particles (soil texture) and soil structure (the arrangement of the soil particles) control the infiltration rate.

Figure (4.4): Infiltrometer test.

4.4.2 Double Rings Infiltrometer

A double ring Infiltrometer is often used for measuring infiltration characteristics in the field, but the measurements using this are time consuming and tedious, especially when several tests are to be monitored at a site. This is because the Infiltrometer in its present form requires continuous attention and therefore limits the number of tests that can be monitored at a site in a given time.

Two concentric rings: Two concentric ring (double ring Infiltrometer) made of mild steel and consisting of an outer ring of 60 cm diameter. Moreover, inner rings of 30 cm diameter as shown in figure (4.5).

Will use to measure the infiltration rates. The purpose of the outer ring is to eliminate the lateral spread of the water in the soil. Constant level of water should be maintained in both rings and then can be determined how long it will take to infiltrate a certain amount of water which is the infiltration rate.

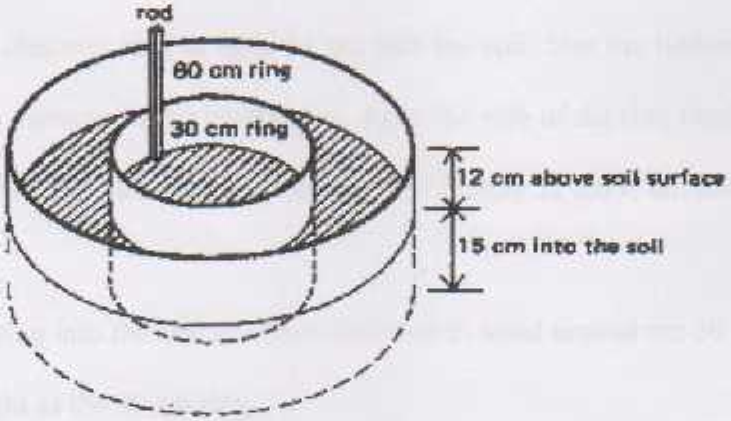

Figure (4.5): Double Ring Infiltrometer

4.4.3 Test Methodology

(a) Equipment required

1- Shovel / hoe.

2. Hammer (2 kg).

3- Watch or clock.

4- 5 liter buckets.

5- At least 100 liters of water.

6- Ring infiltrometer of 30 cm inner diameter and 60 cm outer diameter. Instead of the outer cylinder, a bund could be made to prevent lateral water flow.

7- Measuring rod graduated in mm (e.g. 300 mm ruler).

(b) Method of work

The following steps show how to carry out the experiment of infiltration measurements in the field.

1- Hammer the 30 cm diameter ring at least 15 cm into the soil. Use the timber to protect the ring from damage during hammering. Keep the side of the ring vertical and drive the measuring rod into the soil so that approximately 12 cm is left above the ground.

2- Hammer the 60 cm ring into the soil or construct an earth bund around the 30 cm ring to the same height as the 30 cm ring .

3- Start the test by pouring water into the inner ring until the depth is approximately 70-100 mm. At the same time, add water in the space between the two rings or the ring and the bund to the same depth. Do this quickly.

4- The water in the bund or within the two rings to prevent a lateral spread of water from the infiltrometer.

5- Record the clock time when the test begins and note the water level.

6- After 1-2 minutes, record the drop in water level in the inner ring on the measuring rod and add water to bring the level back to approximately the original level at the start of the test. Record the water level. Maintain the water level outside the ring similar to the level inside.

7- Continue the test until the drop in water level is the same over the same time interval. Take reading frequently (e.g. every 1-2 minutes) at the beginning of the test, but extend the interval between readings as the time foes on (e.g. every 20-30 minutes).

Table (4.6) shows the results of infiltration rate test for the different soils samples by locations.

Table (4.6): Infiltration table:

No.	Coordinate Of soil sample	Infiltration rate(mm/hour)	No.	coordinate	Infiltration rate(mm/hour)
1	(106000,160000)	37	16	(94000,157000)	28
2	(106000,163000)	26	17	(94000,160000)	31
3	(103000,160000)	41	18	(91000,145000)	19
4	(103000,163000)	21	19	(91000,148000)	28
5	(100000,160000)	43	20	(91000,151000)	23
6	(100000,157000)	22	21	(91000,154000)	23
7	(100000,154000)	19	22	(91000,157000)	41
8	(97000,151000)	32	23	(91000,160000)	36
9	(97000,154000)	48	24	(88000,142000)	15
10	(97000,157000)	26	25	(88000,145000)	47

11	(97000,160000)	42	26	(88000,148000)	23
12	(97000,163000)	19	27	(88000,151000)	22
13	(94000,148000)	49	28	(88000,154000)	19
14	(94000,151000)	37	29	(88000,157000)	29
15	(94000,154000)	31	30	(88000,160000)	28

4.5 Soil moisture

Soil moisture can be estimated by butting the sample in furnace at (150 C^0) the difference in the weight is the soil moisture, table (4.7) shows the calculations procedure for soil moisture:

Table (4.7): Soil moisture.

TEST NO	BOTTLE NO	BOTTLE AND WET	BOTTLE AND DRY	LOSS	BOTTLE EMPTY	DRY WEIGHT	MOISTURE CONTENT %	COORDINATE OF SOIL SAMPLE
1	B5	173.75	169.53	4.22	31.23	138.30	3.05	(91000-151000)
2	3	177.85	173.65	4.20	31.46	142.19	2.95	(94000-154000)
3	E6	201.46	191.82	9.64	31.66	160.16	6.02	(88000-142000)
4	A2	235.50	226.72	8.78	31.89	194.83	4.51	(88000-157000)
5	14	199.76	197.96	1.80	30.80	167.16	1.08	(106000-60000)
6	E20	209.27	205.45	3.82	27.53	177.92	2.15	(91000-157000)
7	11	202.70	198.48	4.22	26.62	171.86	2.46	(94000-151000)
8	B15	212.63	205.20	7.43	31.49	173.71	4.28	(91000-160000)
9	160	202.93	187.01	15.92	31.56	155.45	10.24	(91000-148000)
10	E20	194.82	178.47	16.35	30.86	147.61	11.08	(91000-145000)
11	E2	220.50	219.75	0.75	31.38	188.37	0.40	(88000-154000)
12	B9	236.30	231.29	5.01	31.15	200.14	2.50	(88000-145000)
13	40	175.99	172.94	3.05	32.28	140.66	2.17	(88000-151000)
14	5	204.99	190.85	14.14	29.46	161.39	8.76	(91000-154000)
15	B14	168.66	166.46	2.20	26.94	139.52	1.58	(88000-160000)
16	D3	250.46	245.22	5.24	30.82	214.40	2.44	(88000-148000)

17	D13	187.69	179.31	8.38	21.85	157.46	5.32	(94000-157000)
18	D16	178.34	196.91	18.57	30.75	166.16	11.18	(94000-160000)
19	B7	157.85	149.67	8.18	31.28	118.39	6.91	(103000-63000)
20	D7	196.87	190.46	6.41	31.69	158.77	4.04	(103000-60000)
21	E17	186.95	167.21	19.74	32.8	134.41	14.69	(100000-57000)
22	B19	183.28	176.23	7.05	31.86	144.37	4.88	(97000-151000)
23	B8	207.58	199.8	7.78	31.63	168.17	4.63	(100000-54000)
24	E16	211.02	205.79	5.23	31.76	174.03	3.01	(100000-60000)
25	C9	217.59	213.37	4.22	32.31	181.06	2.33	97000-154000)
26	E11	171.02	159.15	11.87	31.7	127.45	9.31	(97000-157000)
27	A19	208.64	203.77	4.87	29.9	173.87	2.80	(97000-160000)
28	C18	203.77	194.09	9.68	30.97	163.12	5.93	(94000-148000)
29	B6	196.69	186.14	10.55	31.65	154.49	6.83	(97000,163000)
30	A11	202.99	198.88	4.11	29.14	169.74	2.42	(106000-63000)

4.6 Organic matter

In this of test the samples are burn at (400 C^0), and then the difference in the weight is the organic content, table (4.8), illustrate the procedure of calculating the organic content:

Table (4.8): Organic matter.

No.	Coordinate of soil sample	Sample weight g	Sample after burn g	Organic content g	%
1	(106000,160000)	118.2	116	2.2	2%
2	(106000,163000)	129.7	126	3.7	3%
3	(103000,160000)	120.5	118	2.5	2%
4	(103000,163000)	96	94	2	2%
5	(100000,160000)	109.3	108	1.3	1%
6	(100000,157000)	122	120	2	2%
7	(100000,154000)	134.1	130	4.1	3%
8	(97000,151000)	102.2	100	2.2	2%
9	(97000,154000)	128.5	126	2.5	2%
10	(97000,157000)	126.3	124	2.3	2%
11	(97000,160000)	143.7	140	3.7	3%

12	(97000,163000)	105.2	102	3.2	3%
13	(94000,148000)	124.7	120	4.7	4%
14	(94000,151000)	103.6	100	3.6	3%
15	(94000,154000)	134	130	4	3%
16	(94000,157000)	126	122	4	3%
17	(94000,160000)	121.4	118	3.4	3%
18	(91000,145000)	133.8	132	1.8	1%
19	(91000,148000)	127.5	124	3.5	3%
20	(91000,151000)	118.8	116	2.8	2%
21	(91000,154000)	99.35	96	3.35	3%
22	(91000,157000)	104.5	102	2.5	2%
23	(91000,160000)	114.2	110	4.2	4%
24	(88000,142000)	104.4	100	4.4	4%
25	(88000,145000)	133.7	128.7	5	4%
26	(88000,148000)	110.5	108	2.5	2%
27	(88000,151000)	118.7	116	2.7	2%
28	(88000,154000)	144.6	144.3	0.3	0%
29	(88000,157000)	123	118	5	4%
30	(88000,160000)	145	144	1	1%

4.7 Contour Map

A contour lines map with 5m contour for West Bank interval is available at the (GIS) lab of Palestine Polytechnic University. The map is clipped to the boundary of the Hebron districted is used to generate the Digital Elevation Model (DEM) of the study area .This (DEM), is used to calculate the (LS) factor of (USLE), figure (4.6), shows the contour map:

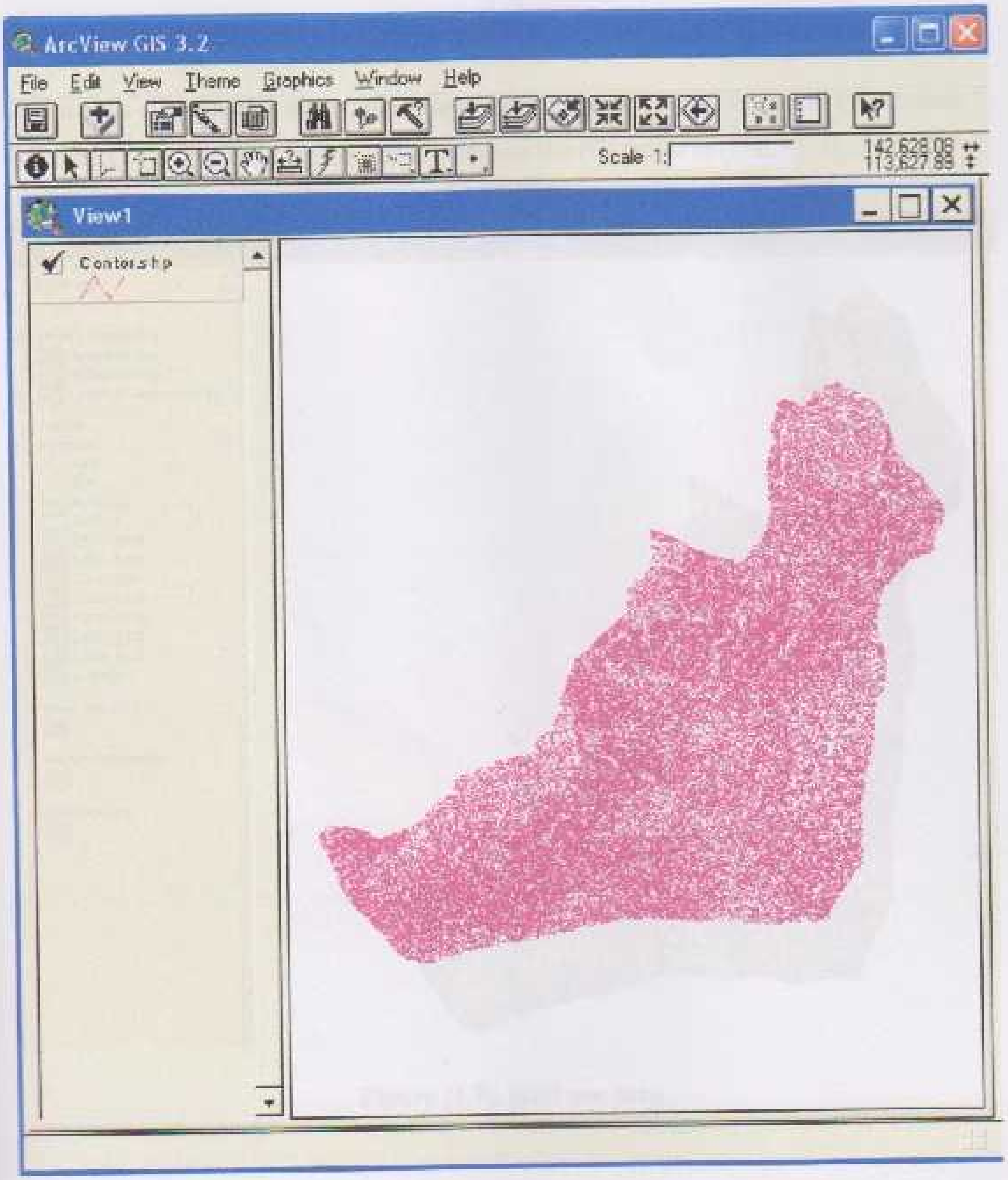

Figure (4.6): Hebron District contour map.

4.8 Land use Map

This map is clipped from the available land map at the GIS lab of Palestine Polytechnic University. The clipped map is used to calculate the (C) factor at (USLE), figure (4.7).

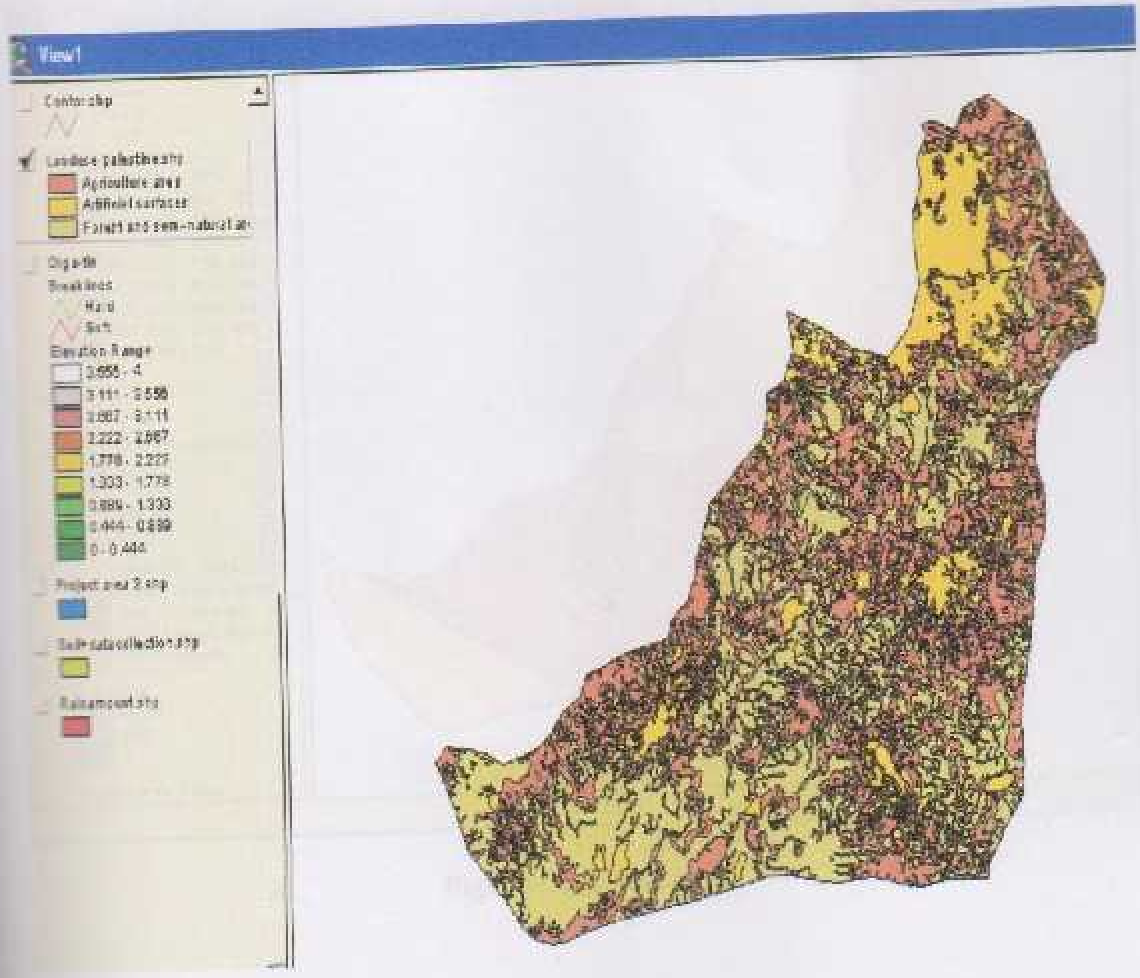

Figure (4.7), land use map

4.9 Soil Map

A soil association map of the study area is digitized from a soil association published by maher owaiwi and wael awadallah (2005).

This map is important to calculate the (K) factor of USLE where the soil texture and the percent of organic matter is determined, figure (4.8).

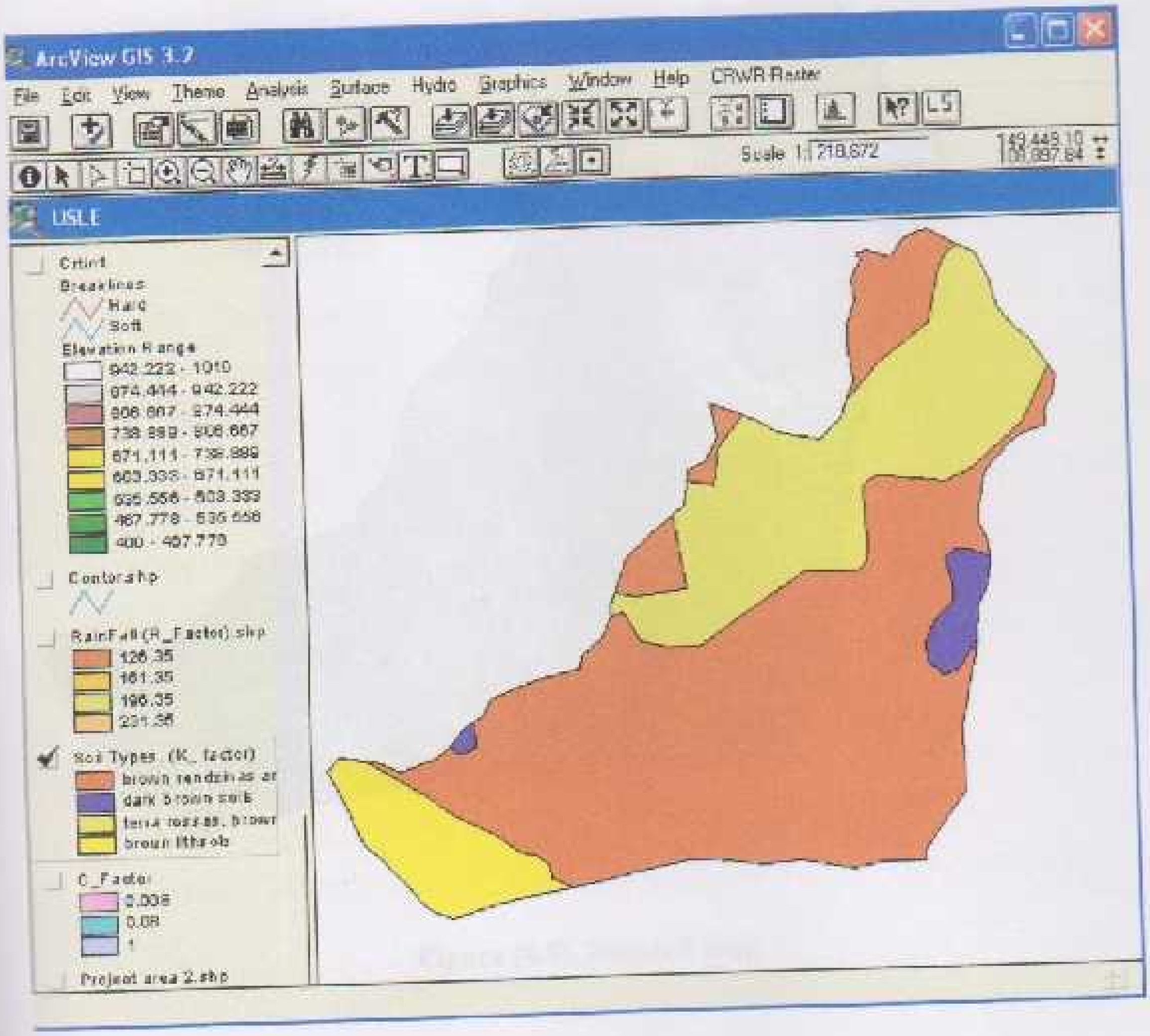

Figure (4.8). Soil map

4.10 Rainfall Map

A Rainfall map is digitized from rainfall map published by maher owaiwi and wael awadallah, 2005. This map is important to calculate the(R) factor of USLE, figure (4.9).

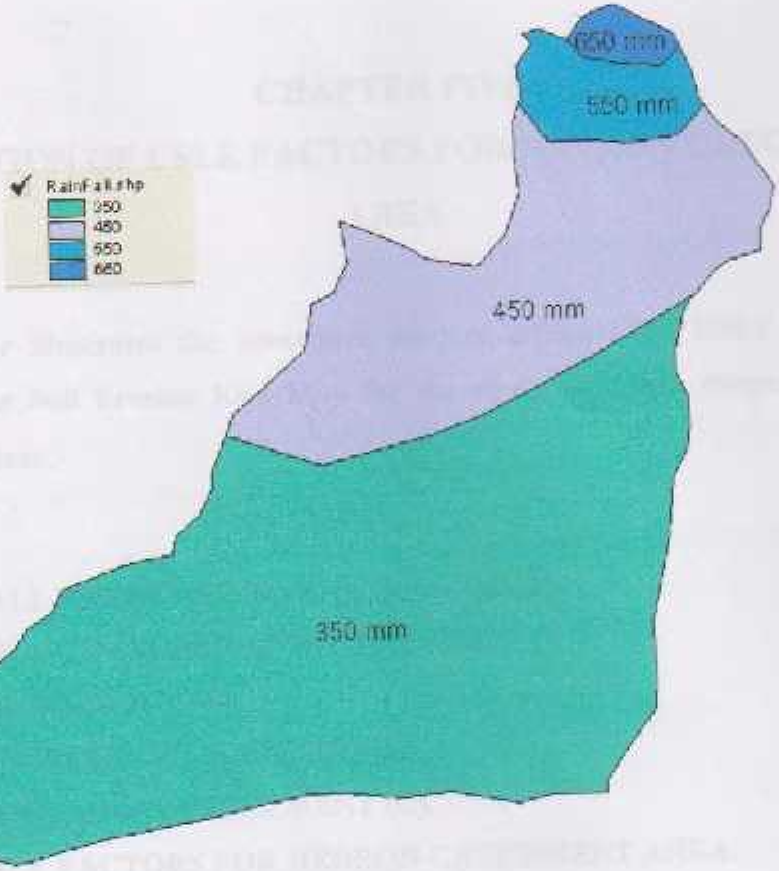

Figure (4.9), Rainfall map

CHAPTER FIVE

ESTIMATION OF USLE FACTORS FOR HEBRON CATCHMENTS AREA

This chapter illustrates the procedure used to estimate the USLE factors, and describes the Soil Erosion Risk Map for the study area, this chapter covers the following Items:

5.1 RAINFALL RUNOFF EROSIVITY FACTOR (R).

5.2 SOIL LENGTH GRADIENT FACTOR (LS).

5.3 SOIL ERODIBILITY (K).

5.4 CONSERVATION PRACTICES (P).

5.5 CROPPING AND MANAGEMENT (C).

5.6 THE USLE FACTORS FOR HEBRON CATCHMENT AREA.

5.7 FINAL USLE EROSION RISK MAP FOR HEBRON CATCHMENT AREA.

5.8 T VALUE.

5.9 MANAGEMENT STRATEGIES TO REDUCE SOIL LOSSES.

CHAPTER FIVE
ESTIMATION OF USLE FACTORS FOR HEBRON CATCHMENTS AREA

5.1 Rainfall-Runoff erosivity factor (R).

Erosion is caused both by the energy of rainfall itself, and by overland flow runoff. The rainfall-runoff erosivity factor "R" estimates the erosive forces of rainfall and its associated runoff, and is directly related to the intensity and depth of rainfall. To calculate rainfall-runoff erodibility factors we will use the following equation :

$$R = 3.85 + 0.35(P)$$

Where, R = rainfall-runoff erodibility,

P = Average annual rainfall (mm/yr).

Rainfall data from different metrological stations distributed all over Hebron District is used to calculate the (R) factor. Table (5.1) shows a sample of rainfall sheet obtained from Hebron station, also a digitized Rainfall map of a rainfall map published by maher owaiwi and wael awadallah is used, figure (5.9).

Table (5.1): Total monthly rainfall for Hebron station (mm), season (2005/2006).

Day	Month											
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1												
2						3		2				
3					34.8			6.5				
4					30.5		0.9	3.5				
5						7.6						
6					44.5	1.2						
7				11.3		26.6						
8				8.2		33.3	0.2					
9						25	16.4					

10							17.4					
11				0.3		10.5						
12						10	5.8					
13							0.7					
14												
15												
16				6.1								
17			47									
18			1.4		1							
19			6.6									
20					1.4	1						
21												
22			26.6									
23			82.6									
24				16.6				0.7				
25				8.2								
26												
27			47									
28		0.9										
29		3.3										
30												
31												
Total	0	4.2	211	49.7	153	118.2	49	12.7	0	0	0	0
Y-Total						598						

5.2 Soil Length gradient factor (LS).

Both the length and steepness of a slope influence soil erosion and need to be part of the topographic factor (LS). The relationship of erosion to slope steepness is best defined by a quadratic equation:

$\text{Erosion} = a(\text{slope})^2 + b(\text{slope}) + c$ (where a, b, and c are constants).

And in other form it can be presented by the next formula:

LS = (L(0.065+0.045*S+0.0065*S^2))^0.5)/22.13

When L is slope length in meter and S slope steepness in percent.

By using this equation and a contour map we will be able to estimate (LS) factor.

5.3 Soil erodibility (K).

(K) is the soil erodibility factor. (see table (5.2), K Factor data). It is the average soil loss in tons per unit area for a particular soils type, continuous fallow with an arbitrarily selected slope length of 22.13 m. and slope steepness of 9%. K is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Texture is the principal factor affecting K, but structure, organic matter and permeability also contribute.

Table (5.2): K Factor Data, ref (4).

	Percent of organic matter		
Textural Class	**Average**	**Less than 2 %**	**More than 2 %**
Clay	0.22	0.24	0.21
Clay Loam	0.30	0.33	0.28
Coarse Sandy Loam	0.07	--	0.07
Fine Sand	0.08	0.09	0.06
Fine Sandy Loam	0.18	0.22	0.17
Heavy Clay	0.17	0.19	0.15
Loam	0.30	0.34	0.26
Loamy Fine Sand	0.11	0.15	0.09
Loamy Sand	0.04	0.05	0.04
Loamy Very Fine Sand	0.39	0.44	0.25
Sand	0.02	0.03	0.01
Sandy Clay Loam	0.20	--	0.20
Sandy Loam	0.13	0.14	0.12
Silt Loam	0.38	0.41	0.37
Silty Clay	0.26	0.27	0.26
Silty Clay Loam	0.32	0.35	0.30

Very Fine Sand	0.43	0.46	0.37
Very Fine Sandy Loam	0.35	0.41	0.33

Soil map for Hebron catchments area is prepared by digitizing exiting soil map with scale 1:250000 see section (4.9). An intensive field sampling of soil sample is conducted to identify the soil class texture and infiltration rate, moisture content and organic matter percent.

5.4 Conservation practices (P)

Factor P represents soil conservation practices that essentially slow the runoff water and thus reduce the amount of soil it can carry , and it depend on the soil type , texture and farming way .

Table (5.3); shows relation between land use patterns and their most common P code values, waniehista and yousef (1993).

Table (5.3): P Factor, ref (14)

Land Use	Code P
Cropland	0.5
Forest	1
Pasture	1
Urban	1

5.5 Cropping and management (C)

The values of C factor for use in rational formula are given by waniehista and yousef (1995) and are given in table (5.4).

Table (5.4): C Factor, ref (14)

Land Use	Code C
Crop land	0.08
Forest land	0.005
Pasture land	0.01
Urban land	1
Bare Rock	1
Water	0

5.6 Estimate of USLE factors for Hebron catchment area

5.6.1 Rainfall-Runoff erosivity factor (R)

Figure (5.1) shows the calculation of R factor using the Field Calculator tool in (ArcView 3.2).

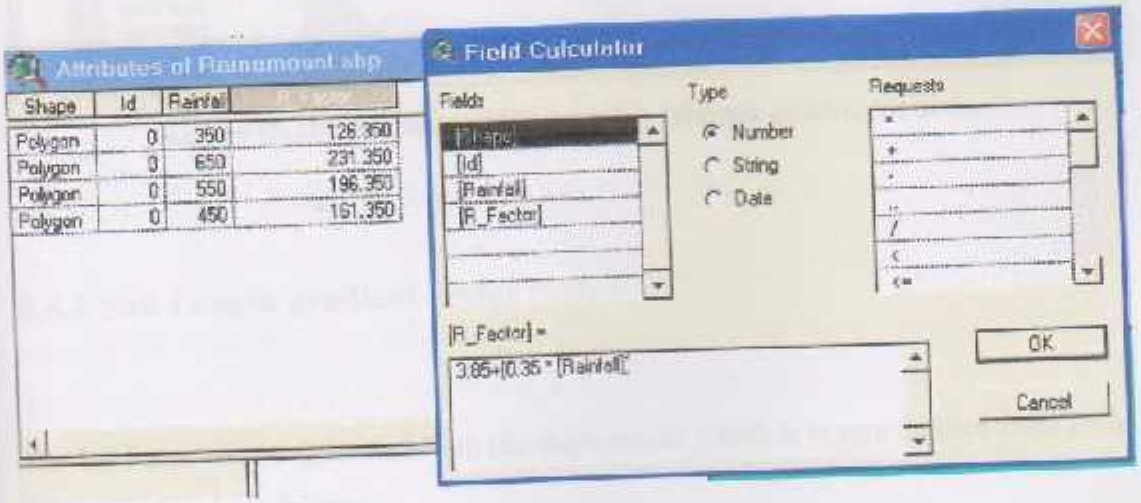

Figure (5.1): Calculation of R factor using the Field Calculator Tool in ArcView 3.2.

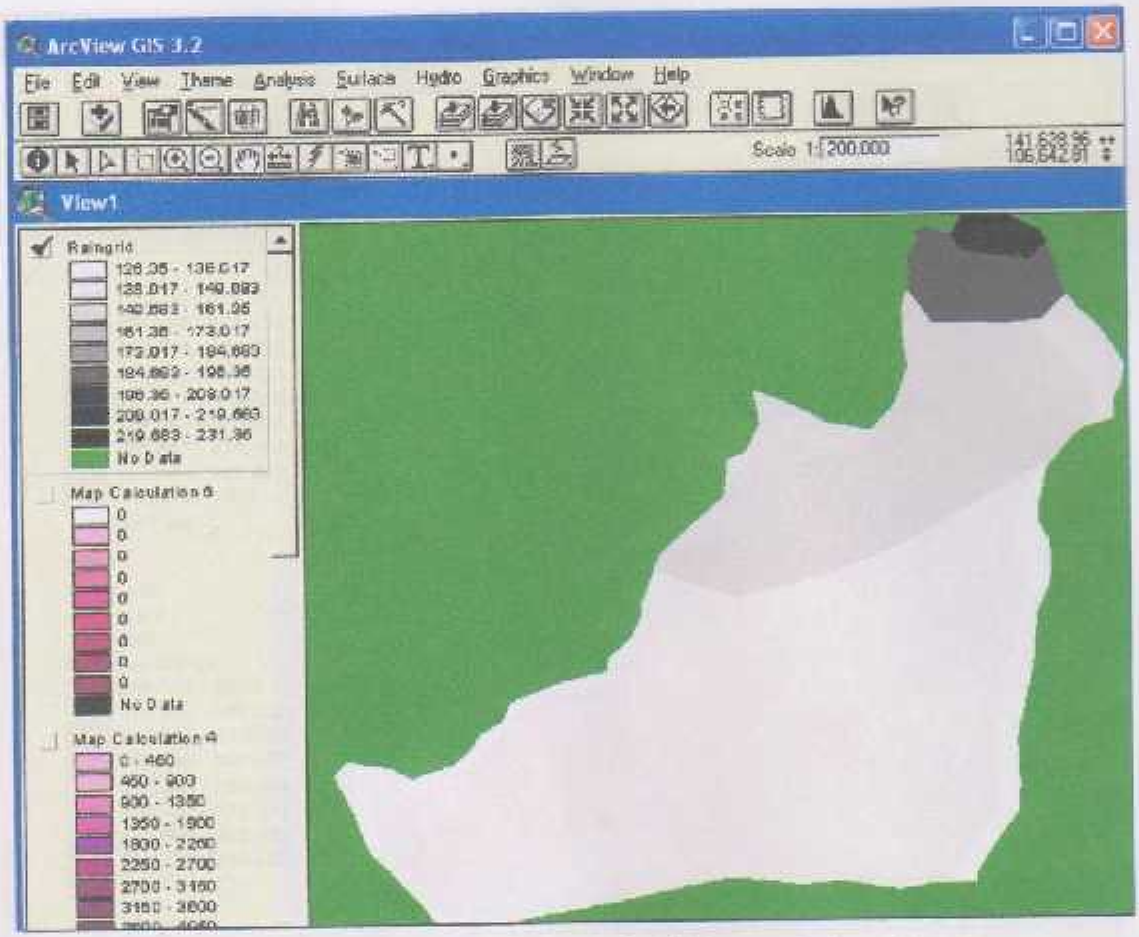

Figure (5.2): The raster rain map for Hebron catchment area.

5.6.2 Soil Length gradient factor (LS)

The LS factor can be estimated from the slope model which is in turn derived from DEM. The procedure is as follow;

Make the DEM active, figure (5.3), select the Surface pull down menu as shown below and select the Derive Slope option.

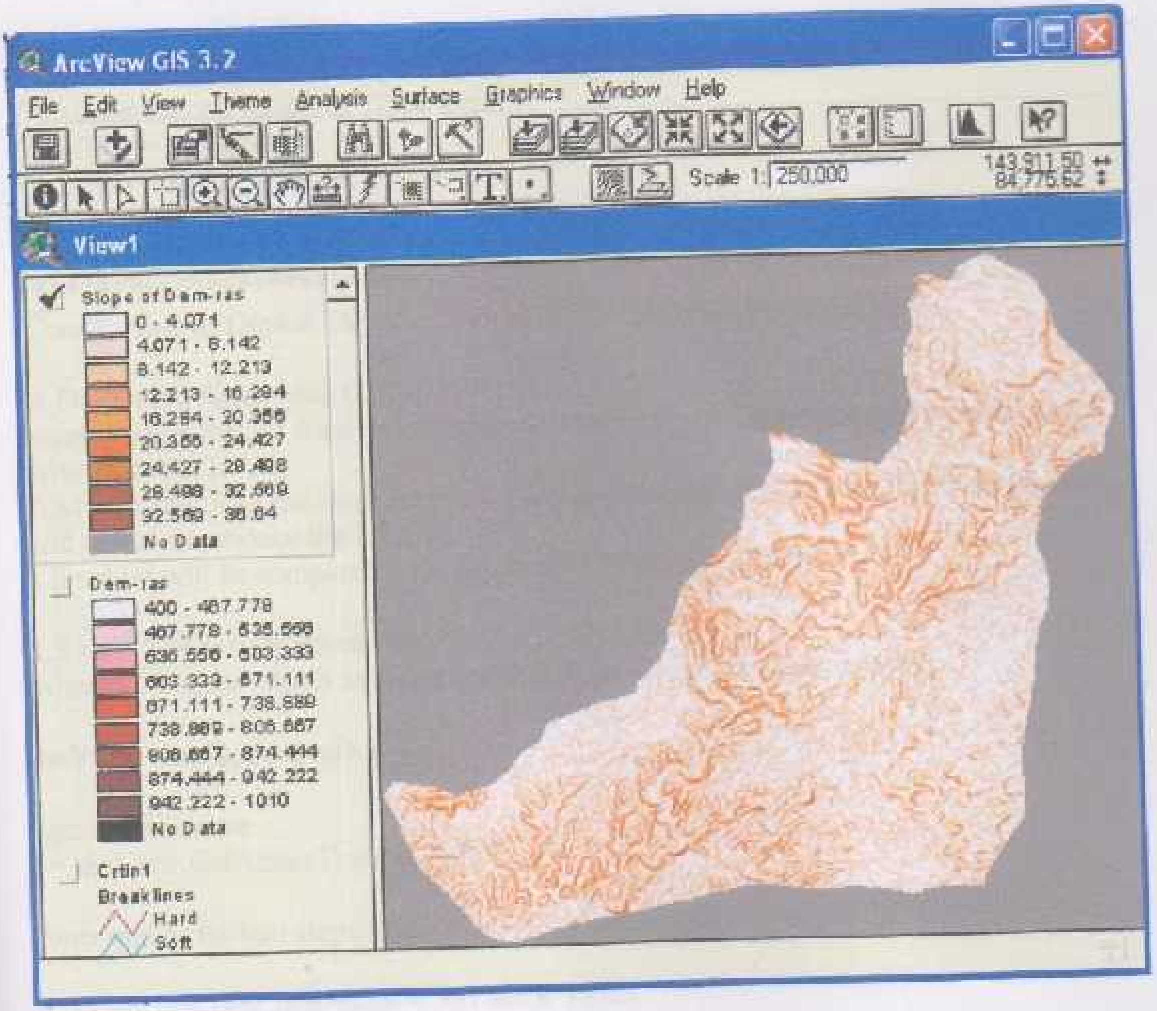

Figure (5.4): Output map for slope.

The following equation is used to calculate the LS factor.

LS = (L(0.065+0.045*S+0.0065*S^2))^0.5)/22.13

When L is slope length in meter and S slope steepness in percent.

The following script shows how to estimate (LS) factor using the previous equation and ArcView:

```
(' Calculate Slope length of Slope Grid
'TanThita = Rise/Run
'CosThita = Run/r ' R is the Diameter
'
'*****************************************************************************
**************************
'Constructing of Digital Elevation Model (DEM) and building the LS map

'A Digital Elevation Map (DEM) will be
'created using the 3D Analyst Extension of ArcView. A slope degree grid model was
drive from the DEM.
'And then calculate the slope length (L) and slope steepness (S) from the slope degree
grid model to produce the LS map.
'LS values will be computed from equation (1) (Morgan, 1986):

'LS = (L(0.065+0.045*S+0.0065*S^2))^0.5)/22.13                                (1)
'where, L is slope length in meter and S is slope steepness in percent (%).

theView = av.GetActiveDoc

' get active theme
t = theView.GetActiveThemes.Get(0)

' turn grid or tin into slope grid

if (t.GetClass.GetClassName = "GTheme") then

  g = t.GetGrid
end
'


' check if output is ok
if (g.HasError) then
  return NIL
end
 Grid.SetVerify(#GRID_VERIFY_OFF)

g = g.int

if (g.isInteger) then   ' beging of if

g.buildVAT
```

```
myvtab = g.getvtab

If (myVtab =nil)then
 end
run =  g.GetCellSize


myVtab.seteditable(True)
'**************************************************************************
SlengthF = Field.Make( "Slengh",#FIELD_CHAR, 15, 0 )
PSlopeF =  Field.Make( "PSlope",#FIELD_CHAR, 15, 0 )
LSF =  Field.Make( "LS",#FIELD_DOUBLE, 15, 3 )

Fieldlist = {}
Fieldlist.add(SlengthF)
Fieldlist.add(PSlopeF)
Fieldlist.add(LSF)

SlenghtF = myVtab.AddFields(Fieldlist)

ValueF = myVtab.FindField("Value")
L = myVtab.FindField("Slengh")
s = myVtab.FindField("PSlope")
LS = myVtab.FindField("LS")

 for each i in myvtab
      thita = myVtab.ReturnValue(ValueF,i)
         r = run / thita.AsRadians.cos
         Rise = run * thita.AsRadians.tan
         PercentSlope = (Rise/Run) * 100

   'Calculate LS
      X =  0.0065 * (PercentSlope^2)
       X1 = (0.045 * PercentSlope)
        X2 =  (0.065 + X1 + X)
        X3 =  (r * x2)^0.5
         LS_Vallue = X3/22.13

      myVtab.SetValue( L, i, r.AsString )
      myVtab.SetValue( S, i, PercentSlope.AsString )
      myVtab.SetValue( LS, i, LS_Vallue.AsString )
'****************************************************************************
****************************************
 end
```

```
' Msgbox.info(mygCellsize.AsString,"Value")
' check if output is ok

 if (g.HasError) then

  return NIL
end
 r = SourceManager.PutDataSet(GRID,"", "maher".AsFilename,TRUE)
 ' check for Cancel from dialog
   if (r = NIL) then
   return NIL
    end
 g.Rename(r)
' create a theme
gthm = GTheme.Make(g)

' set name of theme

' add theme to the specifiedView
theView.AddTheme(gthm)



end    ' end of if  )
```

Figure (5.5), shows how to calculate the (LS) factor using the previous script in ArcView, and figure (5.6). shows the output.

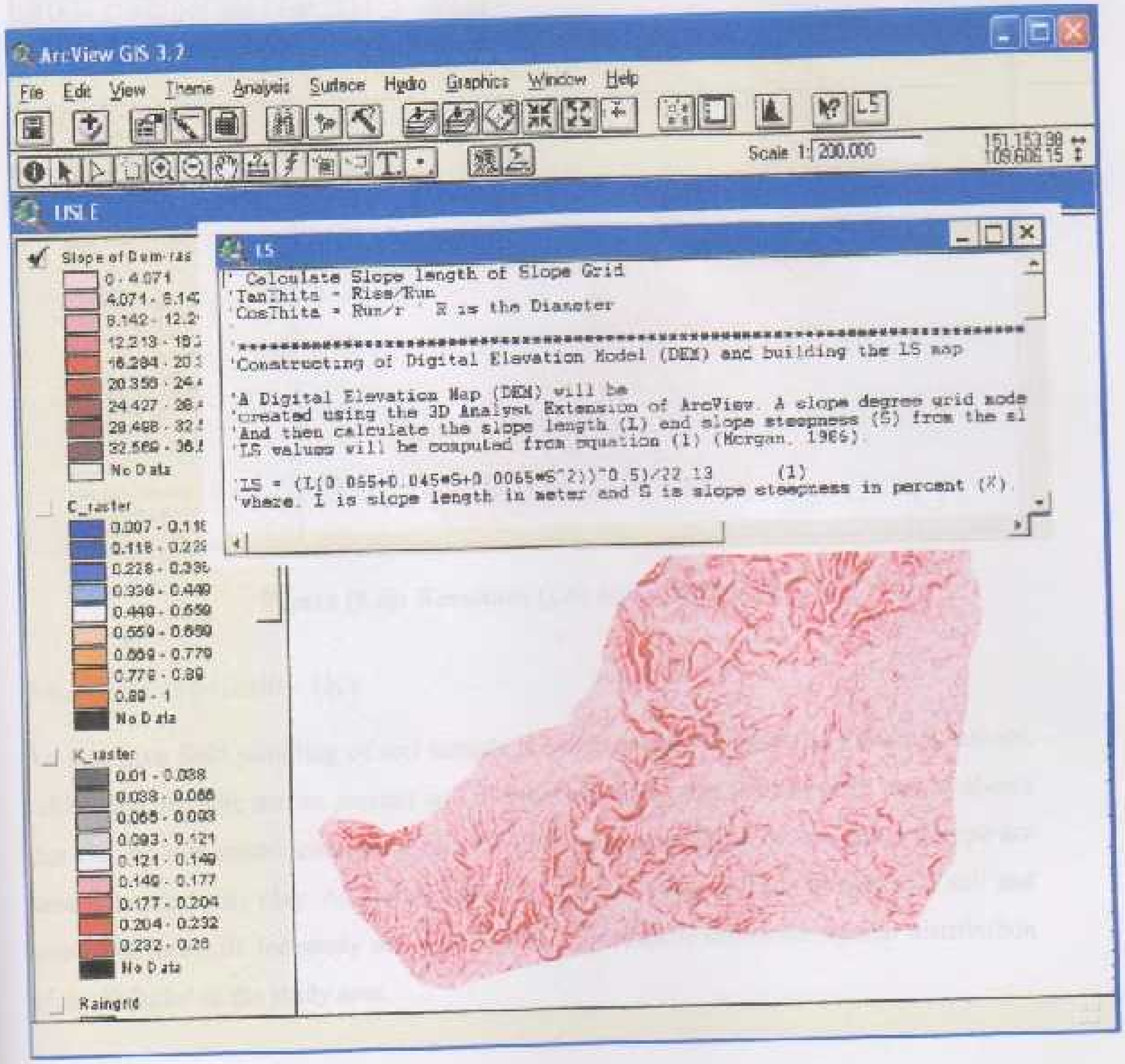

Figure (5.5): Using ArcView to calculate (LS) factor.

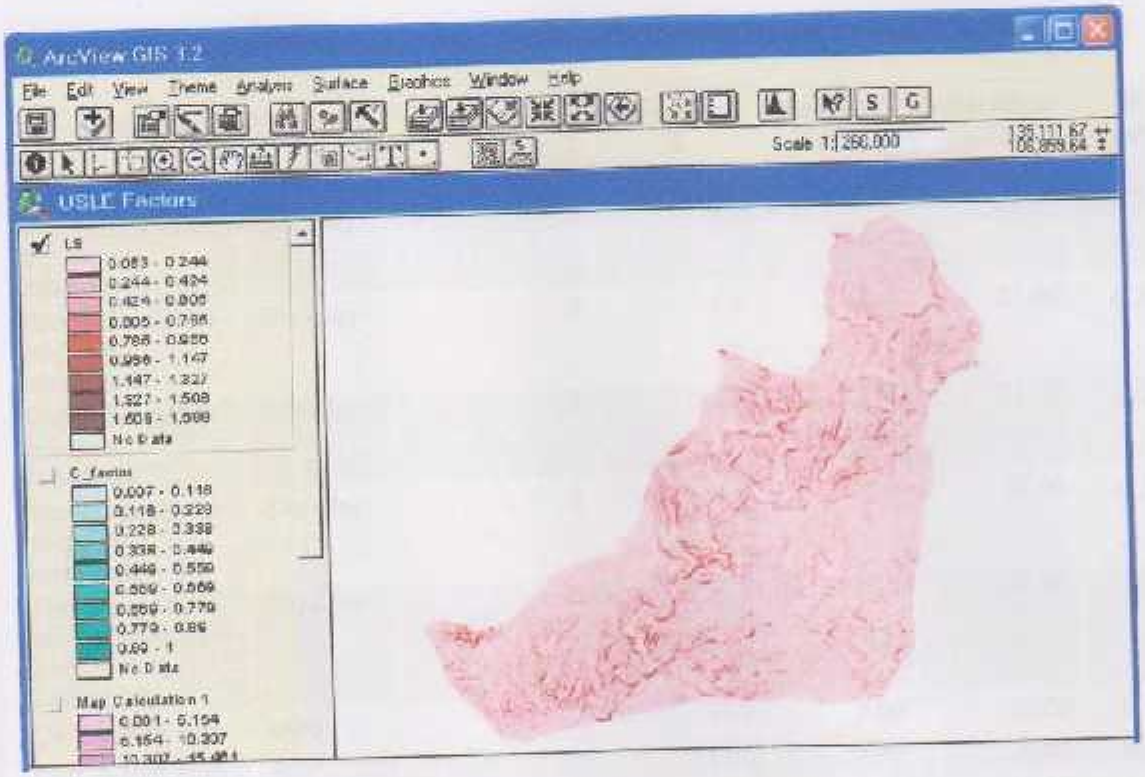

Figure (5.6): Resultant (LS) factor grid map.

5.6.3 Soil erodibility (K)

An intensive field sampling of soil sample is conducted to identify the soil class texture, infiltration, organic matter percent and moisture content. Analyses of field results shows that the organic matter content of all soil types are more than 2% and the soil type are sand, loam and silty clay. And using table (5.2), the K factor is 0.26 for silty clay soil and loam soil, and 0.01 for sandy soil, table (5.5). Figure (5.7) shows the spatial distribution of the K factor in the study area.

Table (5.5), Shows the characteristic of the different Soil Association groups.

Type	Texture	Texture code	Moisture %	Organic Matter %	Infiltration rate mm/hour	K Fcator
Brown rendzinas and pale rendzinas	Sity Clay	2	4.6	2.71	27.47	0.26
Brown rendzinas and pale rendzinas	Sity Clay	2	1.1	2.00	37.00	0.26
Brown rendzinas and pale rendzinas	Sity Clay	2	1.1	2.00	37.00	0.26
Brown rendzinas and pale rendzinas	Sity Clay	2	4.9	2.00	32.00	0.26
Terra rossas, brown revdzinas and pale rendzinas	Sity Clay	2	5.9	2.13	30.88	0.26
Dark brown soils	sand	1	11.0	3.00	30.00	0.01
Dark brown soils	sand	1	11.0	3.00	30.00	0.01
Brown rendzinas and pale rendzinas	Sity Clay	2	6.0	4.00	15.00	0.26
Broun lithosols and loessial serozems	loam	3	6.0	4.0	15.00	0.26

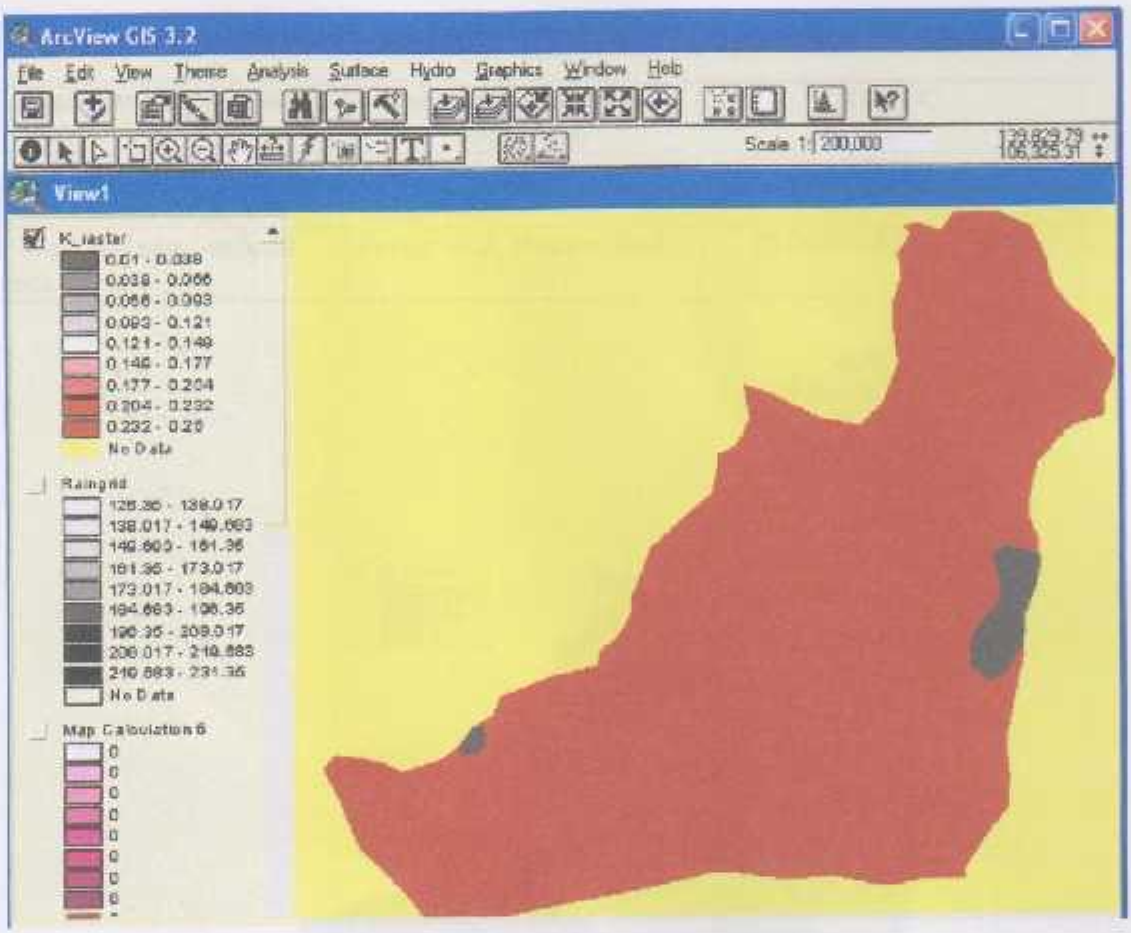

Figure (5.7): (K) factor.

5.6.4 Cropping and management (C)

Table (5.6) shows the Land Use patterns that are expected to be found in Study area and its correlation with wenielish and yousef (1993) suggested land use and C factor, while figure (5.8) and figure (5.9) shows the spatial distribution of the (C) factor in the study area as vector and raster, respectively.

Table (5.6): C Factor

Land Use in study area	Wanielista and Yousef Land Use	Code C
Agriculture area	Crop land	0.08
Artificial surfaces	Urban land	1
Forest and semi-natural area	Forest land, Pasture land	(0.005+0.01)/2=0.008

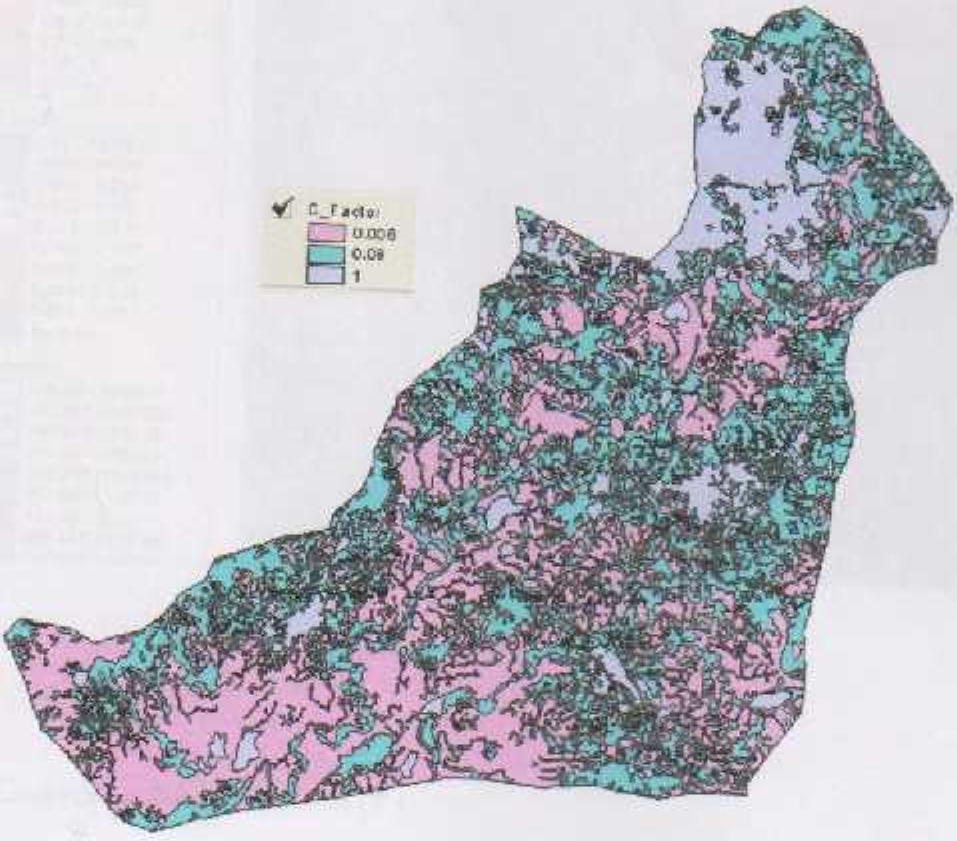

Figure (5.8). The spatial distribution of the C Factor in the study area

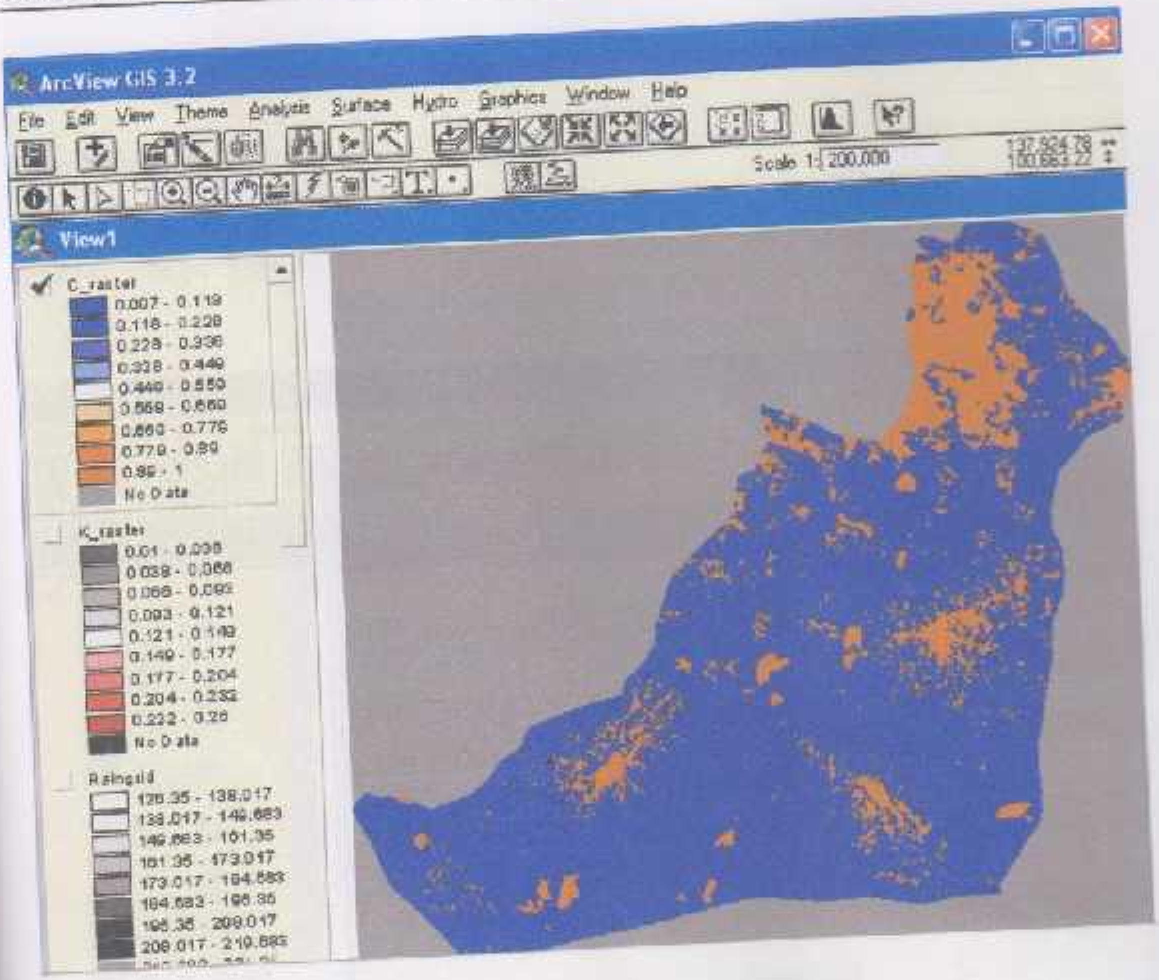

Figure (5.9) :(C) Factor.

5.6.5 Conservation practices (P)

The values of P for use in USLE rational formula as given by Wanielista and Yousef (1993), are given in the Table (5.3).For the study area, the value of P is set to 1.

5.7 Final USLE Erosion Risk Map for Hebron catchment area

By multiplying all the five factors, using ArcView, the final erosion model is calculated, figure (5.10). Figure (5.11) shows the final Erosion Risk map using the USLE model in tons per acre per year.

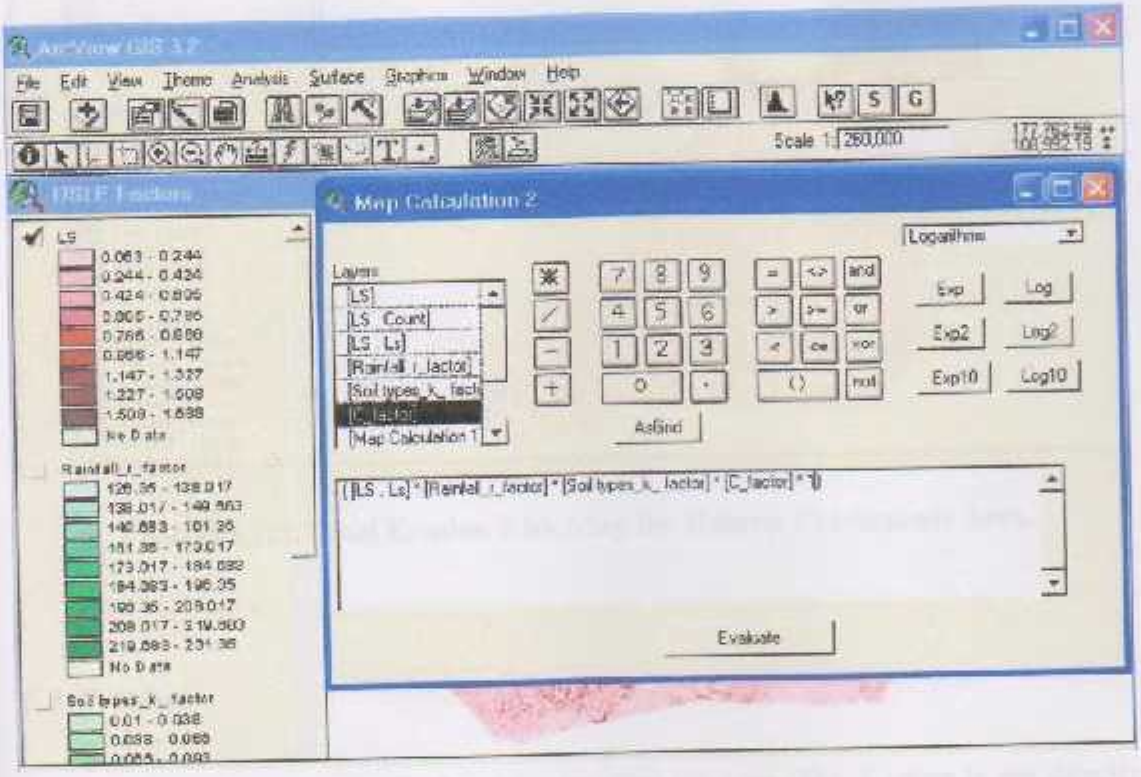

Figure (5.10): Calculating the erosion model

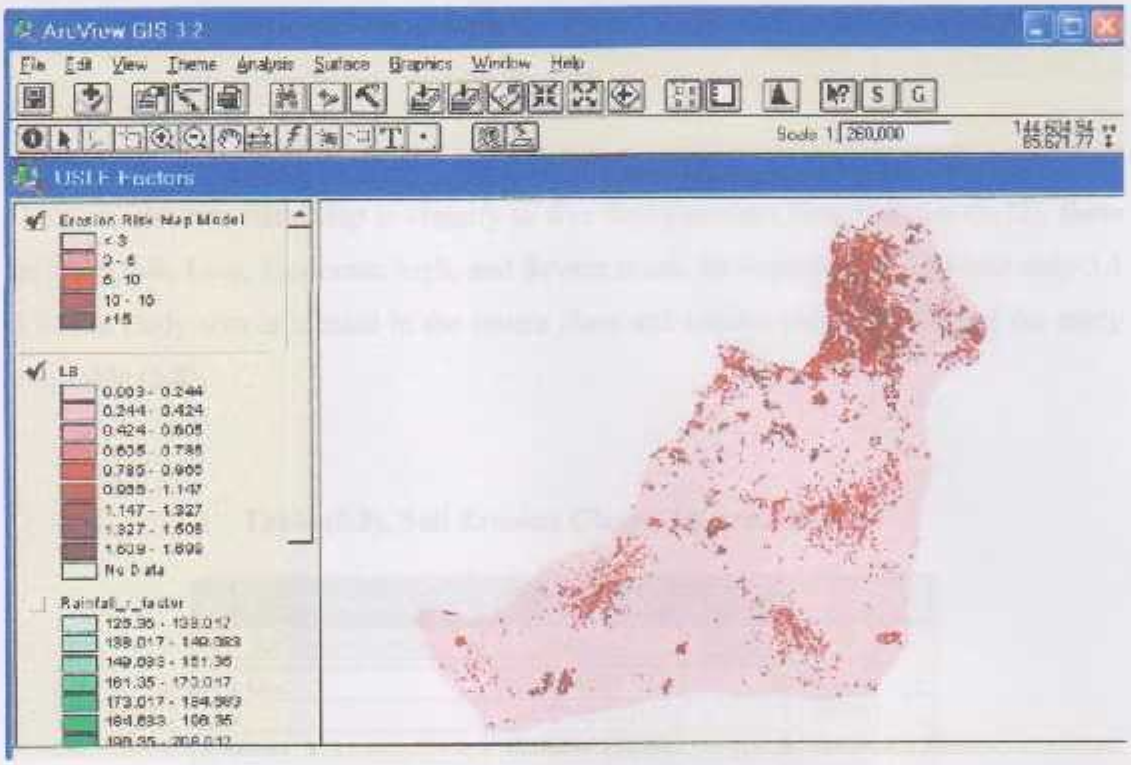

Figure (5.11): Final Erosion Risk Map for Hebron Catchments Area.

5.8 T value

T is soil loss tolerance expressed in tons per acre per year. The T value is not directly used in USLE. However, it is important in the use of the soil loss equation for conservation planning. Soil loss tolerance is the maximum amount of soil loss in tons per acre per year, which can be tolerated and still permit a high level of crop productivity to be sustained economically and indefinitely.

Table (5.7), T value.

Soil erosion class	Potential soil loss (tons/acrs/year)
Very low (tolerable)	<3
Low	3-5

Moderate	5-10
High	10-15
Severe	>15

The Final Erosion Risk Map is classify to five Soil Erosion Classes, figure (5.12), these are Very low, Low, Moderate, high, and Severe areas. Its important to note that only 3.1 % of the study area is located in the severe class and consist about 9.1 Km² of the study area, table (5.8).

Table (5.8), Soil Erosion Classes by area present.

Soil Erosion Classes Summary By Area

Soil Erosion Classes	Area (m2)	% of Area
Very Low	249861549.917700	85.000000
Low	4458790.923400	1.500000
Moderate	15069947.761600	5.100000
High	15574103.399300	5.300000
Severe	9107702.815300	3.100000
Total	294072094.817300	100.000000

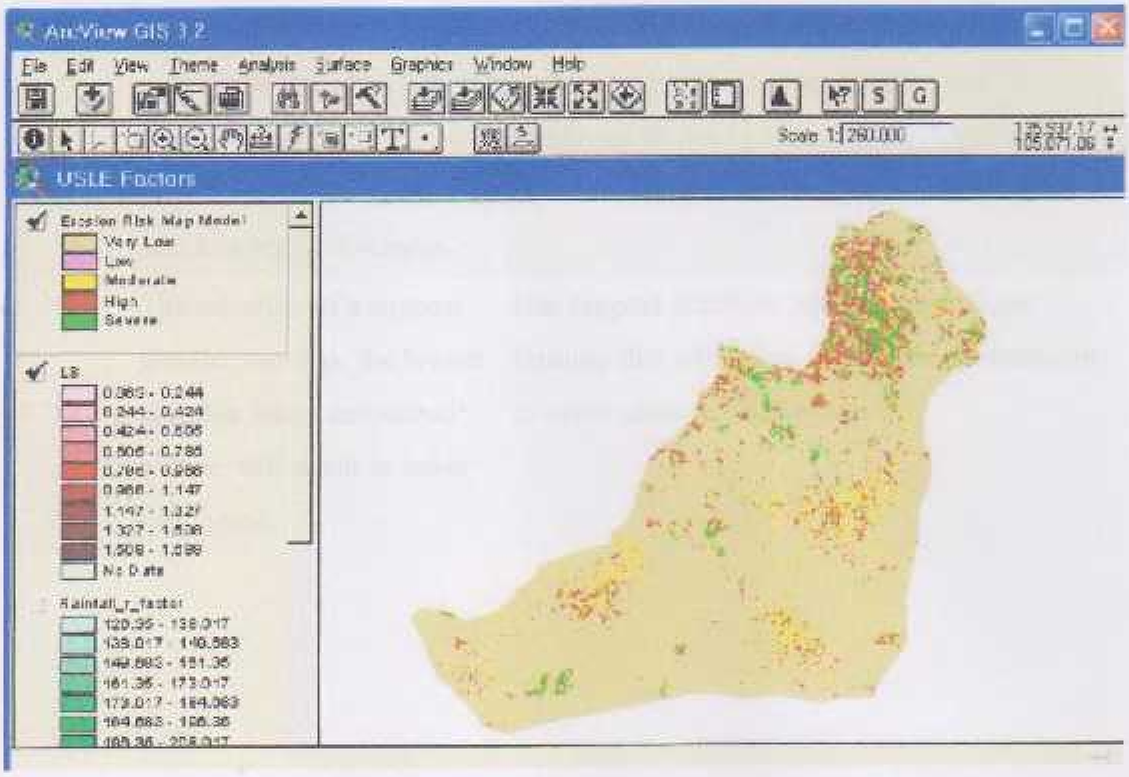

Figure (5.12): Soil Erosion Risk Classes Map for Hebron Catchments Area.

5.9 Management Strategies to Reduce Soil Losses

The table (5.9), below explains the management strategies to reduce soil losses

Factor	Management Strategies	Example
R	The R Factor for a field cannot be altered	---
K	The k Factor for a field cannot be altered	---
Ls	Terraces may be constructed to reduce the slope length resulting in lower soil losses.	Terracing requires additional investment and will cause some inconvenience in farming. Investigate other soil conservation practices first.

C	the selection of crop types and tillage methods that result in the lowest possible C factor will result in less soil erosion.	Consider cropping systems that will provide maximum protection for the soil. Use minimum tillage systems where possible.
p	The selection of a support practice that has the lowest possible factor associated with it will result in lower soil losses.	Use support practices such as cross slope farming that will cause deposition of sediment to occur close to the source.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

1. The visual analysis indicates that the most critical factors in the USLE are:
   a. The topographic (LS) factor; and
   b. The soil erodibility (K) factor.

2. The USLE was used to predict soil erosion in the Hebron Catchment Area. As seen from the derived erosion map, figure (5.12), most areas have minor soil erosion which is less than 3 tons/ac/yr (about 85% of study area). The areas of highest erosion occurred in the places where the slopes are the greatest and consist a bout 3.1% of the study area.

3. The estimated erosion values mostly are below the usual "tolaerable soil loss" of 3 tons/ac/yr.

4. GIS is very useful compared to traditional methods by breaking up the land surface into many small cells which enables an analysis to be performed on both large regions as well as discrete areas. This study demonstrates that GIS is a valuable tool in assessing soil erosion modeling and in assisting the estimation of erosion. Also, Cell size is very important for the data.

Sources of Errors in the Model:

1. Error in this estimation can occur because the USLE is an empirical equation that does not mathematically represent the physical processes of soil erosion.

2. The equation predicts the amount of erosion but due to deposition the actual amount of sediment reaching a given point may be less.

3. Many of the values used to calculate erosion are assumed or estimated.

4. The use of the USLE may not be a good predictive model for erosion in this study area because the extreme slopes throughout the watershed do not correlate well with the USLE model, which was originally developed for mild slopes in agricultural areas. In particular, the LS values will be overweighted in this analysis.

5. The absolute value of the estimation is not helpful. However, the relative results from different years may still be useful to predict the trend of soil erosion.

6.1 RECOMMENDATIONS

1. A erosion control plan can be suggested. For example, some land forming practices such as terraces on the steep slopes to reduce the slope lengths (LS factors), which will slow down the runoff velocities.

2. It is highly recommend to repeat this study for all catchments in Hebron District.

3. Soil Texture analyses using Sieve test is not completed because of missing of sieves number 330 and 400. It is highly recommend to purchase a complete set of sieves.

4. A field test of soil erosion is highly recommended to be conducted at least for different soil associations. The results will be used to calibrate the model.

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APPENDICES

APPENDIX (A)

SIEVE ANALYSIS TABLES

sample coordinate (88000-148000)

sieve number	weight in	percent of wight	total pass
1/2..	302.3	30%	697.7
4	308.2	31%	389.5
10	177.4	18%	514.4
20	140.3	14%	682.3
40	42.1	4%	817.8
60	13.4	1%	944.5
140	7.1	1%	979.5
200	4.8	0%	988.1
plat	4.4	0%	990.6
total	1000		

smaple coordinate (106000-160000)

sieve number	weight in	percent of wight	total pass
1/2..	11.2	1%	988.8
4	104.9	10%	883.9
10	185	19%	710.1
20	263	26%	552
40	144.4	14%	592.6
60	148.2	15%	707.4
140	106.4	11%	745.4
200	26.9	3%	866.7
plat	10	1%	963.1
total	1000		

sample coordinate (106000-163000)

sieve number	weight in	percent of wight	total pass
1/2.	160.6	16%	839.4
4	107.4	11%	732
10	207.5	21%	685.1
20	254.3	25%	538.2
40	110.7	11%	635
60	58.1	6%	831.2
140	58.7	6%	883.2
200	25.5	3%	915.8
plat	17.2	2%	957.3
total	1000		

sample coordinate (103000-160000)

sieve number	weight in	percent of wight	total pass
1/2.	118.6	12%	881.4
4	140.4	14%	741
10	171	17%	688.6
20	190.1	19%	638.9
40	127.4	13%	682.5
60	108.8	11%	763.8
140	103.5	10%	787.7
200	22.5	2%	874
plat	17.7	2%	959.8
total	1000		

sample coordinate (103000-163000)

sieve number	weight in	percent of wight	total pass
1/2..	202.4	20%	797.6
4	256.2	26%	541.4
10	250.6	25%	493.2
20	165.1	17%	584.3
40	63.5	6%	771.4
60	28.1	3%	908.4
140	20.9	2%	951
200	7.1	1%	972
plat	6.1	1%	986.8
total	1000		

sample coordinate (100000-160000)

sieve number	weight in	percent of wight	total pass
1/2..	11.9	1%	988.1
4	79.44	8%	908.66
10	160	16%	760.56
20	202.4	20%	637.6
40	238.56	24%	559.04
60	193	19%	568.44
140	82.6	8%	724.4
200	21.6	2%	895.8
plat	10.5	1%	967.9
total	1000		

sample coordinate (100000-157000)

sieve number	weight in	percent of wight	total pass
1/2	47.4	5%	952.6
4	179.6	18%	773
10	220.2	22%	600.2
20	228	23%	551.8
40	131.8	13%	640.2
60	73.4	7%	794.8
140	66.6	7%	860
200	20.4	2%	913
plat	32.6	3%	947
total	1000		

sample coordinate (100000-154000)

sieve number	weight in	percent of wight	total pass
1/2	114.1	11%	885.9
4	194.4	19%	691.5
10	190.2	19%	615.4
20	182.6	18%	627.2
40	82.1	8%	735.3
60	64.2	6%	853.7
140	125	13%	810.8
200	42.2	4%	832.8
plat	5.2	1%	952.6
total	1000		

sample coordinate (97000-151000)

sieve number	weight in	percent of wight	total pass
1/2	74	7%	926
4	153.3	15%	772.7
10	178.3	18%	668.4
20	284.1	28%	537.6
40	116.4	12%	599.5
60	89	9%	794.6
140	68.6	7%	842.4
200	24.2	2%	907.2
plat	12.1	1%	963.7
total	1000		

sample coordinate (97000-154000)

sieve number	weight in	percent of wight	total pass
1/2..	91	9%	909
4	146.9	15%	762.1
10	173	17%	680.1
20	216.3	22%	610.7
40	136.2	14%	647.5
60	110.9	11%	752.9
140	90.3	9%	798.8
200	18.7	2%	891
plat	16.7	2%	964.6
total	1000		

sample coordinate (97000-157000)

sieve number	weight in	percent of wight	total pass
1/2..	256.3	26%	743.7
4	391.8	39%	351.9
10	181.2	18%	427
20	101.4	10%	717.4
40	33	3%	865.6
60	13.6	1%	953.4
140	14	1%	972.4
200	3.9	0%	982.1
plat	4.8	0%	991.3
total	1000		

sample coordinate (97000-160000)

sieve number	weight in	percent of wight	total pass
1/2..	147.5	15%	852.5
4	102.7	10%	749.8
10	114.9	11%	782.4
20	159.2	16%	725.9
40	124	12%	716.8
60	173.2	17%	702.8
140	135.1	14%	691.7
200	34	3%	830.9
plat	9.4	1%	956.6
total	1000		

sample coordinate (94000-148000)

sieve number	weight in	percent of wight	total pass
1/2	200	20%	800
4	259.4	26%	540.6
10	160.6	16%	580
20	200	20%	639.4
40	57.2	6%	742.8
60	41.5	4%	901.3
140	46.5	5%	912
200	21	2%	932.5
plat	13.8	1%	965.2
total	1000		

sample coordinate (94000-151000)

sieve number	weight in	percent of wight	total pass
1/2	76	8%	924
4	207.2	21%	716.8
10	146.4	15%	646.4
20	213	21%	640.6
40	154	15%	633
60	149.9	15%	696.1
140	11.3	1%	838.8
200	22.1	2%	966.6
plat	20.1	2%	957.8
total	1000		

sample coordinate (94000-154000)

sieve number	weight in	percent of wight	total pass
1/2..	155.4	16%	844.6
4	155.9	16%	688.7
10	201.1	20%	643
20	210	21%	588.9
40	108	11%	682
60	71.7	7%	820.3
140	65.7	7%	862.6
200	18.1	2%	918.2
plat	16.1	2%	967.8
total	1000		

sample coordinate (94000-157000)

sieve number	weight in	percent of wight	total pass
1/2..	47.4	5%	952.6
4	192.4	19%	760.2
10	200	20%	607.6
20	187.3	19%	612.7
40	122.4	12%	690.3
60	118.4	12%	759.2
140	90.4	9%	791.2
200	29	3%	880.6
plat	12.7	1%	958.3
total	1000		

sample coordinate (94000-160000)

sieve number	weight in	percent of wight	total pass
1/2..	58.9	6%	941.1
4	149.7	15%	791.4
10	182.3	18%	668
20	199.1	20%	618.6
40	125.3	13%	675.6
60	87.1	9%	787.6
140	117	12%	795.9
200	56.5	6%	826.5
plat	24.1	2%	919.4
total	1000		

sample coordinate (94000-151000)

sieve number	weight in	percent of wight	total pass
1/2..	72.1	7%	927.9
4	156.6	16%	771.3
10	250.4	25%	593
20	221.8	22%	527.8
40	103.8	10%	674.4
60	73.4	7%	822.8
140	71.8	7%	854.8
200	29.1	3%	899.1
plat	21	2%	949.9
total	1000		

sampe coordinate (91000-145000)

sieve number	weight in	percent of wight	total pass
1/2..	56.1	6%	943.9
4	279.3	28%	664.6
10	269.1	27%	451.6
20	192.5	19%	538.4
40	84.9	8%	722.6
60	46.2	5%	868.9
140	41.4	4%	912.4
200	14.6	1%	944
plat	15.9	2%	969.5
total	1000		

sample coordinate (91000-148000)

sieve number	weight in	percent of wight	total pass
1/2..	178.7	18%	821.3
4	140	14%	881.3
10	109.5	11%	750.5
20	125.6	13%	764.9
40	126	13%	748.4
60	211.3	21%	662.7
140	71.7	7%	717
200	19.2	2%	909.1
plat	18	2%	962.8
total	1000		

sample coordinate (91000-151000)

sieve number	weight in	percent of wight	total pass
1/2..	141.1	14%	858.9
4	194.4	19%	664.5
10	190.2	19%	615.4
20	182	18%	627.8
40	82.1	8%	735.9
60	64.2	6%	853.7
140	100.4	10%	835.4
200	40.4	4%	859.2
plat	5.2	1%	954.4
total	1000		

sample oordinate (91000-154000)

sieve number	weight in	percent of wight	total pass
1/2..	273.8	27%	726.2
4	356	36%	370.2
10	182	18%	462
20	113.4	11%	704.6
40	36.4	4%	850.2
60	15	2%	946.6
140	11.2	1%	973.8
200	4	0%	984.8
plat	8.2	1%	987.8
total	1000		

sample coordinate (91000-157000)

sieve number	weight in	percent of wight	total pass
1/2..	156.7	16%	843.3
4	208.9	21%	634.4
10	190.1	19%	601
20	219.5	22%	590.4
40	97.6	10%	682.9
60	64.4	6%	838
140	45	5%	890.6
200	9.1	1%	945.9
plat	8.7	1%	982.2
total	1000		

sample coordinate (91000-160000)

sieve number	weight in	percent of wight	total pass
1/2..	165.1	17%	834.9
4	178.7	18%	656.2
10	138.6	14%	682.7
20	154.7	15%	708.7
40	109.5	11%	735.8
60	91.1	9%	799.4
140	104.6	10%	804.3
200	45.2	5%	850.2
plat	12.5	1%	942.3
total	1000		

sample coordinate (88000-142000)

sieve number	weight in	percent of wight	total pass
1/2..	141.4	14%	858.6
4	240.9	24%	617.7
10	303.6	30%	455.5
20	174.1	17%	522.3
40	47.2	5%	778.7
60	22.2	2%	930.6
140	35.3	4%	942.5
200	20.7	2%	944
plat	14.6	1%	964.7
total	1000		

sample coordinate (88000-145000)

sieve number	weight in	percent of wight	total pass
1/2..	59.2	6%	940.8
4	144.5	14%	796.3
10	98.8	10%	756.7
20	153.9	15%	747.3
40	119.3	12%	726.8
60	194.9	19%	685.8
140	173.8	17%	631.3
200	41.2	4%	785
plat	14.4	1%	944.4
total	1000		

sample coordinate (88000-151000)

sieve number	weight in	percent of wight	total pass
1/2..	60.6	6%	939.4
4	145.8	15%	793.6
10	173.6	17%	580.6
20	234.4	23%	592
40	160.4	16%	605.2
60	172.4	17%	667.2
140	8.6	1%	819
200	24.2	2%	967.2
plat	20	2%	955.8
total	1000		

sample coordinate (88000-154000)

sieve number	weight in	percent of wight	total pass
1/2..	301.5	30%	698.5
4	190.3	19%	508.2
10	200.4	20%	609.3
20	130.7	13%	668.9
40	63	6%	808.3
60	34	3%	903
140	45.8	5%	920.2
200	26.8	3%	927.4
plat	7.5	1%	985.7
total	1000		

sample coordinate (88000-157000)

sieve number	weight in	percent of wight	total pass
1/2..	80	8%	920
4	140.7	14%	779.3
10	152.4	15%	706.9
20	179.3	18%	668.3
40	110.7	11%	710
60	94.6	9%	794.7
140	158	16%	747.4
200	58.1	6%	783.9
plat	26.2	3%	915.7
total	1000		

sample coordinate (88000-160000)

sieve number	weight in	percent of wight	total pass
1/2..	192.7	19%	807.3
4	234.5	23%	572.8
10	203.2	20%	562.3
20	220	22%	576.8
40	62.1	6%	717.9
60	37.6	4%	900.3
140	33.1	3%	929.3
200	14	1%	952.9
plat	2.8	0%	983.2
total	1000		

APPENDIX (B)

RAIN FALL DATA

Total Monthly Rainfall for Hebron Station (mm)

Season (2004/2005)

Day	Month											
	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.
1												
2						3		2				
3					34.8			6.5				
4					30.5		0.9	3.5				
5						7.8						
6					44.5	1.2						
7				11.3		28.6						
8				8.2		33.3	0.2					
9						25	16.4					
10							17.4					
11				0.3		10.5	7.6					
12						10	5.8					
13							0.7					
14												
15												
16				5.1								
17			47									
18			1.4		1							
19			6.6									
20					1.4	1						
21												
22			26.5									
23			82.5		10							
24				18.6	30.8			0.7				
25				6.2								
26												
27			47									
28		0.9										
29		3.3										
30												
31												
Total	0	4.2	211	49.7	153	118.2	49	12.7	0	0	0	0
Y. Total	598											

Day	Month											
	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.
1								56				
2								1.7				
3						4.1		0				
4					2.8	6.9		3.4				
5			2.4					18.5				
6			13.5									
7			1.4									
8					1.2							
9					13.9		5.4					
10					1.2	0.4	11					
11					0.8							
12					20.2							
13					0.8							
14					5.2	6.2						
15			2.8			14.9		0.2				
16			1.2		4	37.6		3.2				
17				5.8	12.4	12.1						
18				0.4	8.8							
19												
20		10.2	1.1		4.8							
21		0.2	26.8	0.4								
22												
23				4				0				
24				16.6				1.2				
25				33	1.1							
26				22	2.6	0.8						
27					2.7	1.8						
28					3.4							
29												
30												
31												
Total	0	10.4	48.3	84.2	85.9	85.6	16.4	83.2	0	0	0	0
Y. Total	414.0											

Total Monthly Rainfall for Hebron Station (mm)

Season (2003/2004)

Day	Month											
	sep.	oct.	nov.	dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.
1												
2						6						
3				0.8		10.4			0.6			
4				24								
5								1.8				
6				19.6		11.7	7					
7				0.8		5.2	10.8					
8				6.8		0.4						
9					29.6							
10					25.2							
11					1							
12			2.7									
13						4.6						
14					28.5							
15					30.8	4.2	0.7					
16				3	42.6	14.2	0.8					
17				0.6		8.2	4.8					
18												
19												
20				31.9		10.8						
21				54.3		14						
22												
23					8.5	6						
24												
25												
26		0.1										
27					0.1							
28					1.7							
29				0.7	13.6							
30		12.4		2.2								
31												
Total	0.0	12.5	2.7	144.5	182.6	97.7	24.1	1.8	0.6			
Yearly Total	:				466.5							
Yearly Percentage	:				0.78							

Total Monthly Rainfall for Hebron Station (mm)

Season (2002/2003)

Day	Month											
	sep.	oct.	nov.	dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.
1												
2												
3					7		2					
4						12						
5			4.4									
6												
7							11.8					
8						15.1						
9			0.8	18								
10				35								
11				33			3.3					
12			3.7	1.9			33					
13					0.8							
14					8.7	48.7						
15				3.7	15	12.2		0.5				
16		0.2										
17				21	1.1							
18				13.2	2.7		22					
19					6			0.9				
20		1.8		99.6	24.1			1.8				
21				12.4	10.3	12.5	4	1				
22				1.2	0.4	5.9						
23				36		5						
24			6				18					
25				11.6			21.8					
26				1.5			1	8.8				
27								3.7				
28						74.3						
29			4.2									
30		5.4		6								
31		6.7										
Total	0.0	14.2	21.1	292.0	75.6	185.7	116.9	16.1	0.0			
Yearly Total	:				721.6							
Yearly Percentage	:				1.21							

Total Monthly Rainfall for Hebron Station (mm)

Season (2001/2002)

Day	Month											
	sep.	oct.	nov.	dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.
1				7								
2												
3					25.4			9.1				
4				0.2	2.8			8				
5				62								
6				15.5								
7			5									
8			0.6		64.3							
9					81							
10					42.8	12						
11					4.3	3.5						
12					2.7	24.7						
13						20.3						
14												
15				3.6					8.4			
16					0.7				3.5			
17			6.2				0.8					
18			18.5				0.8					
19												
20				37.8	26							
21				9.6	21			2.1				
22			12.6		35.5		1.2	0.8				
23			5.2									
24						0.6						
25												
26			4			0.2						
27		0.1	1.2		1							
28		2			42.2		13.6					
29		6.4	0.3		10							
30							31					
31												
Total	0.0	8.5	53.5	136.5	329.5	61.3	47.4	20.3	11.9			
Yearly Total	:				669.0							
Yearly Percentage	:				1.12							

Total Monthly Rainfall for Hebron Station (mm)

Season (2000/2001)

Day	Month											
	sep.	oct.	nov.	dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.
1				9								
2				7.4					45.9			
3					1.2				11			
4						7.3						
5						19.2		1				
6					4	4						
7												
8						15		4.1				
9				10			4					
10				12		1	15					
11												
12				1.2								
13				18.2								
14				12.5		0.4						
15						3						
16		4.4		0.3		2.7						
17						2						
18						7.6						
19												
20				7.4	36.7							
21		1.2		38.8	0.2	11						
22		1				19						
23		0.5		9.4	1.6							
24		4.9			13.8		5.5					
25		1.2		86.8	56.2		0.3					
26		9.7		6.6								
27					31.8							
28												
29			1.3									
30												
31												
Total	0.0	22.9	1.3	220.8	145.7	92.2	24.8	5.1	56.9			
Yearly Total	:				569.5							
Yearly Percentage	:				0.96							