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USING THE SOTER DATABASE FOR SOIL EROSION ASSESSMENT

with an example for a pilot area in South America

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ISRIC

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ABSTRACT

Since ISRIC was contracted at the 1987 UNEP meeting in Nairobi for the project 'Global Assessment on Soil Degradation' (GLASOD), it has established a worlds's soil degradation map at a 1:15M scale and a procedure for Soils and Terrain digital data management, SOTER.

This project resulted from the increasing demand of information about soils and terrain for soil resource mangers as a consequence of the increasing land pressure and its soil landscape deterioration, especially in developing countries.

SOTER is worlds Soils and Terrain digital database containing digitized map unit boundaries and their attribute database and supported by a file on chosen point data (ISSS, 1986).

SOTER is divided into three levels with increasing detail; SOTER unit-, terrain component- and soil level, having an average scale accuracy of 1:1M. The SOTER geometry is stored in a GIS (ILWIS) whereas the attribute data are stored in a relational database management system (ORACLE).

This study is about the use of this database for soil erosion risk assessment for a pilot area in South America (being one of the SOTER's short term objectives).

A framework was established for the use of the three database levels based on models provided by literature and data provided by the database.

In this report the data from the highest, SOTER unit, level were used to create a first impression on soil erosion risk for the South American pilot area. The simple model is based on the USLE approach: it uses mean monthly and annual rainfall average slope percentages and land use characteristics, to produce the Modified Fournier index, slope factor and cropping factor as control variables. For these three control variables single value ILWIS grid maps were created after which they were multiplied with each other to obtain the erosion hazard map.

The study showed that SOTER provides many attributes for land resource management although on the highest database level these were insufficient to create a satisfying result. It is recommended to use data from the terrain component level data. The use of the cropping factor as a control variable showed to create large errors.

The ILWIS/ORACLE configuration also showed its limitations.

FOREWORD

As a part of my study in Physical Geography at the State University of Utrecht (the Netherlands), I had the opportunity to do a training at the International Soil Reference and Information Centre (ISRIC) in Wageningen, the Netherlands, through participating in the GLASOTER-project.
From the start of my study in Utrecht, I paid several visits to ISRIC, and during the years, it became a primary source of information for my study.
ISRIC could be a relevant and attractive training site. Because of my frequent visits to ISRIC, I started to realize that it represented solid base for a further development of my knowledge.
During my graduate year, in april 1991, I contacted my coordinator Dr. H. Th. Riezebos to find out whether there was a possibility to follow a training at ISRIC. Within a few days he realized the agreement with ISRIC.
For about three months, from May 13 to August 16 1991 I have been participating in the GLASOTER project on the assessment of soil water erosion risk for a pilot survey area in South America. It turned out to be a pleasant and useful task.

ACKNOWLEDGEMENT

A great deal of help I received from Drs. Vincent Van Engelen, Ir. John Pulles and Dr. Roel Oldeman at ISRIC. I am very grateful for their positive anticipation and critical remarks. Furthermore I wish to thank Dr. Hans Th. Riezebos, at the Department of Physical Geography in Utrecht, for his arrangements and his critical comments on my work. Without him it would have been impossible to organize the training.
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Some last words of appreciation are dedicated to all the other members of ISRIC, from whom I received lots of bits of help, their patience and their good sense of humour. Especially I want to thank Rob Bleyert, for his amusing and educating discussions.
All these factors made it a pleasant and instructive stay and created an excellent working environment.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ANNEXES

1. THE DESIGN OF A WORLD SOILS AND TERRAIN DATABASE

1.1. Introduction

Due to the increasing pressure on land throughout the world, resulting in a deterioration of the soil landscape and, consequently, a decrease of productivity, soil resource managers are, increasingly, in need for information on soils and terrain, but see themselves confronted with a critical lack of data, particularly in developing countries. These are strong arguments for:

-strengthening the awareness of decision- and policy-makers on the dangers resulting from inappropriate land and soil management;

-improved mapping and monitoring of land resources;

-development of an information system capable of providing the necessary information on land resources.

1.2. Evolution

During the 1970s and mainly since the release of the FAO/UNESCO Soil Map of the World at a scale of 1:5M, completed in 1980, several working groups under the commission of the International Society of Soil Science (ISSS), have been working on the exploration of applications of new technologies for the management of soil resources (Baumgardner and Van de Weg, 1988).

As a consequence of the activities in the ISSS a working group was established in 1985 to consider the feasibility and desirability of a world soils and terrain digital database, at a map scale of 1:1M. These considerations resulted in several background papers (Sombroek, 1985; Baumgardner and Oldeman, 1986), and the release of a proposal to develop a World Soils and Terrain Digital Database (SOTER) at a scale of 1:1M (ISSS, 1986). This SOTER proposal was further endorsed at the ISSS congress in Hamburg, Germany, August 1986.

Because of their intense interest in global databases for environmental sciences, officials of the United Nations Environment Program (UNEP) expressed an interest in SOTER, especially if the project could make a significant contribution to the assessment of degradation of global soils and terrain resources.

After the meeting held at the UNEP Headquarters in Nairobi in May 1987, UNEP contracted ISRIC for a project entitled: "Global Assessment of Soil Degradation (GLASOD)" (Oldeman et al., 1990). This contract comprised two primary tasks: the first was to produce a general soil degradation map of the world at a scale of 1:15M, the second to develop a soils and terrain digital database at a scale of 1:1M for an area of 250,000 km^2 which includes portions of Argentina, Brazil and Uruguay.

A continuation of their activities started in 1991 with the name GLASOTER. Apart from training participants in the use of the SOTER database, applications had to be developed.

1.3. Objectives

The overall general objective of the SOTER project is to utilize emerging information technology to produce a World Soils and Terrain Digital database containing digitized map unit boundaries and their attribute database, and supported by a file on chosen point data (ISSS, 1986).

One of the short term objectives of the SOTER project is, as quoted by Shields and Coote, 1989, to document procedures for water and wind erosion risk assessment under conditions of bare, unprotected soils as well as under the present vegetation cover

1.4. Objective of this study

This paper comprises the following:

-1) the assessment of water erosion rate and risk for the soils of a pilot area in South-America using the SOTER database,
-2) to determine attributes that function as control variables for appropriate models in order to create an output of erosion hazard risk and/or erosion rate,
-3) the use of GIS technology for display.

The results should be seen as a contribution to the quoted short term objective.

2. SITUATION OF THE STUDY AREA

The study area is the first pilot area of the SOTER project, in South-America (LASOTER area). It comprises parts of Argentina, Brazil and Uruguay (fig 1). It is situated along and east of the Rio Paraná and the Rio Uruguay (28°00' - 32°30'S/54°00' - 60°00'W), and covers about 280,000 km^2.

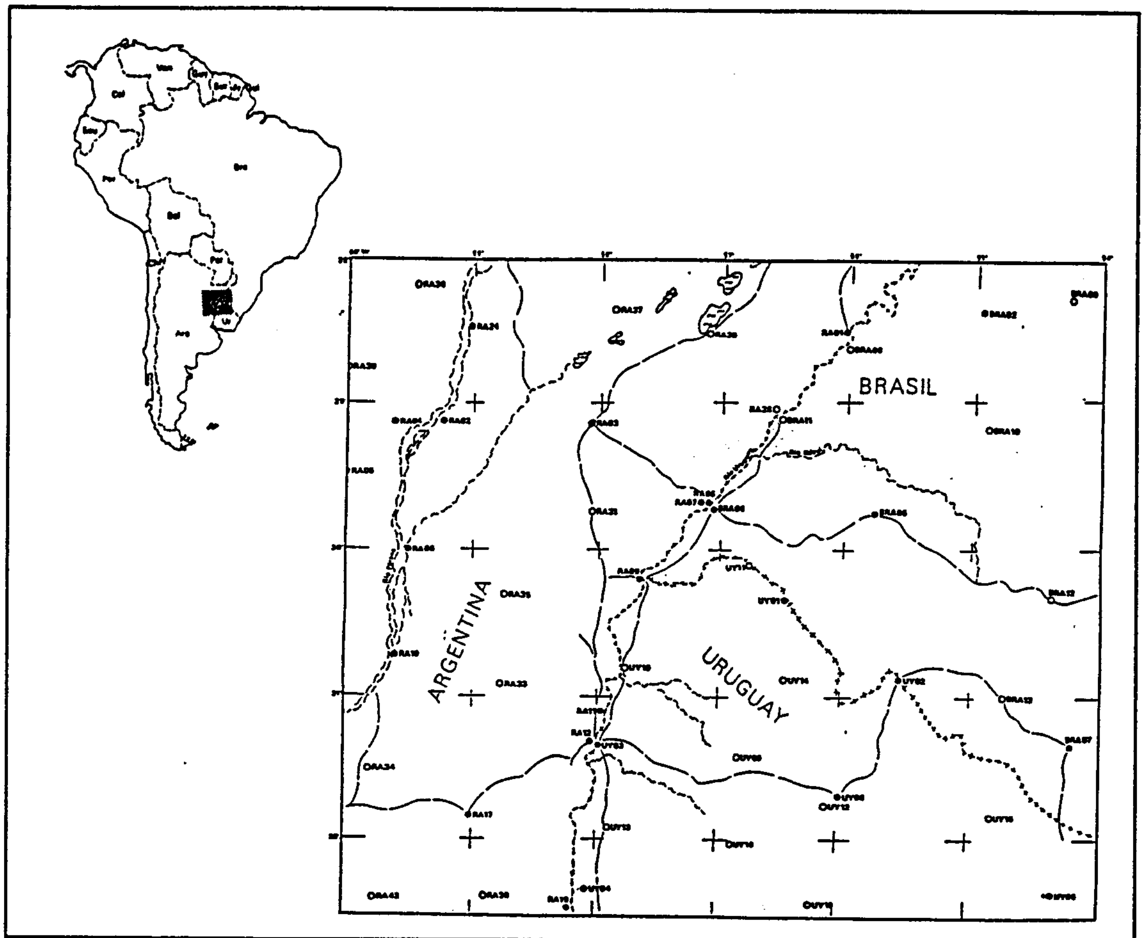

Figure 1: Situation of the Pilot survey area in South America. (Peters, 1988)

3. THE SOURCE OF INFORMATION

3.1. Characteristics of the SOTER database

The SOTER database will generally be used for improved mapping and monitoring of changes of the world soils and terrain resources, and the development of an information system capable of delivering accurate, useful, and timely information about soils an terrain resources to decision- and policy-makers (Van Engelen and Pulles, 1991).

In this survey especially it will be used to test the availability and quality of the data in the proposed assessment.

The database has the following characteristics (Van Engelen and Pulles, 1991):

- a general average scale or accuracy of 1:1 million,
- compatible with global databases of other environmental resources,
- amenable to updating and purging of obsolete and/or irrelevant data,
- accessible to a broad array of international, regional, and national decision- and policy-makers to provide them with interpretative maps and tabular information essential for development, management, and conservation of environmental resources, and
- transferable to and useable by developing countries for national database development at larger scales.

3.2. Approach

The assessment is based on the SOTER approach from Shields and Coote (1989), Because data for the LASOTER area were obtained and stored according to this manual. This manual has recently been revised by Van Engelen and Pulles (1991).

Basic in the SOTER approach is the mapping of *SOTER units* or *polygons*, characterized as terrain units, with a distinctive, often repetitive pattern of landform, surface form, slope, parent material, and soils. The term *SOTER unit* was introduced by 1991 SOTER manual version. The 1989 version used the term polygon. The term SOTER unit will be used throughout this report.

Each SOTER unit consists of one or more terrain components, each having particular surface form, slope, micro relief and parent material aspects. For each terrain component at least 1 soil is characterized (figure 2).

3.3. Database structure

In every discipline involved in mapping of spatial phenomena, two types of data can be distinguished:

-geometric data; location and extent of an object are represented by a point, line or delineated area and topology (shapes, neighbours and hierarchy).
-attribute data; characteristics of the object.

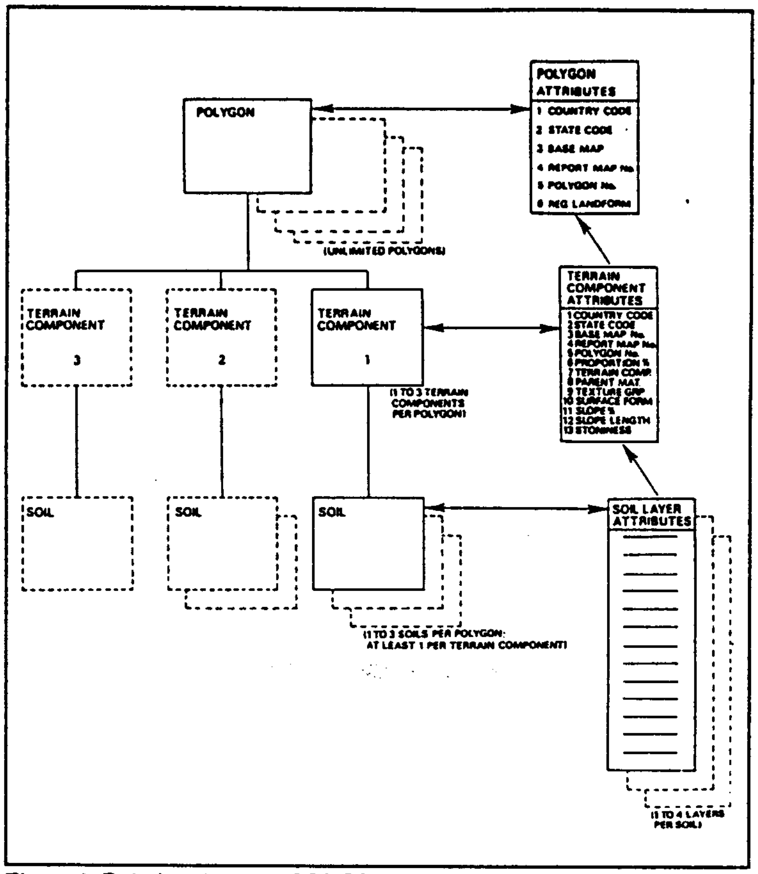

Figure 2: Relations between SOTER attribute files (Baumgardner and Van de Weg, 1988; picture is an adaptation from the original in Shields and Coote, 1989).

In SOTER the geometry is stored in a Geographical Information System (GIS), whereas the attribute data are stored in a DataBase Management System (DBMS). A unique label, the coding_ID (poly_id), attached to both the geometric and the attribute data forms the link to connect these two types of information (fig. 3). The storage of the data is done by the relational database management system (RDBMS) ORACLE, which are handled by the SQL*plus database language. Processing and displaying of the data were originally handled by the Integrated Land and Watershed Management Information System (ILWIS) (Meijerink et al., 1987). In a later stage of this study, ILWIS showed to be limited in several procedures. This necessitated to leave the ORACLE-ILWIS configuration and the use of different, although similar, programmes (LOTUS, GEOEAS, IDRISI). (See discussion, chapter 6.)

3.4. Attribute data

On SOTER unit level the terrain is described in terms of general relief, elevation, lithology and land use. Within the SOTER unit the separate terrain components are described with more detailed attributes, such as texture group of non-consolidated parent material, slope-length and -gradient, rooting depth and vegetation. The terrain component is also characterized by the proportion it occupies within the SOTER unit.

The soils of the terrain components are characterized by properties of so-called "representative profiles", selected by the surveyor.

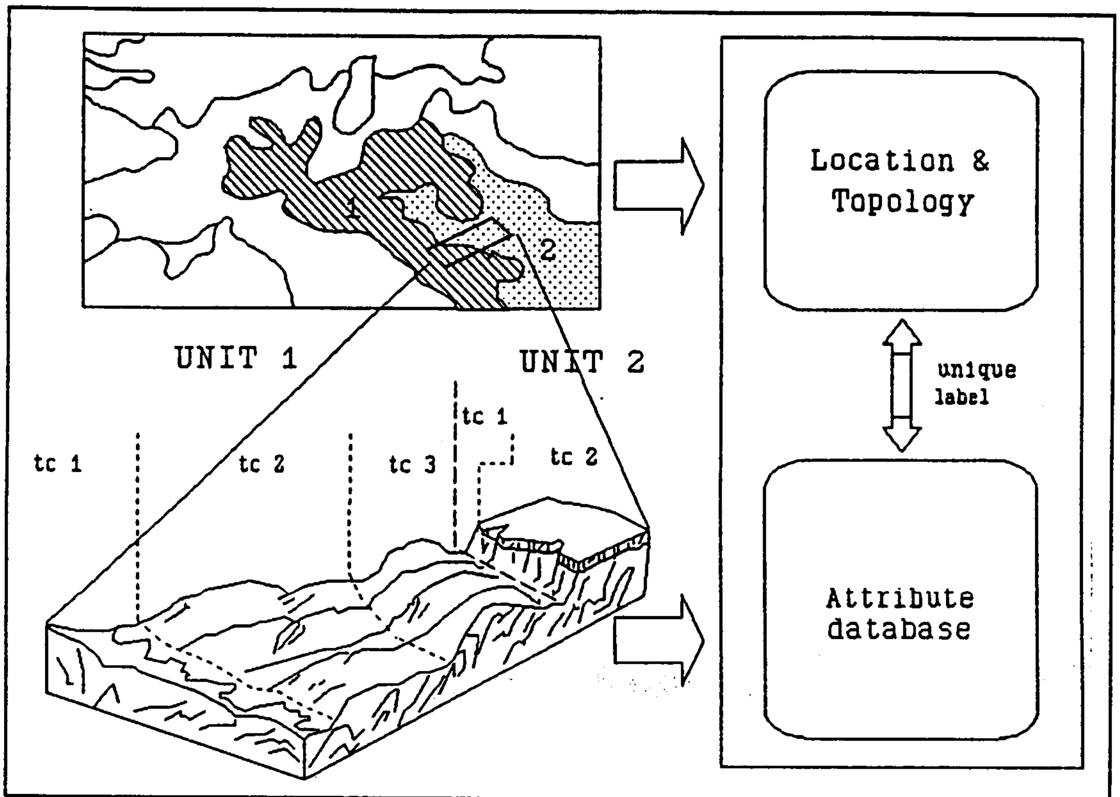

Figure 3: SOTER units (unit 1 and 2), their terrain components (tc), attributes, and location (Van Engelen and Pulles, 1991).

Soil attributes are divided into three parts:

-the 'soil table' contains information to link the soil to the terrain component and to the 'profile table' and the proportion of the area it occupies within the SOTER unit.
-the 'profile table' carries information valid for the whole profile and,
-the 'layer table' holds information on each soil profile layer.

The following attributes in the subsequent SOTER tables,can be relevant for erosion hazard assessment:

On the *SOTER unit* level:

-regional landform
-predominant general land use and vegetation
-general relief
-general surface lithology
-river and stream drainage density

On *terrain component* level:

-dominant slope length
-slope gradient
-texture group
-predominant land use/vegetation type
-local surface form
-unrestricted rooting depth
-surface drainage

The most detailed information can be derived from the *soil* level:

-internal soil drainage class	(profile file)
-total sand %	(layer file)
-very fine sand %	(")
-total silt %	(")
-total clay %	(")
-texture class	(")
-coarse fragments %	(")
-clay mineralogy class	(")
-organic carbon %	(")
-water content at pF2	(")
-water content at pF4.2	(")
-bulk density	(")
-infiltration/percolation	(")
-saturated hydr. conductivity	(")
-structure class	(")
-stable aggregate %	(")

The structure of the SOTER attribute database is given in figure 4. All blocks shown in it represent tables in the SOTER database. Data records are linked to each other through their unique labels.

Climatic data are stored separately from the SOTER database. These data are not directly linked to the SOTER units. Climate data are based on point observations (the meteorological stations). The link can be made through the geographical locations of these points.
In the LASOTER database the data are stored in a classified format (e.g. slope gradient in the terrain component file is defined as '01' for the '1-3%' slope gradient class, as '04' for the '4-9%' class, etc). According to the procedure described in the new SOTER manual (Van Engelen and Pulles, 1991), the data will be stored exactly as they were measured.

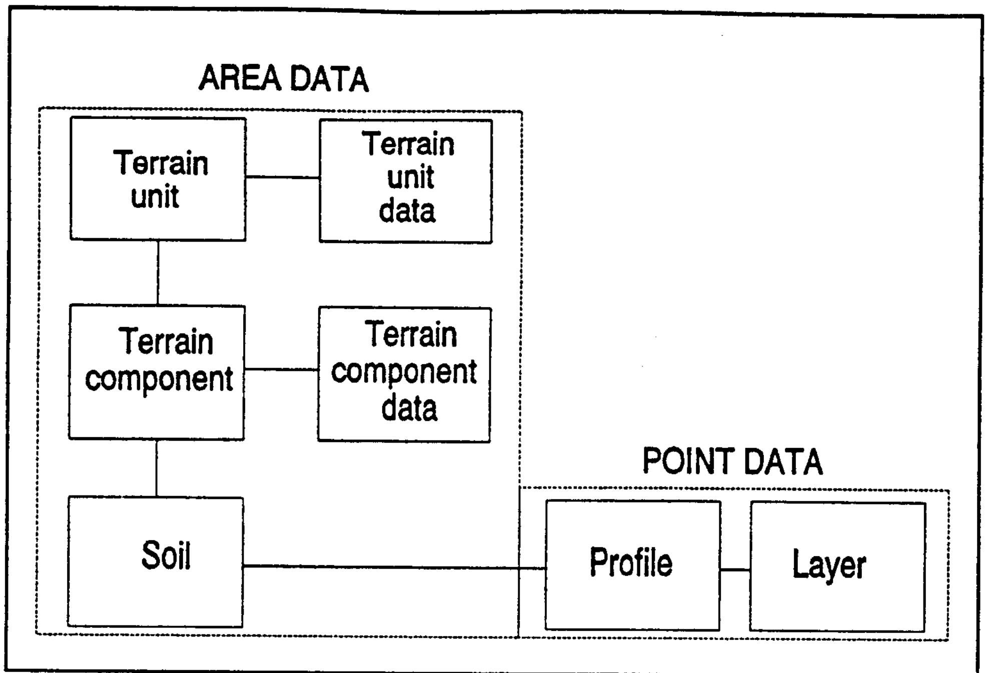

Figure 4: SOTER attribute database structure with area and point data (Van Engelen and Pulles, 1991).

4. ASPECTS OF EROSION MODELLING

4.1. Introduction

Mass movement, *soil erosion* and *solution* are the tree major processes of surface material removal. These are normal aspects of landscape development. Soil erosion is the removal of surface material by wind and water.

Each of these processes may dominate the process of denudation in a specific environment. The slower process of soil erosion becomes dominant once slopes are stable with respect to the quick process of mass movement (Kirkby, 1980).

Soil erosion depends on many factors. The most important are: (1) effective ground cover, mostly in the form of vegetation or cultivated crops, (2) climate, (3) topography and (4) soil characteristics.

Soil erosion is traditionally associated with agriculture. In recent years erosion and soil degradation form an increasing threat throughout the world. Its severity is difficult to quantify as basic data have not been systematically collected (De Ploey, et al.). A qualitative investigation was recently finished in the form of the Global Assessment of Human Induced Soil Degradation, GLASOD (Oldeman et al., 1990). That study showed that more than 15% of the total land surface is affected by soil degradation.

Collecting and evaluation of data, for soil erosion assessment in particular and land resource evaluation in general, is one problem. A method to analyze these is another.

The most satisfactory methods of soil erosion hazard assessment are based on predicting soil losses by modelling the determinants of climate, soil, slope and vegetation, (FAO, 1983) and their interactions.

Modelling of erosion has been a major task for soil conservationists. Until now this has resulted into the design of a scala of soil erosion models each containing its own viewpoint , approach and prospective on soil erosion.

The most widely used models for soil erosion are 'semi'-empirical 'grey-box' models. They use experimentally observed simple and multiple regressions to determine the values of the most important control parameters, related to the soil loss (Burrough, 1988). The most common examples are the Universal Soil Loss Equation, USLE (Wischmeier and Smith, 1978), the Soil Loss Estimation Model for Southern Africa, SLEMSA (Elwell, 1978; Stocking et al., 1988). Furthermore we refer to the Areal Nonpoint Source Watershed Environment Response Simulation, ANSWERS (Beasley and Huggins, 1982), the Morgan, Morgan and Finney method, MMF (Morgan et al., 1984), and the Land Erodibility Assessment Methodology, LEAM (Manrique, 1988).
Other erosion models are deterministic, e.g. CREAMS (Knisel, 1980). These kind of models incorporate the laws of conservation of mass and energy.

4.2. Appropriate models for soil erosion hazard assessment

The assessment of erosion hazard is a specialized form of land resource evaluation, the objective of which is to identify those areas where the maximum sustained productivity from a given land use is threatened by excessive soil erosion (Morgan, 1986).

The desired models must find an optimum balance between accurateness and simplicity. The chosen model should be simple enough to be linked with the SOTER database and sophisticated enough to provide accurate results. With this in mind, three, from the above quoted, related models have been taken into consideration.

The first two models are the most widely known and tested soil erosion models available: the Universal Soil Loss Equation, **USLE**, and the Soil Loss Estimation Model for Southern Africa, **SLEMSA**. These two models are (as most soil erosion models are) field level based, thus bound to a specific scale level to be implemented. The third model is the simple, 'quick and dirty' approach of the Land Erodibility Assessment Methodology, **LEAM**, which has been primarily developed for developing countries (Manrique, 1988).

4.3. Description of the models

4.3.1. USLE

The most widely used method of soil loss prediction by conservationists in the United States is the Universal Soil Loss Equation, **USLE** (Kent Mitchel, 1980). USLE is an empiric linear regression field-level model concerning the most important factors inducing erosion: Rainfall erosivity, soil erodibility, slope-length and -gradient, cropping and control practice factors. The model is given as:

$$A = (0.2241)\ R \times K \times LS \times C \times P$$

where:

A = Mean annual soil loss in tons per ha.,

R = Rainfall erosivity factor, given as the total kinetic rainfall energy times the maximum 30-minutes storm intensity, the EI_{30}.

K = Soil erodibility factor, a quantitative description of the inherent erodibility of a particular soil.

LS = Slope (Length and Steepness) factor, the expected ratio of soil loss per unit area from field slope to that from a 22.13 m length of uniform 9-percent slope under otherwise identical conditions.

C = Cropping factor, the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled, continuous fallow, and

P = Management practice factor is the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down-slope culture (Wischmeier and Smith, 1978)(see fig. 5).

The constant 0.2241 is the conversion factor of US Tons per Acre to Metric Tons per Hectare.

This model predicts soil loss rates from inter-rill and rill erosion for *small field plots*.
The total detached soil (R x K) on a specific slope (LS) determines the soil loss from bare soil, which is restricted by the cropping - (C) and management practice (P) factor.

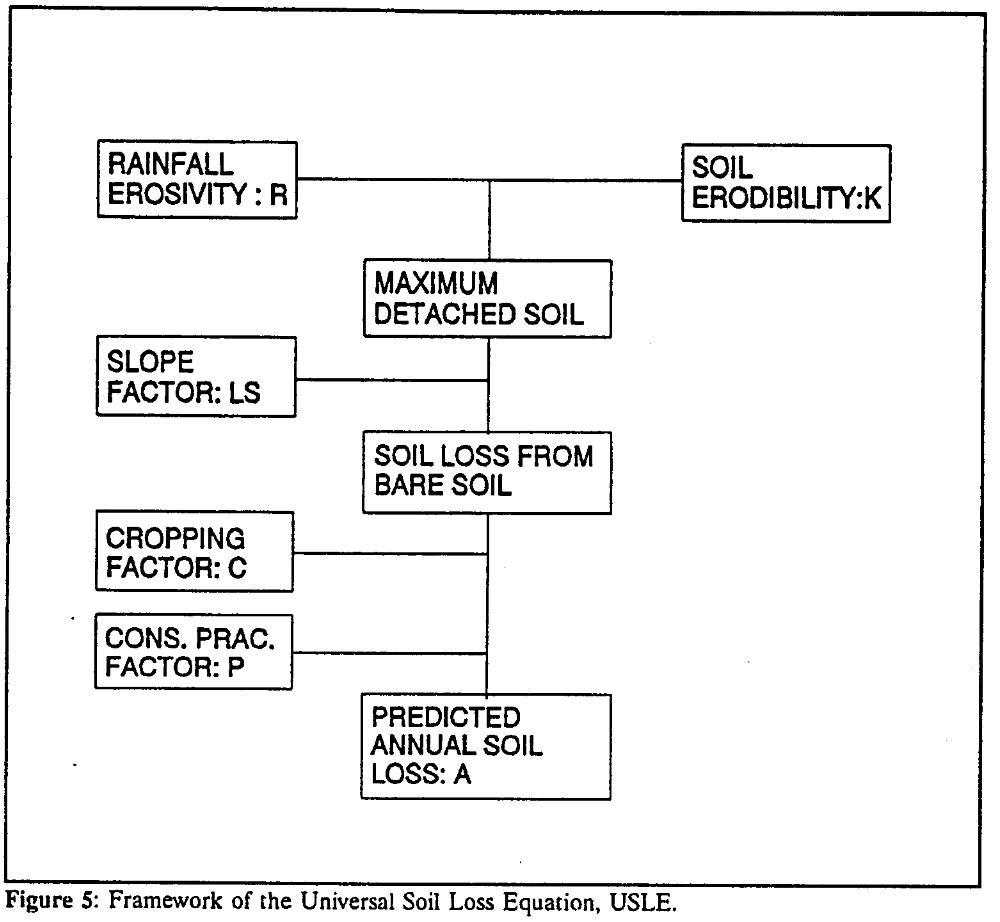

Figure 5: Framework of the Universal Soil Loss Equation, USLE.

The data requirements for USLE are :

-The EI_{30}, rainfall records per specific storm event.
-Slope percentage and slope length for each field.
-Texture, organic matter content, structure, and permeability to determine the soil erodibility.
-Detailed land use records, for each growing season.
-Quantified description of management practices for erosion control.

4.3.2. LEAM

The Land Erodibility Assessment Methodology, **LEAM** is designed primarily for use in developing countries using a systematic procedure which extracts information from soil survey based on Soil Taxonomy (Soil Survey Staff, 1975). This information is used to define and categorize potential erosion risk in quantitative and operational terms (Manrique, 1988).

This approach attempts to estimate land erodibility which is defined by three major characteristics: (i) slope hazard, (ii) rainfall erosivity risk and (iii) soil erodibility. Each major land characteristic is defined by other land characteristics known as diagnostic criteria. In the absence of diagnostic criteria, alternatives are provided for each land characteristic.

Slope hazard is defined as the slope factor in USLE, as is the soil erodibility defined as the K factor in the same model. The rainfall erosivity risk is determined as the modified Fournier's index defined by Arnoldus (1980), for which only mean monthly rainfall data are required.

Although the output is in numeric terms the results can be interpreted as soil loss rates or ratios.
The framework of LEAM is simple, and is arranged in two categories: class and subclass. A specific combination of the classified land characteristic places it in a specific subclass. This subclass reflects the kind of limitations within each class. The class reflects the degree of potential erosion risk.

4.3.3. SLEMSA

SLEMSA is, according to Elwell (1978), a field level mathematical modelling approach the purpose of which is to bring together all sources of information into a formal arrangement representing the best advice available.

This model was developed to estimate annual soil loss from agricultural land in the central part of Zimbabwe. The model was devised to estimate soil losses from sheet erosion.

SLEMSA considers five control variables: seasonal rainfall energy, E; the amount of rainfall intercepted by the crop, i; soil erodibility, F; slope length, L; and slope percentage, S.

The control variables where arranged into three sub-models (see figure 6); a principle sub-model to estimate soil loss form bare soil, K; a sub-model accounting for cropping practices, C; and one to account for differences in topography, X.

The main model is formulated as follows:

$$Z = K \times X \times C$$

where:

Z = the predicted mean annual soil loss in tons per hectare per year,

K = the mean annual soil loss, in tons per hectare per year, from a standard conventionally-tilled field plot (30 m x 10 m at a 4.5% slope), for a soil of known erodibility, F, under a weed-free bare fallow,

X = the ratio of soil loss from a field slope of length L in meters and slope percent S, to that lost from the standard plot (same as in USLE) and

C = the ratio of soil loss from a cropped plot to that from bare fallow (see fig. 6).

The SLEMSA data requirements are somewhat less than those for the USLE:

-Daily rainfall (eventually from automatic rain gauges), in order to obtain rainfall energy.
-Crop cover percentages to determine the energy interception.
-Slope gradients and slope lengths to determine the topographic factor.
-Soil characterisation (soil type, texture, substrata type and lithic phase) in order to obtain the erodibility of the soil.

Rainfall energy and soil erodibility together determine the soil loss from bare soil. The crop factor and topographic factor are correction factors between 0 and 1, connected to the bare soil loss, resulting in a prediction of actual soil loss.

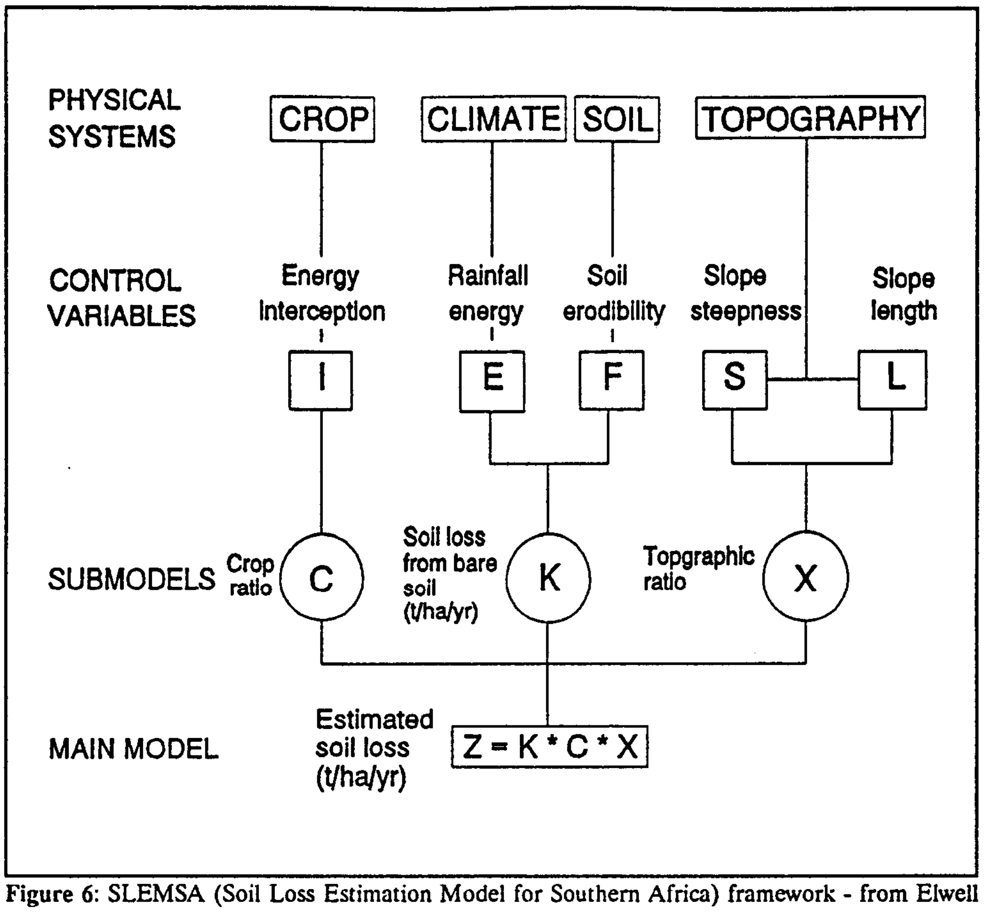

Figure 6: SLEMSA (Soil Loss Estimation Model for Southern Africa) framework - from Elwell and Stocking, 1982 (Stocking et al., 1988).

4.3.4. Modified SLEMSA

USLE and SLEMSA are originally designed for field-level applications, thus at scales larger than 1:50,000. The working scale of SOTER is 1:1M. USLE and SLEMSA may not be applied recklessly on this scale.

Stocking et al. (1988) provided an 'improved methodology for erosion hazard mapping'. This methodology is based on the SLEMSA framework, and has been applied in Lesotho (Chakela and Stocking et al., 1988). The technique does not predict soil erosion loss on field level but erosion hazard over large areas.

The data requirements are the following:

- Annual rainfall data and a regression equation to obtain rainfall energy.
- Crop cover measurements are necessary to derive the rainfall energy interception factor.
- Average slope can be determined from 1:50,000 scale topographic maps.
- The index of erodibility is obtained through ratings and modifiers per soil type, texture, substrata type and lithic phase (the same as the original SLEMSA approach).

The output of this modified SLEMSA is in Erosion Hazard Units (E.H.U.'s) in stead of soil loss in tons per ha. per year. Chakela and Stocking (1988) applied the model to map blocks of about 100 km^2 on a 1:50,000 map.

Stocking posed restrictions to the topographic sub model (X). He states that the SLEMSA slope gradient is based only on slopes up to 20 percent. On slopes above 20 percent any small increase has a disproportional large influence on the calculation.

He also states that the final erosion hazard will be for slopes that are assumed to have a maximum length of 100 m, since it has not been experimentally verified for slopes in excess of 100 m, for their influence on erosion. However these restrictions may be equally valid for the other erosion models.

4.4. The choice of appropriate attribute data and models.

Since USLE and SLEMSA are bases on studies based on plot level scale, the models are not appropriate for this assessment. The modified SLEMSA and LEAM were developed for use on smaller scales, e.g. smaller than 1:100,000.

Each model requires specific data to determine control variables. These requirements depend on the scale on which the model is based. The data in the SOTER data base are based on 1:1M scale. In the Lesotho example (Chakela and Stocking, 1988), the modified SLEMSA was applied to a scale of approximately 1:1M., which compares to the level of generalization of the SOTER database. This model seems to be the most promising if all required data were available. As can be verified in paragraph 3.4. this is not the case. For this reason the choice is a simplified model of one of the above.

5. METHODS FOR THE PROCEDURE OF SOIL EROSION HAZARD ASSESSMENT

5.1. Introduction.

The procedure depicted in the present chapter is based on attribute data selected from the terrain unit level. A framework was set up for a procedure involving terrain component- and soil level attributes, but this will be elaborated in a follow-up study.

5.2. The choice of the model

Because of the scale argument in paragraph 4.3.4. the original USLE and SLEMSA are not to be used. The same applies to the modified SLEMSA, because the lack of data in the SOTER database. The LEAM model may be used, but the utilization of it does not take full advantage of the relative high degree of detail in the SOTER database.

Figure 7 gives a framework for the use of a simplified USLE for the SOTER approach on all three database levels. A similar framework may be used for a simplified 'modified SLEMSA'.

5.3. The choice of the attribute data

On each level in the database mandatory and optional attributes have been identified and selected for the assessment of soil erosion hazard (see paragraph 3.4).

All the data, even on the soil level, in the profile- and layer-file, do not represent regionalized variables. There is no information available about spatial variance between nor within SOTER units, terrain component units, or soil units.

Contrary to the soil level data, the climatic data are stored as point data with coordinates and may therefore be seen, and used as regionalized variables. These data are stored in the climatic data file 'climkey', containing data of about 20 variables of 59 stations in and around the LASOTER area.

In a first attempt to obtain an output of erosion hazard, only data from the SOTER unit level and climkey file were used. From the selected attributes, three could be used, in order to satisfy one of the proposed models. These were the following:

1 -mean monthly rainfall
2 -regional landform
3 -predominant general land use/vegetation.

This simplifies the model to three control variables. The model is given by:

$$A = R \times S \times C \qquad \text{where:}$$

A = erosion hazard factor given in 'erosion units'
R = control variable 'rainfall erosivity factor', resulting from the mean monthly rainfall data from the climkey file
S = control variable 'slope factor', resulting from the landform attribute from the SOTER unit file
C = control variable 'crop factor', resulting from the land use attribute from the terrain unit file.

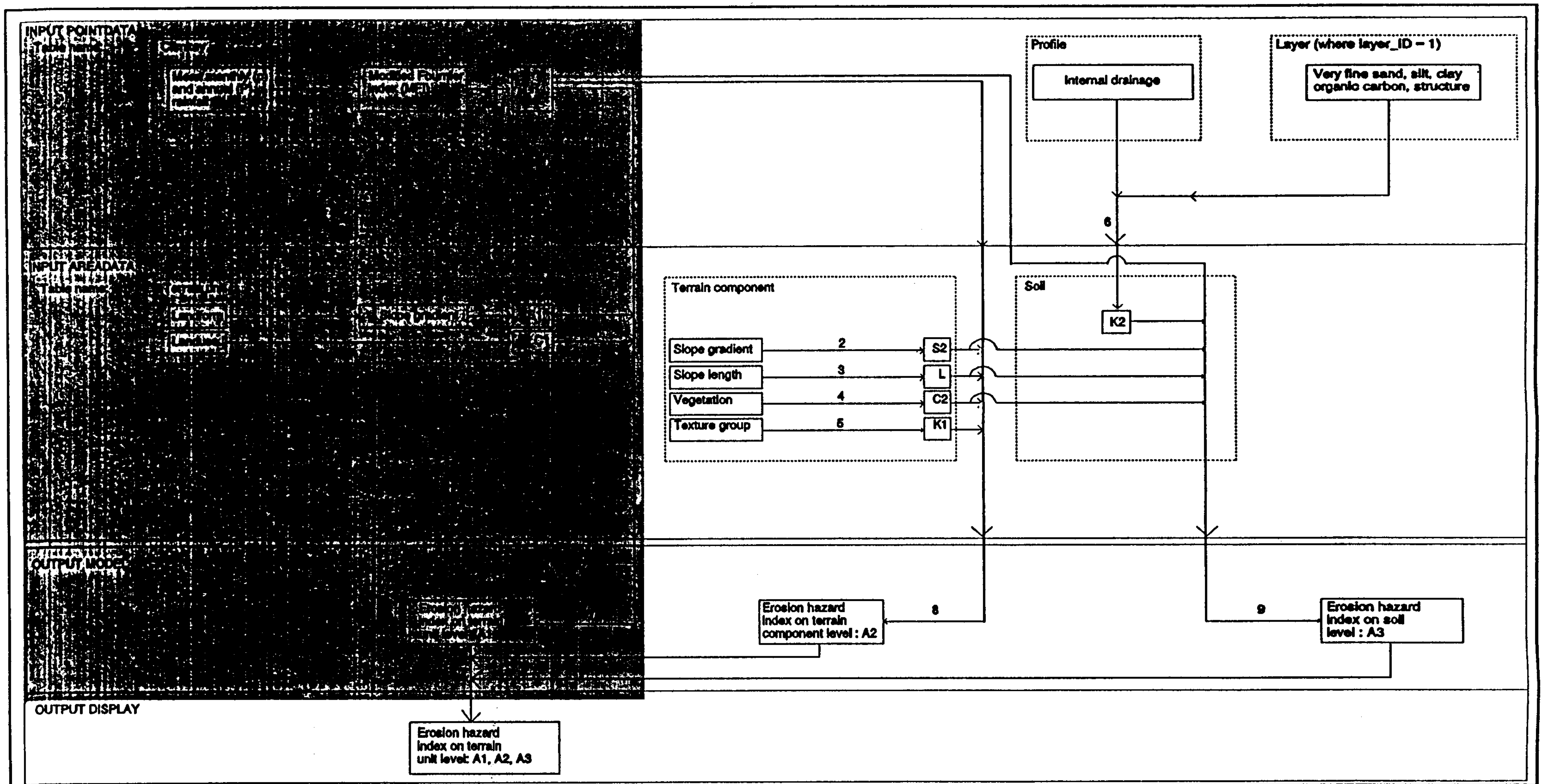

Figure 7: Model for the use of the three SOTER database levels for assessment of soil erosion hazard (explanation codes, see next page).

(Cont. fig. 7) Transfer functions for the assessment of erosion hazard using the SOTER database

1: $MFI = \sum_{i=1}^{12} (p_i^2)/P = R$

p_i = mean monthly rainfall in mm
P = mean annual rainfall in mm
MFI = Modified Fournier Index.

2: $S = 0.065 + 0.045(s) + 0.0065(s^2)$

S = Slope factor
s = Slope gradient in % (max. 20%; see Stocking et al., 1988)

3: $L = \left[\frac{x}{22.13}\right]^m$

L = Slope length factor
x = Slope length in m (max. 100m; see Stocking et al., 1988)
m = exponent:

m = 0.5 if s =	> 5%
m = 0.4 if s =	3 - 5%
m = 0.3 if s =	1 - 3%
m = 0.2 if s =	< 1%

4: USLE cropping factors table. (see annex 5)

5: USLE erodibilty factors table.

6: $K = 0.02241\ [0.00021\ \{12\text{-}o\}\ \{f(100\text{-}c)\}^{1.14} + 3.5\ (s\text{-}2) + 2.5\ (p\text{-}3)]$

K = Erodibility factor
o = % organic matter
f = % very fine sand + silt
c = % clay
s = soil structure class
p = permeability class.

7:	A_1	=	R	x					S_1	x	C_1
8:	A_2	=	R	x	K_1	x	L	x	S_2	x	C_2
9:	A_3	=	R	x	K_2	x	L	x	S_2	x	C_2

The landform attribute contains information about the general slope gradient of the most appearing general landform. The landform types present on the LASOTER area are:

2a	-hilland	dominated
2b	-upland	dominated
2c	-valley	dominated
2d	-plain	dominated

The description of these four landforms is designed with an interval of dominating slope gradient in the SOTER unit. The four landforms are designed with the following intervals of slope gradients:

-hilland	:16 - 30 %
-upland	: 4 - 16 %
-valley	: 4 - 16 %
-plain	: 0 - 4 %

The land use types present in the LASOTER area are:

3a	-	annual cropland
3b	-	pasture land
3c	-	grassland
3d	-	shifting cultivation
3e	-	forest land
3f	-	plantation land

5.4. The control variables

5.4.1. R-factor

The rainfall erosivity factor is represented by the Modified Fournier index (Arnoldus, 1980). It is defined as the sum of the quotient of the squared mean monthly rainfall (p) and the mean annual rainfall (P), given as:

$$\sum_1^{12} (p^2/P)$$

5.4.2. S-factor

The slope factor was designed by calculating the USLE slope factor for the slope gradient classes for each landform. The slope gradient factor is given as:

$$S = 0.065 + 0.045(s) + 0.0065(s^2)$$

Where S= the slope factor and s= the slope gradient in %.

As we saw earlier, Stocking et al. (1988) posed a restriction to the slope gradient which we must take into account. The variable 'hilland' is designed with a slope gradient interval from 16 to 30%. This interval is reduced to 16 - 20 %.
The control variable classes have to be translated into single values in order to produce single value maps. This is done by taking the class middle as the single value and labelling it with a range.

This results into the following slope factor intervals and single values:

-hilland:	1.120 - 3.570	hilland	: 2.35 ± 1.22
-upland :	0.840 - 1.120	upland	: 0.98 ± 0.14
-valley :	0.840 - 1.120	valley	: 0.98 ± 0.14
-plain :	0.065 - 0.840	plain	: 0.45 ± 0.39

5.4.3. The C-factor

The control variable 'crop factor' was created by attaching crop factor intervals derived from the USLE computer program (Jetten, 1988) to the general land use. The procedure resulted in the following cropping factor intervals and single values:

-forest:	0.001 - 0.004	forest	:0.0025	± 0.0015
-grassland:	0.004 - 0.009	grassland	:0.0065	± 0.0025
-shifting cultivation:	0.01	shifting cultivation	:0.01	± 0
-pasture:	0.025 - 0.10	pasture	:0.0625	± 0.0375
-plantation:	0.20 - 0.30	plantation	:0.25	± 0.05
-annual cropping	0.30 - 0.50	annual cropping	:0.40	± 0.15

5.5. Result example

Before coming to the design of the control variable maps and the final output procedure we will illustrate the result of the assessment for four contrasting SOTER units

SOTER unit 23: is an upland area in Brazil, at the border with Argentina, with annual cropping as general land use. It covers about 1100 km^2.

SOTER unit 33: is a hilland area in Brazil where shifting cultivation takes place. It covers about 1500 km^2.

SOTER unit 1003: is a SOTER unit in the SW of the LASOTER area, being part of the Rio Paraná river plain in Argentina. Here, pasture is the general land use. It is a small unit covering about 100 km^2.

SOTER unit 2007: is a valley unit in Uruguay generally occupied with grassland and covering about 12000 km^2.

The Modified Fournier Index, MFI, characterizing the rainfall intensity increases from SW to NE. The MFI is lowest for SOTER unit 1003, and highest for unit 23. The mean MFI's for the example units are:

- 23: 143
- 33: 135
- 1003: 105
- 2007: 115

The S- and C-factor are defined according to their landform and land use (see paragraph 5.2.). For the example units they are:

SOTER unit	S-factor	C-factor
23	0.98	0.40
33	2.35	0.01
1003	0.45	0.0625
2007	0.98	0.0065

The resultant erosion hazard indices are:

- 23 : 56.1
- 33 : 3.2
- 1003: 3.0
- 2007: 0.7

5.6. Design of the single value maps

The three control variables result in three different maps containing, for each 1x1 km pixel of the LASOTER area, a single value for each control variable. The overlay of these maps results in a map containing erosion hazard units of the LASOTER area for each SOTER unit.

The area data control variables, in the ORACLE database can be linked with the integer-binary ILWIS grid file, containing SOTER unit_ID's, the LASOTER map. This is to be seen in figure 8. This is done by means of the ATTRAS module in ILWIS. The SOTER units 1 to 156 are to be found in Brazil, those with ID's 1001 to 1264 in Argentina and 2001 to 2083 in Uruguay.

The ILWIS grid files may contain every *integer* value between -32768 and 32768. The attribute values of the control variables in the database contain *real* values with up to 4 decimals.
In order to convert these real values into integer values, they have to be multiplied by 10,000 for C-factor and 100 S-factor. After this operation the values of the C-factor reach from 25 to 4000 and of the S-factor from 45 to 235. (compare with original values)
These maps are shown in Annex 2 and 3.

The creation of an ILWIS file for the Modified Fournier Index (MFI), required more handling. The variables 'longitude', 'latitude', 'station number', 'mean monthly rainfall' and 'mean annual rainfall' of the 59 stations in and around the LASOTER area where selected from the 'climkey' table in ORACLE and stored in a newly created table. These data were exported to the LOTUS spreadsheet, in order to calculate the MFI. The data could have been interpolated in ILWIS, to obtain a grid map of the MFI. However, the quality of the interpolation procedure in ILWIS is rather limited. (see annex 1.)

In order to obtain a proper grid map of the MFI, we choose the method optimal interpolation also known as kriging (Burgess and Webster, 1980a,b,c)

Before interpolation, it is necessary to create a graph, representing the semi-variance of the data. The semi-variance is a measure of relationship between separate observations based on their distance (Burgess and Webster, 1980a). The graph, the semi-variogram, is the principle tool in kriging. The creation and fitting of the graph was done using SEMIVA/WLSFIT (latter: Weighted Least Square FITting of semi-variograms, G. Heuvelink, 1988). The final interpolation was done in GEOEAS.

ORACLE ATTRIBUTE TABLE

ID	ATTRIB UTE
1	5
2	6
|	|
|	|
1001	8
1002	5
|	|
|	|
2001	6
2002	9
|	|

\+

LASOTER ILWIS-GRID MAP

1001	1001	1001	1001	1001	1001	1	1	1	1
1001	1001	1001	1001	1002	1002	1	1	1	1
1001	1001	1002	1002	1002	1002	2	1	1	1
1001	1002	1002	1002	1002	2	2	2	1	2001
1001	1002	1002	1002	2	2	2	2001	2001	2001
1002	1002	1002	2	2	2001	2001	2001	2001	2001
1002	1002	2	2001	2001	2001	2001	2002	2002	2001
2001	2001	2001	2001	2001	2002	2002	2002	2002	2001
2001	2001	2001	2001	2002	2002	2002	2002	2002	2001
2001	2001	2002	2002	2002	2002	2002	2002	2002	2002

-->

ATTRIBUTE ILWIS-GRID MAP

8	8	8	8	8	8	5	5	5	5
8	8	8	8	5	5	5	5	5	5
8	8	5	5	5	5	6	5	5	5
8	5	5	5	5	6	6	6	5	6
8	5	5	5	6	6	6	6	6	6
5	5	5	6	6	6	6	6	6	6
5	5	6	6	6	6	6	9	9	6
6	6	6	6	6	9	9	9	9	6
6	6	6	6	9	9	9	9	9	6
6	6	9	9	9	9	9	9	9	9

Figure 8: Creation of an attribute grid file from an ORACLE attribute table and the LASOTER map through the ATTRAS module in ILWIS.

This resulted in 10x10 km grid file of the MFI (a real-ASCII file). This file was translated into a integer-binary grid file for ILWIS. This map was converted into a 1x1 km grid map, by enlarging the map 10 times, and reduced, to fit within the proper (survey area) limits of the LASOTER area. (from 700x820 km to 504x590 km) The GEOEAS/ILWIS conversion was handled by a small program called EAS2ILW (Pulles, 1991). (See Annex 6.)

5.7. Output procedure

Generation of output implies creation of proper single value grid files and the erosion hazard grid file, and colour prints of the three single value maps and the erosion hazard map.

As stated in the previous paragraph, ILWIS grid files contain integer values. Therefore the real values of the S- and C-factor in the database had to be converted to integer values.
The ILWIS integer grid maps were converted into IDRISI (Geographical Analyze System, Eastman (1988)) real grid maps. Ultimately the Erosion hazard map could be created. This map was reclassified and converted for ILWIS in order to create the final erosion hazard map. (See annex 4.)

Summarizing: in order to create the erosion hazard map of the LASOTER area in this assessment, the path, shown in figure 9 was followed.

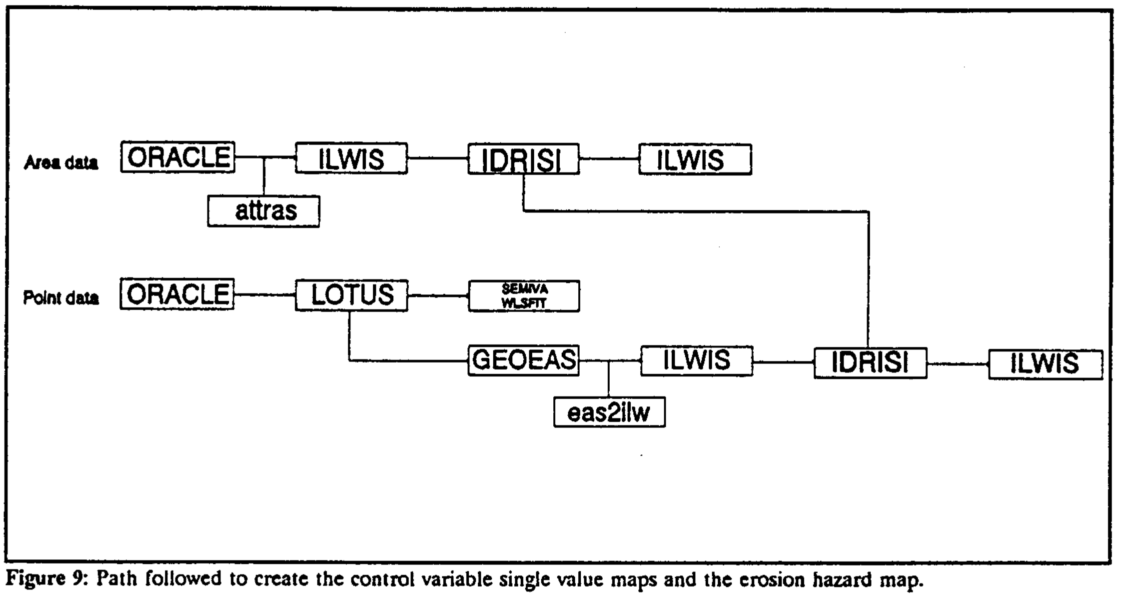

Figure 9: Path followed to create the control variable single value maps and the erosion hazard map.

The resultant erosion hazard map was reclassified according the following class limits:

No hazard	<0.2			EHU	
Very slight	0.2	-	1	EHU	
Slight	1	-	6	EHU	
Moderate	6	-	12	EHU	
Severe	12	-	24	EHU	
Very severe			>24	EHU	(see annex 4)

6. DISCUSSION

The Modified Fournier Index was used to characterize the rainfall 'aggressiveness'.
It is a good representative for the rainfall erosivity on the mapping scale of 1:1M. It has been used in former studies on comparable scale (Manrique, 1988). Stocking et al. (1988) stated that for wide geographical coverage, the simpler the variable and the better available it is, the better will be the resultant assessment of erosivity.

The land use parameter was used to obtain a control variable to depict the influence of the crop type. This was done by choosing USLE cropping factors from tables. Although care was taken to choose the best fitting C-factors, the procedure was more or less arbitrary, and, therefore, remains very doubtful!

Some remarks are to be placed onto the result of the example in paragraph 5.5. The MFI values are obtained by taking the weighted average for the units. The S- and the C-factors are derived from the attribute tables in paragraph 5.2. The chosen values here, especially those for the S- and C-factor may cause large errors. These values are the class middle values. The minimum and maximum values for those classes differ significantly.

We can illustrate this by calculating minimum and maximum erosion hazard for the example units.

For unit	23:	minimum :	140 x 0.84 x 0.30	= 35.3
		maximum :	147 x 1.12 x 0.50	= 82.3
For unit	33:	minimum :	130 x 1.12 x 0.01	= 1.5
		maximum :	140 x 3.57 x 0.01	= 5.0
For unit	1003:	minimum :	100 x 0.065x 0.025	= 0.2
		maximum :	110 x 0.84 x 0.10	= 9.2
For unit	2007:	minimum :	110 x 0.84 x 0.004	= 0.4
		maximum :	120 x 1.12 x 0.009	= 1.2

These results give the effective range of the erosion hazard for the four units. This may not seem a satisfactory result, but it gives an impression of the variance of the erosion hazard within a unit, caused by this procedure.

The data from the 'climkey' file in the SOTER database were exported to the LOTUS spreadsheet to calculate the Modified Fournier Index, because of the limited mathematical possibilities of ORACLE/SQL*plus.

The calculation of the erosion hazard map in ILWIS, created the problem that all resultant values were larger than the maximum integer value of 32768. The minimum integer value in the three control variable maps are 90, 25 and 45 for MFI, C- and S-factor map respectively. The product of these values is 101,250 > > > 32768.

For this reason the ILWIS-ORACLE configuration had to be left for a second time. The Geographical Analyze System IDRISI (Eastman, 1988) provides the possibility to use real values in grid maps.

The LASOTER database provides a file containing data about extent, degree and severity of different types of land degradation (the 'degradation'-file). These are results from expert's judgments in the field.

Annex 7 and 8 show severity of topsoil loss and terrain deformation due to water erosion in recent years. These two maps indeed show that it is the NE of the LASOTER area which is affected by water erosion. This is the most significant parallel with the outcome of this study (compare with annex 4).

Most obvious are the contradictions between annex 7/8 and annex 4. The valley area at the Brazil/Uruguay border shows that the map items are 'not applicable'; in the 'degradation'-file this unit is indicated as 'naturally stable'.
To the east and west of this valley, (in annex 7 and 8) areas are indicated that suffer from severe topsoil loss and terrain deformation. These areas are not indicated in the erosion hazard map. The same goes for a central SOTER unit in annex 8 (moderate terrain deformation).

These differences may be caused by the choice of 1 single value for each general land use type. Within 1 land use type there may be a variety of land use types, each having a different impact on erosion.

The error resulting form these choices of single values for C - and also S-factor was already illustrated in the above example. Minimum and maximum erosion hazard may differ up to a factor 10 or even more.

It also may result from the lack of detail in the data on the highest - SOTER unit - level of the database. It will be necessary to use terrain component data to obtain results comparable with expert's judgment results as in annex 7 and 8.

The application of the new, 1991 SOTER version may also improve the results.

7. RECOMMENDATIONS AND CONCLUSIONS

The framework shown in figure 7 shows the possibility to assess the erosion hazard, using attributes from the terrain component file and profile/layer file (the soil level, see fig. 4). Up to the moment this report is written a procedure for this low level output has not been established. It will be elaborated during a follow up survey.

The control variable modules in the framework are in terms of USLE but the contents may be changed with control variables' transfer functions from other models.

During this study it showed that SLEMSA, and especially the modified SLEMSA links up with the application of SOTER. The elaboration implies the estimation of transfer functions to overcome the lack of data in order to obtain approximate values to utilize the modified SLEMSA on the lower database levels.

Although produced results have their limitations, they give an overview of the problem areas. These areas are the uplands of Brazil in which mainly annual cropping takes place and the valleys in Brazil. These are the areas to focus on. Another part of interest may be the area in Argentina, situated along the Rio Uruguay. Although flat, the results indicated quite high erosion risks.

The results of the assessment can be cross checked using the 'degradation' file in the SOTER database. It gives severity of the some land degradation processes based on the judgement of experts in the field (see annex 7 and 8).

The maps showing severity of top soil loss and terrain deformation caused by water erosion.

The objective to determine quantitative erosion rates for the LASOTER area turned out to be impossible to reach. This is only possible using field level based models on the, for these models applicable scale.

The attributes determined according to the SOTER concept, and data in the database of the LASOTER area, are insufficient to run more refined models. With the new SOTER manual this situation will be improved.

ILWIS and ORACLE showed their limitations. For this kind of study we were forced to leave the ILWIS/ORACLE configuration. The path showed in figure 9. can be simplified by executing the interpolation procedure in ILWIS. As it showed to create comparable results in the case of the Modified Fournier Index.

The mathematical limitations of ORACLE/SQL*plus were overcome by changing to the LOTUS spreadsheet. Another spreadsheet program, SQL*CALC, links directly to ORACLE, and attribute rasters may be created without leaving the ILWIS/ORACLE configuration.

The use of published tables to estimate the USLE cropping factors remains doubtful. It causes large error when compared with experts judgments on topsoil loss and terrain deformation observed in the field. Therefore it is recommended to use other functions or tables, e.g. Leaf Area Index or the interception rates of vegetation types as used in the Modified SLEMSA model.

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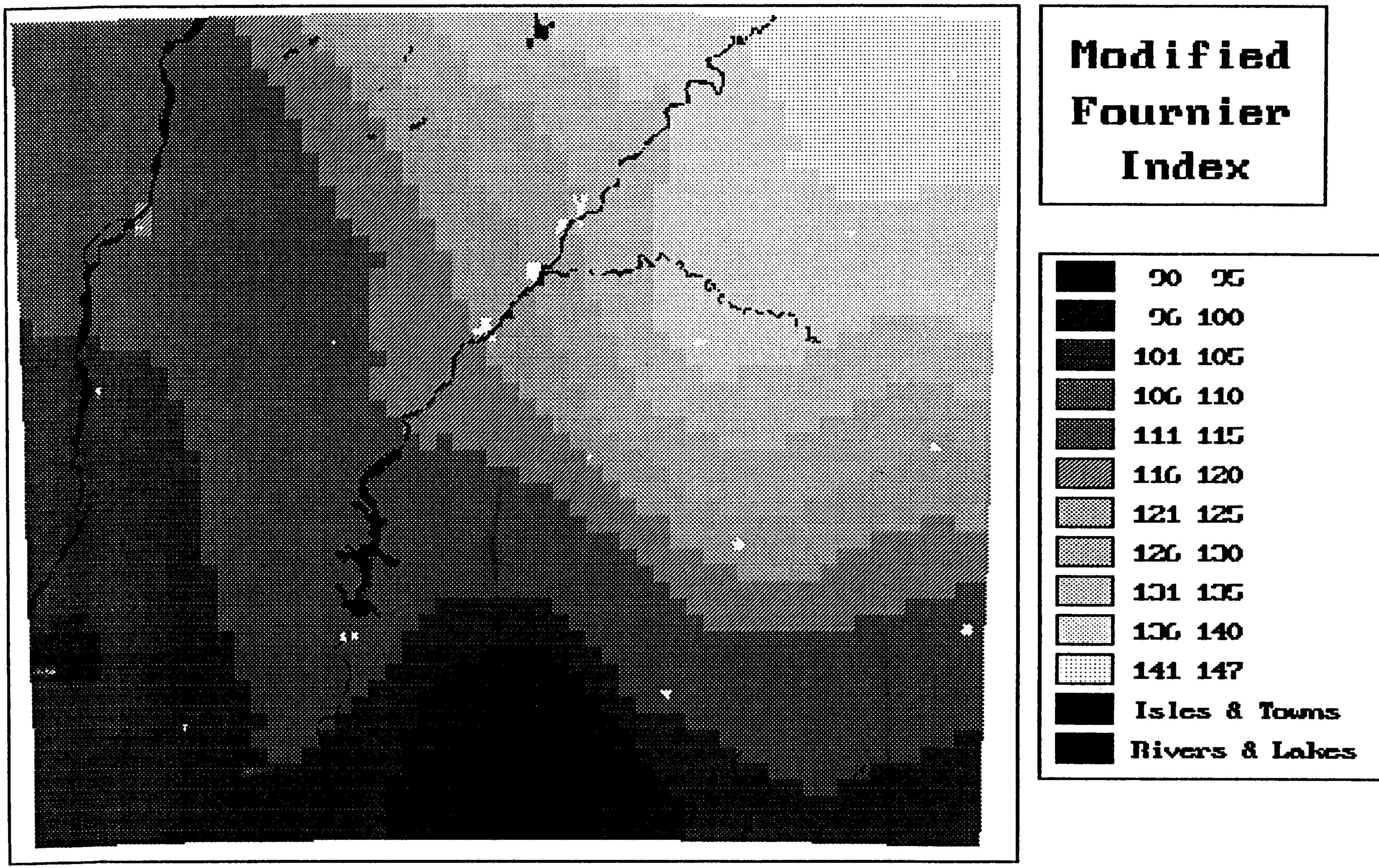
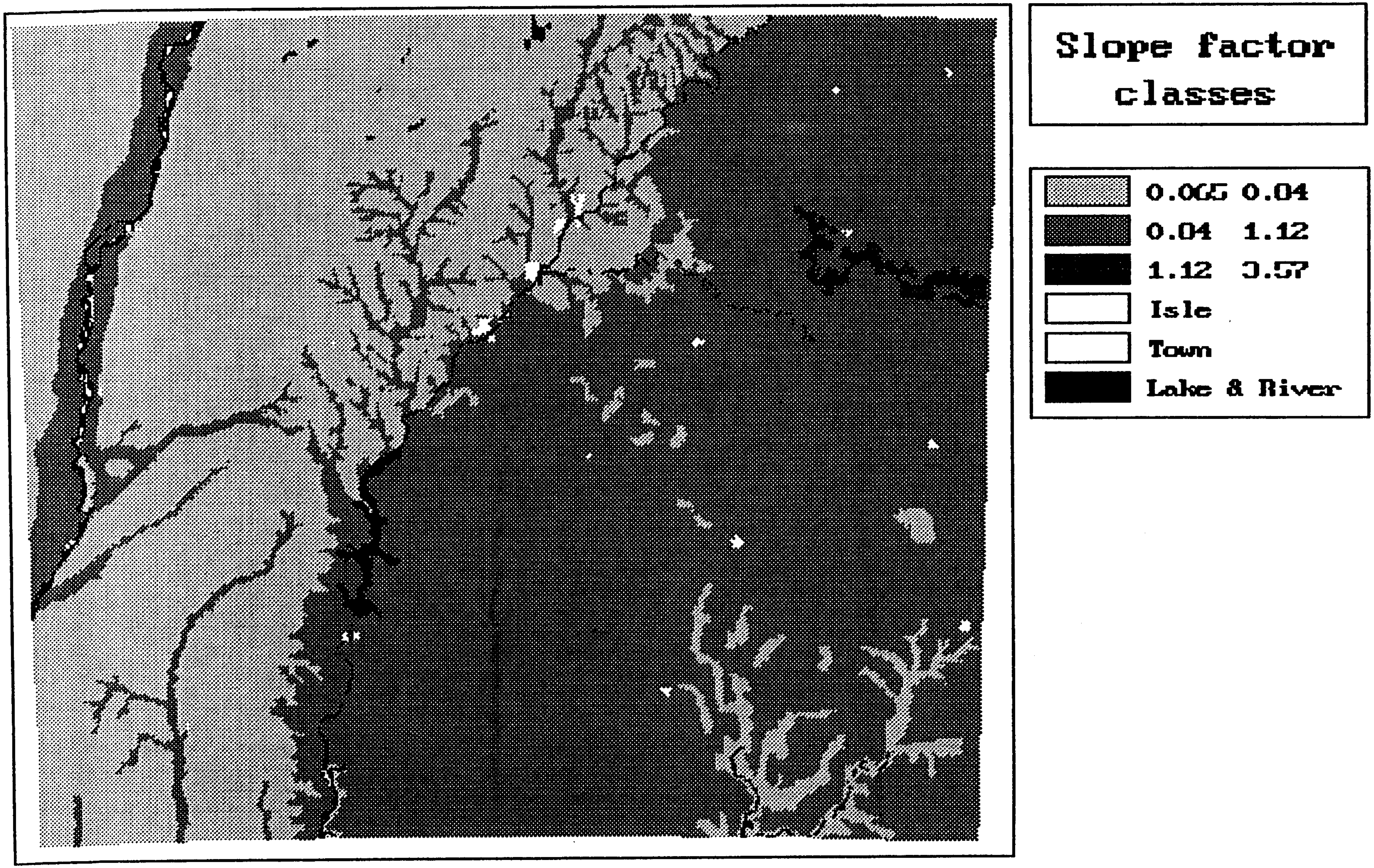
ANNEX

Annex 1



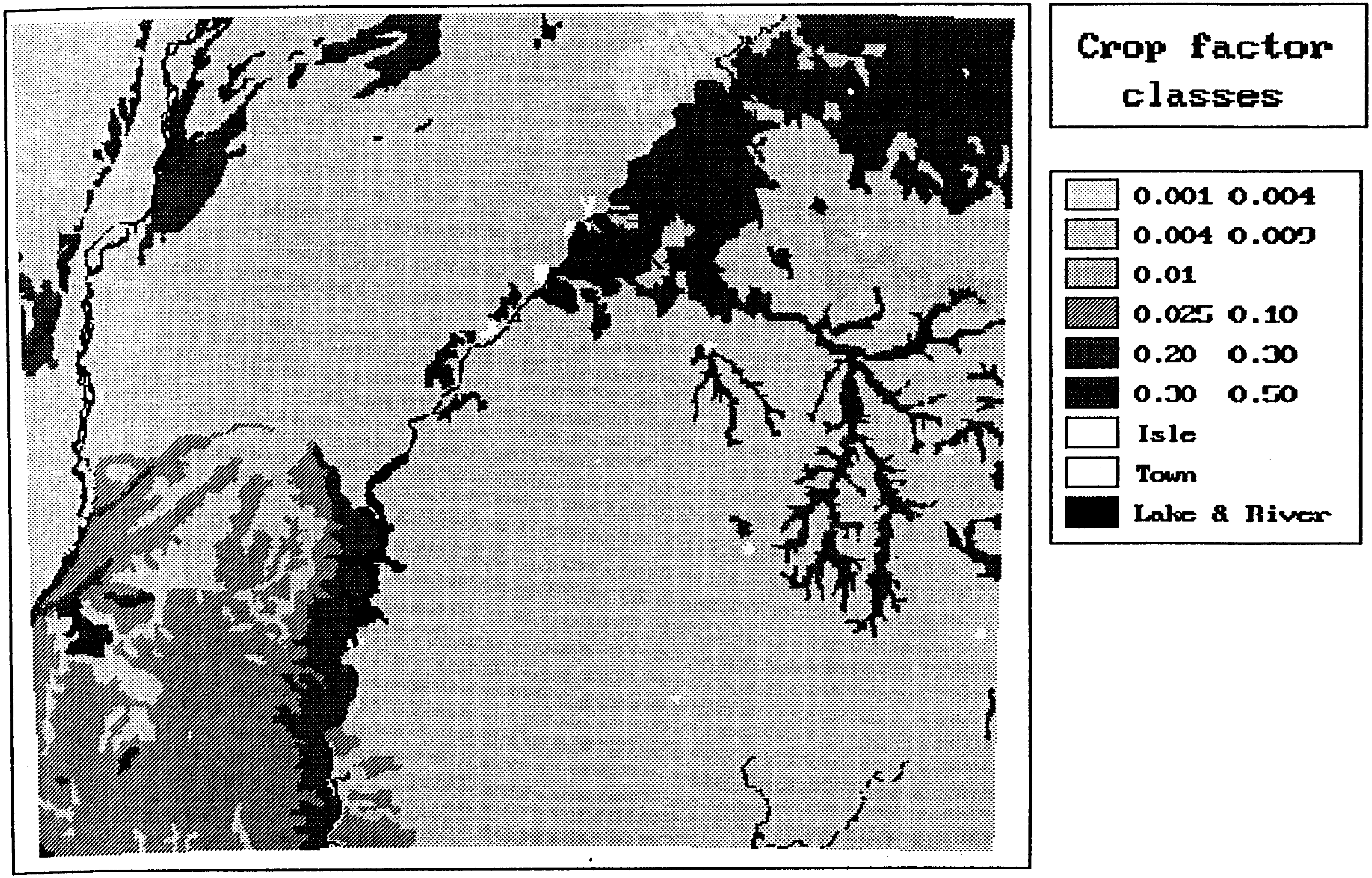
LASOTER pilot area

Annex 2



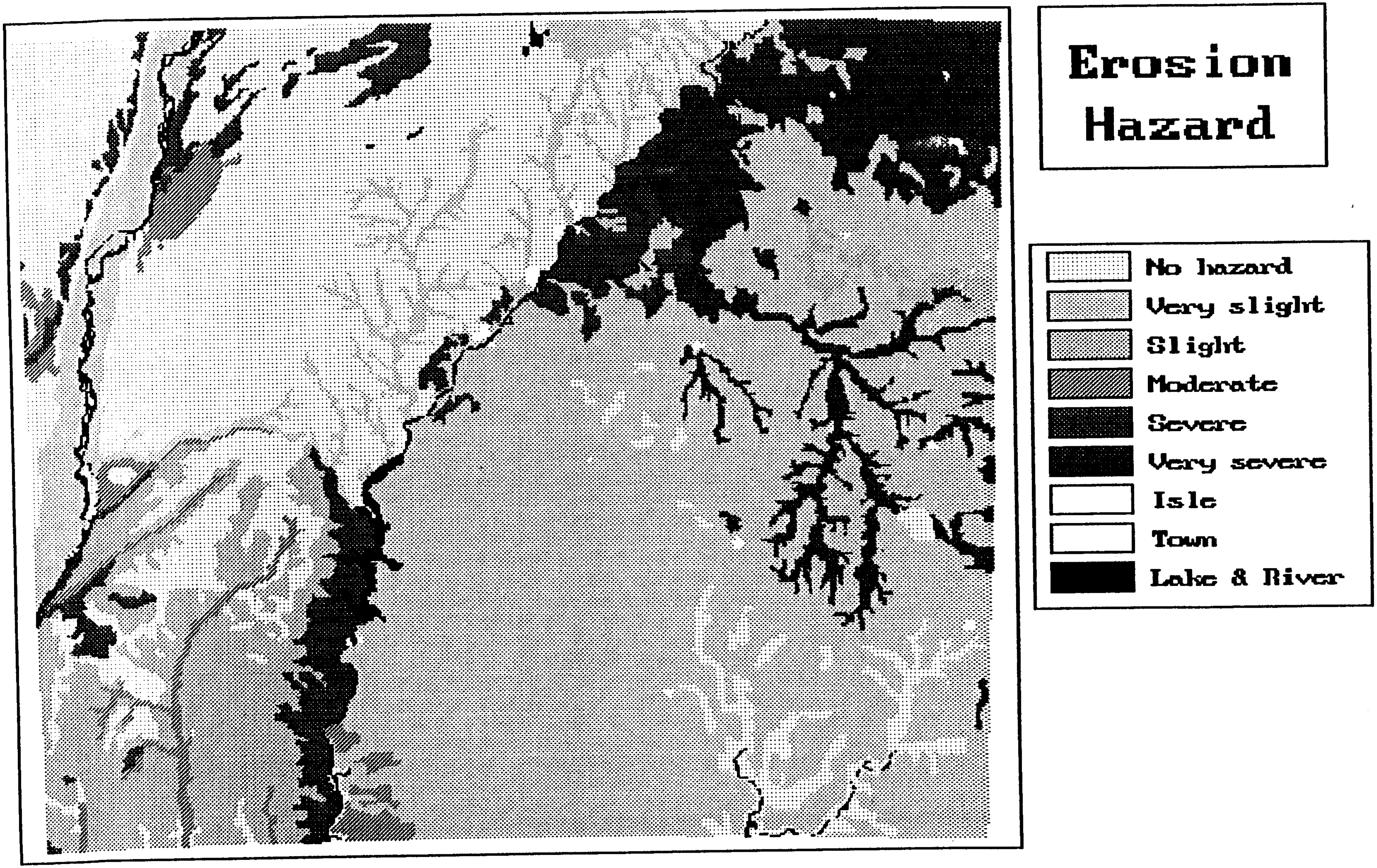
LASOTER pilot area

Annex 3



LASOTER pilot area

Annex 4



LASOTER pilot area

Annex 5

Grain Page 2

Crop: MAIZE — Area: Europe

Growing Stages:	1	2	3	4	5	6
Conventional	0.32	0.94	0.45	0.12	0.09	0.44
"spurlockerung"	0.32	0.54	0.45	0.12	0.09	0.44
Stripcropping						
with barley	0.32	0.36	0.21	0.12	0.09	0.44
Mulching	0.20	0.11	0.07	0.02	0.01	0.10
Minimal tillage	0.08	0.08	0.06	0.02	0.01	0.10
planted after meadow						
1st year	-	0.15	0.30	0.27	0.15	0.22
2nd year	-	0.32	0.51	0.41	0.15	0.26
3rd year	-	0.36	0.63	0.50	0.26	0.30

Grain Page 1

Crop: MAIZE — Area: North West USA

Growing Stages:	1	2	3	4	5	6r/6a
1st year after meadow						
Low yield	0.15	-	0.32	0.30	0.19	0.30/0.50
Medium yield	0.10	-	0.28	0.19	0.12	0.18/0.40
High yield	0.08	-	0.25	0.17	0.10	0.15/0.35
2nd year, medium yield						
Residues removed	0.60	-	0.65	0.51	0.24	- /0.65
Residues left	0.32	-	0.51	0.41	0.22	0.26/ -
left+winter grass	0.20	-	0.37	0.33	0.22	0.15/ -
Continuous, medium yield*						
Residues removed	0.60	-	0.65	0.51	0.24	- /0.65
Residues left	0.32	-	0.51	0.41	0.22	0.26/ -
Res. left+winter grass	0.20	-	0.37	0.33	0.22	0.15/ -
Planted after oats						
legume inters.	0.25	-	0.40	0.38	0.24	0.30/ -

Grain Page 3

Crop: MAIZE — Area: Tropics

Growing Stages:	1	2	3	4	5	6	mean annual
Kenia	0.9	0.7	0.4	0.4	0.7	0.1	-
Ethiopia	-	-	-	-	-	-	0.10
West Africa	-	-	-	-	-	-	
high yield	-	-	-	-	-	-	0.40
medium yield	-	-	-	-	-	-	0.65
low yield	-	-	-	-	-	-	0.90
Jamaica	-	-	-	-	-	-	0.29-0.64
Tropics general	-	-	-	-	-	-	0.20

Grain Page 4

Crop: WHEAT, SORGHUM, MILLET, SMALL GRAINS

Growing Stages:	1	2	3	4	5	6	Annual Mean
Tunesia, Wheat	0.53	0.68	0.60	0.38	0.15	0.30	
USA, Small grain	0.65	0.70	0.45	0.05	0.03	0.20	
Tunesia,							
Wheat/stubble-grazing	-	-	-	-	-	-	0.40
Ethiopia, Sorghum	-	-	-	-	-	-	0.10
West Africa, Sorghum/Millet							
(function of yield)	-	-	-	-	-	-	0.4/0.9
Jamaica, Sorghum	-	-	-	-	-	-	0.24
Tropics general							
Wheat, winter sown	-	-	-	-	-	-	0.1/0.2
Wheat, spring sown	-	-	-	-	-	-	0.2/0.4
Barley	-	-	-	-	-	-	0.1/0.2
Rice, normal	-	-	-	-	-	-	0.01
intensive fertilization	-	-	-	-	-	-	0.1/0.2
North West Pacific							
Wheat, stubble not burned	-	-	-	-	-	-	0.60
Wheat, stubble burned	-	-	-	-	-	-	0.75

Grain Page 5

Crop: SMALL GRAINS

Cropping system	Crop residues: removed	left
Strubble mulch residue tillage with cropping sequences of high yield:		
1. Grain, 4 yr pasture, summer fallow	0.12	0.11
2. Grain, 3 " "	0.12	0.11
3. Grain, 2 " "	0.13	0.12
4. Grain, 1 " "	0.14	0.13
5. Grain, summer fallow	0.16	0.15
Conventional tillage with cropping sequences of high yield:		
1. Grain, 4 yr pasture, summer fallow	0.16	0.14
2. Grain, 3 " "	0.17	0.15
3. Grain, 2 " "	0.19	0.17
4. Grain, 1 " "	0.21	0.19
5. Grain, summer fallow	0.23	0.20
Conventional tillage with medium yield		
1. Grain, summer fallow	0.24	0.21

Fruit

Crop: PINEAPPLE, BANANA

	Annual Mean
West Africa	
Pineapple, on contour, burned	0.2 - 0.5
buried	0.1 - 0.3
mulching	0.01
tied-ridging (slope 7%)	0.1
Jamaica	
Pineapple	0.40
Banana	0.55
Pacific	
Pineapple	
Spring planted	0.17 - 0.19
Summer planted	0.29 - 0.18
Fall planted	0.31 - 0.31
Winter planted	0.20 - 0.24

Pasture Page 1

Crop: PASTURE, SAVANNA, PRAIRIE

Growing Stages:	1	2	3	4	5	6
Southern Europe						
Pasture 1st year	0.65	0.30	0.25	0.20	0.15	0.025

	Annual Mean
Southern Europe	
Perennial pasture	0.025
North West Pacific	
Pastures, humid region or irrigated	0.001
Range or poor pasture	0.05 - 0.10
Grass/ legume hay land	0.05
Lucerne	0.10
USA	
Continuous annual grass	
or legume pasture or hay (100% cover)	0.10
Continuous perennial grass (100% cover)	0.003
Established grass and legume meadow	0.40

Pasture Page 2

Crop: PASTURE, SAVANNA, PRAIRIE

	Annual Mean
Tunesia, Permanent Pasture	0.01
Ethiopia, Dense grass	0.01
Degraded grass	0.05
West africa	
Savanna, prairie in good condition	0.01 - 0.002
Savanna, prairie overgrazed	0.1
Sahel Natural herbaceous cover	
- good cover	0.01
- Scanty cover	0.45 - 0.47
Jamaica, Pasture	0.01
Tropics general	
Cultivated grass	0.004 - 0.1
Prairie/Savanna grass	0.01 - 0.1

Pasture Page 3

Crop: PASTURE

	Annual Mean
Tropics General,	
Pastures non-irrigated	
Land prep. to planting:	
- minimum tillage	0.40 - 0.30
- plowing and sprigging	0.70 - 0.60
- furrowing and sprigging	0.50 - 0.40
Planting to close in	
- Minimum tillage	0.40 - 0.20
- Plowing and sprigging	0.60 - 0.20
Close in to grazing or cutting	0.20 - 0.05
Grazing or cutting to full cover	0.05 - 0.01
Pastures irrigated	
Land prep. to planting	0.80 - 0.70
Planting to close in	0.70 - 0.20
Close in to begin first grazing	0.20 - 0.05
Begin to end first grazing	0.05 - 0.01

Tree crops Page 1

Crop: COFFEE, COCONUT, RUBBER, THEA, CASHEW

	Annual Mean
Tunesia, Olives(12 * 12m) with wheat stubble	0.60
Jamaica	
Coffee, with bare soil	0.60
Coffee, with groundcover	0.20
Cocoa (coconut)	0.80
Palmtree, coconut	0.70
Cashew	0.50
West Africa,	
Coffee	0.1 - 0.3
Palm tree, coconut with crop cover	0.1 - 0.3
Tropics General,	
Tea	0.1 - 0.3
Coconut	0.1 - 0.3
Rubber	0.2
Palm tree, Oil	0.1 - 0.3
Coffee (general)	0.1 - 0.3

Tree crops Page 2

Crop: COFFEE, ORCHARD

Growing Stages:	1	2/3	4-1st harvest	2nd harvest
Tropics General				
Coffee, normal grown	0.40	0.30	0.10	0.05
Coffee, shade grown	0.30	0.20	0.10	0.05

	Annual Mean
Tunesia	
Orchard without groundcover	0.90
Southern Europe	
Orchard without undercover	0.90
Orchard with undercover	0.20
California	
Orchard cover crop, spring disked	0.25
[illegible] untilled, mowed	0.10

Tree crops Page 3

Crop: FOREST

	Annual Mean
Tunesia, Dense forest	0.003
Ethiopia, Dense forest	0.001
Other forest	0.01
West Africa, Forest or dense shrub	0.001
Tropics General	
Forest/Woodland (with undergrowth)	0.001 - 0.002
Coniferious/tropical	0.001 - 0.004
Temperate broad leaved	0.001 - 0.004
Jamaica, Forest	0.003
North West Pacific, Forest duff	0.001
Southern Europe, Forest	0.01

Others

Crop: COTTON, SUNFLOWER, TOBACCO, VINEYARDS

Growing Stages:	1	2	3	4	5	6
USA, 1yr cotton after meadow	0.15	0.34	0.40	0.30	0.30	-
2yr cotton after meadow	0.35	0.65	0.68	0.46	0.42	-
Cotton continuous	0.45	0.80	0.80	0.52	0.48	-
Tunesia, Sunflower	0.43	0.64	0.56	0.43	0.32	0.37

	Annual Mean
NW Pacific	
vineyards, with cover crops	0.20
vineyards, clean tilled	0.90
Pacific, Sugarcane irrigated: Spring planted	0.13 - 0.18
Summer planted	0.15 - 0.17
Fall planted	0.27 - 0.27
Winter planted	0.29 - 0.24
West Africa, Cotton, Tobacco (second cycle)	0.5 - 0.7
Jamaica, Chilly Peppers	0.80
Cotton	0.85
Tobacco	0.16
Sugarcane	0.30
Tropics General, Cotton	0.3 - 0.7

Intercropping

Crop: INTERCROPPING

	Annual Mean
Tunesia	
wheat / pasture / stubble-grazing	0.43
wheat / stubble-mulch / legumes	0.53
beans / wheat / fodder / wheat	0.59
wheat / fallow / fodder / fallow	0.60
wheat-18 months fallow	0.66
3 x pasture - wheat / barley	0.15
3 x pasture - wheat / fallow / wheat	0.23

Tuberous crops

Crop: (SWEET) POTATO, SUGARBEET, YAM, CASSAVA, TARO

Growing Stages:	1	2	3	4	5	6
Tropics General, Yam	0.70	0.60	0.50	0.40	0.20	0.10
Europe						
Potato	0.32	0.80	0.40	0.05	0.08	0.44
Sugarbeet	0.32	0.85	0.45	0.05	0.03	0.44
Sugarbeet with mulching	0.20	0.09	0.06	0.03	0.03	0.15

	Annual Mean
Tropics General	
Cassava/Yam	0.2 - 0.8
Potato	0.2 - 0.3
Sugarbeet	0.2 - 0.3
West Africa, 1st year Cassava and Yam	0.2 - 0.8
Jamaica	
Sweet Potato	0.40
Irish Potato	0.45
Yam	0.70
Cassava	0.65
Taro	0.70

Legumes/vegetables

Crop: BEANS, PEAS, GROUNDNUT, CABBAGE, RAPESEED

Growing Stages:	1	2	3	4	5	6
Europe						
Vegetables conventional	0.32	0.46	0.38	0.03	0.01	0.02
Veg. minimum tillage	0.08	0.08	0.06	0.01	0.01	0.02
Rapeseed	0.32	0.46	0.38	0.03	0.01	0.01
Tropics General	1/2		3/4	5	6	
Pigeon peas, minimum tillage	0.40		0.30	0.20	0.20	
complete plowing	0.80		0.70	0.20	0.20	
Vegetables (general)	0.70		0.60	0.40	0.20	

	Annual Mean
West Africa, Peanuts	
(function of yield and date of planting)	0.4 - 0.8
Ethiopia, legumes (general)	0.15
Tropics General	
Beans	0.2 - 0.4
Groundnut	0.2 - 0.8
Cabbage/ Brussels sprouts	0.3

Fallow/mulching

Crop: fALLOW, BADLANDS, MULCHING

	Annual Mean
Bare soil (potential soil loss)	1.00
Ethiopia	
Badlands hard	0.05
Badlands soft	0.40
Fallow hard	0.05
Fallow ploughed	0.60
West Africa	
After clearing of tropical rainforest	0.01
Mulching with milletstraw (depending on soil)	0.17/0.38
Mulching with sugarcane residue	0.013
Mulching with Pineapple residue	0.0001
Soil protected with gauze	0.049
California	
Continuous clean-tilled fallow (research plots)	1.00
Continuous tilled fallow, 1000 pounds straw/acre maintained on soil surface	0.50
Continuous bare soil surface, untilled	0.50

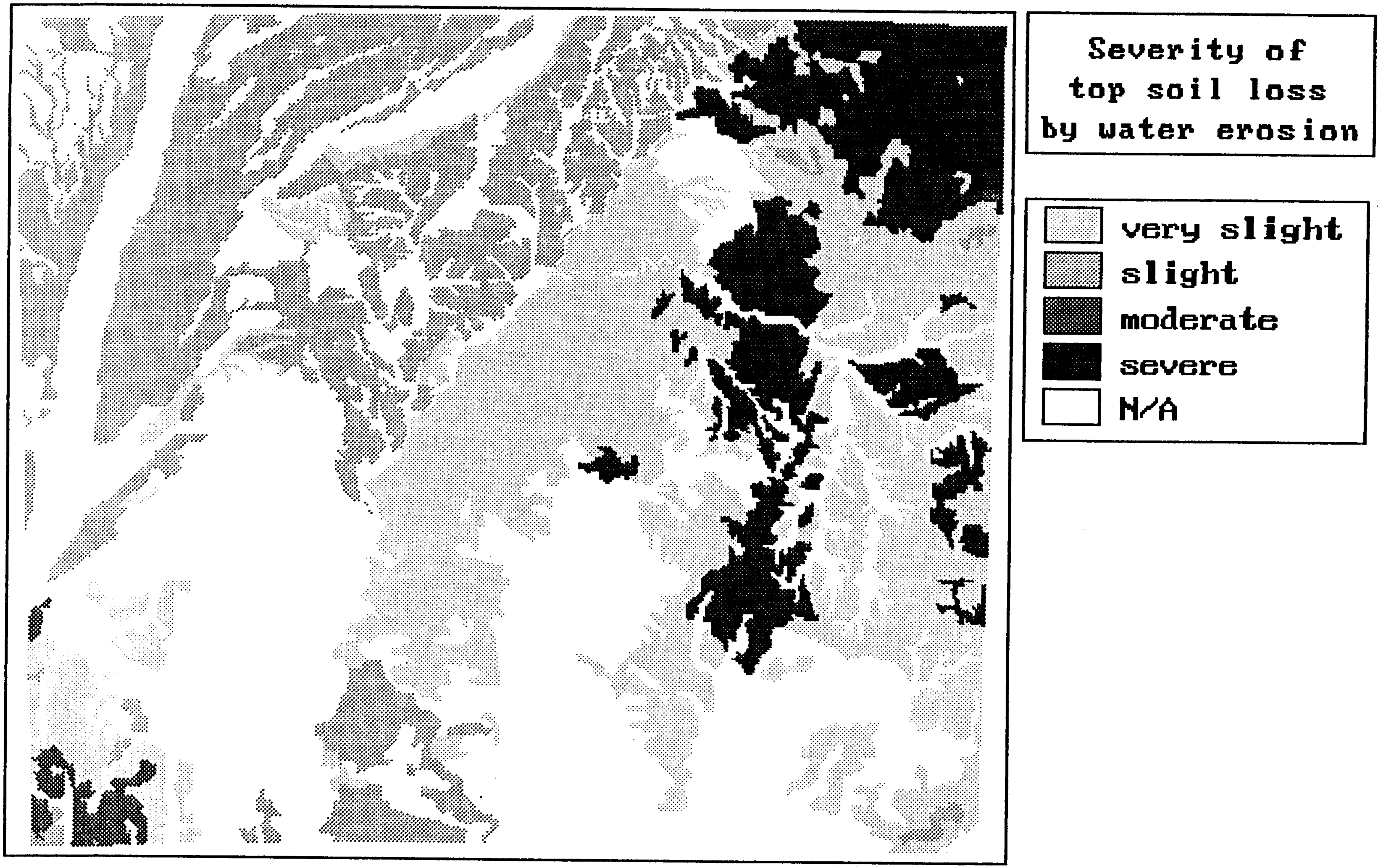
change page   select C-factor   Esc return to menu

Annex 6

```
/* EAS2ILW.C */
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <math.h>
#include <ilwis.h>

struct mpi mpi;

void main( int argc, char *argv[] )
{
	FILE *filin, *filout;
	char dummy[132], fname[144];
	/* static int raster[70][82]; */
	int *raster;
	double f[4], n, sd, scalefact;
	int i, j, rijen, kolommen, var;

	if( argc < 6 )
	{
		printf( "Format: eas2ilw infile outfile rows columns {0|1|2|3}\n" );
		printf( "  0=x, 1=y, 2=value, 3=sd" ), exit(0);
	}
	if( (rijen = atoi( argv[3] )) <= 0 )
		printf( "Number of rows must be positive." ), exit(1);
	if( (kolommen = atoi( argv[4] )) <= 0 )
		printf( "Number of columns must be positive." ), exit(1);
	if( !(raster = malloc( rijen*kolommen*2 )) )
		printf( "Not enough memory for raster." ), exit(1);
	if( (var = atoi( argv[5] )) < 0 || var > 3 )
		printf( "Select from columns 0 to 3." ), exit(1);

	strupr( strcpy( fname, argv[1] ) );
	if( !strstr( fname, ".GRD" ) )
		strcat( fname, ".GRD" );
	if( !(filin = fopen( fname, "rt" )))
		printf( "Error opening '%s'\n", fname ), exit(1);

	/* lees over de header heen indien aanwezig */
	if( fscanf( filin, "%lf", &n ) == 0 )
	{
		for( i = 6; i > 0; i-- )
			fgets( dummy, sizeof(dummy), filin );
	}
	else
		fseek( filin, 0L, SEEK_SET );

	for( i = 0; i < kolommen; i++ )
	{
		for( j = 0; j < rijen; j++ )
		{
			if( fgets( dummy, sizeof(dummy), filin ) == NULL )
			{
				printf( "Error: no more lines in input" ), exit(1);
			}
```

```
			if( sscanf( dummy, "%lf %lf %lf %lf\n", &f[0], &f[1], &f[2], &f[3] ) != 4
)
			{
				printf( "Error: not 4 numbers on one line: %s", dummy ), exit(1);
			}
			n = f[var];
			raster[(rijen-j-1)*kolommen+(i)]  =  (n  ==  .1E+32)  ?  -32767  :
(int)(n+0.5);
			printf( "%03d:%03d\r", i, j );
		}
	}
	fclose( filin );

	/* open and write MPD file */
	strupr( strcpy( fname, argv[2] ) );
	if( !strstr( fname, ".MPD" ) )
		strcat( fname, ".MPD" );
	if( !(filout = fopen( fname, "wb" )))
		printf( "Error opening '%s'\n", fname ), exit(1);

	fwrite( raster, 2*rijen*kolommen, 1, filout );
	fclose( filout );

	/* schrijf MPI file */
	mpi.row_count = rijen;
	mpi.col_count = kolommen;
	mpi.map_type = 2;
	mpi.max_value = -1;
	strcpy( strrchr(fname,'.'), ".MPI" );
	filout = fopen( fname,"wb" );
	fwrite( &mpi, sizeof(mpi), 1, filout );
	fclose( filout );

	free( raster );
}
```

Annex 7



LASOTER Pilot Area