DESIGN OF AN INFORMATION SYSTEM

TO SUPPORT SOIL DEGRADATION MAPPING AND MONITORING IN LAKE NAIVASH AREA (KENYA)

SOMIA ABDELATI M. A.
February 2002

DESIGN OF AN INFORMATION SYSTEM
TO SUPPORT SOIL DEGRADATION MAPPING AND MONITORING IN LAKE NAIVASH AREA (KENYA)

SOMIA ABDELATI M. A.

Thesis submitted to the International Institute for Geo-information Science and Earth observation (ITC) in partial fulfilment of the requirements for the degree of Master of Science in Natural Recourse Management (NRM)

<u>Degree Assessment Board</u>

Assoc. Prof. Dr D.G. Rossiter	(Head of Division)
Prof. Dr. Ir. A. Bregt (WAU)	(External Examiner)
Dr. K.de Bie (ITC)	(Internal Examiner)
Ir.B.Krol (ITC)	(Main Supervisor)
Dr A. Farshad (ITC)	(Student Advisor)

ITC

INTERNATIONAL INSTITUTE FOR GEO-INFORMATION SCIENCE AND EARTH OBSERVATION
ENSCHEDE, THE NETHERLANDS

Disclaimer

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Soil degradation is one of the serious global issues and it will remain an important issue for the 21st century (H.Eswaran et al., 2001). According to Oldeman, 1988, it can be defined as a process that describes human–induced phenomena, which lower the current and /or future capacity of the soil to support life. Similarly it has a direct impact on the environment and seriously affects the land use (Shrestha, 1989).Steiner, 1996 reports that 20%of the world agricultural land has been irreversibly damaged in the last 50 years due to soil degradation.

Human–induced soil degradation has been classified into four types (Oldeman et al., 1991):
1) water erosion 2) wind erosion 3) chemical degradation and 4) physical soil degradation. Lal, 1994 stated that about 1.1 billion hectares of world′s soils are affected by water erosion, 0.55 billion hectares by wind erosion, 0.24 billion hectares by chemical and 83 million hectares by physical degradation. This indicates that soil erosion caused by wind or water is the most important form of degradation. In Africa the problem is so severe that about 494 million hectares in total are affected by soil degradation, out of which 85% are caused by water and wind erosion(Oldeman et al., 1991).

Soil degradation as it occurs in different forms has negative impacts on land (the word “land” refers here to all component of the landscape: soil, vegetation cover, hydrological systems and land use) such as declining land productivity, loss of biodiversity and increasing the sedimentation of reservoirs.
The assessment and monitoring of soil degradation is very important for setting polices and formulating plans for the affected areas and vulnerable areas. This is quite important for all countries that affected by degradation, in particular those countries depending on agricultural production with lack of alternative economic activities. Kenya is one of these countries where two–thirds of the country is arid to semi arid and rain-fed agriculture is confined to the remaining one-third of the country; with the increasing demand of food most of the agricultural activities expanded to the fragile areas and steep slope without proper conservation plans, which is results in land degradation (Wangati and Said, 1997)

Therefore database for land degradation is expected to be in a great demand nationally and regionally instead of written reports and analogue maps. These written reports and analogue maps does not allow retrieval, update and analysis of data within an acceptable time, as it required in change detection. Information systems could help to overcome some of these issues; it provides structure and tools to improve data accessibility, analysis and update. However, most of the research related to soil in general and soil degradation does not take the temporal factor into consideration although it is recommended (Zinck, 1992). The Second International Conference on Land Degradation held in Thailand (1999) strongly recommended developing databases and information systems to support research on land degradation (Anecksamphant et al., 1999).

Sanders, 1994 stated that although many efforts have been done on the last decade in the field of soil degradation assessment, the global assessment of soil degradation (GLASOD) is still the only acceptable approach up to now, but still at small scale.
So, designing a soil degradation information system for large-scale degradation assessment and monitoring is the major goal for this study. The information system will help in generating useful and timely information about land degradation trends and status.

1.1. Problem statement

In many developing countries still the traditional system for data storage and processing is dominant with the data analysis and update being difficult and time consuming. In the Naivasha area in Kenya, some research has been started in the field of information system development and soil data management for improving user access to soil information in general (Tilaye 2001), but this does not emphasize aspects of land degradation. However degradation is taking place in different degree from extreme to light and, furthermore soil erosion is seriously affecting the agricultural production and the volume of fresh water in lake Naivasha (Hamududu, 1998)

Naivasha is an area where commercial farming takes place, making it a backbone of Kenyan economy; this area is affected by water and wind erosion due to intensive agriculture (Hamududu, 1998), removal of the original vegetation in rainfed areas (Nagelhout, 2001). Overgrazing, deforestation and cropping in hill slope in the upper part of the catchments (Ringo, 1999). For all these reasons many studies have been conducted (Hamududu 1998,Nagelhout2001, Ringo1999 and Orare 2000) and much data have been collected for different purposes; including soil degradation. These data have been stored in different levels of spatial detail, and using different approaches. This makes it difficult for the user to categorize or combine such data for further studies.

1.2. Objectives

The general objective of this research is to design a prototype information system for storing, retrieving and analysing soil degradation status and trends in Naivasha area.
The specific objectives of this study are

1. To develop a working approach with an information system for soil degradation monitoring in lake Naivasha area in the information system context including 1) data needs 2) conceptual framework (e.g. GLASOD).

2. To organize the available multi-source, multi-temporal soil degradation data for lake Naivasha area in a common data base structure including appropriate metadata.

1.3. Resarch questions

1. What is the demand for land degradation information around lake Naivasha?

2. What soil and land resource data are needed for spatio-temporal analysis of land degradation?

3. Can existing working approaches for small-scale degradation assessment (i.e. GLASOD) be applied to large-scale studies as well?

4. Which database model is most suitable to store, organize multi- scale, multi -temporal data for soil degradation assessment and monitoring?

5. What is a suitable standard and tools for Metadata documentation for these diverse data sources?

2. LITERATURE REVIEW

2.1. Land degradation studies and soil information systems for the Naivasha area

Over the past years various research projects dealing with soil degradation have been conducted in the Naivasha area (see also figure1). (Hamududu, 1998) conducted his research for assessing soil erosion (water erosion) for Naivasha using the Morgan model .He focused on the relation between reflectance (using Landsat TM, data), rainfall and landcover. Covering the watershed area[1] he stated that the actual erosion is low in this area but in some areas the rate is high (the scarp and the steeper slopes), and the potential erosion is very high in the area.

Ringo, 1999 carried out a water erosion assessment using the USLE model. This study-covered area about 63.100 hectare[2]. He concluded that the actual erosion in the area is low but the erosion susceptibility is generally high to very high.

Nagelhout, 2001 used the concepts of GLASOD approach in combination with small format aerial photography for studying wind erosion, covering an area of about 360 hectare[3]. This research concluded that about 4.5% of the area was affected by severe to very severe wind erosion and that most of the degradation features have started only recently. (Orare, 2000) covered an area of about 7000 hectare[4]. According to his results about 75 % of the central and southern part of this area (7000 ha) is severely to very severely damage by wind erosion and 20% is still relatively unaffected (following a reconnaissance survey approach with remote sensing).

There is only one research on this area in the field of information system development and data management, by (Tilaye Bitew Bezu, 2001). His thesis deals with soil information system design emphasising multi source data integration to improve user access to soil data in general. In his study the non-spatial element has been emphasized.
Figure 1 shows the spatial areas covered by above-mentioned studies

[1] Between 0 00 to 1 00 S and 36 00 to 36 45 E
[2] Between 0 24 04 S 36 23 23 E
[3] Between 0 49 to 0 53 S and 36 27 TO 36 29 E
[4] Between 0 47 S TO 0 59 S and 36 26 to 36 21 E

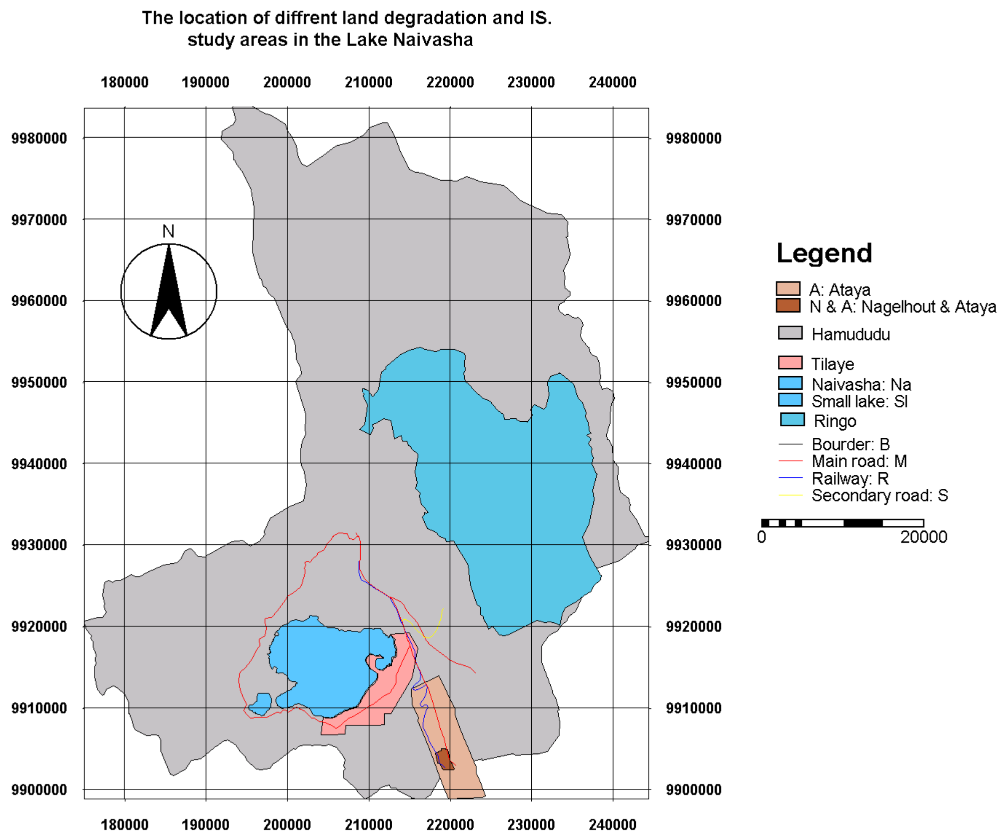


Figure 1 the location of different land degradation and IS Study Areas in the Lake Naivasha area

2.2. Land degradation assessment and mapping

Mapping the spatial distribution of land degradation plays a vital role in management planning. (Hoosbeek et al, 1997) divided degradation mapping techniques into two models: qualitative and quantitative. For qualitative models he stated that the qualitative models drive from Jenny ′s equation, by adding the management factor to Jenny's equation. The soil characteristics can be predicted as function of these forming factors while the management factor allows defining the susceptibility to degradation. He stated that the interaction between those factors could help in mapping units and predicting other areas.
The quantitative approach focuses on the use of geostatistices models by means of interpolation from point data. These two methods are in correspondence with modelling real words as discrete (DMSV) and continuous model (CMSV). The first model (DMSV) can be applied for mapping land degradation features like water and wind features but for chemical and physical degradation the CMSV can be used.

Shrestha, 1989 mentioned the use of remote sensing techniques for the assessment of land degradation. He indicated that some degradation process like rill and gully forming a spatial pattern in the landscape could be assessed directly from aerial photos or high-resolution satellite images. But chemical, physical or biological degradation is difficult to map directly from RS imagery although, salinity could be mapped if it is very severe. Also he pointed out that other degradation processes like loss of nutrients, and soil pollution could be inferred from vegetation cover, but it is very difficult to map the extent of the problem in such cases.

Orare, 2000 used aerial photographs and Landsat TM images to assess and map soil degradation in relation to land cover and land use. He considered a combination of aerial photo interpretation with NDVI images and field visits to assess wind erosion. However, [(Nagelhout, 2001) stated that interpretation of photogrammetric aerial photographs is not an effective approach to map wind erosion. He used Small Format Aerial Photography (SFAP) for assessing and mapping wind erosion. The advantage of this procedure is that it can provide up to date and high-resolution information (colored) but the disadvantage of this method is the small coverage of (SFAP) as compared to conventional aerial photography.

To overcome the limitation (spatial & spectral resolutions) of using one type remote sensing imagery (Dwivedi et al, 1997) integrated different remote sensed data (MSS, TM, IRS- IA, LISS-II) for mapping soil erosion using interpretation of Land sat MSS/TM, IRS –IA, LISS-II with other information on lithology. They delineated three different classes. The accuracy of overall interpretation after the field visits was very high at 88.69 %

the remainder of this section describes shortly how land degradation can be assessed using different approaches. And why the information about land degradation can vary in scale and nature according to the techniques applied. Storage and retrieval of such data is rather difficult. Computer oriented data management could help in such situation.

2.2.1. Legend in mapping soil degradation

Legend here refers to the approach used in grouping land degradation entities in the map or in other words about classification systems that used to describe theses land degradation.
Here two types of classification system in land degradation can be distinguished. The first one is developed by Soil Survey Division Staff of USDA. It can be used for the specific purposes of mapping erosion severity class, which give different classes depending on the rate of soil loss per each class (USDA, 1993).
The second one developed by ISRIC[5] /GLASOD/ approach, which is used to create awareness for the status of global soil degradation. The GLASOD approach gives information about the type of soil degradation (refers to the process that causes the degradation). Main types are subdivided into more specific sub types. A final level is the degree of soil degradation (refer to the present state of degradation) (Oldeman, 1988) GLASOD discussed in details in section 2.3.

2.2.2. Small scale vs. large scale mapping of soil degradation

Scale is an important concept in mapping in general. Determination of the scale in soil degradation assessment depends on the purpose of the assessment according to (Hoosbeek et al, 1997). Being developed for global assessment of soil degradation GLASOD uses a scale of 1:10 million, thus only giving a general impression of areas with different degree of degradation. ASSOD (Assessment of Soil Degradation of South Asia) used a scale 1:5 million to assess national level soil degradation in 17countries south and Southeast Asia. If we compare between these two scales we will find that a maximum of two types of degradation is identified per map unit in GLASOD where no restrictions for the number of types per map units occur in ASSOD (Van Lynden and Oldeman, 1997). Dwivedi et al, 1997 investigated the role of the remote sensing image scale on the detectability of eroded areas using two different scales:- 1: 250,000 and 1:50,000. Their study showed that more polygons could be delineated at large scale and the number of polygons per erosion class is larger in large scale than small scale.

2.2.3. Soil degradation monitoring

Monitoring oil degradation helps not only in the study of the changes in the real extent of erosion during a time span. But also enables the evaluation of progress of soil conservation programmes executed in an area (Dwivedi et al., 1997). According to (Eswaran and Kapur, 1998) before monitoring we should determine what we will monitor and what the time interval for monitoring should be because different processes of degradation need different time intervals to be recognizable. According to (Eswaran and Kapur, 1998) salinization monitoring probably should be done every year, (if there is reason for that), where sheet erosion-monitoring needs five years and monitor gully erosion even more.

[5] International Soil Reference and Information Center

2.3. Global Assessment of Soil Degradation GLASOD

GLASOD (Global Assessment Of Soil Degradation) is both the name of a project and an approach to mapping soil degradation, which is used to create awareness for the status of global soil degradation (Oldeman, 1988).
This UNEP project was implemented and coordinated by the International Soil Reference and Information Centre (ISRIC) in the Netherlands. The objective of this project was to create awareness on the part of decision makers about the degradation danger resulting from inappropriate land and soil management, by showing the current types and extent of land degradation.

The GLASOD methodology applies a stepwise approach .The first step involves delineation of map units which show a certain degree of homogeneity with respect to their topography, climate, vegetation and land use and therefore may be expected to have similar degradation problems. The methodology does not specify how this delineation is to be done. The second step is the evaluation of the status of human-induced soil degradation that is present in each map unit. In the GLASOD project this evaluation has been done by expert consultation, but could be partially automated. Any delineation is considered separately. The information about GLASOD presented in the following sections is based on (Oldeman, 1988) and (Oldeman et al., 1991)

2.3.1. The legend of GLASOD:

Map units represented on a GLASOD map are characterized by a *colour* and associated shading and by a *symbol*. These might better be termed hue (= colour) and saturation and chroma (=shading) in standard Munsell terminology. The *colour* indicates the main degradation **type.** The *shading* of the colour indicates the **severity** level. Each mapped unit has also a symbol giving a more description of the type, subtype, degree, and relative extent, causative factors and the recent- past rate of soil degradation. What each one means and how they are symbolized on the map is explained below.

Types of soil degradation refer to the process that causes the degradation. This is one of (1) water (2) wind (3) chemical and (4) physical degradation. In GLASOD the type of degradation are represented by a two-letter code, the first capital letter giving the major degradation type, and the second lower case letter giving the subtype. This is a consistent legend, which described below.

2.3.2. Mapping symbols for soil degradation types and subtypes

GLASOD recognizes the following symbols for land degradation types and subtypes.
W: Type “Water Erosion”, with the following sub-types
Wt: loss of topsoil by sheet erosion/surface wash
Description: decrease in depth of topsoil layer due to more or less uniform removal of soil material by run off.
Wd: terrain deformation by gully and/or rill erosion or mass movements.
Description: an irregular displacement of soil material (by linear erosion or mass movement) causing clearly visible scars in the terrain.

This dose not seems to include accumulation out side a zone of erosion while in ASSOD (the Assessment of the Status of human –induced Soil Degradation in south and southeast Asia) they introduced that as an off site effect of water erosion and coded as(wo)**.** See also (Van Lynden and Oldeman, 1997)

E: Type " wind Erosion", with the following sub-types

Et: loss of topsoil by wind action.

Description: a decrease in depth of topsoil layer due to more or less uniform removal of soil material by the wind.

Ed: terrain deformation

Description: an irregular displacement of soil material by wind action, causing deflation hollows, hummocks and dunes.

Eo: off-site effects of wind erosion

Description: coverage of the land surface by wind carried particles (over blowing) it may occurs at the same map unit or adjacent.

P: Type "Physical Deterioration of the soil ", with the following sub-types

Pc: compaction, sealing and crusting

Description: deterioration of soil structure by trampling by cattle and /or frequent use of heavy machinery and sealing and crusting of the topsoil by raindrop if it is not sufficiently protected. Both compaction and crusting will lead to decrease the infiltration rate of the water, which will turn in significant water erosion.

Pw: water logging

Description: effects of human-induced hydromorphism; flooding and submergence (excluding paddy fields as it conceder to be an improvement rather than a degradation of the soil).

Ps: subsidence of organic soils

Description: subsidence of organic soils as caused by drainage and /or oxidation (its mentioned but does not seem to be mapped)

C: Type " Chemical Deterioration ", with the following sub-types

Cn: loss of nutrient and /or organic matter

Description: decrease of nutrient and or organic matter in the soil due to the agricultural practice on poor or moderately fertile soil without sufficient application of manure or fertilizers. The loss of nutrient by erosion of fertile soil is considered to be a side –effect of erosion, and not distinguish separately.

Cs: salinization

Description: change of salinity status of the soil due to human-induced activities such as irrigation.

Ca: acidification

Description: reduction of agricultural potential of the soils because of extremely low PH value due to over-application of acidifying fertilizer, or due to drainage of pyrite –containing soils. (Both types of acidification were occurred which was difficult to separate them during mapping)

Cp: pollution

Description: soil degradation due to bio –industrial sources (waste accumulation). Excessive addition of pesticides, manuring and oil pills.

2.3.2.1. Degree of soil degradation

This refers to the degree to which the soil is presently degraded. It is estimated in relation to changes in agriculture suitability, to declined productivity and in some cases to the biotic function. Four levels are recognized:

1.**Slight**: the terrain has somewhat reduced agricultural suitability but still suitable for farming system and restoration to full productivity is possible by modifications.

2.Moderate: the agricultural productivity has reduced greatly but the terrain still suitable for farming; major improvements are required to restore productivity.

3.Strong: the terrain is non reclaimable at farm level. Major engineering works are required for terrain restoration.

4.**Extreme**: the terrain is irreclaimable and beyond restoration.

The degree of degradation represented in the map by **a numbers** that is placed immediately after the degradation type symbol, for example **Wt2** ('2' here represents the degree).

2.3.2.2. Relative extent of soil degradation

Five categories are recognized:

1.Infrequent: up to 5% of the unit is affected
2.Common: 6 to 10 % of the unit is affected
3.Frequent: 11 to 25 % of the unit is affected.
4.Very frequent: 26 to 50% of the unit is affected.
5.Dominant: over 50% of the unit is affected.

It is represented in the map by a number which is placed after the degree of degradation number, and separated from it by a stop ".", e.g.**Wt2.3** ('3' here indicate the relative extent).

2.3.2.3. The severity of soil degradation

The severity of soil degradation is indicated by a combination of the degree and the relative extent of the process. Since there are four degrees specified and the relative extent is given in five categories in total 20 combinations are possible. Theses 20 combinations are then grouped into four severity classes for visualization purposes, which are termed 'light', 'moderate', 'strong' and 'extreme'. On the map each group is represented by different colour shades.

2.3.2.4. Causative factors

Five causative factors are recognized. On the map they are represented by a single lower case letter.

a : agricultural activities

Defined as improper management of agricultural land. It includes excessive use of fertilizers, short period of fallow in shifting cultivation and the use of poor quality irrigation water.

e : overexploitation of vegetation for domestic use like fuel wood, fencing, this causative factor does not involve complete removal of natural vegetation. However, the remaining vegetation provide insufficient protection against erosion.

f : deforestation and removal of natural vegetation

Defined as removal of natural vegetation (usually forest) of stretches of land, for example converting forest into agricultural land, road construction, urban development, etc.
i : (bio)industrial activities which leads usually to degradation type (Cp).
g : overgrazing beside actual overgrazing of the vegetation by livestock other phenomena were considered, such as trampling and decrease of vegetation cover.

2.3.2.5. Recent-past rate of soil degradation

Erosion rate is not strictly defined but GLASOD uses a scale of 5 to 10 years to define whether the rate is low, medium or rapid. If it is low, no indication is given on the map. Two categories are shown with special symbols:
↑ Medium.
↑↑ Rapid.

2.3.2.6. Off –site effect

Only one form of off-site effect is reported (uncontrolled human-induced flooding), but this does not seem to be used on the map, although a symbol is shown in the legend (a wavy underline).

2.3.2.7. Types of map unit

This GLASOD legend is used on the map for several types of homogeneous and compound map units. Two independent types of degradation are presented on the map unit but the causes were compound (two different factors causes only one type or two types caused by only one factor

2.4. Information-system development methodology

According to (Avison and Fitzgerald, 1988) a method is a collection of procedures, techniques and tools and documentation aids, which will help the system developer in their effort to implement new information system. (Paresi, 2000) said the most important factor for the need of methodologies is the limitation of the human mind to perceive and retain all information it requires and act on it promptly. And the main benefits from applying methodology are to get a good information system at reasonable cost and better control during the design process (Paresi, 2000).

Generally there are five methodologies for developing an information system according to (Paresi, 2000). Out of it the Socio Technical System development Methodology, Object Oriented System Development Methodology and Structured System Design Methodology.
In principal these methods used two opposite approaches in development process: linear and evolutionary design (Hawryszkiewycz, 1998) and (Krol, 1998).

2.4.1. Linear versus evolutionary design

Linear design is made up of a sset of subsequent phases. Only after one phases is complete a next phase can start. This approach is appropriate if the problem is well defined and the requirements for each phase can be specified precisely. This approach implies that if there is any new idea or problem

discovered later it couldn't implement or solve in the system. While in evolutionary approach the system is developed gradually. Development starts with some small part of the system. During the time experience is gained and new requirements evolve which are then implemented as well.(Hawryszkiewycz, 1998)
The structured System Design methodology is following an evolutionary approach. This methodology was used as development approach in this research.

2.4.2. Structured System Design Methodology (SSDM)

The Structured System Design Methodology combines many technique and tools and integrate them into system development life cycle (Hawryszkiewycz, 1998).
This system composed of five phases used to build the system, which is 1) problem definition 2) feasibility study 3) system analysis 4) system design 5) system realization. Figure 2 shows the main phases of this system.

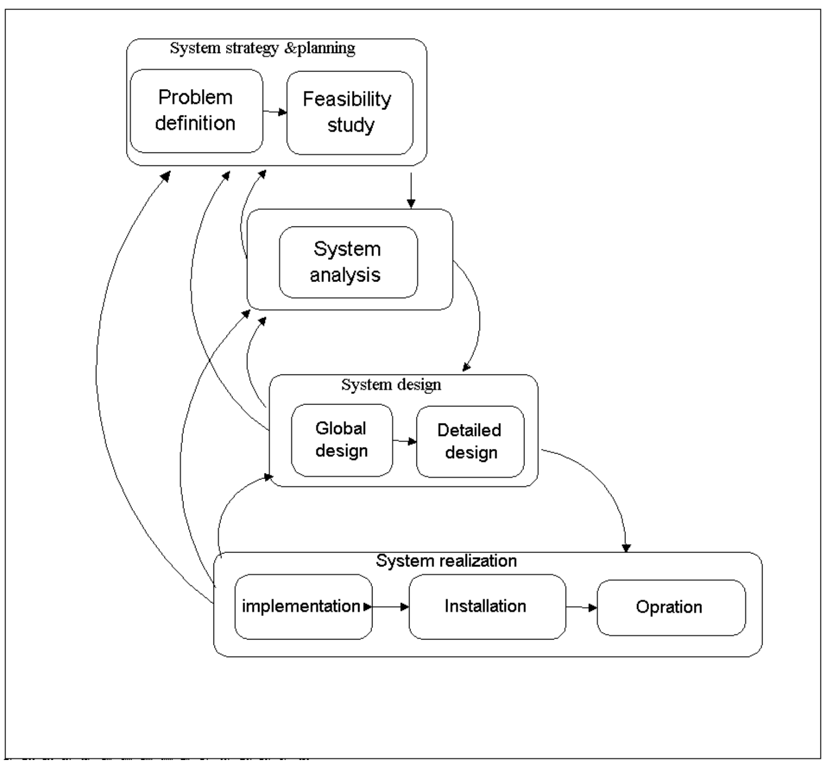


Figure 2 Structured System Design Methodology major phases
Source (Paresi, 2000)

2.5. Database design

Database design is the development of the structure of the database, as well as the definition of its contents and the specification of constrains to be placed on the validity of the data

The goals of database design are: to assure that all data needed to satisfy users requirements are stored in the data base; to provide away to understand the organization of the data and defined the functions for updating (De By, 2000) and to eliminate redundant data (Howe, 1989)

Generally there are three levels of database design (Krol, 1998):

1) Conceptual design, which is the concise description of the data requirements of the user that includes detailed description of the data types, the entities, the relationships and the data constrains.

2) Logical design; the main task of this phase is the translation of the conceptual schema into the data model of the database management system.

3) Physical design; the main task of this phase is implementing the table structure in a DBMS Software environment.

2.5.1. Database modelling

There are several models for structuring the database system. Among these are the hierarchical model, network model and relational model. At present the relational model is the main database model being applied in commercially available database management softwares (Krol, 1998).

The E-R diagram is defined as a diagram or a representation that shows individual entity occurrence and their relationships (Howe, 1989). (Bedard and al., 1996)said that an E/R model is based on three main concepts: entity, relationship and attribute. An entity represents an object with its own existence. A relation is a representation of associations between entities and the attribute contains the basic data that makes it possible to describe entity and relationship characteristics.

2.6. The temporal aspect

Time aspect is very essential issue in monitoring geographical features. (Cole and King, 1969) As cited by (Davis, 1989) considers time as temporal relationships between events and objects in space. While (Raza, 2001) defined the time as the phenomenon that can be seen by its effect.

According to (Langran, 1992) and (De By et al, 2000) there are four models that can be used to describe the change of the geographical phenomena with the time. In these models change can be described by:

1) Keeping the spatial domain fixed and changing the attribute over time for a given location in the space i.e. land use change over time from farm to pastoral area, while its boundary does not change.

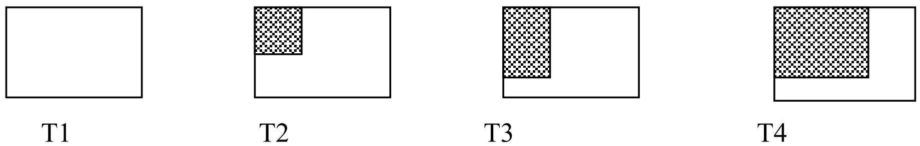
2) The attribute domain is fixed and the spatial changing over time i.e. the river shifting

3) Both spatial and attribute are variable over the time

The description of the four temporal models described below is based on (Langran, 1992) and (De By et al, 2000)

2.6.1. The snapshot model

In the snapshot model, we record only series of layers for the same theme at different moment in time. We do not have any information about the events[6] that caused the different state[7] between layers. In other words each snapshot describes what exist in Ti but to detect how Ti+ difference from Ti the two snapshots must be compared.



This snap-shot has some limitations the most important are:

- Redundant data storage (all the state has to be stored).
- No error detection (each snap is totally separate data layer).
- Hidden temporal structure (no information on the process casing the change).

2.6.2. The space-time cube model

This model depicts the process of two-dimensional space that is extended to only third temporal dimension. The space- time cube could be constructed by adding the third dimension (time) in two-dimensional space based on base state with overlay. The operations (mainly accessing and manipulation) of information in this cube are more complex and would increase the data volume.

2.6.3. The space-time composite model

The model starts with a two dimensional situation (plane or layer) at a given starting time. Every change of features that happens later is projected into the initial layer and intersected with the existing feature. Thereby, it will create polygon mesh. Over time, more and more polygons will be stored in that data layer. Every polygon has its attribute history stored with it. The attribute domain is fixed and the spatial domain variable.

These three models have a space as primary component. There is another approach in which time is primary (2.6.4).

2.6.4. The event- based model

In an event –based model, we start with an initial state and record event along the time line. Whenever a change occurs, an entry is recorded. This is a time-based model; the spatial and thematic attributes are secondary.

2.7. Metadata standards

A standard refers to the way of representing data in a system in terms of content, type and format. A standard creates a common language for users and producers. Metadata standards provide appropriate and adequate information for the design of metadata (De By et al, 2000). The Federal Geographic Data Committee (FGDC) is one of the key innovators in metadata standards and they are responsible

[6] An event is the occurrence that causes a given state to change.

[7] State is comprised of features and attributes.

for the Content Standard for Digital Geospatial Metadata (CSDGM), which is one of internationally accepted standard. For this research this metadata was used.

2.7.1. Metadata tools

Deciding between holdings the metadata in a database or produce discrete metadata documents for each data set depends on the variety and volume of the data sets, as well as how often they (and the metadata) are updated. This decision will determine which metadata tools are appropriate to consider for use (Hart and Philips, 2001). The Federal Geographic Database Committee recommends that metadata could be stored in a database if the data set is subject to frequent change, or some of the metadata is common to many of the data sets. If the data holdings have few metadata elements in common, then discrete metadata documents are a simple way to hold the metadata, and almost any tool can be used to produce it (Hart and Philips, 2001).

Categories for metadata tools including Intelligent, ASCII and word processor templates, Form based and Utilities from theses tools ASCII and word processor templates were used because its simple and it will not require special GIS software.(Hart and Philips, 2001)

3. The study area

3.1. Location

Lake Naivasha is shallow, tropical fresh water lake situated in the rift valley in Kenya (ITC&WRAP&KNWTP, 1998)) it is about 100 km North direction of Nairobi.
Naivasha area is heavily relied on the lake, as only source of fresh water for drinking, fishing, and for agriculture. The lake basin has become a major fruit and vegetable producer as well as a commercial producer of fresh cut flowers for exports. These activities (agricultural farms, fishing and flowers plantation) provide huge employment opportunities for resident in Naivasha. Figure 3 shows the general location of Naivasha with in Kenya

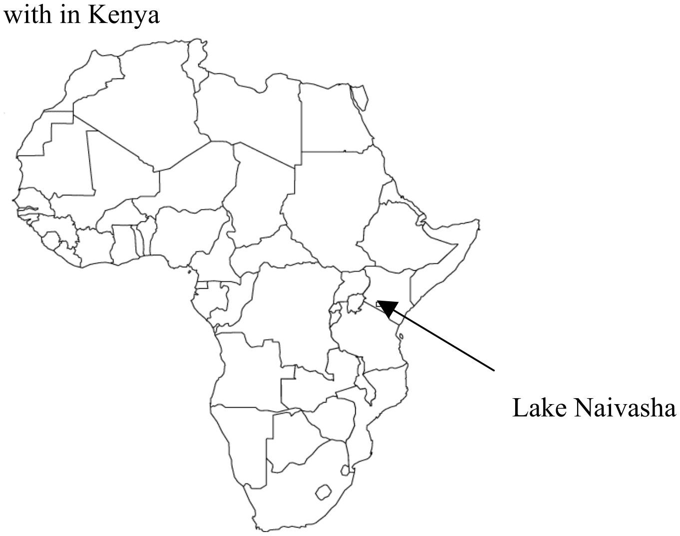


Figure 3 the general location of Naivasha with in Kenya
Source, http://www.worldatlas.com

The study area is located with in UTM zone 37 and lies between the following co-ordinates East-West (36º 26´ 05.04″ – 36º 10´ 29.56″ E)
South –North (00º 54´ 03.25″ –00º 36´ 32.34″ S)

This geographic location includes Niavasha lake and its surrounding .The user need assessment studied all the area around the lake but the spatial data collected in tow priority areas (Longonot and Ndabibi) figure 4 show the two areas and the farms where the interviews was carried out.

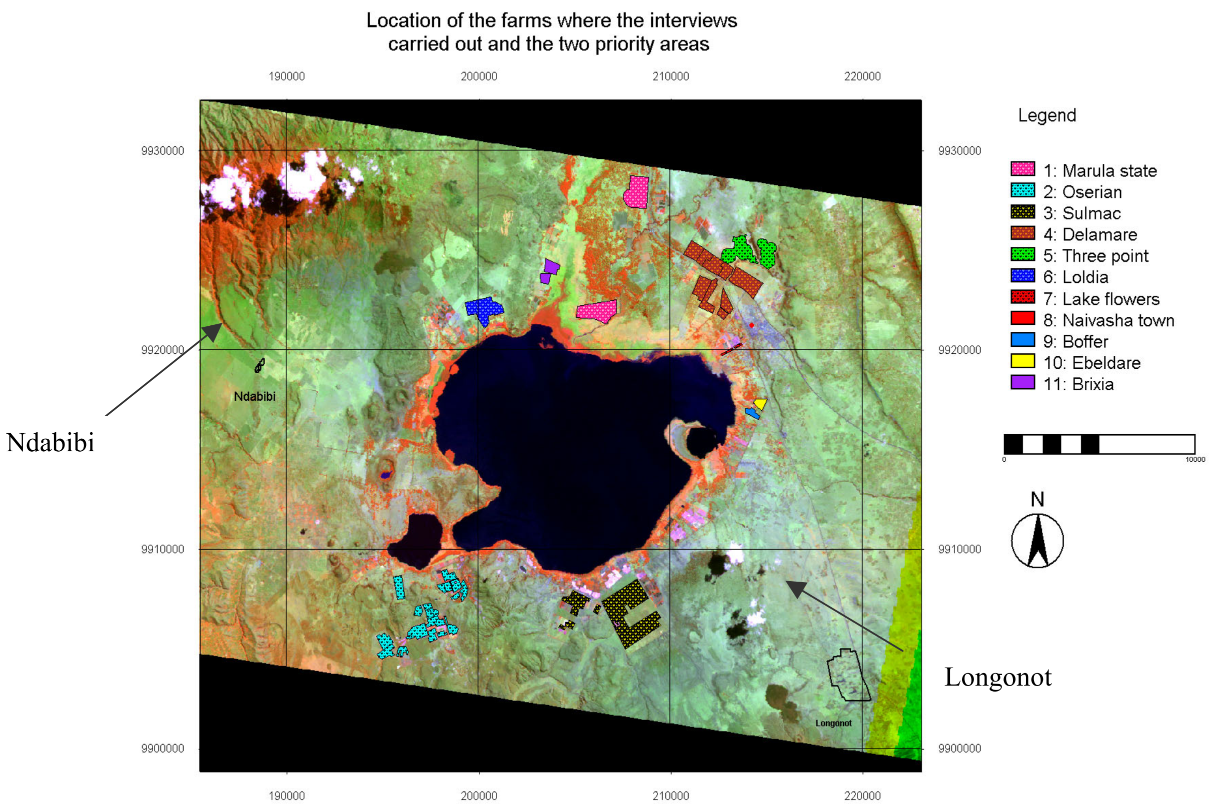


Figure 4 The location of different farms where the interviews
Carried out and the two priority areas

3.2. Climate

The Naivasha area has a semi-arid climate with an average annual rainfall ranging from about 600mm/year (around the lake) to 1200mm/year in the upper catchment (ITC&WRAP&KNWTP, 1998). The mean annual temperature ranges from 15.5 to 18.3 Cº, with minimum and maximum temperature of 7.9 Cº and 27.3 Cº respectively (P.T.Kamoni, 1988)
Figure 5 showing the mean Climatic Graph of Naivasha for the period of 1966-1980.

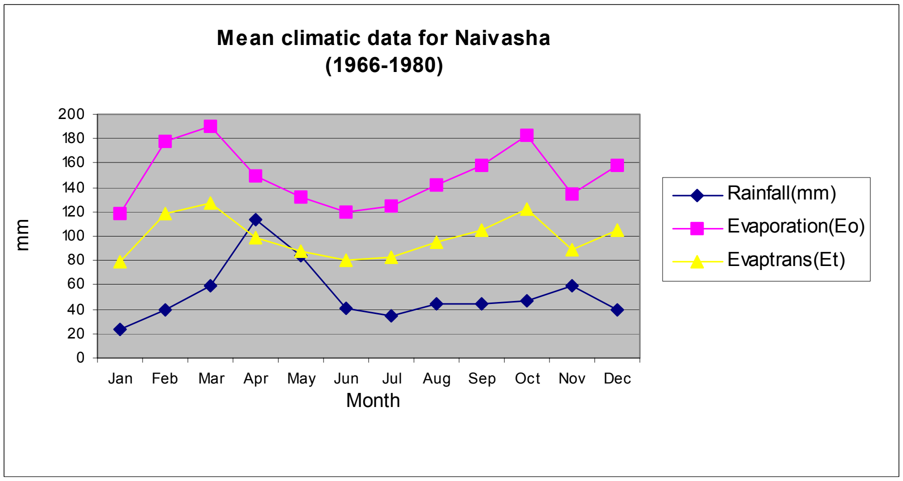


Figure 5 Mean climatic data for Lake Naivasha
Source (P.T.Kamoni, 1988)

As becomes clear from the graph the evapotranspiration exceeds the rainfall. The rainfall cannot satisfy crop water requirements (except in April). Therefore, supplementary irrigation is required to cover the deficits during the rest of the year.

3.3. Geology

The study area is covered by two types of quarternary deposits, one of which is lacustrine deposits and the other volcanic in origin (A.O.Thompson and R.G.Dodson, 1958). The older deposits in addition to clay and silt also contain a large proportion of volcanic material in the form of ashes.
The oldest rocks found insitu in the area have been dated to the tertiary era, and some rock fragments ejected by volcanoes may even be older. The volcanic rocks in the area consist of tephrites, basalt, trchytes, ashes, tuffs, agglomerates and acid lava, royalties, comendite and obsidian (A.O.Thompson and R.G.Dodson, 1958) Geological report and map of the area at scale 1:100 000 is available .

3.4. Geomorphology and soils

3.4.1. Geomorphology

(A.O.Thompson and R.G.Dodson, 1958) identified three major landscapes in the area:
1) Kinangop Plateau 2) Mau Escarpment and 3) The Rift Floor.

1) Kinangop plateau: located in the north- eastern part of area between the Aberdare range and the Rift floor. Kinangop plateau is broad flat plain ranging in height from 2.379 to 2,44 m. it's deeply incised by Turasha River.
2) Mau Escarpment: this Escarpment forms the western wall of the rift valley in Naivasha. It is composed largely of soft volcanic ashes and tuffs with rare out crop of agglomerate and lavas. Ndabibi area is located in the foot slop of this Escarpment.
3) The Rift floor: the Rift floor forms part of the Gregory Rift Valley, is diverse in its structures and topography (volcanic cones and craters, scarps and lakes). Longonot and Euburru form the highest point in the Rift, both of which rise over 2.745m. Longonot area is located with in the rift floor.

3.4.2. Soils

The soils of lake Naivasha area have been influence by the variation in relief, climate, parent material and human activities. The soil are derived mainly from weathered volcanic and basement rocks. Generally soil in the area can be group into two: soils developed on the lacstrine plain and soil developed on the volcanic plain (Dung, 2001).
Soils developed in the lacustrine plain are well drained to moderately well drained, very deep, dark brown to olive brown, silty-clay to clay- loam (Girma et al, 2001).
Soils developed in the volcanic plain are well drained, very deep, dark brown to pale brown, loams to clay loams with none calcareous to moderately calcareous top soils, and moderately to strong calcareous sub-soil (Girma et al, 2001). In particular soil in Ndabibi Escarpment has a sandy loam to sandy clay loam and pH from 4.5-5 while in Longonot area range from 5 to 5.5

3.5. Land use

The upper catchment is covered by protected forest, moore and bamboo zones. Dairy farming and cultivation of crops like maize, Pyrethrum and vegetables for subsistence and local markets is located in the middle catchment. On the valley bottom there are large commercial farms for meat production, dairy with irrigated fodder crops, irrigated vegetables and citrus for local and foreign markets, irrigated flowers for exports only.
Several private game sanctuaries and the geothermal power plant, which generate 20% of the electricity of the country, are situated in the rift valley as well (ITC&WRAP&KNWTP, 1998).

4. MATERIALS AND METHODS

This chapter deals with the specific material and procedures followed for answering the research questions formulated in chapter 1.3. It includes sections on materials, information system development methodology, database structures, metadata format and tools, the selected approach for adapting GLASOD to large-scale mapping and an overview of the research framework.

4.1. Materials

The following data and equipment were used in this research:

- Topographic maps of Kenya, 1975, scale 1:50,000 (index No 133/1 Ol Doinyo Opuru, 133/4 Longonot) by Survey of Kenya
- Geological map of Kenya, scale 1:100,000 by (Woodhall et al., 1988)
- Soil map, of Kenya, scale 1:1000,000 by (W.G. Sombroek et al., 1980)
- Landsat TM satellite images of February 2000 (Kenya), bands 2,4,5
- Wind Erosion Features map on Longonot area, scale1: 500000 by (Nagelhout, 2001)
- Garmin 12XL GPS receiver, PC interface cable, Gartrip software,
- Measuring tape, Compass

4.2. Methodological approach

The development of an approach for organizing spatio-temporal land degradation data for the Naivasha area is done in the framework of information System Development Methodology (SDM). The selected SDM provides a structured environment as well as a set of techniques and tools to help carry out selected research activities, which have been defined as follows:

- Selection of a system development methodology.
- Analysis of land degradation information requirements.
- Design of a database structure for spatio-temporal land degradation data.
- Adapting GLASOD to large-scale mapping.
- Metadata documentation.

4.2.1. Selection of system design methodology

For the overall design of the land degradation database for the Naivasha study area Structured System Design Methodology was selected because 1) it's well known, tested and widely used; 2) it's based on a life cycle approach for project management, with clear and well defined phases and activities; 3) user participation is highly conceded in this type of method and 4) they are associated with a number of tools and techniques that make use of graphical presentations see also: (Hawryszkiewycz, 1998; Paresi, 2000)

It recognises a set of iterative main activity steps: -

- Problem definition and Feasibility study
- System analysis
- System design

- System realisation

In this thesis a problem definition and feasibility study is not considered as such. Instead the research outline provides the input for further system analysis and design.

4.2.1.1. Information system analysis

In general this phase involves a detailed analysis of information system requirements.
If a system exists already this also implies an analysis of the present system and its problems. Contrasting with specified requirements results in a specification of modified system requirements (Paresi, 2000).
In this study there is no information system in place already. Furthermore, this research emphasises the design of a geographical database component of a land degradation information system. It does not focus on the management of information and related organisational issues. Therefore this phase concentrated on the identification of main users groups and their requirements from an information perspective. Information requirements were obtained by interviewing representatives of a number of pre selected potential users of land degradation information in Lake Naivasha area using standard questionnaires.
The information obtained from the interviews was used as basis for the specification of data needs for the design of the database.

4.2.1.1.1 Designing the questionnaires

Determination of the user requirements in Naivasha, Kenya was done by using questionnaires. These questionnaires were designed according to the following criteria:

- Short questionnaires that will not take more than 15 min.
- Comprised of four groups of questions (personal, about the degradation, the status of the farms, the need of information and how they like it to be visualised).
- Some of the questions are direct and others are open questions.

The objectives of these questionnaires are:

- Identifying key user groups in the area.
- Assessing their needs for land degradation information.

These questionnaires were designed based on the previous related research in the area (Tilaye Bitew Bezu, 2001).
The questionnaires are presented in appendix A.

4.2.1.1.2 Carrying out the interviews

An overview of information requirements was obtained by interviews with representatives (key persons) of the identified potential users in lake Naivasha area. The strategy followed involved formal interviews using the standard questionnaires with occasional help of the interviewer in interpreting some questions if so required by the interviewee.

4.2.1.2. Information system design

In this phase the most important activity was to model the user requirements that were obtained in the system analysis into system environment. Data Flow Diagram (DFD) and Entity Relational Diagram (ERD) are the most important tools for modelling the processes and the data of the system. The System Development Workbench (SDW) was the software tool used for the modelling.

DFD is a graphical representation for the system components. Theses system components are the 1) processes, 2) data stores, 3) external entities (stakeholders) and 4) the information flow in the system. Following the top-down approach first the whole system is modelled as one-sigle processes. The DFD representing that is termed as a context diagram (or -global system design) in information system terminology.

As the contextual diagram does not describe the system in detail a top level DFD is needed. The top-level (detailed system design) shows the various processes that make up the whole system. The important difference between the contextual diagram and the top-level diagram is the identification of the data stores (data repository) in the top-level diagram. Data store form the basic for the database in the information system.

The contextual diagram and top-level diagram for LDIS presented in chapter 5 sections (5.4.1.1 and 5.4.1.2)

Starting from the DFD the identified data stores with the external requirements are used as an indicator for major system entities and attributes. The conceptual level data modelling results in an Entity Relation Diagram (ERD) or conceptual database design in database terms.

Next, this ERD is converted to a logical database structure by identifying the logical relationships between the different entities. Since these entities may contain redundant data a so-called normalization process (removing redundant data) is carried out.

The final result is non-redundant relational model

Next the data modelling will be discussed in detail. Emphasis is on the conceptual and logical database design for this system.

4.2.2. Data modelling

Land degradation database has two components spatial and non-spatial data. For implementing those two components there are two approaches, hybrid and integrated GIS (Krol, 1998) and (De By et al, 2000). In the integrated approach the spatial and non-spatial data are integrated in the same structure but in the hybrid approach the spatial and non-spatial data are stored and managed independently in a GIS. For this research the hybrid approach was used.

4.2.2.1. Conceptual database design

The conceptual database design for LDIS depends on

- The user requirements, which are determined by the analysing of the questionnaires.
- The temporal model, which was applied for this project (see 4.2.3)
- GLASOD legend (see 4.2.4)

From these three items twelve entities with different size of attribute were identified 1) map of soil degradation, 2) degradation map unit2000, 3) GLASOD map unit2000, 4) national map unit2000, 5) degradation (polygon) delineation2000, 6) severity level, 7) Soil map,8) soil map unit, 9) polygon delineation, 10) soil components, 11) observation at sight, 12) observation at horizon level (this twelve entities in time Zero here 2000)

These 12 entity conceptually represented two types of data (**non-spatial** data i.e. degradation map unit (**DMU**), soil map unit **(SMU)** and **spatia**l data like degradation polygon delineation (**DD**) and soil polygon delineation **(Poly_id)**.

4.2.2.2. Non-spatial data modelling

The Entity –Relationship (E-R) model is a popular high-level conceptual data modelling have been selected as most suitable data modelling methods to organise the available land degradation data of lake Naivasha. The entity relationship diagram was done using SDW soft ware (figure 11), while the internal entity design handle in MS Access database management software.
The time dimension represented in the non-database as table with the year correspondent to the time (time stamps) of the data figure 11 shows that.

4.2.2.3. Spatial data modelling

As far as spatial data model is concerned, in spatial database, we distinguish between vector and raster data models. For this study the vector models was used to handle the maps, for example the map showing the status of water erosion.

4.2.2.4. Logical database design

In the logical design the conceptual data model was converted into relational table structure
The relational data structure for the LDIS will be presented in two components. These two components are the 1) soil map and 2) degradation map because of two reasons

- The soil map unit and a degradation map unit are two independent features in space and time. While soil map unit may change in the long term the degradation unit it may change in short term (e.g. it depends on the rate of erosion on the area).
- A degradation map unit can cross boundaries (it may fall into two soil map units). For these reasons, the logical design of land degradation database will be presented as two independent components.

Since this structure may contain a number of inconsistence (data redundancy), a so-called normalization process was carried out before the implementation to a relational table structure.

4.2.2.5. Information System Realisation

This is the last step in information system development methodology where by the following major activities are to be done:

- System implementation
- System installation
- System operation
- System evaluation

Of the above-mentioned activities only elements of system implementation are considered in this research. The system implementation involves creating the database; acquiring the hard and soft ware and integrating the separately developed system components.
For the actual implementation the MS Access DBMS was used to implement the relational attribute data model, the Integrated Land and Water Information System (ILWIS) was used to handle the spatial data.

4.2.3. Selection of a temporal model

For including the time aspect into this information system the snapshot model was used because of the complexity of the problem of land degradation for example,

- The degradation features shape and size and location may change against the time. The change will occur because some feature can be merged others be more eroded.

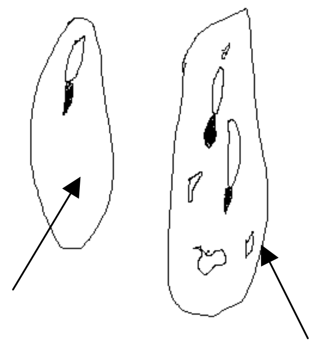
- Likewise the attribute that is describing these features it will change. For example the depth of a deflation may increase.
- For these two reasons, using the time slice may be the wise selection technique in this situation as (Guptill, 1995) clamed.

4.2.4. Adapting GLASOD to large-scale map

The GLASOD Methodology has been described in detail in chapter 2 section 2.3. This methodology describes the degradation in an area in the following points:
1-Type: water, wind, physical and chemical. (Represented by capital letter).
2-Sup type: giving more description of the type (represented by lower case letter).
3-Degree of degradation: estimated in relation to change in agricultural suitability (represent by numbers from 1- 4).
4-Extent of degradation: approximate area covered (represent by numbers 1-5)
5- Rate of degradation: based on the experience (two classes rapid and medium)
6-Severity class: this derived class from degree and extent of degradation and indicated by different shades of colours.
7-Causative factor: five causative factors identified and represented by lower case letter.

In total GLASOD legend contains seven elements in its codes (one capital letter, two lower case, two numbers an arrow and colour shade). For example (Wt2.3g ↑) this code means a degradation type 'loss of topsoil through water erosion' (Wt) that has moderate degree "2" and covers an area of 11 to 25% of a map unit "3" and the causative factor is overgrazing and the rate is medium.
One of the research questions deals with the applicability of GLASOD for large-scale maps with emphasis to water and wind erosion in the Naivasha area. Two priority areas were selected: Longonot and Ndabibi.
In Longonot area a detailed research has been conducted by (Nagelhout, 2001) for mapping deflation and depositional features using Small Format Aerial Photography) this work taken as a base for the field work in his area.
Here the applicability of GLASOD in the area was discussed from two points:
1- Assuming that all degradation features fit in the GLASOD;
2- considering that this is not the case.

First point *assuming that all the features existing in the area are represented by a code in the GLASOD legend.*
If an exisitng map of (Wind Erosion Features) by (Nagelhout, 2001) taken as an example, probably large map units could be coded according to the original GLASOD legend using the percentage of the area coverage by the deflation and depositional features in specific map unit (the density of the features in a map unit). Even if the area is 1-2 Km still it can be coded with GLASOD (see the schematic figure below for two map units affected with degradation



Ed4.1g↑ Ed4.5g ↑

(In Longonot situation)

Figure 6 Relative areas affected by degradation in two map units

But if the individual features need to be mapped then the GLASOD method is not appropriate any more.

In the example of the same area (e.g. Longonot) where the main features are deflations and depositional or loss and gain area, using GLASOD these two features will be classified as follows:

Deflation: wind erosion, train deformation, unsuitable for agriculture, 100% of the area affected, overgrazing "causative factor", rapid change. (**Ed4.5g↑)**.

Depositional: wind erosion, train deformation, unsuitable for agriculture, 100% of the area affected, overgrazing, rapid change. **(Ed4.5g↑)**

It's evident that GLASOD does not differentiate between these two features. Furthermore, the GLASOD approach does not talk about how the severity for these individual features can be determined.

Second point *where the first assumtion in the first point is not the case*

In Naivasha area also that the occurrence of some local features was found which are not considered by GLASOD This of course due to the fact that GLASOD is not designed to code detailed features.

So the major constrains of GLASOD in mapping detailed features are:

1-No difference between the gain and loss area.

2-No possibility to quantify the severity for those features.

3-Some features occurring locally not described in small scale.

So in adapting GLASOD for large scale mapping for Naivasha area, four main points were considered:

1-Maintaining the existing structure of GLASOD.

2-Maintaining the major type and sub-types as it is in GLASOD.

3-Adding two additional levels class and sub-class *to allow description of small features.*

4-Anew additional sub types were proposed in some cases.

In order to maintain as much as possible the original GLASOD framework some options can be followed:

1- Map the detailed features but also delineate the large map unit (i.e. SMU) generalizing the detailed feature. Using GLASOD principle for coding this map unit (Ed3.2g↑) , and adding additional elements to the code for describing the detailed feature: (Ed3.2 g ↑ **x x)** where 'xx' for describing the small feature. The advantage of this approach is that the GLASOD code is retrained. The disadvantage is that very long codes will result.
2-Removing the numerical part in the legend and replace them with detailed description of the feature: 'Ed xxg↑'. Where 'xx' describes the features.

The second option it seems quite applicable thus avoiding the long codes. This second option was used in this research. Where the main idea is to allow more description of the small features. Taking the subtype **deformation, which** is divided to two levels **(classes)**, which is deflation (coded: f) and depositional dunes (coded: n). More descriptive criteria are indicated in the sub-class level.

The other constraint with the original GLASOD is the determination of the severity of the feature itself. Four severity classes were identified with respect to GLASOD: "slight, moderate, high, severe" coded 1, 2, 3 and 4. The determination of the severity is derived from the field measurement. So a deeply deflation feature in Longonot can be coded as (Edf4) while the depositional one is likely to be (Edn4).

The third constraint is some other local features they don't recognize by GLASOD a tentative (sub type) was introduced with the code.
This approach was conducted in (Longont and Ndabibi) areas using

1- on site observations and measurements,
2-Literature review.

4.2.4.1. On-site observation and measurements

The on site observations were conducted in two priority areas:
1) In the southeastern part of the lake (Longonot), which is mainly affected by wind erosion.
2) In the western part (Ndabibi), being affected by water erosion.
The on site observation and measurements are explained briefly in chapter 5 section 5.3.1.

4.2.4.2. litrture review

Literature review was considered where no field data were available and/or collected (due to fieldwork schedule). This literature review mainly emphasised other land degradation classes like rill and gully erosion) (Wdg & Wdr). More descriptive sub classes were given according to (Shrestha, 2000) On the other situation it was used for describing local features like accumulation out side a zone of erosion here the guideline of ASSOD was used

4.2.5. Metadata

Metadata is defined as data about data. It explains the content of the data; how the data have been obtained. Who made it and the accuracy of the data set. The metadata tool and format applied for this research is Tkme version 2.8.15 metadata editor and compiled by the "mp" version 2.7.23 metadata compiler.
This software was developed by Peter N. Schweitzer, who is staff member of the United State Geological Survey (USGS). Both are available on the Internet (Schweitzer, 2001)

4.3. Logical frame of the research

This research was conducted in three phases

4.3.1. Pre-field work

- Collection of existing data
- Preparing of questionnaires
- Preparing format for data collection
- Preliminary database structure
- Set-up a system design

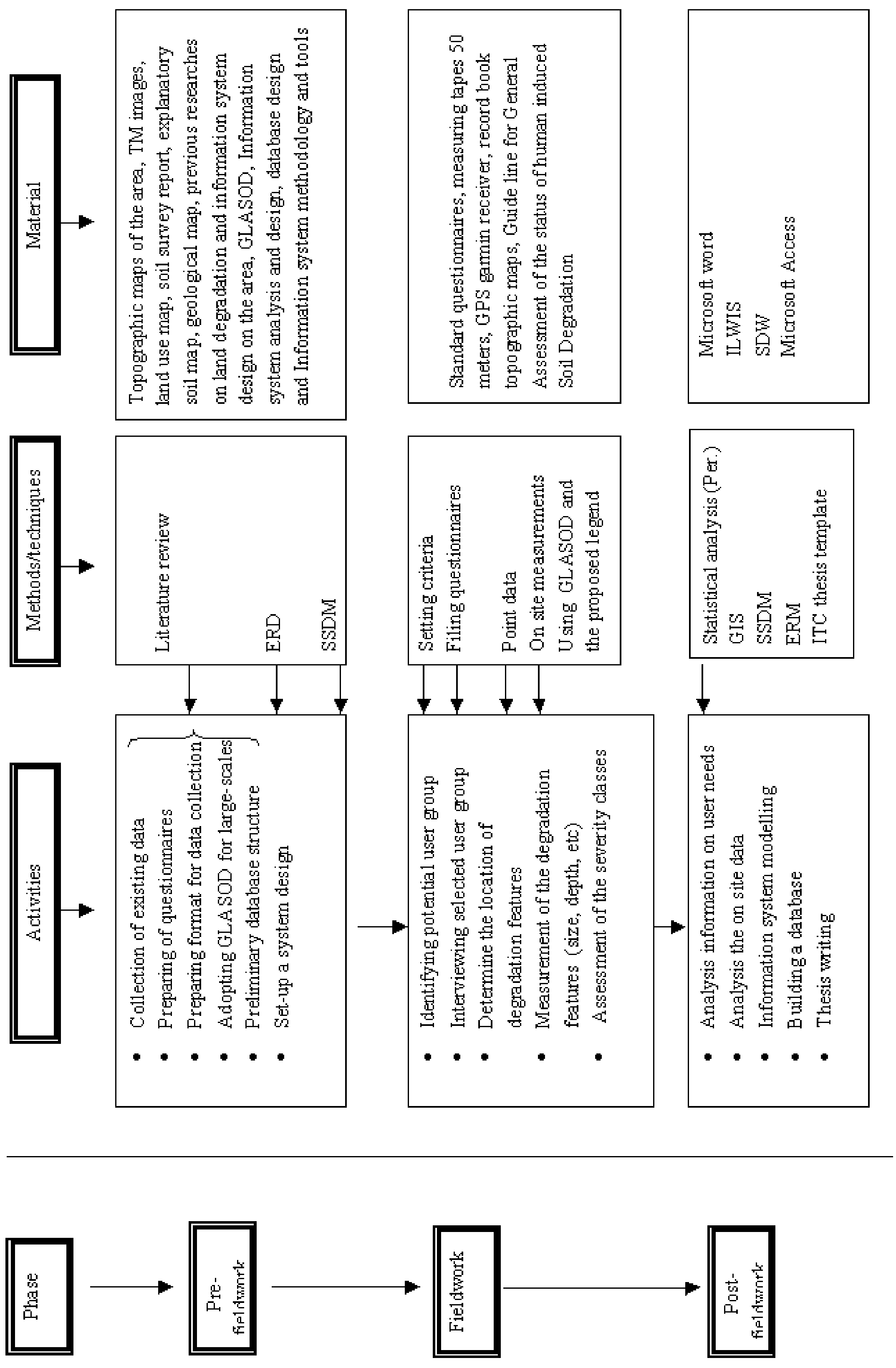
4.3.2. Field work

- Identifying potential user groups.
- Interviewing selected user groups.
- Determine the location of degradation features.
- Measurement of the degradation features (size, depth, etc)
- Assessment of the severity classes.

4.3.3. Post-field work

- Analysis information on user needs.
- Analysis the on site observations data.
- Information system modelling.
- Building a database.
- Thesis writing.

Figure 7 logical frame for the research



5. RESULTS AND DISCUSSION

This chapter deals with outcomes related to the demand of information on land degradation around lake Naivasha area, the use of GLASOD for large-scale maps as one of the methodology for assessing the degradation problem. Furthermore the data needed for the spatio-temporal model as apart of land degradation database and metadata documentation.

5.1. The demand for land degradation information around lake Naivasha

One of the research questions dealt with the demand for information on land degradation in the study area. This also to verify whether land degradation indeed is perceived by the people in the area as a problem, which affects land use activities

The assessment was carried out by interviews using standard questionnaires with the selected potential users of the information system (see questionnaire forms in appendix A).

5.1.1. The interviews

The interviews were conducted during the fieldwork period with representatives of the three selected key user groups in the study area. The three user groups identified according to the following criteria which is

1- Governmental organizations and offices involve in development planning, natural resource management in the area directly or in directly i.e. RCSMRS which is involve in building capacity and providing images and related issues.

2- NGO's dealing with natural resource management.

3- Farmers affecting with land degradation.

Table 1 show the list of the interviewed persons.

Table 1 the list of the interviewed persons.

No	Name of the farm or office	Type	Date	Name of Interviewee	Occupation
1	Marula state	Commercial	27-9-01	Francisco Natha	Manager
2	Oserian development company ltd	Commercial	29-9-01	Eric Dood Eman	Farm agronomist
3	Sulmac farm	Commercial	3-10-01	Monica	Production unit
4	Delamare farm	Commercial	24-9-01	R.M.Retief	Manager
5	Three point farm	Commercial	12-9-01	Igal R.Elfezouaty	Manager/Owner
6	Loldia	Commercial	26-9-01	Karioki	Manager
7	Lake flowers	Commercial	25-9-01	Mohamed bdullah	Director
8	Agricultural office	Governmental	25-9-01	Justus M. Kimotho	Agricultural officer
9	Boffer farm	Small farm	2-10-01	Benjamin Luvui	Manager
10	Ebeldare state	Small farm	25-9-01	Clavdlo minchio	Owner
11	Brixia farm	Small farm	26-9-01	Villa	Owner
12	LNROA	NGO	18-9-01	Sarah Higgins	Secretary
13	KSS,	Governmental	1-10-01	P.T.Gicheru	Head of KSS
14	RCSMRS	Governmental	1-10-01	Wilber K. Ottichilo	Director
15	KWS	Governmental	2-10-01	George E.Otianga - Owiti	Principal

Key

KSS Kenya Soil Survey
KWS Kenya Wild life service
LNROA Lake Naivasha Riparian Owners Association
RCSMRS Regional Centre for Services in Surveying Mapping and Remote Sensing

The total number of interviews was 15,of which 10 are farmers. (This research does not intend to include exhaustive and complete stakeholders/users identification. It selected some key user groups in the area as an example). The results of interviews are summarized in table 2 & 3 below.

Table 2 Summary of interviews with 10 farmers

No	Issues raised in the questionnaire	Response		Percentage	
		Positive	Negative	Positive	Negative
1	Having one or more types of land degradation on the farm	7	3	70	30
2	Does the problem of land degradation affecting the production	7	3	70	30
3	The problem of land degradation increasing	0	10	0	100
4	The problem of land degradation decrease	0	10	0	100
6	The quality of the land in recent years improving	2	8	20	80
7	The quality of the land in recent years degrading	0	10	0	100
8	The quality of the land in recent years keeping the same quality	8	2	80	20
9	Doing Specific test to determine if there is a problem	10	0	100	0
10	Having maps or any spatial information about land degradation.	0	10	0	100
11	Require information regarding land degradation in future in the farm	8	2	80	20
13	Require maps showing types of degradation only	2	8	20	80
14	Require graphics showing the process of land degradation only	0	10	0	100
15	Require reports showing express how land degradation occurs only	0	10	0	100
16	Require maps graphs and reports	8	2	80	20

As is shown in the table 2 the majority (70%) of the farms recognises one or more land degradation problems. This problem varies from one farm to another according to the location of the farm, soil type, farm management and the source of the water (for irrigation) and the land use. In other words we can say these problems vary according to land utilization type (according to FAO definitions for LUT). The common problems are salinity, compaction and alkalinity. In some areas the farmers mentioned that the pH is very high (without giving range of values); some farms are even using sulphuric acid to reduce the pH of the soil. This is common on the areas where they are using the water from the lake. In some other farms where they are using ground water (Delamare farms) they have problem with salinity beside other problems like sealing and crusting. In one farm (Sulmac) more than three types of land degradation (wind, water, salinity and compaction).

The problem of land degradation seems to affect the production of about 70% of the interviewed farms in different percentage. One of the farmers emphasized that he is not getting 50% out of his input. Another things we have to point it out that none of these farms has any spatial information about land degradation (maps) or about its distribution on their farms.

All most all the farmers continuously carry out tests to determine if they have problem or not. Most of these tests are routine soil analysis and bulk density (compaction), which confirm the need of monitoring.
80% out of these farms express the need for spatial information about land degradation in future. Obviously the kind of information they need to help them in the problem occurring in their farms. Generally we can say these common problems are salinity compaction and acidity.

Table 3 Summary of interviews (Governmental offices &NGO)

No	Issues raised in the questionnaire	Response		Percentage	
		Positive	Negative	Positive	Negative
1	Dealing with land degradation or involving in the study of land degradation	5	0	100	0
2	Having maps or any information	1	4	0	100
3	Require information regarding land degradation in future	4	1	80	20
4	Require maps showing types of degradation only	0	5	0	100
5	Require graphics showing the process of land degradation only	0	5	0	100
6	Require reports showing express how land degradation occurs only	0	5	0	100
7	Require maps graphs and reports	4	1	80	20

- All these governmental and NGO around the area dealt with land degradation or involve in studying land degradation.
- Water and wind erosion their major concern because it is affecting the lake and the environment around the lake (the wild life, the quality and quantity of the water lake and the natural vegetation and the forest).
- None of these offices has maps or other spatial information regarding land degradation except KSS, which does have maps in small scale for all the country.
- The majority (80 %) of these governmental offices indicate need for spatial information about land degradation in future.

Conclusion

- Out of table (1) and (2) it becomes clear that the majority of interviewed farms in the area are affected by one or more types of land degradation (salinity, acidity and compaction) in such a way that farm production is affect.
- The majority of them (80%) require spatial information in the future.
- All the governmental offices and NGO'S they involve in studying or measuring the problems of land degradation and the majority of these governmental office require spatial information in the future on land degradation

- The overall demand for information about land degradation is relatively high in the Naivasha area (80 %)

The users requirements form an essential part in the land degradation information system in particular system design and database design, which is, depend mainly on users need assessment according to the applying information system methodologies.

5.2. Land degradation in Naivasha area

Wind erosion in Naivasha area has been recognized as a most serious problem as results of previous study show. It affects an area of about 28 hectare out of 370 hectare studied by (Nagelhout, 2001) while in 1991 the total area that affected by wind erosion was 1.4 ha according to the same source. The farmer in the area confirmed this increase by saying that all these deflation started in the area recently (Orare, 2000).

Water erosion is the other problem in the area. The actual erosion is very low (Hamududu, 1998; Ringo, 1999) but the susceptibility to water erosion is very high (25-60 ha/yr) in Turasha Chatshment. In other areas (Ndabibi) about 13 ha was affected by sheet wash according to field visit this year.

Wind and water erosion in Naivasha are a major concern of the LNROA (an NGO) and governmental offices, because they affect the lake and its surroundings.

For these reasons this research concentrated on water and wind erosion in the area.

Other things the farmers in the area they have different type of land degradation. The common type of degradation in the farms is **alkalinity (**pH**), compaction** (bulk density) and **salinity** (EC) these are the major types of land degradation in the farms around lake Naivasha.

These could be considered as a fertility problem but according to (Gabriels et al, 1997) land degradation is also about a change of the physical, chemical and biological properties of the land, which from an agricultural point of view results in a reduction or loss of productivity.

5.3. GLASOD for assessment of land degradation in Naivasha area

GLASOD was used for assessing land degradation in Naivasha because 1) no approach and system for degradation description and classification is available in Kenya. And 2) the use of GLASOD would allow for correlation with other areas. It was used in this research by adapting the same legend for large scale maps using the

- On site observation
- Literature review

5.3.1. On site observation

Observations and measurements were done in two priority areas: Longonot and Ndabibi.

1-**Longonot area**

This area is located in the southeast of lake Naivasha (figure3 chapter 3). In this site data on deflation and depositional features at 11 point's were collected to give more description for these small features.

At each point the deflation depth, length and width as well as depositional depth and length was measured (Tables 4 & 5). The number of measurements for each feature depends mainly on the uniformity of the features. However, these length and width are not taken into consideration in describing those two features.

Table 4 The measurements of depositional features (Longonot area)

Point No	X	Y	Length Meter	Depth Meter	Code
1	219245	9903627	38.9	0.35	Edn3
2	219164	9903585	42.4	.03	Edn3
3	219289	9903599	125	.03	Edn3
4	219003	9903478	270	.3	Edn3

Table 5 The measurements of deflation features (Longonot area)

Point No	**X**	**Y**	Width (1) Meter	Width (2) Meter	Width (3) Meter	Mean Width	Depth (1) Meter	Depth (2) Meter	Depth (3) Meter	Mean Depth	Length Meter	Code
1	219281	9903632	10.95	15.1	16.5	14.16	.97	1.32	1.02	1.1	38.9	Edf4
2	219228	9903605	10.3	17.8	17.3	15.13	.88	1.0	1.05	.97	66.17	Edf4
3	219310	9903604	11.6	10.5	12.9	11.66	1.2	1.5	1.8	1.5	42.4	Edf4
4	219029	9903484	-	-	-	10.7	-	-	-	1.45	46.5	Edf4
5	219066	9903376	21.2	21.4	-	21.32	1.2	.95	-	1.07	50.3	Edf4
6	219001	9903386	-	-	-	22	-	-	-	1.2	142.6	Edf4
7	219018	9903411	21.2	17.8	-	19.5	1.4	.9	-	1.15	107.1	Edf4

Each point in the area was coded according to the proposed legend, which is explained in chapter 4 section (4.2.4). For these measurement mainly the depth (table 4 & 5) was used for describing the severity class for each feature.

First the deflation features:
The Longonot area is affected by severe wind erosion as evidenced by:
1) The depth of most of the deflation is about 1m to 1.5 m (Table 4).
2) The area is totally abandoned, except for two or three fenced fields that are remaining from an earlier large wheat-growing scheme.
3) With respect to the four severity levels in GLASOD, which is named here as 'slight, moderate, high and severe'

4-Assuming this 1-meter depth is an indication for the severity class of the wind erosion on this area. Then the feature can be coded as '**Edf4'** which means "wind erosion terrain deformation, deflation, severe". Three different classes less severity were identified arbitrary.
"This severity level could in principle be determined also by asking the farmers in the area, however here they are none".
Second the depositional features:
Following the same principle the depositional features were given four different severity classes And coded as (Edn1),(Edn2), (Edn3) and (Edn4).

2-**Ndabibi area**

The area is located in the western part of the lake (figure chapter 3 chapter 3). This area is affected by sheet, wash and gully erosion. In this area actual field mapping was done using G.P.S. for delineating the erosion features by means of point data (115 points). The identification of the type of erosion is not so difficult but the determination of the severity level and the boundary between each class was not easy.
So the features was used here is the surface wash which is dominant and the type was water erosion. For determining the severity level for these feature two indicators were used:
1) The difference between the soil that accumulated near the roots and the topsoil (in cm) used for determining the removal of topsoil
2) The percentage of the bare soil and vegetation cover
Assumed that those two indicators will give full idea about the severity in the area. Accordingly three different classes of sheet erosion were recognized as follows:
Class (1) slight sheet erosion (code Wts1)
This class is characterized by slight sheet erosion and was observed in the southeast of the escarpment (within Ndabibi area). The loss of topsoil in this area is less than 5cm and the vegetation cover is about 80%. This class covers an area of three hectares approximately.

Class (2) moderate sheet wash (code Wts2)
This class is characterized by moderate sheet erosion and was located in Northeast of the escarpment. The removal of the topsoil in this class is between 5-15 cm associated with rills and shallow gullies. The vegetation cover is about 50-60 %. This class covers about five and half hectares. The area is used for grazing and for cutting the trees for charcoal. (See the photo in figure 8)

Class (3) severe sheet wash (code Wts3)
This class is characterized by severe sheet erosion (surface wash) associated with shallow rills and gullies. The loss of topsoil is more than 25 cm. The vegetation cover in the area ranges from 30 to 40%. This erosion class is mainly found in the west of the escarpment covering an area of about four hectares.

5.3.2. Literature review

The measurement and observations were made in two priority areas. But they do not cover all the possible sub types of wind and water erosion. An additional literature review was used for describing the remaining sub types; also for adding new subtypes when it's required.

* This analysis also dose not include the types of land degradation associated with commercial farms Probably the same principal could be applying for more detailed description.

Tables 6 &7 below showing the differences between the original GLASOD legend and the proposed one, table 8 shows the two new sub types.
The Modified GLASOD legend was presented in table 9

Table 6 The original legend of GLASOD

Type	Sub-type	Description	Code
Wind (E)	Terrain deformation (d)	Uneven displacement of soil materials by wind action leads to deflations and dunes	Ed

Table 7 The two levels (class and sub –class) Introduced to GLASOD legend

Type	Sub-type	Class	Sub-class	Code
Wind (E)	Terrain deformation (d)	Deflation (F)	Deflation depth<25 cm Deflation depth 25-50 cm	Edf1 Edf2

Table 8 the two new sub-types

Type	Sub-type	Class	Sub-class	Code	Remarks
Water W	Off-site effects (o)	Flooding (f)	Accumulation of sediments associated with scattered shrubs and caused by constructed Activities (1)	Wof1	Classified according to ASSOD guideline (Van Lynden and Oldeman, 1997) observed by (Nagelhout, 2001)
Physical P	Dissected (d)	Road cut (r)	Disturbance of the soil according to human activities like road cut and soil digging	Pdr1	Local degradation features observed by (Nagelhout, 2001)

Table 9 Modified GLASOD legend (for large –scale)

Major Type	***Subtype***	***Class***	**Sub-class**	***Severity (level)***	***Code***
Wind erosion (E)	Loss of top soil (t)	Sheet (s)	Loss of top soil <5cm	Slight	Ets1
			Loss of top soil 5-15cm	Moderate	Ets2
			Loss of top soil 15-25cm	High	Ets3
			Loss of top soil >25cm	Severe	Ets4
	Terrain deforma-tion (d)	Deflation (f)	Deflation depth 25cm	Slight	Edf 1
			Deflation depth 25-50cm	Moderate	Edf2
			Deflation depth 50-75cm	High	Edf3
			Deflation depth >100cm	Severe	Edf4
		Deposition/ (dunes) (n)	Depositional depth >5cm	Slight	Edn1
			Depositional depth between 5-25 cm	Moderate	Edn2
			Depositional depth 25-50 cm	High	Edn3
			Depositional depth <50cm	Severe	Edn4
Water erosion (W)	Loss of Topsoil (t)	Sheet erosion (s)	Loss of top soil <5cm	Slight	Wts-1
			Loss of top soil 5-15cm	Moderate	Wts-2
			Loss of top soil 15-25cm	High	Wts-3
			Loss of top soil >25cm	Severe	Wts-4
	Terrain deforma-tion (d)	Rill erosion (r)	Shallow rill <3cm	Slight	Wdr1
			Incision rills which occurs in steep slope<10 cm	Moderate	Wdr2
			Wider braided rills 10—15 cm	High	Wdr3
			Wider braided rills 15--- 20cm	Severe	Wdr4
		Gully (g)	Shallow gully 30 cm –1m	Slight	Wdg1
			Deep gully 1-5 m	Moderate	Wdg2
			Very deep gully >5 m	High	Wdg3
			V. V. deep >30 m	Severe	Wdg4
	Off sight effects (o)	Flooding (f)	Accumulation of sediments associated with scattered shrubs and caused by constructed Activities	Slight	Wof1
Physical (P)	Dissected (d)	Road cut (r)	Disturbance of the soil according to human activities like road cut and soil digging	Slight	Pdr1

Figure 8 Class (2) Moderate sheet erosion

5.4. Land Degradation Information System (LDIS) Developments

Information system is defined by (Paresi, 2000) as a system to transform data into information, the decision makers and farmers in Naivasha area can use this information.
The need of various users for the LDIS is discussed in 5.1.1 while the analysis of the data to meet the users requirements is given in 5.5.1.1

5.4.1. System design

Under system design we have the global system design (contextual diagram) and the detailed system design (Top-level diagram) these two stages of system design presented as below:

5.4.1.1. Global system design

The global system design or what we call contextual flow diagram for LDIS was derived according to the interviews and literature survey. Nine stakeholders was form the boundary of the system (beyond it the system has no mandate) those stakeholders can be divided into users and data providers. The main users are NGO'S, ministries, and institutions (KWS, NGO'S, ect) requiring an overview of the degradation status and trends and farmers requiring detailed information on the type, degree and location of degradation.
The main data providers are various KSS, RCSMRS, metrology station and researchers they provide different types of data like maps, reports and satellite images.
Figure 9 shows the global system design (contextual diagram) where all major users and data providers are presented with arrows indicating the direction of data flow.

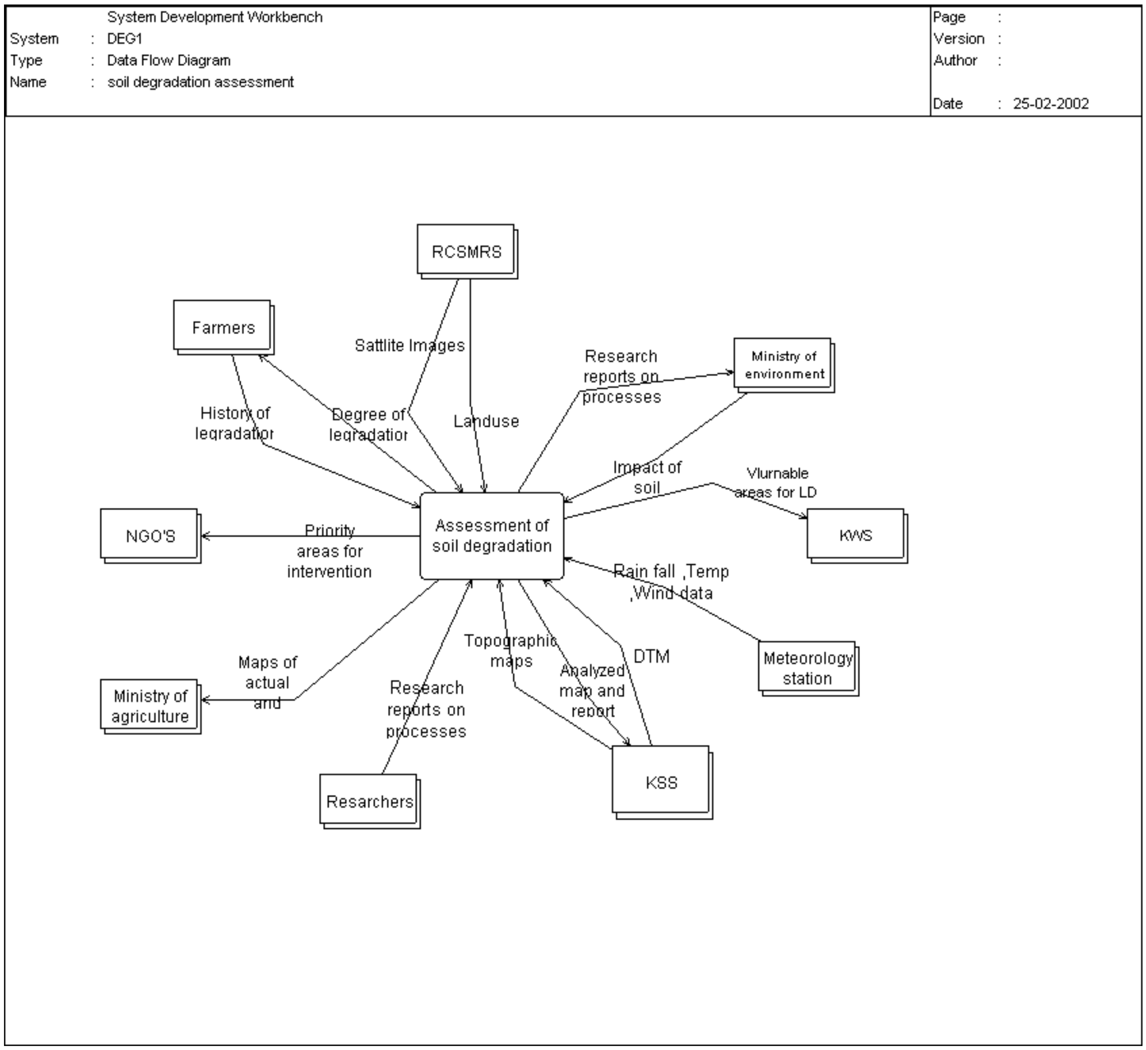


Figure 9 the contextual flow diagram.

5.4.1.2. Detailed system design

The main objective of this phase is to break down the contextual level into main process. These process was determined a according to the functionality of the system. Which could help in assessment and monitoring land degradation in Naivasha area.

The main processes in land degradation assessment are:

1- Data collection, which deals with the collection of all the existing data.
2- Data management, here all the types of conversions can be done before interpretation like from contour map to DEM, conversion from one approach to another and the data quality control.
3- Interpretation and assessment of land degradation. Here all the type of analysis and interpretation of land degradation will be done
4- Information dissemination. The main task here to process the data and information for the users.

Beside these processes two data stores were identified. The data stores are based on the users need.

The data store for LDIS is
1-Primary data storage, in the system refers to the common soil database. This database stores information on different soil units and the primary users are the farmers. Next to a general description of the soil units it contains data related to the soil properties like salinity, ph compaction ect. The database is linked to the soil map. The development of this database based on (Tilaye Bitew Bezu, 2001).

Developing an extension to this common database to include soil degradation information (the main topic of this thesis). The other data store was identified; and the main users of this information are NGO's and government offices
2-The spatio temporal Land Degradation Database (LD DB) is based on the following points:

- The degradation features which classified according to the modified GLASOD.
- Time factor which is represented by different snap shot i.e. the data has been entered to the system now at 2000 and 2001 if again new assessment was conducted at 2005 it can be stored as well in new table in MS Access. But these data in Access depend mainly on the spatial issue (the map)

The different relations between process, data, information and the flow of the data is shown in figure 10

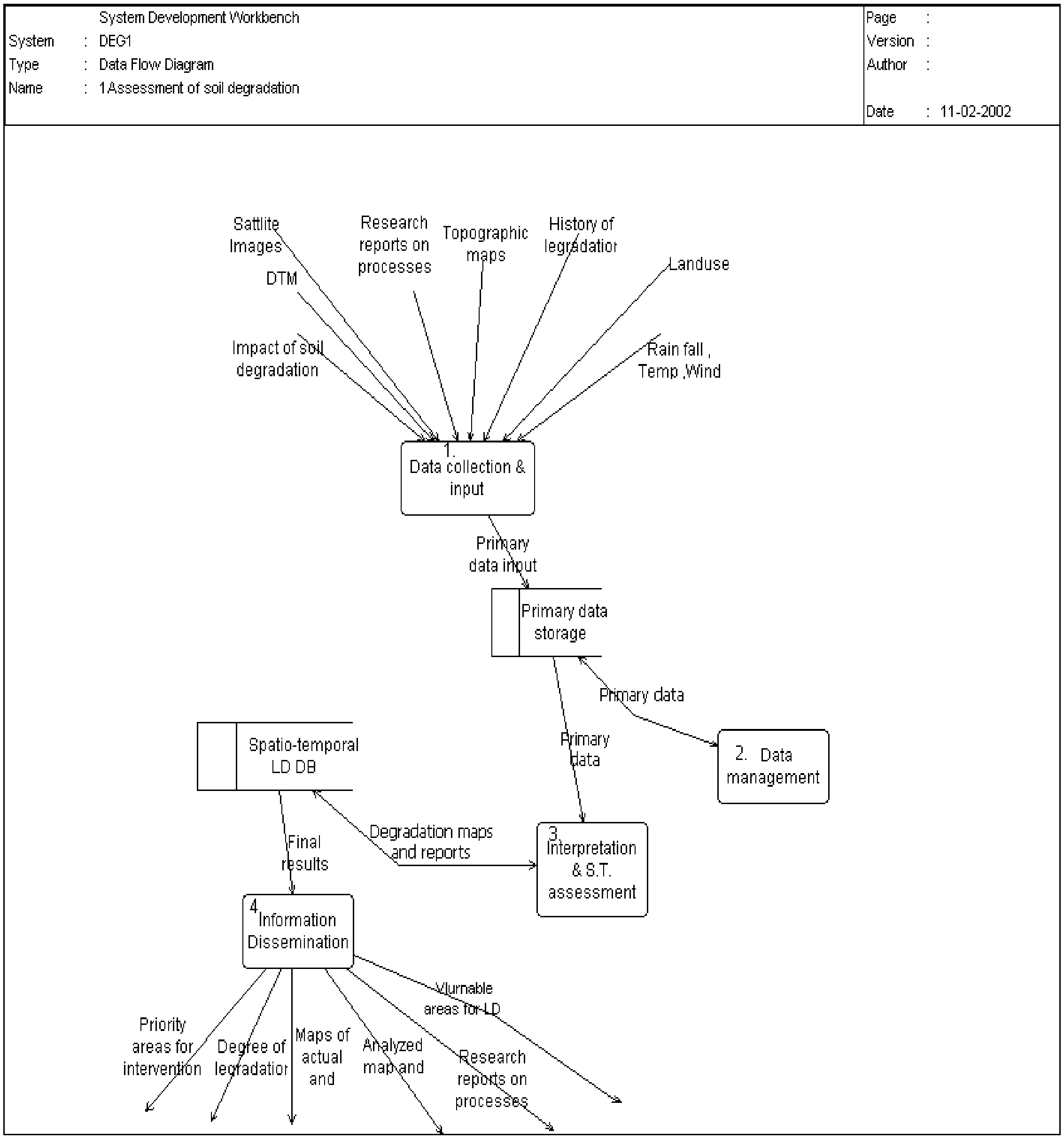


Figure 10 the top-level diagrams

5.5. Land degradation database

In the top-level analysis (figure 10) two data stores are identified:
1- The primary data store
2- The land degradation database (LDDB)
The primary data store contains soil database while LDDB contains the degradation related data this LDDB database contain three items:

1. Non-spatial database,
2. Spatial database,
3. Temporal aspects in land degradation database (how it can be represent in the database).

5.5.1. Non spatial database

The non-spatial database for LDIS was organised to satisfy the users need around Lake Naivasha. In this chapter the discussion was concentrated on two elements with respect to non-spatial database. The two elements are:
1- the users need.
2- the entity relational diagram.

5.5.1.1. The users need

The need of various users for the LDIS is discussed in 5.1.1 while in this subsection the emphasis on the data to meet the users requirements. The data needed for assessment and monitor wind and water degradation is mainly in this situation as the research follows GLASOD methodology. It concentrates on identification of the type; sup type and classes of soil degradation and tries to give severity level according to some measurements. These descriptive classes were presented in two tables in the database (GLASOD map unit& severity level). Also these descriptive classes can be visualized using any G IS. Software as maps or graphs. The main users are NGO'S and governmental offices.

Farmer's data needs depend mainly on the type of degradation that affect the farm. The most common types on the farms are compaction, salinity and alkalinity. These parameters it can be measured by means of soil pH (soil reaction) EC (Electronic conductivity) and BD (Bulk density).

The user needs was used as base for the entity relational diagram. Before these entities can be grouped into the main entities and attributes in a relationship, the data constraints were identified for this database, and represented below in two elements as the structure of the database.

1) Soil elements

- A soil map contains many soil map units
  A Soil map unit can occurs in most in one soil map

- A soil map unit contains many delineations
  Delineations belong to one soil map unit

- A soil map unit may contain many soil component
  One soil component may occur in many soil map units

- A soil component can occur at many site observations
  An observation is classified one soil component

- An observation may contain many horizons
  A horizon can occur at most in one observation

2) Land degradation element

- A land degradation map contain many land degradation units
  A degradation map unit can occur at most in one degradation map

- A degradation map unit contain many delineations
  A delineation belong to one degradation map unit

- A degradation map unit can be describe by one severity level
  A severity level can describe many degradation map unit.

5.5.1.2. Entity relationship model

The entity relational model was defined based on the data constrains stated on section 5.5.1.1.the model consist of 12 entities in time zero which are: (1) map of soil degradation (2) degradation map unit2000 (3) GLASOD map unit2000 (4) national map unit2000 (5) degradation delineation2000 (6) severity level (7) soil map (8) soil map unit 9) soil delineation (10) soil components (11) soil site (12) soil at horizon level

These entities with their relationship are shown in figure11below:

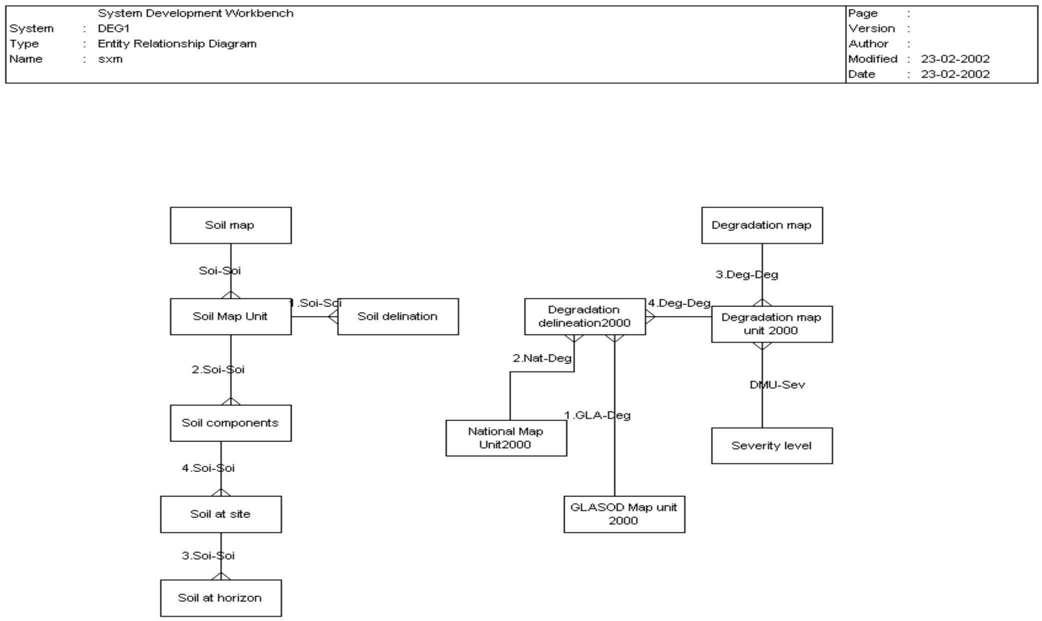


Figure 11 Entity relational diagram

Some points about this structure:

- This structure contains two components soil component and land degradation component.
- In the component of land degradation as users may use methods for assessment vary from area to area. **This structure allows the users to select the methodology they want**. This by giving three different options in a form of tables. These tables are

1- GLASOD degradation unit (which it can be use if GLASOD methodology applied in the area. "So this table contains the structure of the proposed legend in this situation except the severity level presented in different table."

2- Degradation map unit "if there is local methods "district level "for assessing land degradation in the area."

3- National degradation map unit "if there is national methods "

- Two of these tables or all it can be used in case of comparing between different methodology
- The relation ship between a degradation delineation and a soil delineation only established during spatial analysis (by map overlaying of a degradation map and the soil map).

5.5.2. Spatial database

The spatial database has been organized in ILWIS and it contains an attribute map for Longonot area based on the work done by (Nagelhout, 2001) (5.5.2.1).and point map for the Ndabibi area, which is converted to polygon map section (5.5.2.2) .

5.5.2.1. Longonot area

An existing wind erosion features map in longont (Nagelhout, 2001) was used. The polygon was re-named using correlation table with the code in the proposed legend for large scale
Table 10 show the correlation table used for creating the map and the map presented in figure 12

Table 10 the correlation table between legends used by Nagelhout and the modified GLASOD

Description by A.Naglehout in the area	Former code	Codes according to Modified legend
Brown eroded Bw horizon exposed at surface	D1	Edf1
Deflation depth< 1.0 m	D21	Edf2
Deflation depth between 1.0-2.0m	D22	Edf4
Deflation depth >2.0m	D23	Edf4
Sheet depth <5 cm	S1	Edn1
Sheet depth <5-25 cm	S21	Edn2
Sheet depth >25	S22	Edn3
Gully wash fan grey pumice gravel with scattered shrubs	W1	Wof1
Gully wash fan light yellowish brown	W2	Wof2
Complex of W1&W2	W3	Wof1&Wof2
Other degraded area (crust & sealed as cattle residential area)	O1	Pc1
Other degraded area caused by road cuts & disturbing soil by digging	O2	Pdr1

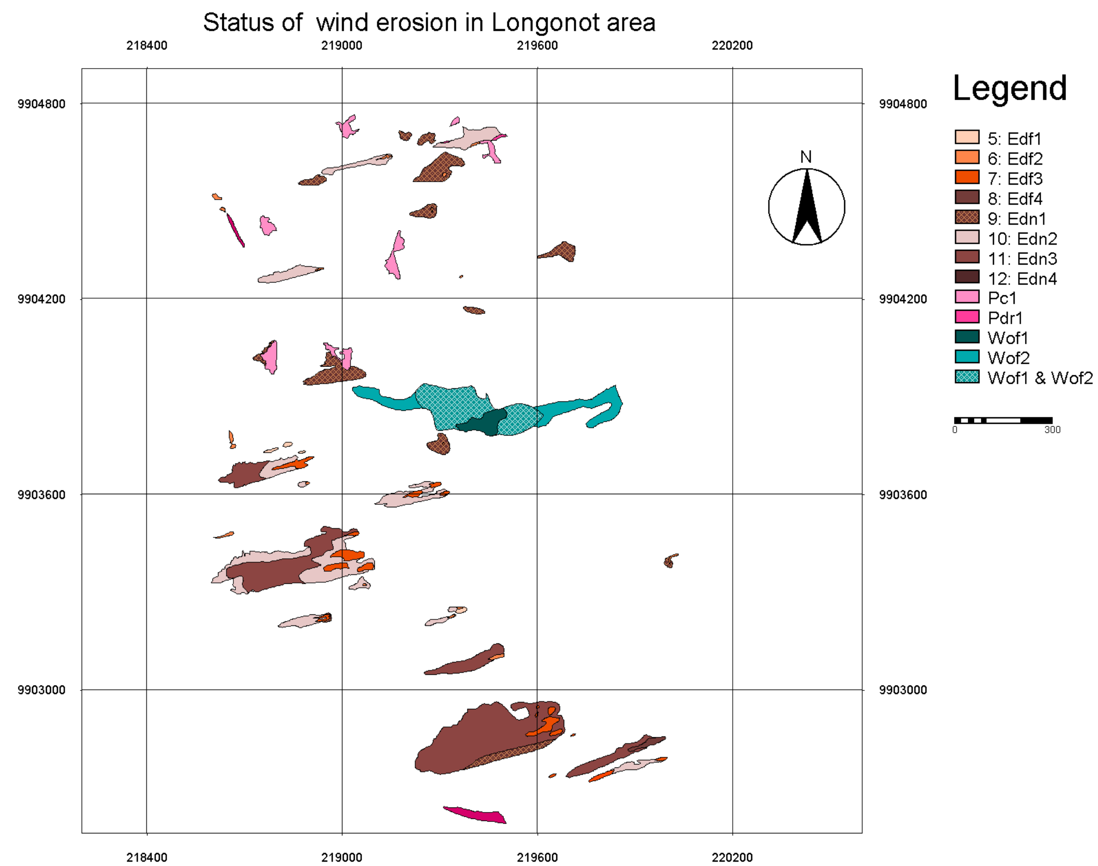


Figure 12 map of the status of wind erosion in Longonot area

Based of the Wind erosion Features map created by (Nagelhout, 2001)

5.5.2.2. Ndabibi area

In this area a polygon map with three different classes was made following the main steps

1-Creation of segment map using the point data collected in the field.

2-Checking all the type of segments error.

3-Polygonization of the segment map into sheet erosion classes.

Figure 13 shows map of status of sheet erosion in Ndabibi Escarpment.

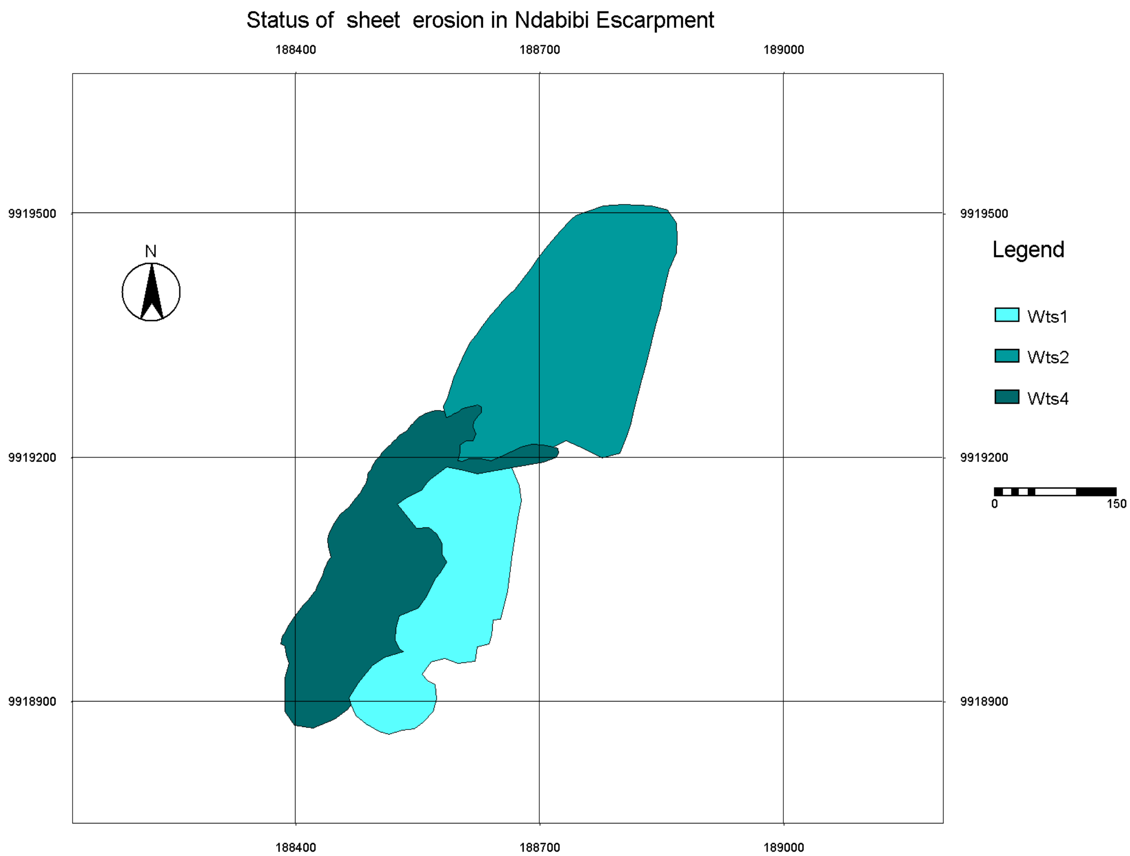


Figure 13 status of sheet erosion in Ndabibi Escarpment

5.5.3. Temporal aspect in land degradation database

The time was presented in this database by the snap shot models or (discrete time model).
This was presented in a table as time stamp (i.e. degradation map unit 2000). Except in the map level it was presented as an attribute. Validation of the database required attachment of new sets of tables with new time stamps.
The advantage of this model is the simplicity structure while the disadvantage is the amount of data storage become high and after the validation. The other option available could be used is presenting all the time stamps as an attributes in all the tables which make the data retrieval very slow.

5.6. IMPLEMETATION

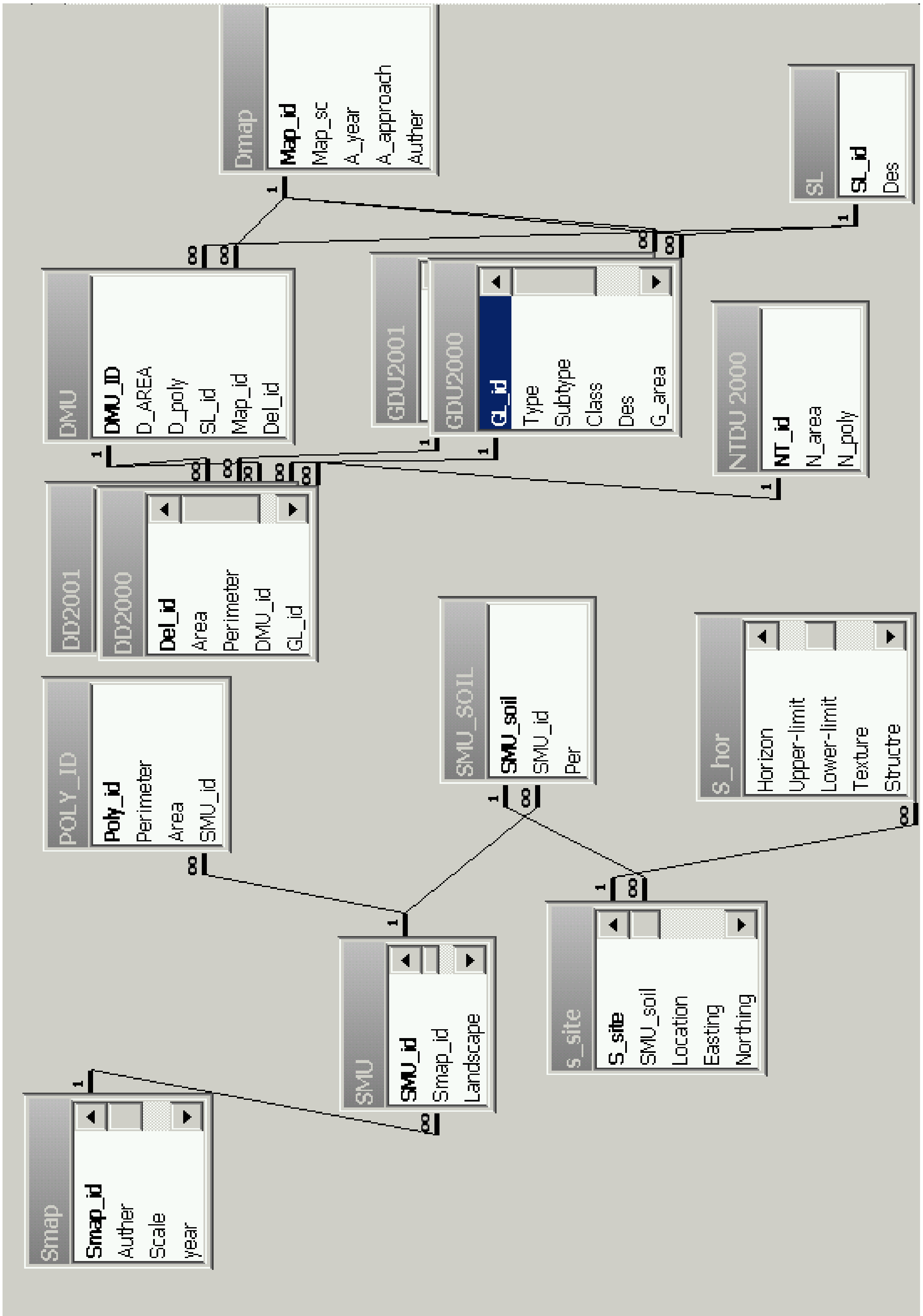
The entity relation diagram (figure 11) was the basis for the implementation of the non-spatial database under MS Access.
Table 11 related the names in the entity relation diagram to table names in MS Access. The description of the attributes in the individual tables is given in the Appendix B

Table 11 the name in the entity diagram and the names in MS Access

Entity Relation Diagram	**Access table**	**Comment**
Degradation map	Damp	
GASOD unit 2000	GDU2000	
GASOD unit 2001	GDU2001	This time stamp is not in E-R
Degradation delineation 2000	DD2000	
Degradation delineation 2001	DD2001	This time stamp is not in E-R
Severity level	SL	
Degradation map unit	DMU	Not used in the thesis*
National map unit	NTU	Not used in the thesis*
Soil map	Smap	
Soil Map Unit	SMU	
Soil components	SMU_soil	
Soil at site	S_site	Description of soil at site level
Soil at horizon	S_hor	Description of soil at horizon level
Soil delineation	Poly _id	

*Degradation map unit and National map unit are built into the system to allow using different methodology.

Figure 14 the structure of the database as it implemented in MS Access



5.6.1. Possible queries

As there are three main users group for the land degradation information system, the queries section showing the possibility of extracting information needed to satisfy each group taking into consideration that the NGO'S and the governmental office almost they have the same interest.

Query 1:
The first query deals with all the users around the area (Farmers, NGO'S and governmental offices). As these users primarily need information about the type of degradation and the area affected and the severity level.
The SQL statment used to extract the **area** affected by **wind erosion** at the **year 2000**. And it has severity level "**slight**" or "**severe**" is as following:
SELECT
DD2000.Area, DD2000.GL_id, GDU2000.Sl_id, GDU2000.Des, GDU2000.Type, DD2000 *
FROM
GDU2000 INNER JOIN DD2000 ON GDU2000.GL_id = DD2000.GL_id
WHERE
(((GDU2000.Sl_id)="slight" Or (GDU2000.Sl_id)="severe") AND ((GDU2000.Type)="wind"));

Result:
The result of the query is a tabular data set containing five attributes /fields and twenty records. Ten of them are presented in table 12

Table 12 Different areas affected with slight and severe wind erosion in 2000
as extracted from land degradation database

DD2000.Area	DD2000.GL_id	Sl_id	Des	Type	Del_id
74	Edf1	Slight	Deflation depth 25 cm	Wind	39
98	Edf1	Slight	Deflation depth 25 cm	Wind	42
50	Edf1	Slight	Deflation depth 25 cm	Wind	43
92	Edf1	Slight	Deflation depth 25 cm	Wind	71
32	Edf1	Slight	Deflation depth 25 cm	Wind	75
3	Edf1	Slight	Deflation depth 25 cm	Wind	78
264	Edf4	Severe	Deflation depth>100cm	Wind	90
119	Edn1	Slight	Depositional depth < 5cm	Wind	04
170	Edn1	Slight	Depositional depth < 5cm	Wind	05
460	Edn1	Slight	Depositional depth < 5cm	Wind	10

According to limitation of ILWIS soft ware this tabulated data it can't be mapped directly after the query. This table (11) was imported to ILWIS. An attribute map was created to show the spatial distribution of the affected area figure 15

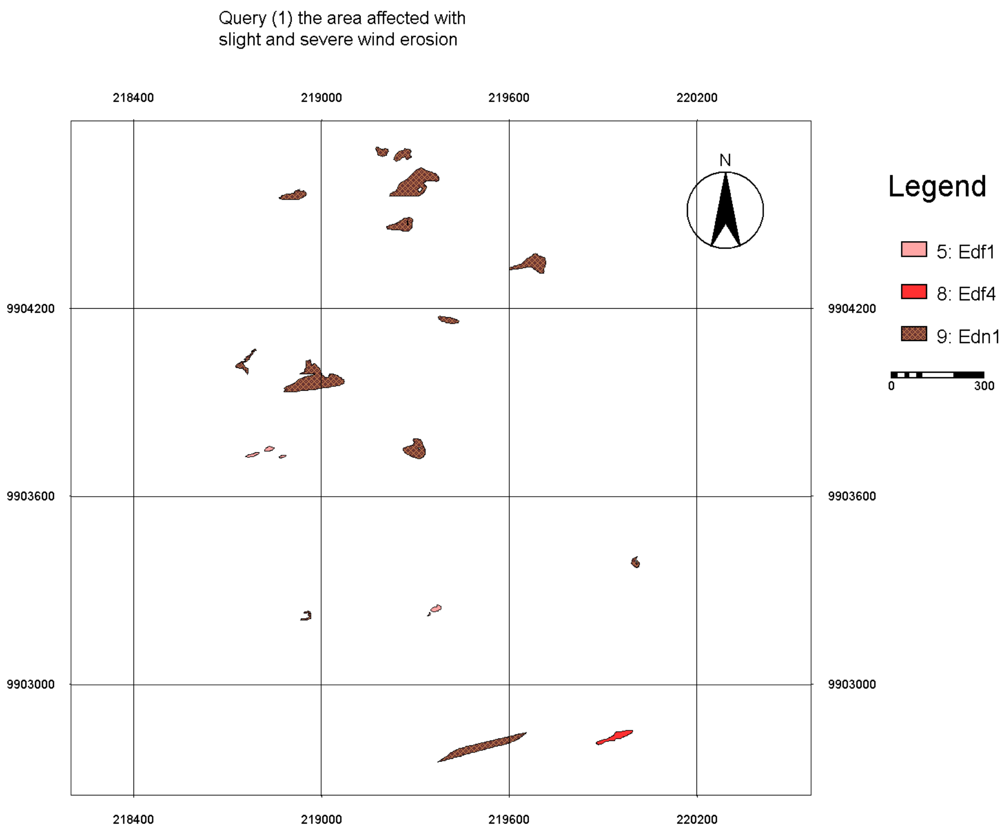


Figure 15 the spatial distribution of the affected area
(Using query 1)

Query 2

The NGO'S, governmental offices and researchers may need to know the trend of degradation between two different years how much area was increased for specific land degradation of different deflation classes. To supply these information three tables have to be joined to run the query and seven attributes was displayed to give full information regarding the GLASOD and to show the polygon identifier (DD2000.del) as an indicator for the same areas in those two years. The query was used for monitoring land degradation between 2000 and 2001 is the following:

SELECT
[dd2000].[del_id], [dd2001].[del_id], [dd2000].[Area], [dd2001].[area], [dd2000].[gl_id], [des], [SL_id]
FROM
dd2000, dd2001, gdu2000
WHERE
[dd2000].[del_id]=[dd2001].[deL_id] And [gdu2000].[GL_id]=[dd2000].[GL_id] And [dd2000].[GL_id] In ("Edf1","Edf2","Edf3");

Result:

The result is attribute data set containing six attributes/fields and four records showing the different in the area (per polygon) for the selected land degradation classes at four records. For area in 2001there is no real record (no data available) a zero value was used for demonstration prepuces. By this result its clear the possibility of getting information regarding the monitoring of land degradation in the area between two years or more. Also if the information is available this tabulated data it can be seen as graph for determining the trend in the area. Table 13 shows the result.

Table 13 the possibility of monitoring land degradation as extracted from the database

DD2000. Del_id	DD2001. Del_id	DD2000. Area	DD2001. Area	Gl_id	Des	SL_id
12	12	109	0	Edf2	Deflation depth25-50cm	Moderate
09	09	77	0	Edf2	Deflation depth25-50cm	Moderate
50	50	101	0	Edf3	Deflation depth50-100cm	High
40	40	22	0	Edf2	Deflation depth25-50cm	Moderate

If the actual degradation maps for those two years would be indeed available the spatial query result also could be displayed (using map crossing) as the area where the change occurs.

Query 3

Governmental offices and NGO's they may need general information about the total area affected by different class and the total number of polygons per each class. This information would be useful in two ways: first if there is conservation project in the area its effects could be followed by assessing the total area affected in different years (is it stable, increase or decrease).

Second by knowing the total number of polygons per each class in different years also it will give an idea about the spread of land degradation in the area (if there is new area affected or just expansion of the same features existing already).

The query used to generate such information is as follows:

SELECT
GDU2000.G_area, GDU2001.G_area, GDU2001.G_poly, GDU2000.G_poly, GDU2000.GL_id
FROM
GDU2000 INNER JOIN GDU2001 ON GDU2000.GL_id = GDU2001.GL_id
WHERE
(((GDU2000.GL_id)="Wts1" Or (GDU2000.GL_id)="Wts2" Or (GDU2000.GL_id)="Wts4" Or (GDU2000.GL_id)="Edf2" Or (GDU2000.GL_id)="Edn1" Or (GDU2000.GL_id)="Edn2"));

Result

The result is tabulated data set showing the total area affected by each class of above mentioned classes and the number of polygon per each class for two different years (zero was used for showing the possibility of getting the information from the structure because there is no data). This result it can be used by the users who don't want to see the difference spatially they can get the information even from the tables. The result was shown in table 14

Table 14 the number of polygons and the total area affected by selected Land degradation class for two years (2000 & 2001).

GDU2000.G_area	GDU2001.G_area	GDU2001.G_poly	GDU2000.G_poly	GL_id
3098	0	0	18	Edf2
35477	0	0	13	Edn1
53857	0	0	18	Edn2
0	32661	1	0	Wts1
0	57868	1	0	Wts2
0	43022	1	0	Wts4

This type of query it can't be displayed spatially

Soil database and land degradation database (the link)

Governmental offices and researcher may need of the same area both information about the soil and the affected area by a given type of degradation. This kind of information will help in getting a complete picture about the relation between soils and different types of land degradation (e.g. if soil type is more vulnerable to erosion than others). The Land degradation information system has no tools to supply information about soil characteristics and land degradation **non-spatially** in the same moment. But it can be displayed spatially using spatial analysis like overlaying. An overlay operation was carried out between the result from query 1 (see figure 15) and the soil map units in the area. The result is presented in figure 16

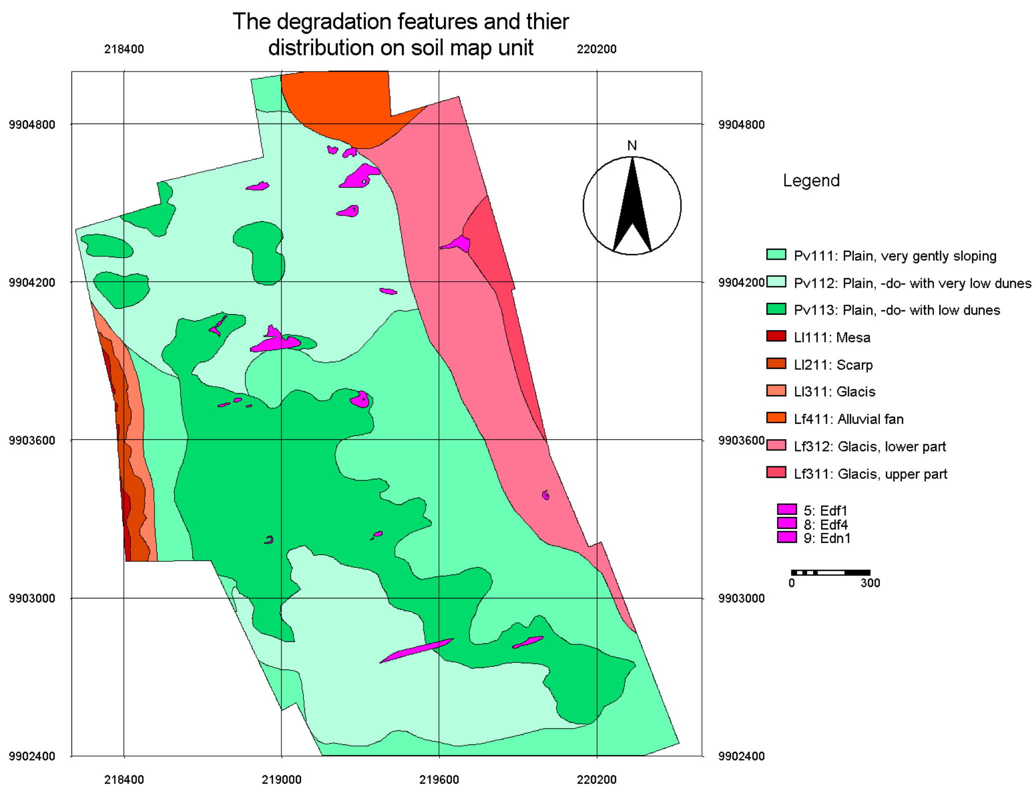


Figure 16 the spatial query of the degraded area and the soil map unit
Source of soil map unit (Nagelhout, 2001)

It's clear according to query 1 and soil map unit that the volcanic plain is more vulnerable area and with in the volcanic plain the map unit (pv112) has got the large number of degradation polygons. Information about the soil and its characteristics it can be retrieved from the soil database.
This is shown with query 4:

Query 4

Researchers and other scientific users may need to know more about the soil in this map unit. The SQL command used to extract information about texture, structure, stoniness and colour in the first two horizons "1&2" with respect to the geographical position.

SELECT
SMU_SOIL.SMU_id, s_site.Easting, s_site.Northing, S_hor.Texture, S_hor.Structre, S_hor.[Colour/dry], s_site.Stoniness, S_hor.[Horizon no]
FROM
SMU_SOIL INNER JOIN (s_site INNER JOIN S_hor ON s_site.S_site = S_hor.S_site) ON SMU_SOIL.SMU_soil = s_site.SMU_soil
WHERE
(((SMU_SOIL.SMU_id)="pv112") AND ((S_hor.[Horizon no])=1 Or (S_hor.[Horizon no])=2));

Result

The result of this query is tabular data containing seven attributes and six records. This result was shown in table 15 as extracted in MS Access.

Table 15 soil characteristics in Pv112 in the first and second layers

SMU_id	Easting	Northing	Texture	Structure	Colour/dry	Stoniness	Horizon no
Pv112	219083	9904577	Loamy sand	Moderate medium sub angular blocky	((2.5Y3/2)	None	1
Pv112	219083	9904577	Loamy sand	Medium to coarse sub angular blocky	(5Y3/2)	None	2
Pv112	219466	9902824	Sand	Course and medium sand	(2.5Y3/2)	None	1
Pv112	219466	9902824	Sand	Course and medium sand	(2.5Y3/1)	None	2
Pv112	219087	9904107	Loamy sand	Moderate medium sub angular blocky	(2.5Y4/3)	None	1
Pv112	219087	9904107	Loamy sand	Fine angular blocky	(2.5Y4/2)	None	2

Query 5

Framers may need to know about the pH and Ec and Bd in thire farms. To supply this information, three entities have been joined to run the query .The SQL statement language query used is the following:

SELECT

SMU_SOIL.SMU_id, s_site. Easting, s_site.Northing, S_hor.Ph, S_hor.Bd, S_hor.Ec

FROM

SMU_SOIL INNER JOIN (s_site INNER JOIN S_hor ON s_site.S_site = S_hor.S_site) ON SMU_SOIL.SMU_soil = s_site.SMU_soil

WHERE

(((SMU_SOIL.SMU_id)="pv111" Or (SMU_SOIL.SMU_id)="pv112" Or (SMU_SOIL.SMU_id)="lf312") AND ((S_hor. [Horizon no])=1));

Result

The result of this query is tabular data containing five attributes and six records as extracted from MS Access in table 16.

Table 16 Soil pH, Bd and Ec as extracted from the database

SMU_id	Easting	Northing	Ph	Bd	Ec
Pv112	219083	9904577	4.5	-	-
Pv112	219466	9902824	4.5	-	-
Pv111	219470	9903703	4.5 - 5	-	-
Lf312	219745	9903738	4.5	-	-
Pv111	219939	9902938	4.5	-	-
Pv112	219087	9904107	5	-	-

This table to show how the system working and how information regarding soil can be extracted. Due to the lack of data in this area this values remain empty.

5.7. Metadata documentaion

Metadata documentation was done for the two maps (Longonot and Ndabibi) independently an example of these metadata documents is represented in appendix E and the basic standard information includes in each metadata document contains:

Identification information.

Data quality information

Spatial data organization information.

Spatial reference information.

Entity attributes information.

6. CONCLUSIONS AND RECOMMENDATIONS

The main objective of this research is the developing of a working approach for assessing and monitoring land degradation in Naivasha area in an information system context. On the basis of the result and discussions, the following conclusions and recommendations can be made:

6.1. Concolusions

The demand of information about land degradation around lake Naivasha area is relatively high (80%) according to the interviews carried out in the area. This probably due to
1-Different NGO'S and governmental institutes working in the area around the lake need data about land degradation, however no information in place. There is clear need for tool to help in assessing and monitoring land degradation data.
2--Farmers in the area also express their need for land degradation information and soil related elements, they collect the data but they don't have tool to store and analysis this data. Furthermore, they express their needs for spatial information for their farms area.

The NGO'S and governmental offices have a different perception of land degradation than the farmers. NGO's and governmental offices require information about the water and wind erosion. The farmers required information could help in increasing farm production. But both of them they required these information in the form of maps.

The identification data requirements for spatio temporal analysis for land degradation depend mainly on the selected methods of assessment and monitoring to display chances in land degradation.

The GLASOD methods have been develop for mapping land degradation at small scale, which make it difficult to apply this methods in the large scale mapping its main deficiency is lake of detail description of the erosion features, the determination of the severity level of those features and some features occurred locally is not considered. A modified legend proposed by adding some sub types, classes and subclass with out affecting GLASOD structure.

Time in the developed land degradation information system (LDIS) was presented using snap shot model. The main advantage of this approach its simple while the disadvantage is the structure of the data has to be modified when a new snap shot needs to be added i.e. for 2005 the user should make a new set of 2005 tables. This also increases the volume of the data.
Using snap shot model makes it difficult telling any things about the process of the change but at least statement about the status and trends can be made.

6.2. Recommendations

1- In case of the development of an operational LDIS a detailed users requirements should be carried out the Naivasha area. This would enable developers to built up more complete understanding of potential users of such an information system, their land degradation related problems and their information needs.

2- Further study of the temporal dimintion by using other approach of spatio-temporal model, may help in building up additional understanding the process of soil degradation.

3- The proposed GLASOD legend for large scale could be extend to the other types of land degradation that occur in the farms around the lake such as compaction, salinity ect.

4- Further study of an approach for combining the soil database and the land degradation database components into a unified database structure is recommended. This may allow retrieving data about degradation and related soil characteristics directly.

References

A.O.THOMPSON & R.G.DODSON. (1958) Geology of the Naivasha area.

ANECKSAMPHANT, C., CHAROENCHAMRATCHEEP, C., VEARASILP, T. & ESWARAN, H. (1999) Conference Report. In: *2nd International Conference on land degradation*, pp. 35, Khon Kaen, Thailand.

AVISON, D. E. & FITZGERALD, G. (1988) *Information systems development: methodologies, techniques and tools*. Blackwell Scientific, - Oxford etc, 323 pp.

BEDARD, Y. & AL., E. (1996) Adapting data models for the design of spatio - temporal databases. *Comput, Environn, and Urban Systems*, **20**(1), 19-41.

COLE, J. & KING, C. A. M. (1969) Geography and three space dimentions. In: *Quantitative geography, technique and theores in geography*, pp. 155-182. Jone Wiley and Cons.

DAVIS, B. E. (1989) The five dimentions of GIS., Orlando, Florida.

DE BY, R. A. (2000) *Database design*. ITC, Enschede, 43 pp.

DE BY, R. A., KNIPPERS, R. A., SUN, Y., ELLIS, M. C., KRAAK, M. J., WEIR, M. J. C., GEORGIADOU, Y., RADWAN, M. M., VAN WESTEN, C. J., KAINZ, W. & SIDES, E. J. (2000) *Principles of geographic information systems : an introductory textbook*. ITC, Enschede, 230 . pp.

DUNG, D. V. (2001) Evaluation of irrigation practice at farm level using GIS. and Rs data and SWAP model case study at Lake Naivasha Kenya. MSc thesis, ITC.

DWIVEDI, R. S., RAVISANKAR, L., VENKATARATNAM, L., KARALE, S. P., GAWANDE, K. V., SESHAGIRIRAO, K. V., SENCHAUDHARY, S., BHAUMIK, K. R. & MUKHARJEE, K. K. (1997) The inventory and monitoring of eroded lands using remote sensing data. *international journal of remote sensing*, **18**(1), 107-119.

ESWARAN, H. & KAPUR, S. (1998) Land degradation newsletter of the international task force on land degradation, *Vol. 2001*.

GABRIELS, D., HORN, R., VILLAGRA, M. M. & HARTMANN, R. (1997) Assessment, prevention and rehabilitation of soil structure caused by soil surface sealing, crusting and compaction. In: *Methods for assessment of soil degradation* (Ed. by R. Lal), pp. 558. CRC Press, Boca Raton etc.

GIRMA, A., ROSSITER., D., SIDERIUS, W. & HENNEMAN, R. (2001) Soils of the Lake Naivasha area,Kenya, pp. 26. ITC, Enschede.

GUPTILL, S. C. (1995) Temporal information. In: *Elements of spatial data quality* (Ed. by S. C. Guptill and J. L. Morrison), pp. 153-165. Elsevier on behalf of the International Cartographic Association (ICA), Oxford etc.

H.ESWARAN, R.LAL & P.F.REICH. (2001) Land degradation an overview, *Vol. 2001*.

HAMUDUDU, B. H. (1998) Erosion assessment for large basins using remote sensing and GIS a case study of Lake Naivasha Basin, Kenya. ITC MSc-thesis, ITC.

HART, D. & PHILIPS, H. (2001) Metadata primer,a" how to" guide on metadata implementation, *Vol. 2001*.

HAWRYSZKIEWYCZ, I. T. (1998) *Introduction to systems analysis and design*. Prentice-Hall, Sydney etc, 484 pp.

HOOSBEEK, M. R., STEIN, A. & BRYANT, R. B. (1997) Mapping soil degradation. In: *Methods for assessment of soil degradation* (Ed. by R.Lal, W.H.Blum, C.Valentine and B.A.Stewart), pp. 558. CRC Press, Boca Ratonc New York.

HOWE, D. R. (1989) *Data analysis for data base design*. Edward Arnold, London etc., 317 pp.

ITC&WRAP&KNWTP. (1998) Confilict and trade-offs: The Lake Naivasha Case, Enschede.

KROL, B. (1998) GIS Database. ITC, Enschede.

LAL, R. (1994) Soil and land degradation conservation. In: *8th international soil conservation conference abstracts Soil and water conservation challenges and opportunities*, pp. 470. Oxford & IBH, NewDelhi-India.

LANGRAN, G. (1992) *Time in geographic information systems*. Taylor & Francis, London etc, 189 pp.

NAGELHOUT, A. (2001) Performance analysis of small format erial photography SFAP in assessing current status and trends in wind erosion : a case study in the Longonot - Kijabe hill area, Naivasha district, Kenya. ITC MSc-thesis, ITC.

OLDEMAN, L. R. (1988) Global Assessment of Soil Degradation (GLASOD) Gidelines For Genral Assessment of The Status of Human -indused Soil Degradation, pp. 11. ISRIC, Wageningen.

OLDEMAN, L. R., HAKKELING, R. T. A. & SOMBROEK, W. G. (1991) World map of the status of human - induced soil degration an explanatory note Global Assessment of Soil degradation GLASOD Second revised edition, pp. 34. Nairobi International Soil Reference and Information Centre (ISRIC), Wageningen.

ORARE, A. C. (2000) Wind erosoin of volcanic soils ,a reconnaissance study in the southern catchment of lake Naivasha region ,Kenya. ITC MSc thesis, ITC.

P.T.KAMONI. (1988) Detalied soil survey of apart of quarantine farm National Husbandry Resarch Station,Naivasha,(Nakuru district), pp. 24, Naivasha.

PARESI, C. M. (2000) Information system development methodologies,techniques and tools,an overview, Enschede.

RAZA, A. (2001) *Object -Oriented temporal GIS.for urban applications*. ITC, Enschede, 244 pp.

RINGO, D. E. (1999) Assessment of erosion in the Turasha catchment in the lake Naivasha area Kenya. ITC.MSc. thesis, ITC.

SANDERS, D. W. (1994) Global perspective on soil degradation and its socioeconomic impact the problems of sessment. In: *8th international soil conservation conference abstracts Soil and water conservation challenges and opportunities*, pp. 470. Oxford & IBH, NewDelhi-India.

SCHWEITZER, P. N. (2001) Tools for creation of formal metadata (mp) acompiler for formal metadata.

SHRESTHA, D. P. (1989) Remote sensing application to land resources, pp. 155-165, rome.

SHRESTHA, D. P. (2000) Soil degradation, pp. 31. ITC, Enschede.

STEINER, K. G. (1996) *Causes of soil degradation and development approches to sustainabl soil management*. Margraf Verlag, 50 pp.

TILAYE BITEW BEZU. (2001) Building a soil information system for multi - source data integration : acase study in lake Naivasha area, Kenya. ITC MSc-thesis, ITC.

USDA. (1993) *Soil survey manual*. USDA, Washington,dc 20402, 437 pp.

VAN LYNDEN, G. W. J. & OLDEMAN, L. R. (1997) The Assessment of the Status of human-indused Soil Degradation in South and Southeast Asia, pp. 36. ISRIC, Wageningen.

W.G. SOMBROEK, BRAUN, H. M. H. & POUW, B. J. A. V. D. (1980) Exploratory soil map and agro - climatic zone map of Kenya. Kenya Soil Survey, Ministry of Agriculture, National Agricultural Laboratories, Nairobi.

WANGATI, F. J. & SAID, M. Y. (1997) Overview. In: *National degradation assessment and mapping in Kenya*, pp. 144.

WOODHALL, D. G., CLARKE, M. C. G., MWAGONGO, F. M., KORIO, R. & NDOGO, M. (1988) Geological map of Longonot volcano,the Greater Olkaria and Eburru volcanic complexes,and adjacent areass. Hammond &Kell LTD.

ZINCK, J. A. (1992) Soil survey perspectives and strategies for 21th century, pp. 132. ITC, Enschede.

APPENDICES

Appendix A: Standard interview questionnaires

(Governmental offices & NGOS)

A) General information

1-Date…………………………

2- Name of organization……………………………………………….. .

3- Name of interviewee……………………………………………………

4- Occupation…………………………………………………………

5-What is the scope of your organization?

……………………………………………………………………………………….

B) Land degradation

6- Does your organization have experience in dealing with land degradation before?

………………………………………………………………………………………

7- What type of land degradation do you deal with?

………………………………………………………………………………………..

7b-how severe is it? ……………………………………………………………….

……………………………………………………………………………………….

C) Existing information about land degradation

8-Do you have any maps or other kind of information concern land degradation?

…………………………………………………………………………………….

D) Information requirements concern land degradation

9- Does your organization requires information about land degradation in future?

……………………………………………………………………………

……………………………………………………………………………

10- What level of detail would you like to have this information?

……………………………………………………………………………

……………………………………………………………………………

11-In which format would you like to get this information?

Maps with the location of different kinds of degradation

Graphics showing the extent and progress of degradation

Reports explain how degradation occurs

12-Do you share this data with others organizations?

(Farmers)

A) General information
1-Date…………………………………………………………………………
2- Name of the company farm……………………………………………..
3- Name of interviewee…………………………………………………….
4-- Occupation (position)?…………………………………………………
5-What is the main farm enterprises?………………………………………
……………………………………………………………………………...
B) Land degradation (On-farm status)
6a- What types of land degradation if any do you have in your farm?
………………………………………………………………………………………
6b- Is it affecting your production?…………………………………………………
6c-how severe is it? …………………………………………………………………
……………………………………………………………………………………….
6d- Is it increasing?
C) Existing information about land degradation

6e-Do you have any maps or other kind of information on past or current on-farm land degradation concern land degradation?
………………………………………………………………………………………
7a-Do you think your land is degrading, improving or keeping the same quality in recent years?……………………………………………………………………………..
7b-In what respects?
………………………………………………………………………………………..
………………………………………………………………………………………..

7c- How you determine this (do you do any specific tests to see if you have a Problem?………………………………………………………………………………………
D) Information requirements concern land degradation

8- Does your farm requires information about land degradation in future?
…………………………………………………………………………………………
9- On what kind of land degradation would you like to have this information?
………………………………………………..
10-In which format would you like to get this information?

- Maps with the location of different kinds of degradation
- Graphics showing the extent and progress of degradation
- Reports explain how degradation occurs

11-Do you share this data with others organizations?

Appendix B: Entity description

B1 Data dictionary for Entities in LDDB (time zero):

Entity name and code	Attributes	Description	Formation
Degradation map (Dmap)	Map_id, map scale, Year, Approach of assessment, author	A two dimensional representation of the status of degradation in an area and contains one or more degradation map unit	Higher-level aggregation or grouping of delineation.
GLASOD map unit (GDU2000)	GLASOD _id (the code), type, subtype, class, subclass, description. Total area, total no of polygon	Two dimensional representation contain one or delineation	It's grouping by similar polygons that contain same degradation attributes.
Degradation (polygon) Delineation (DD2000)	Polygon_id, area, Perimeter	A terrain unit with two-dimensional spatial extent containing same degradation types all over the terrain area.	Its form from degradation process
Severity level	Severity _id, description	A description of the degradation unit. It's not an object in reality.	------
Degradation map unit (DMU 2000)	DMU_id, total area, Total number of polygon	Two dimensional representation contain one or delineation	It's grouping by similar polygons that contain same degradation attributes.
National map unit (NTDU2000)	NT_id, total area, total number of polygon	Two dimensional representation contain one or delineation	It's grouping by similar polygons that contain same degradation attributes.

Appendix C: Internal design parameters and specification of entities.

Entity Name: Degradation map (Dmap) Entity type: object in reality

No	Field Name	Data type	Field Size	Required	Allow Zero length	Indexed	Description
1	Map _id	Text	20	Yes	No	Yes	Unique map identifier
2	Map _sc	Text	50	No	Yes	No	Map scale
3	Year	Number	Integer	No	Yes	No	Year of the assessment
4	Approach	Text	50	No	Yes	No	Assessment approach
5	Author	Text	50	No	Yes	No	Author of the map

Entity Name: GLASOD map unit (GDU) Entity type: object in reality

No	Field Name	Data type	Field Size	Required	Allow Zero length	Indexed	Description
1	GL_id	Text	50	Yes	No	Yes	Unique map unit identi-fier
2	Type	Text	50	No	Yes	No	Type of degradation
3	Subtype	Text	50	No	Yes	No	Subtype of degradation
4	Class	Text	50	No	Yes	No	Degradation class
5	Des	Text	50	No	Yes	No	Sub class of degrada-tion
6	G_area	Number	Long integer	No	Yes	No	Total area per GL_ id
7	G_poly	Number	Long integer	No	Yes	No	Total number of poly-gon per GL_ id
8	Map _id	Text	20	No	Yes	Yes	Foreign key
9	SL_id	Text	2o	No	Yes	Yes	Foreign key

Entity Name: Degradation delineation Entity type: object in reality

No	Field Name	Data type	Field Size	Re-quired	Allow Zero length	Indexed	Description
1	Del_id	Text	10	Yes	No	Yes	Unique de-lineation identi-fier
2	Area	Number	Long integer	No	Yes	No	Area of the de-lineation
3	Perimeter	Number	Long integer	No	Yes	No	Perimeter of the delineation
4	GL_id	Text	50	No	Yes	No	Foreign key
5	DMU_id	Text	50	No	Yes	No	Foreign key
6	NT_id	Text	50	No	Yes	No	Foreign key

Entity Name: Severity level (SL_id) Entity type: non-object in reality

No	Field Name	Data type	Field Size	Required	Allow Zero length	Indexed	Description
1	SL_id	Text	20	Yes	No	Yes	Unique identi-fier of the se-verity
2	Des	Text	50	No	Yes	No	Description of the severity level

Entity Name : Degradation map unit(DMU) Entity type: object in reality

No	Field Name	Data type	Field Size	Required	Allow Zero length	Indexed	Description
1	DMU _id	Text	20	Yes	No	Yes	Unique deg-radation unit identifier
2	D_area	Number	Long integer	No	Yes	No	Total area per DMU
4	G_poly	Number	Long integer	No	Yes	No	Total number of polygon per DMU

Entity Name: National map unit Entity type: object in reality

No	Field Name	Data type	Field Size	Required	Allow Zero length	Indexed	Description
1	NT _id	Text	20	Yes	No	Yes	Unique unit identifier
2	N_area	Number	Long integer	No	Yes	No	Total area per NT
4	N_poly	Number	Long integer	No	Yes	No	Total number of polygon per NT

Appendix D: Data dictionary for processes and data stores

D1: Data dictionary for data processes

Process No	*Process name*	*Process description*	*Input data*	*Output data*
1	Data collection	Primary data collection if it exist or from the field	Rainfall, temp, wind Land use maps, Topographic maps, DTM, history of degradation, Impact of degradation, Satellite images	Primary data
2	Data management	Analogue to digital conversion, contour maps to DTM, data quality control	Primary data	Primary data
3	Interpretation and S.T assessment	Analysis and interpretation of the data automatically and manually	Primary data Degradation maps and reports	Degradation maps and reports
4	Information dissemination	Processing the request data from clients, disseminating data or information to users via digital and or analogue format	Final results	Vulnerable areas for LD, research report on process, analyzed maps, maps of actual and potential degradation, degree of degradation, priority area for intervention

D2: Data dictionary for the data stores

Data store name	Store description
Primary data storage	Refer to common soil database, this database stores the information on different soil units ,data related to soil properties, like salinity and compaction and other soil properties.
Spatio temporal LDDB	Based on the methodology for classification the degradation in this situation (GLASOD) and the time aspect (Here snap shaots) this information is full spatially but like to the data in Access

Appendix E: Metadata

Land Degradation Database For Lake Naivasha Area, Kenya

Metadata also available as

Frequently anticipated questions:

- What does this data set describe?
  1. How should this data set be cited?
  2. What geographic area does the data set cover?
  3. What does it look like?
  4. Does the data set describe conditions during a particular time period?
  5. What is the general form of this data set?
  6. How does the data set represent geographic features?
  7. How does the data set describe geographic features?
- Who produced the data set?
  1. Who are the originators of the data set?
  2. Who also contributed to the data set?
  3. To whom should users address questions about the data?
- Why was the data set created?
- How was the data set created?
  1. From what previous works were the data drawn?
  2. How were the data generated, processed, and modified?
  3. What similar or related data should the user be aware of?
- How reliable are the data; what problems remain in the data set?
  1. How well have the observations been checked?
  2. How accurate are the geographic locations?
  3. How accurate are the heights or depths?
  4. Where are the gaps in the data? What is missing?
  5. How consistent are the relationships among the data, including topology?
- How can someone get a copy of the data set?
  1. Are there legal restrictions on access or use of the data?
  2. Who distributes the data?
  3. What's the catalog number I need to order this data set?
  4. What legal disclaimers am I supposed to read?
  5. How can I download or order the data?
- Who wrote the metadata?

What does this data set describe?

Title: Land Degradation Database For Lake Naivasha Area, Kenya

Abstract:
The land degradation features assessment around Lake Naivasha kenya cover south east and we stren part of the Lake.The data was collected at two diffrent times
1-In September 2000 for acadimic learning the research was conducted .The total area covered by the study was 370 ha(i.e. the study area of Naglhout).the researcher used Small Format Aerial Photography(SFAP)to prepare an erosion feature map at scale 1:5000 the result was finalized on febrouary 2001.

2-In September 2001 for academic research the west part was assessed.The total area covered was 13 ha (Somia's study area).The method was used actual field mapping using GPS. to prepare map on status of sheet erosion in Ndabibi Escarpment at scale 1:2000. the result was finalized in February 2002.

1.How should this data set be cited?
Somia Abdelati Mohammed Ahmed, March 2002., Unpublished material, Land Degradation Database For Lake Naivasha Area, Kenya.

Other_Citation_Details:

1-From the Digital MSc.thesis document entiteld as"Performance analysis of Small Format Aerial Photography (SFAP)in assessing current status and trends in wind erosion a case study in the Longonot-Kijabe hill area,Navasha district,Kenya MSc. thesis, 2001, by Naglehout.ITC,Enschede

2-From Digital soil database bulid by Tilaye Bitew Bezu,2001.in the thesis entiteld as"Buliding a soil information system for multi source data integration acase study in lake Naivasha area, Kenya "

2.What geographic area does the data set cover?

West_Bounding_Coordinate: +36.1749
East_Bounding_Coordinate: +36.4347
North_Bounding_Coordinate: -0.6090
South_Bounding_Coordinate: -0.9009

4.Does the data set describe conditions during a particular time period?

Calendar_Date: 2000
Currentness_Reference: Observation time

5.What is the general form of this data set?
Geospatial_Data_Presentation_Form: Vector didital data, Raster digital data& Tabular data.

a.How are geographic features stored in the data set?

Indirect_Spatial_Reference:
The geometry of the spatial data set is according to the geometric definition of the topographic map of Kenya,1975

b.What coordinate system is used to represent geographic features?

Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: -37
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.9996
Longitude_of_Central_Meridian: 39.0
Latitude_of_Projection_Origin: 0.0
False_Easting: 500000
False_Northing: 10000000

Planar coordinates are encoded using Coordinate pair
Abscissae (x-coordinates) are specified to the nearest 0.01 meter
Ordinates (y-coordinates) are specified to the nearest 0.01 meter
Planar coordinates are specified in Planar coordinates are specified in meters

7.How does the data set describe geographic features?

Entity_and_Attribute_Overview:
The spatial database of lake Naivasha area (In the Southeast and part of the West) contain two poly gons maps of stustus of wind erosion and status of water erosion in the area.

The non spatial database for land degradation for Lake Naivasha area contains total of 13 entities. Summary of information of each entities data set is the following:

1-Entity name = Degradation map,code (Dmap)the degradation map contains four attributes. These are (Map_id), Map scale code (Map_sc),The year of the assessment code (A_year),Assessment approach code (A_approch).

2)Entity name = Degradation map unit, code DMU.The DMU contains six attributes These are:total area covered by DMU code (D_area), the total number of polygons for DMU code (D_polygon),The severity level code (Sl_id),(Map_id),(Del_id).

3)Entity name =GLASOD map unit code (GDU)the GDU contains eight attributes (to explain the herarical system of GLASOD) These are
(GL_id),(type),(subtype),(class),(description),(G_area),(G_polygon),(Map_id) and (SL_id).

4)Entity name = National degradation map unit code (NDU),the NDU contains five attributes.These are

(NT_id),(NT_area),(NT_polygon),(Map_id),and(SL_id).

5)Entity name = Degradation delineation 2000 code (DD2000),this entity contains six attributes. These are (Del_id),(DMU_id),(GL_id),(NTU_id),area and perimeter.

6)Entity name = Degradation delineation 2001, code (DD2001), this entity contains six attributes. These are (Del_id),(DMU_id),(GL_id),(NT_id),area and primeter.

7)Entity name =Severity level code (SL_id) the severity level contains two attributes these are (SL_id)and description.
8)Entity name =Soil map code (Smap)contains eight attributes.
9)Entity name =Soil map unit (SMU)contains seven attributes.
10)Entity name =Polygon delineation code(Poly_id)contains four attributes .
11)Entity name = Soil component code (SMU_soil) contains four attributes.
12)Entity name = Soil observation at sight code (S_site) this entity contains more than 60 attributes.
13)Entity name =Soil observation at horizon code (S_hor)contains more than 50 attributes.

Note: On Lake Naivasha land degradation database the following remarks should be considered before using the data:

A)the temporal dimention indecated in this database as snapshot.These snap shots represented in adatabase as tables with the crosspondet time at level of degradation map unit (DMU) and degradation delineation (DD)i.e. (DMU2000) (DMU2001), (DD2000)ect.But at the map level the time factor was presented as an attribute.
B)The entity GDU,NTU and DMU are in th same level and the selection between them based on the methods will be used. Its also possible using more than one.
C) Data related to soil element based on the work done by Tilaye Bitew Bezu "Soil geographical database for Naivasha, Kenya in 2001 "more information about the data and the metadata of this digital database can be accessed through Internet (Network Nighbourhood/Entire network/ha2/Pc 4014-03/Naivasha/Nested.

Entity_and_Attribute_Detail_Citation:

1- A.Nagelhout,2001.Performance analysis of Small Format Aerial Photography(SFAP)in assessing current status and trends in wind erosion a case study in the Longonot_Kijabe hill area,Naivasha district, Kenya

2-Tilaye Bitew Bezu,2001.Buliding a soil information system for multi source data integration acase study in lake Naivasha area, Kenya

Who produced the data set?

1.Who are the originators of the data set? (may include formal authors, digital compilers, and editors)

Somia Abdelati Mohammed Ahmed, March 2002.

2.Who also contributed to the data set?

The data set credit goes to the following individuals, staff members and institutions. 1)To Mr Na gelhout who carried out his resarch in Longont area mainly south east the Naivasha lake .

2)To ITC libarary and soil science division staff who made possible the availability of the copy of the original data.

3.To whom should users address questions about the data?

Soil Science division,ITC
c/o C/o Dr.D.G. Rossiter
ITC,Hengelostraat,99
Enschede, Overijsel,06 7500 AA
The Netherlands
+31(0)53 487 4444 (voice)

Why was the data set created?

The main purpose of this data is to develop a working approach for land degradation assessment and monitoring in Naivasha in the information system context. The other purpose to orgnize the available multi-souce and multi- temporal data for the area.

How was the data set created?

1) First data set for the Longonot area was obtained using Small Format Aerial Photography (SFAP). the avarge error
is 1.19 meter.

2)Second data set for Ndabibi area was collected by subjective field identificationof degradation features no dificulty
deciding one type of features but degree was sometimes difficult.

4.Where are the gaps in the data? What is missing?

5.How consistent are the relationships among the observations, including topology?

The data set in the non spatial database can be manipulated or retrieved using SQL .The entities are well related
according to the rules of data integrity.the database has been tested by data extraction mentioned above.

How can someone get a copy of the data set?
Are there legal restrictions on access or use of the data?
Access_Constraints: none
Use_Constraints: ITC(International Institue for Geo-information science and Earth Observation)the orgnaization and the compiler M.A.Somia should be acknoledged/mentioned as the source in any product derived from this data set.

Dates:
Last modified: 2002

Metadata author:

Soil Science Division, ITC
c/o Dr.D.G.Rossiter
ITC,Hengelostraat 99,7500AA
Enschede, Overijsel province 06
The Netherland

+13(0)53 487 4444 (voice)

Metadata standard:
Fedral Geographic Data Committee (FGDC)Content Standers for Digital Geospatial Metadata(CSDGM)
(FGDC-STD-001-1998)

Generated by mp version 2.7.23 on Wed Feb 20 17:03:03 2002