CHAPTER II
LITERATURE REVIEW

As specified in the introductory part, the important backgrounds for this research were divided into 3 categories, including analysis in heavy metal concentration in sediments, how to determination of rates of sedimentation and erosion, and what GIS applications can be applied to mitigate environmental problems. Thus, it is essential to mention theoretical backgrounds related to these categories.

2.1 Sources and Transportation of Heavy Metals

Pollutants are substances causing damage to 'targets' (Holdgate, 1979) as they are emitted from sources and reach the target through delivery pathways (Figure 2.1). This definition includes the useful concepts of sources (which have spatial locations), pathways (linking locations), and targets (which also have locations). The 'target' can for instance be the air, water or soil within a region.

Pollution and pollution control exhibit the inherent space/time frameworks performed by geographers. Pollution has patterns and processes which are open to geographical treatment – it can be mapped and modeled (Newson, 1991). Much of the scientific work has been carried out by focusing on separate sources or processes (Newson, 1994). By focusing, on pollution via subsurface runoff from a specific agricultural area, our knowledge on the transport process involved can be increased and possibly incorporated into our understanding and models dealing with the broader theme of diffuse pollution from rural areas.

Diffuse pollution (European Enviroment Agency,1999), often referred to as non-point sources pollution (Laubel,2004), refers exclusively to pollution from diffuse sources. Point sources such as urban areas and industry are not included. In practical terms this implies that sampling and investigations on diffuse pollution are not as easily undertaken as when dealing with point sources. Diffuse pollution to the aquatic environment is governed by large spatial and temporal extent and therefore difficult to assess and manage (Kronvang, 1996). In contrast to point sources, diffuse sources consist of extended geographical areas. Major types of diffuse sources are agricultural land, forested land, natural land, mining areas and atmospheric deposition. All other sources of pollution can preferably be regarded as point sources. Sources such as freshwater fish farms and scattered dwellings are according to the above definition regarded as point sources.

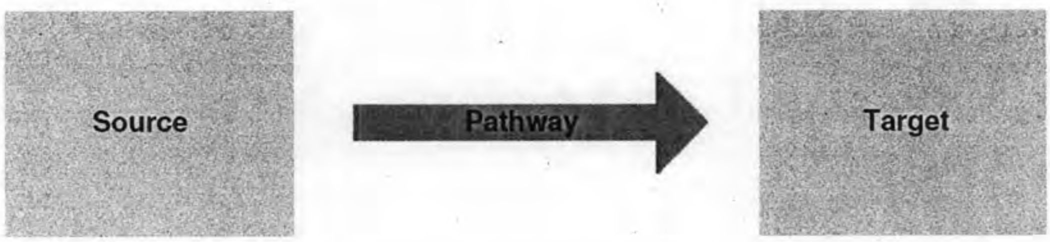


Figure 2.1 Diagram showing the concept of pollution. Pollutions reach the target area by transportation from a source area .

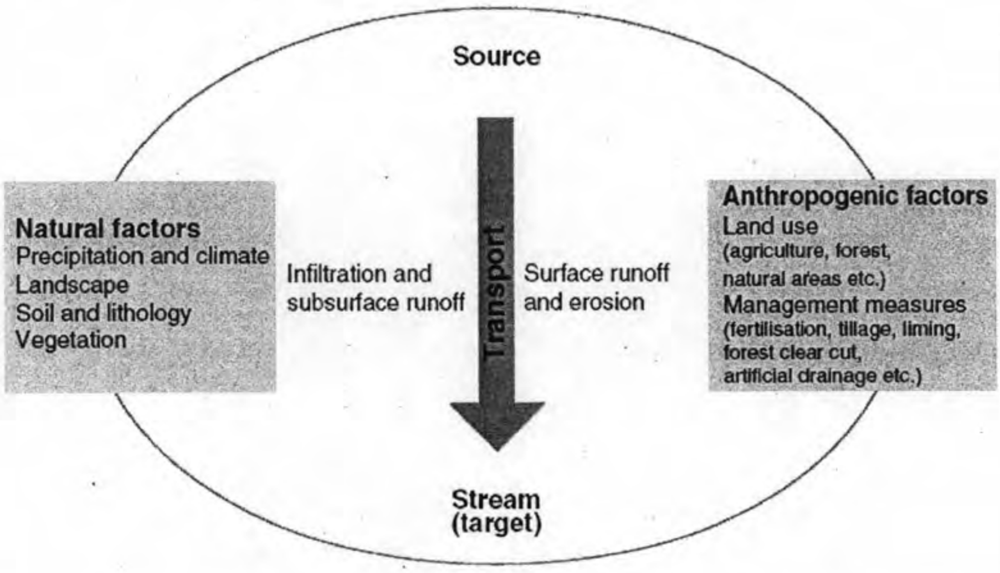


Figure 2.2 Diagram showing the natural and anthropogenic factors that influence source and transport of sediment-associated substances (Laubel, 2004).

The factors influencing diffuse pollution can, according to the definition on pollution, be divided into two groups, i.e. those influencing: the source and its content of pollutants and the transport from source to target (Figure 2.1).

In practical terms a number of factors convey an influence both on the source and the transport. For instance, climate has a major influence on transport (via precipitation regulating the runoff) and also on the source content of elements, such as by affecting the rate of soil weathering and organic matter production and break down. The pollutant content of a source is often a product of both natural and anthropogenic influences (Figure 2.2). Agriculture and forest being diffuse sources are under influence from both natural and anthropogenic factors. Their metal and phosphorus contents are products of the natural metal and phosphorous contents of parent soil materials and of anthropogenic factors, such as fertilization of soils with chemical fertilizer and manure. In many countries, the impacts from anthropogenic factors are more important than those from natural factors.

For some purposes, it is useful to distinguish between different soil - or sediment - compartments within a source or catchment area. A differentiation between topsoil and subsoil compartments makes sense within in the source-transport-target concept. The topsoil compartment may in some cases (depending on the local conditions and the elements studied) be simplified as being the only source, or in other cases topsoil and subsoil compartments can be differentiated by their different content of elements.

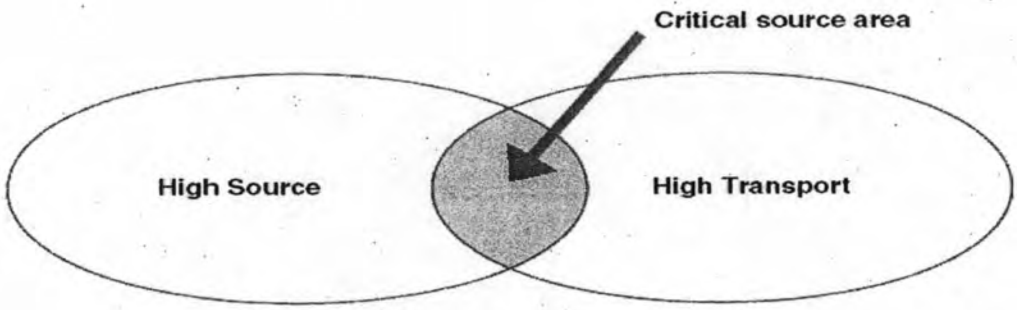


Figure 2.3 Critical source areas have a high risk for transport (Laubel, 2004).

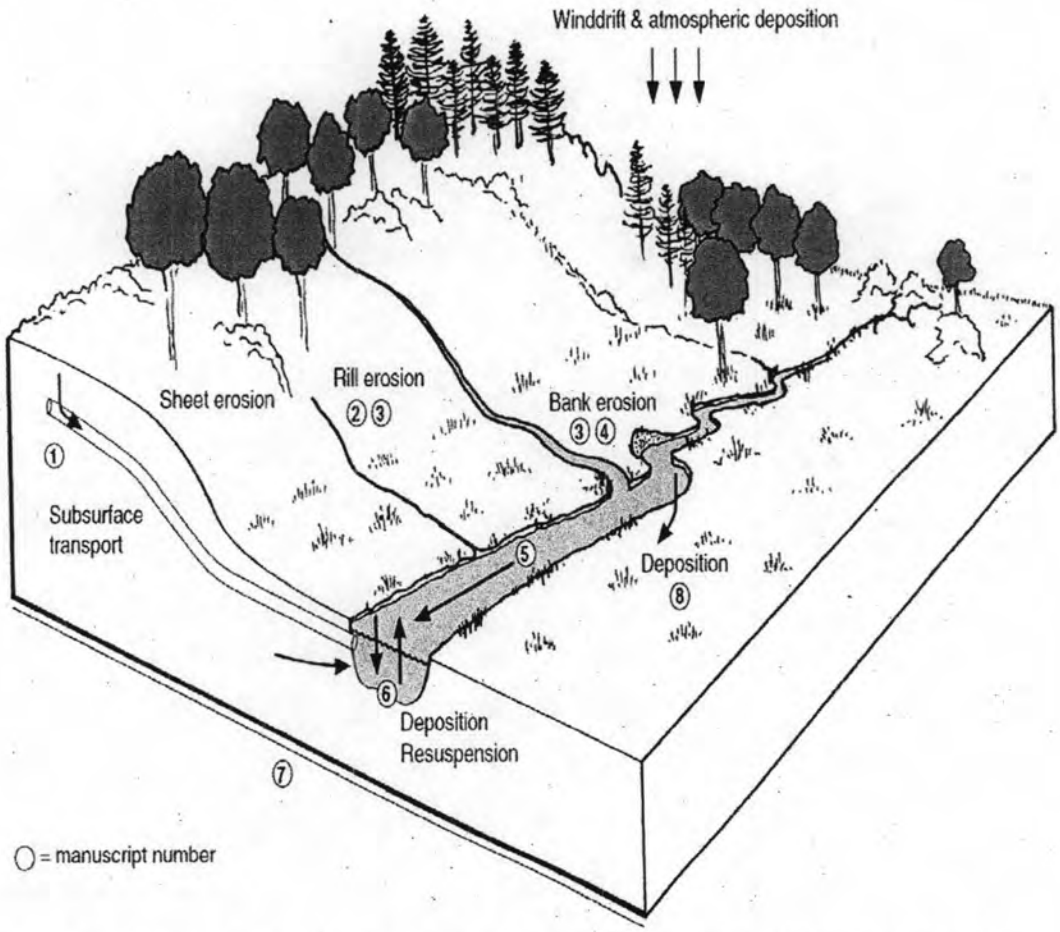


Figure 2.4 Delivery pathways for sediment and sediment associated substances of diffuse sources (Laubel, 2004).

In Denmark, the phosphorus content is higher not only in agricultural soils than forest soil but also in top soil than in subsoil. The same applies for a range of heavy metals (Table 2.1). The delivery of sediment-associated substances to streams is generally higher from agricultural sources than from forest or natural sources - as both the source and the transport is higher from agriculture. When a source area is both high in its elemental content, there also exists a high transport linkage from source to stream, the area is called a "Critical Source Area" (Rubak et al.,2006) (Figure 2.3).

The concept of Critical Source Areas opens up different possibilities related to management and remedial strategies. Critical source area management integrates all sources and all modes of transport and focuses on either just one element or on a range of different elements. For phosphorus, the critical source area management approach is an integrated management aspect in North America and is becoming more applied in other parts of the world (Lauble,2004). In Denmark, it is an integrated part of management strategies presently considered in relation to the implementation of a third Danish Plan for the Aquatic Environment. Recently, McDowell et al. (2002) suggested the application of remedial measures in parts of central Pennsylvania, USA, where minimizing the phosphorous export should focus on critical source areas, while minimizing the nitrogen (N) export should be source based, concentrating on more efficient use of N by crops. Especially in relation to sediment-associated pollutants, the critical source area concept is undoubtedly useful as it offers an opportunity to integrate different aspects related to the different sources and different transport pathways (see Figure 2.4).

2.2 Lake Sediment and Heavy Metals Deposition

In aquatic systems, sediments are increasingly recognized as the most important sink of contaminants and as a reservoir and possible future source of pollutants (e.g. Li et al., 2000). Pollutant metals are often weakly bound within sediments, facilitating their chemically or biologically mediated release into interstitial and surface waters (e.g. Blasco et al., 2000; Cheevaporn et al., 1995; Förstner, 1983;

Tessier and Campbell, 1988). Sediments provide a historical record of environmental pollution, which manifests as a spike in sediment pollutant accumulation compared with natural background levels in the chronological sequence.

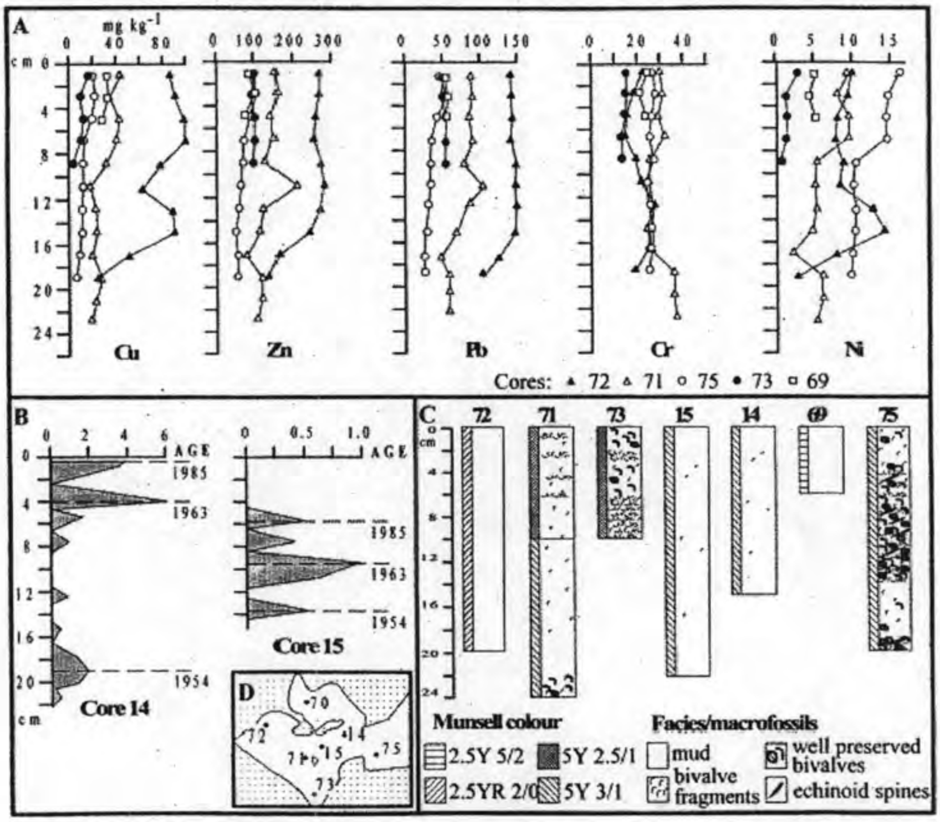


Figure 2.5. The example of the vertical variation of sediment, heavy metal, and dating of the selected cores from Tolo Harbour. A: Downcore variations in Cu, Zn, Pb, Cr, and Ni for five cores. B : Cs-137 in core showing peak values and their corresponding inferred dates. C : Sediment logs for cores shown in 'A' and 'B' (Owen and Sandhu, 2000).

Sediment dating enables the accurate determination of the onset, and thus the likely source, of the pollutant input (e.g. Isaksson and Safvestad, 1996; Li et al., 2000; Pettersson and Ingri, 2001). Hence, sediment analyses are useful tools in investigating the history of effluent contamination, the processes involved in the removal of pollutants from the water column, and the stability and future pollution potential of the sediments.

Wetlands and Lakes have been extensively researched and implemented as pollution remediation facilities (e.g. Dunbabin and Bowmer, 1990; Hammer, 1990; Kadlec and Knight, 1996). Many natural wetlands and lakes have been found to function successfully in ameliorating the environmental impact of mining and industrial effluent (e.g. AMC, 1999; Komex International, 2002; Kwong and Van Stempvoort, 1994; Mays and Edwards, 2001; Mungur et al., 1995). However, this protective function of natural wetlands often comes at the cost of substantial environmental degradation (e.g. Crowe et al., 2002, Johns, 1995).

Lake sediment analyses have been essential in assessing the impact of (e.g. Chague-Goff and Rosen, 2001) and in determining processes of metal effluent remediation and the potential of the sediment as a source of pollution (e.g. Blasco et al., 2000, Limpitlaw, 1996, Sobolewski, 1996).

The chronological geochemical record contained within sediments has been used worldwide to describe the history of contamination. Sediment analysis has proven invaluable in ascertaining the source of pollution, the processes leading to pollutant attenuation and the potential downstream impacts through remobilization of toxicants. Good examples of heavy metal distribution are shown in Figure 2.5 and 2.6.

2.2.1. Determination of Rates of Sedimentation

2.2.1.1 Determination of Rate of Sediment Deposition

In order to estimate and evaluate rates of deposition sediment and heavy metal in lake, age and depth of sediment are the basically data that we need to know. The dating techniques and depositional rate calculation will be described as below.

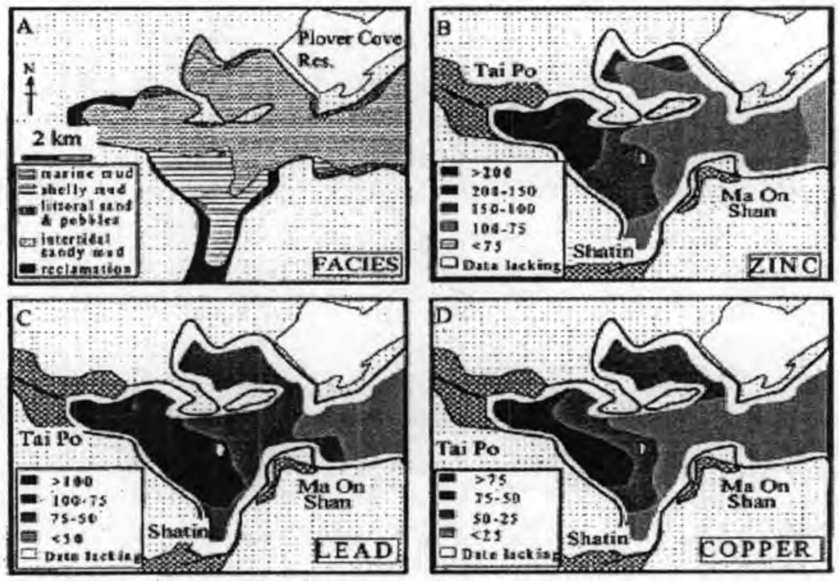


Figure 2.6 The example of the lateral variation of heavy metal distribution in Tolo Harnbour. Data in mg/kg. A: Simplified facies map. B and D: Distribution maps for Cu, Pb, and Zn in the upper 2 cm of sediment profiles (Owen and Sandhu, 2000).

A. Dating Techniques

There are several methods applied to dating young sediments, such as Carbon-14 dating, thermoluminescense dating, radiochemistry dating (Cs-137 and Pb-210), and paleomagnetism dating.

In this study, three dating techniques for age determination of sediment were used. They are Cs-137, thermoluminescense (TL), and carbon-14 datings.

A1. Cs-137 Dating

Cs-137 (half-life 30.2 years) is a man-made radionuclide occurring in the global fallout of debris from nuclear weapons tests during the 1950s and 1960s. Cs-137 is strongly absorbed by clay and organic matter in the topsoil. Cs-137 loss by uptake by vegetation can be negligible (Ritchie and McHenry, 1990) and its leachability is low (de Jong et al., 1986; Lowrance et al., 1988), so it is usually concentrated in the topsoil. After deposition as fallout, its redistribution is mainly associated with soil physical processes, such as erosion and tillage. Since its introduction in 1960s (Rogowski and Tamura, 1965; Ritchie et al., 1974).

Cs-137 has been widely used as a valuable tracer in soil erosion and sediment delivery studies. It has also been used to indicate environmental changes and human disturbance of soils in the last 30–50 years (Ritchie and McHenry, 1990). Although the Cs-137 technique has wide application in water erosion research in humid regions (Wise, 1980; Ritchie and McHenry, 1990), there have been few similar studies in arid and semiarid environments (Sutherland et al., 1991; Walling and Quine, 1992; Chappell, 1999; Collins et al., 2001).

Some recent workers have estimated average wind erosion rates or total soil losses using Cs-137 measurements (Sutherland and de Jong, 1990; Sutherland et al., 1991; Harper and Gilkes, 1994; Chappell, 1995, 1996, 1998, 1999; Chappell et al., 1996, 1998; Bajracharya et al., 1998; Pu et al., 1998; Yan et al., 2001).

The Cs-137 determination (with lower precision) can be used by gamma counting (Santschi, 1989) or neutron activation analysis (NAA) (Tsukada and Nakamura, 1999).

A2. Thermoluminescence Dating

This technique involves exposing minerals (quartz, feldspar, calcite, and clay) to heat until they emit light. Defects within the mineral crystal structure attract free electrons that are produced due to nuclear radiation exposure. By heating these crystals the electrons escape the crystal defects and migrate to another defect known as a luminescence center. This movement of free electrons results in the emission of photons which can be measured as a light signal. The amount of light obtained is related to the amount of radiation that the minerals have been exposed to in the natural environment since deposition (Gregory and Schofield, 2000).

In order for the TL value to be zeroed the mineral must be exposed to heat or sunlight for a long period of time. The sunlight bleaching effect does not empty all defects, but does empty the majority of them.

2.2.1.2 Deposition Rates

From dating model, a sedimentation rate is also derived for each layer of the stations by depth, so it is possible to study the evolution of the sedimentation rate versus the time. (Clifton et al., 1994). The sediment deposition rate can be calculated using Wan (1999)'s equation (1)

$$P = Zm/(Tc - Tm) \qquad (1)$$

where P is the deposition rate of the sediment (cm/yr), Zm is the horizon depth (cm) of a dating value, Tc is the sampling year (a) and Tm is the dated year of the horizon.

2.3 Soil Erosion

2.3.1 General Background and Processes

Various aspects of the modeling of erosion and sediment generation, transport and deposition processes have been reviewed previously in the literature. The processes of sediment generation, transport and deposition have been well described elsewhere (e.g. Rose, 1993; Haan et al., 1994) and are discussed in this review only to introduce the concepts used in modeling these processes. Bull and Kirkby (1997) traced the development of gully erosion models, from the first stochastic models to the more recent process-based representations of the system. Prosser and Rustomji (2000) reviewed the representations and use of sediment transport capacity relationships in modeling sediment transport in overland flow. The concept of sediment transport capacity is commonly used in modeling sediment movement via overland flow and in channel transport models (Merritt et al., 2003).

The process of erosion can be described in three stages: A) detachment, B) transport and C) deposition. Detachment of sediment (Figure 2.7) from the soil surface was originally considered to be exclusively the result of raindrop impact (e.g. Hudson, 1975), although the importance of overland flow as an erosive agent has now been recognised. Rainfall detachment is caused by the locally intense shear stresses generated at the soil surface by raindrop impact (Loch and Silburn, 1996). Likewise, overland flow causes a shear stress to the soil surface which, if it exceeds the cohesive strength of the soil (termed the critical shear stress), results in sediment detachment. In different situations, the major processes leading to sediment detachment will differ.

There are four main types of erosional processes: sheet, rill, gully and in-stream erosion. Sheet erosion refers to the uniform detachment and removal of soil, or sediment particles from the soil surface by overland flow or raindrop impact evenly distributed across a slope (Hairsine and Rose, 1992a). Together with rill erosion, sheet erosion is often classified as 'overland flow' erosion, detaching sediment from the soil surface profile only.

For purposes of simplification, the two processes are often considered together in erosion modelling. Rill erosion occurs when water moving over the soil surface flows along preferential pathways forming an easily recognisable channel (Rose, 1993). These rills are generally small erosion features, and have been defined by Loch and Silburn (1996) as being 'flow channels that can be obliterated by tillage'. Rill initiation is controlled by the cohesive strength of the soil and the shear forces exerted on the soil.

Flow in rills acts as a transporting agent for the removal of sediment downslope from rill and interill sources, although if the shear stress in the rill is high enough the rill flow may also detach significant amounts of soil (Nearing et al., 1994).

In contrast to rill erosion, Gully erosion describes channels of concentrated flow that are too deep to be obliterated by cultivation (Rose, 1993; Loch and Silburn, 1996). Gully flows differ from sheet and rill flows in that raindrop impact is not an important factor in terms of flow resistance or in sediment particle detachment (Bennett, 1974). Gully development is considered to be controlled by thresholds, as with rills, although these thresholds have been related to slope and catchment area rather than flow erosivities (Loch and Silburn, 1996).

In-stream erosion involves the direct removal of sediments from stream banks (lateral erosion) or the stream bed. Sediment also enters the stream due to slumping of the stream bank resulting from bank erosion undercutting the stream bank. During high flow periods, a large proportion of the sediment that is transported through the stream network can originate from the stream channel. The potential exists to lump stream bank erosion processes with gully erosion for description by considering either as a specific form of the other.

These erosion types do not necessarily occur in isolation from one another. They are influenced by the landscape factors as well as rainfall characteristics. Loch and Silburn (1996) stated that the development of rill and gully erosion requires the concentration of flow and discharges that exceed critical thresholds, and as such will occur as the length of the slope increases. Hence, the dominant erosion process would be expected to follow a downslope sequence of splash–sheet–rill–gully (Loch and Silburn, 1996). As will be discussed in later sections, most erosion models tend to predict erosion for one of these erosion types, or at most a couple. In a catchment scale modelling exercise, this raises the possibility that in certain areas of the catchment the processes considered by the model being used are not truly representative of the processes actually occurring in the catchment.

Many different erosion and sediment/nutrient transport models are currently available, ranging across the broad model categories described in Section 3. These models differ in complexity, the processes modelled, the scale to which they are applied, and assumptions on which they are based. This section provides an outline of a number of currently available models. Not all models are considered, the intention being to illustrate the range of models available. Models are reviewed in terms of their model structure (and the implications of this structure on model outputs), input data requirements, and their spatial and temporal resolution. Table 2.2 summarizes these models in terms of their classification, scales of application and input data requirements.

2.1.2 USLE and Modifications

The Universal Soil Loss Equation (USLE) is a soil erosion model used widely within the United States and worldwide (Merrit et al.,2003). Developed in the 1970s by the USDA, the model has undergone much research and a number of modifications (e.g. MUSLE; USLE-M, Kinnell and Risse, 1998). The model has also been upgraded to take into account additional information that has become available since the development of the USLE (RUSLE, Renard et al., 1994). Although developed for application to small hillslopes, the USLE and its derivatives have been incorporated into many catchment scale erosion and sediment transport modelling applications.

- Model outputs

The typical output from the USLE is an annual estimate of soil erosion from hillslopes.

- *Input data*

Input data requirements are low compared with most other models. Annual rainfall, an estimate of soil erodibility, land cover information and topographic information is required.

- *Model structure*

The basic USLE is an empirical overland flow or sheet-rill erosion regression equation based primarily on observations (Merrit et al.,2003). Model outputs are both spatially and temporally lumped. As with most empirical models, the USLE is not event responsive, providing only an annual estimate of soil loss. It ignores the processes of rainfall runoff, and how these processes affect erosion, as well as the heterogeneities in inputs such as vegetation cover and soil types.

- *Erosion/transport modeling*

The USLE estimates the average annual soil loss from:

$$A = R * K * L * C * S * P$$

Where; A is the estimated soil loss per unit area,

R is the rainfall erosivity factor,

K is the soil erodibility factor,

L is the slope-length factor,

S is the slope-steepness factor,

C is the cover and management factor, and

P is the support practices factor (Wischmeier and Smith, 1978).

- *Predictive accuracy/limitations*

The simplicity of this equation and the availability of parameter values, at least in the United States, has made this model relatively easy to use (Loch and Rosewell, 1992). There are a number of limitations to the USLE. The model is not event-based and as such cannot identify those events most likely to result in large-scale erosion.

Gully erosion and mass movement are ignored and the deposition of sediments is not considered to occur in the modelled area (Zhang et al., 1995). Runoff leaving a field generally concentrates in a few major channels, the profiles of which are often concave, such that ephemeral gully erosion can occur along the upper reach of a channel and deposition occurs in the lower reaches of the channel. This gully erosion can be as extensive as sheet and rill erosion (Lane et al., 1992). Additionally, unlike in the United States, the use of USLE outside the US has been limited by the perceived lack of data for the parameters required to run the model under new conditions (e.g. Loch and Rosewell, 1992). Nearing et al. (1994), however, noted that the adaptation of USLE to a new environment requires a large investment of time and resources to develop the database required to run the model. With regards to applications to mine spoils, Evans et al. (1992) identified that due to rainfall variability, data must be collected for at least 10 years and this, combined with the lack of data for overburden spoil and replaced spoils, was a disadvantage for the use of this model in spoil pile erosion prediction. Due to the identified limitations of USLE, a number of modifications and revisions to the basic format for have been proposed in the literature. These include the modified USLE, the revised USLE (Renard and Ferreira, 1993; Renard et al., 1994), and the USLE-M (Kinnell and Risse, 1998). These continue to improve components of the model making it more process-based.

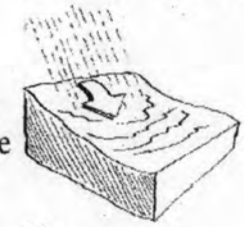
RUSLE maintains the basic form of the USLE, although all equations used to arrive at the factor values have been modified (Lane et al., 1992). Changes to the form of the length of slope (L) factor in RUSLE enables the prediction of soil loss due to Hortonian overland flow in three dimensional terrains with convergent and divergent slopes (Ryan and McKenzie, 1997). The main advantage of RUSLE over the USLE is that it has the capacity to estimate the *C* factor from information on vegetation form, decay and tillage practices rather than from experimental plot data as used in the USLE. USLE-M, for example, provides a more complex representation of processes than the USLE as it more directly considers the effect of runoff on erosion with changes to the R factor (Kinnell and Risse, 1998).

Common types of erosion

- **Rain-splash erosion** Occurs when raindrops fall on unprotected ground. The impact on the soil splashes away soil particles and digs a crater.

Rain-splash erosion

- **Sheet erosion** Occurs when thin layers of the topsoil are moved by the force of the runoff water, leaving the surface uniformly eroded.



Sheet erosion

- **Rill erosion** Caused by runoff water when it creates small, linear depressions in the soil surface. These are easily removed during land tillage.

Rill erosion

- **Gully erosion** Unlike rill erosion, gullies are too deep to be removed during normal cultivation with ordinary farm implements. They are formed from small depressions, which concentrate water and enlarge until several join to form a channel. The deepening channel undermines the head wall, which retreats upslope. The gully then widens as the side-walls are worn back.

Gully erosion

Figure 2.7 Common types of soil erosion (UNDP SANE, 2000)

Figure 2.8 Gully erosion evidences (A) along the Dolores River in Colorado's Paradox Valley near Bedrock. (B) at the North America (http://www.earthscienceworld.org)

Nonpoint source pollution (NPS) has become a topic for research that resulted in the development of numerous models and modeling techniques. Most models simulate hydrologic, chemical, and physical processes involved in the entrainment and transport of sediment, nutrients, and pesticides (Young et al., 1987 and schulla, 1997). The difficulty in modeling NPS is the problem of identifying sources and quantifying the loads. In contrast to a point source, where a known volume of contaminant is discharged from a single identifiable source, diffuse pollution is an aggregate of small contaminant inputs distributed through a watershed. Thus, NPS models require a distributed modeling approach.

Most of these models simulate processes of interception, infiltration, surface storage, and surface flow for the hydologic component. Some of them use the soil conservation service runoff curve number approach, combined with a unit hydrograph type for uniform rainfall. Erosion is based on the USLE, or modifications of it like RUSLE, to estimate the soil loss caused by rainfall and runoff.

2.4 GIS Applications to Lake and Watershed Management

Geographic data have previously been presented in the form of hard-copy maps. But the recent rapid development of computer hard- and software help introducing them in a digital form which is more applicable. Many organizations now spend so much money on establishing Geographic Information Systems (GIS) and the geographic data bases. In recent years, the demand for the storage, analysis and display of complex and voluminous environmental data has led, in recent years, to the use of computer for data handling and the creation of sophisticated information systems. Effective use of large spatial volumes depends on the existence of efficient systems that can transform these data into usable information. Geographic Information Systems (GIS) becomes an essential tool for analyzing and graphically transferring knowledge.

GIS is a "powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for particular set of purposes" (Burrough, 1986).

According to Bonham-Catter (1996), the GIS is a computer system for managing spatial data. The word geographic implies that the locations of the data items are known, or can be calculated, in terms of geographical coordinates. The word information implies that the data in GIS are organized to yield useful knowledge, often as colored maps and images, but as also statistical graphics, tables and various on-screen responses to interactive queries. The word system implies that a GIS is made up from several interrelated and linked components with different functions. Thus, GIS has functional capabilities for data capture, input, manipulation, transformation, visualization, combination, query, analysis, modeling and output (Figure 2.10).

Based on the above application, GIS are certainly contradicted to the belief that GIS is only a Computer Aided Drawing (CAD) software or only a drawing tool. Generally, CAD can only constitute a small portion of the whole integrated system, whereas an ideal GIS and its possible integrated components are as shown in Figure 2.9 and 2.10. GIS, if based on the right components, should answer several questions as shown in Figure 2.11.

More over the products of mapping and inventory are being stored in data banks for their ultimate retrieval or combination with data from other sources. Often they are incorporated GIS or LIS (Land Information Systems) which serves as a base for programmable data manipulation and selective information extraction for planning and project assessment.

The development of GIS and LIS is of considerable interest in the context of satellite surveying, change detection, and monitoring. The flexibility of digital data processing combined with quick input of new data (possible from updating on the basis of satellite remote sensing records) offers new possibilities to the surveyor, cartographer and planner (Sgzen,2002).

It is clear that in a rapidly developing society, change detection is of great importance. In modern society, mapping suffers from high rate of change, such as, change in land use in rural and urban areas, change in requirements for maps and inventories, change in concepts in the various disciplines of earth and social sciences, leading to different interpretations of the same data, and change in the economical and technical factors on which mapping methods were based.

According to ESRI (2004), a geographic information system can supports 3 views for working with geographic information; namely; geodatabase view, geovisualization view, and geoprocessing view (Figure 2.12).

2.4.1 Geodatabase View

A GIS is a spatial database containing datasets that represent geographic information in terms of a generic GIS data model (features, rasters, topologies, networks, and so forth). It's including of 3 major components, as, geographic representations, descriptive attributes, and thematic layers and datasets.

2.4.1.1 Geographic Representations

As part of a GIS geodatabase design, users specify how certain features will be represented. These features are collected into feature classes in which each collection has a common geographic representation.

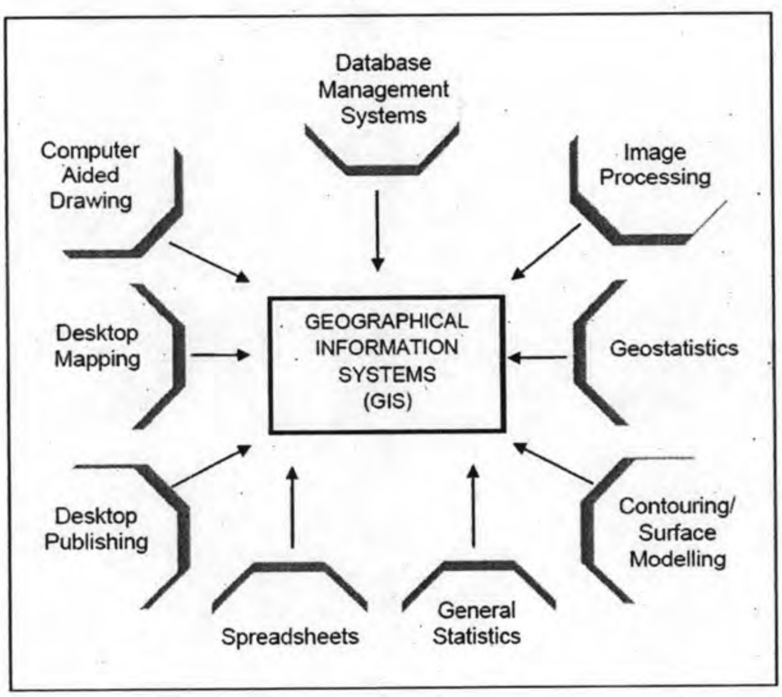


Figure 2.9 GIS and its related software systems as components of GIS (Sgzen, 2002)

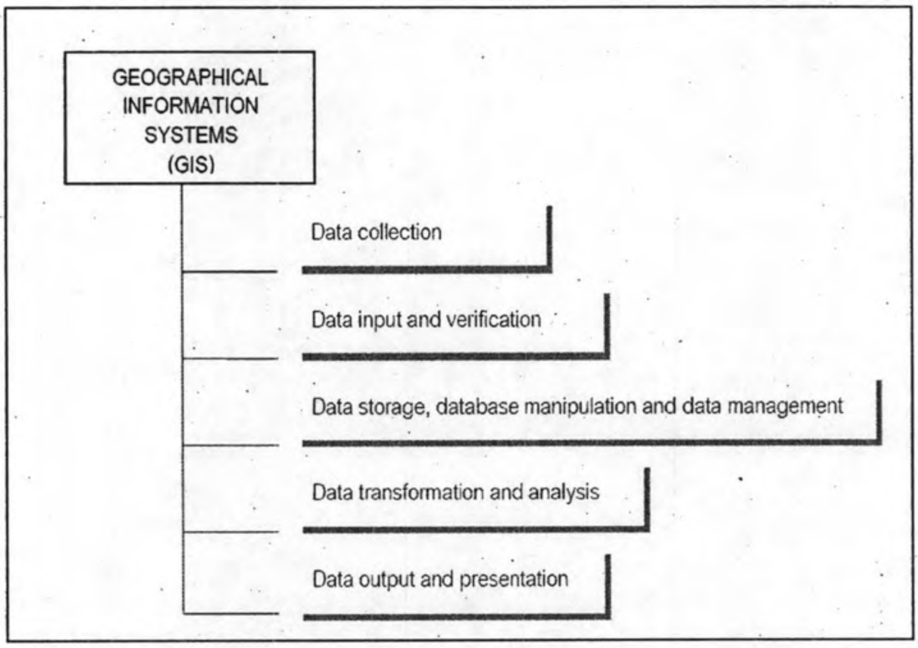


Figure 2.10 Phases of a GIS (Sgzen, 2002).

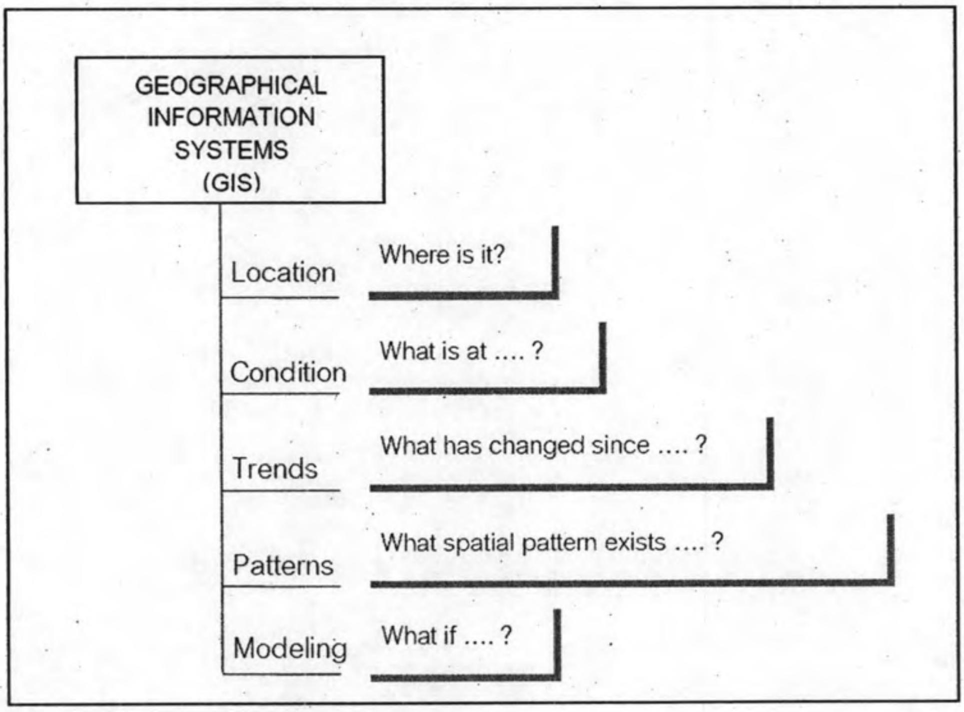


Figure 2.11 Questions which a well-built GIS should answer (Sgzen, 2002).

2.4.1.2 Descriptive Attributes

In addition to geographic representations, GIS datasets include traditional tabular attributes that describe the geographic objects. Many tables can be linked to the geographic objects by a common thread of fields. These tabular information sets and relationships play a key role in GIS data models, just as they do in traditional database applications.

2.4.1.3 Thematic Layers and Datasets

GIS organizes geographic data into a series of thematic layers and tables. Since geographic datasets in a GIS are georeferenced, they have real-world locations and overlay one another.

In a GIS, homogeneous collections of geographic objects are organized into layers such as parcels, wells, buildings, orthophoto imagery, and raster-based digital elevation models (DEMs). Precisely defined geographic datasets are critical for useful geographic information systems, and the layer-based concept of thematic collections of information is a critical GIS dataset concept (Figure 2.13).

2.4.2 The Geovisualization View

A GIS is a set of intelligent maps and other views that show features and feature relationships on the earth's surface. Various map views of the underlying geographic information can be constructed and used as "windows into the database" to support queries, analysis, and editing of the information.

A GIS includes interactive maps and other views that operate on the geographic datasets. Maps provide a powerful metaphor to define and standardize how people use and interact with geographic information.

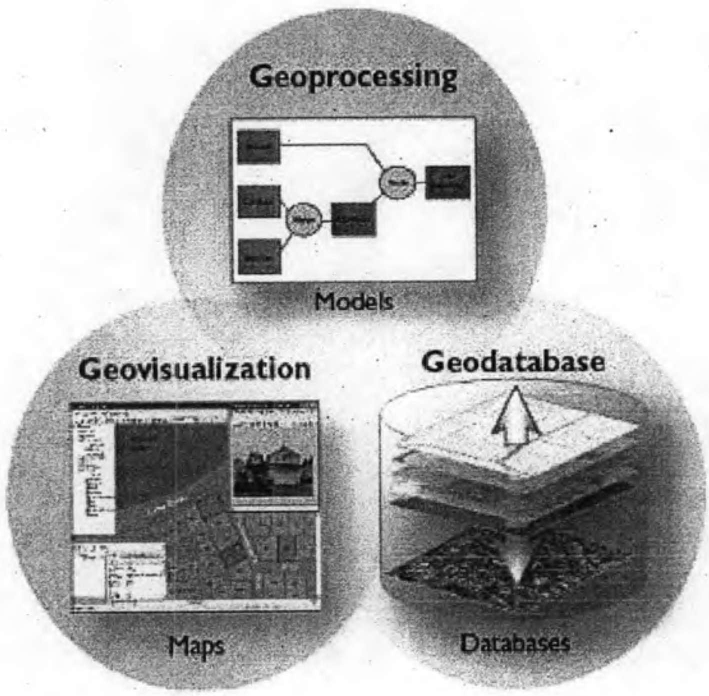


Figure 2.12 Three views of GIS (ESRI, 2004).

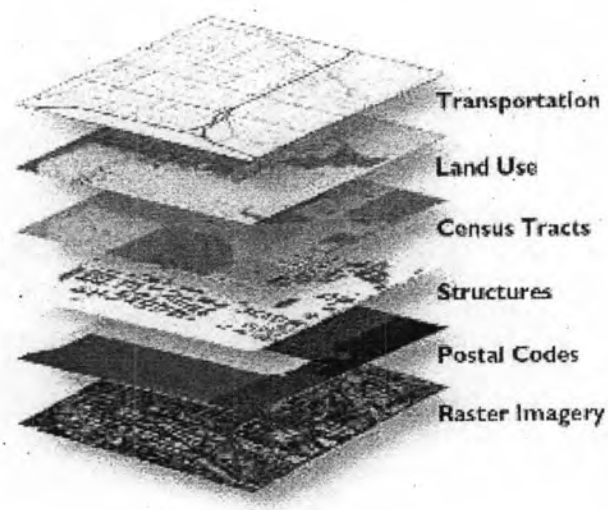


Figure 2.13 GIS integrate many of spatial data (ESRI, 2004).

2.4.3 The Geoprocessing View

A GIS is a set of information transformation tools that derive new geographic datasets from existing datasets. These geoprocessing functions take information from existing datasets, apply analytic functions, and write results into new derived datasets.

A GIS includes a rich set of tools to work with and process geographic information. This collection of tools is used to operate on the GIS information objects such as the datasets, attribute fields, and cartographic elements for printed maps. Together these comprehensive commands and data objects form the basis of a rich geoprocessing framework (ESRI, 2004).

Data + Tool = New Data

GIS tools are the building blocks for assembling multi-step operations. A tool applies an operation to some existing data to derive new data. The geoprocessing framework in a GIS is used to string together a series of these operations. Stringing a sequence of operations together forms a process model and is used to automate and record numerous geoprocessing tasks in the GIS. The building and application of such procedures is referred to as geoprocessing (Figure 14).

2.5 Scale Factor in Analysis

Before starting any data collection, an earth scientist working on a hazard analysis project should have to answer a number of interrelated questions below.

- What is the aim of the study?
- What scale and with what degree of precision must the result be presented?
- What are the available resources in the form of money, data and manpower?

As the aim of the study would be previously defined, the scale and the precision are the first parameters to be defined prior to the start of the project. Hence, the scale factor must be determined at the first glance as it controls the type of the input data, nature of the analysis, and the output data of the study. The outcome precision also depends on the scale chosen; however is independent parameter regarding the nature of the project. The necessary adjustments should be made with the scale until the output precision and the desired precision fulfills the project conditions. The resource analysis will be conducted after the aim and scale is fixed.

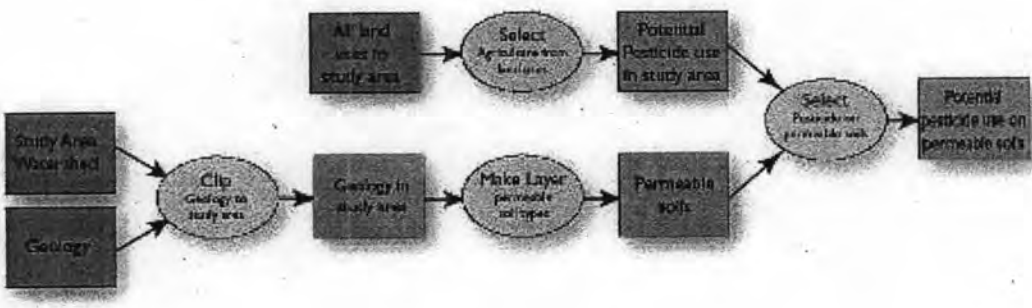


Figure 2.14 A flowchart showing an example of GIS model using ArcGIS9.0 (ESRI, 2004).

In the following topic, the scales of analysis, which were presented in the International Association of Engineering Geologists (IAEG) Monograph on engineering geological mapping (IAEG, 1976), can also be distinguished in general natural hazard zonation (Figure 2.15).

2.5.1 National Scale (<1:1,000,000)

The national scale analysis is used only to outline the problem, give an idea about the hazard types and affected hazard prone areas. They are prepared generally for the entire country and the required map detail is very low, even in the best case giving only data based on records in the form of an inventory. The degree of the hazard is assumed to be uniform. These kinds of maps are generally prepared for 25 agencies dealing with regional (agricultural, urban or infrastructure) planning or national disaster prevention / hazard assessment agencies.

2.5.2 Regional/Synoptic Scale (< 1:100,000)

The scale is still so small to be used in any quantitative method, but these maps are for regional planning and in early stages of appropriate region planning activities. The areas to be investigated are still too large, in an order of thousands of square kilometers, and the map detail is also low. Only simple methods are used with qualitative data combination and the zoning is primarily based on regional geomorphological Terrain Mapping Units / Complexes (TMU) or dependent on regional geological units.

2.5.3 Medium Scale (1:25,000 -1:50,000)

These hazard maps are made mainly for agencies dealing with inter municipal planning or companies dealing with feasibility studies for large engineering works. The areas to be investigated will be of several hundreds square kilometers. At this map scale, considerably more detail is required than at the regional scale. These maps do serve especially the choice of corridors for infrastructure construction or zones for urban development. Statistical techniques are dominantly used in this scale.

2.5.4 Large Scale (> 1:10,000)

These hazard maps are produced generally for authorities dealing with detailed planning of infrastructure, housing or industrial projects or with evaluation of risk within a city or within a specified project area. They cover very small areas hence the deterministic hazard analyses become available to be used. The detail level of the maps is set into a maximum. They are based on physical numerical models that require extensive data collection in the field and laboratory surveys.

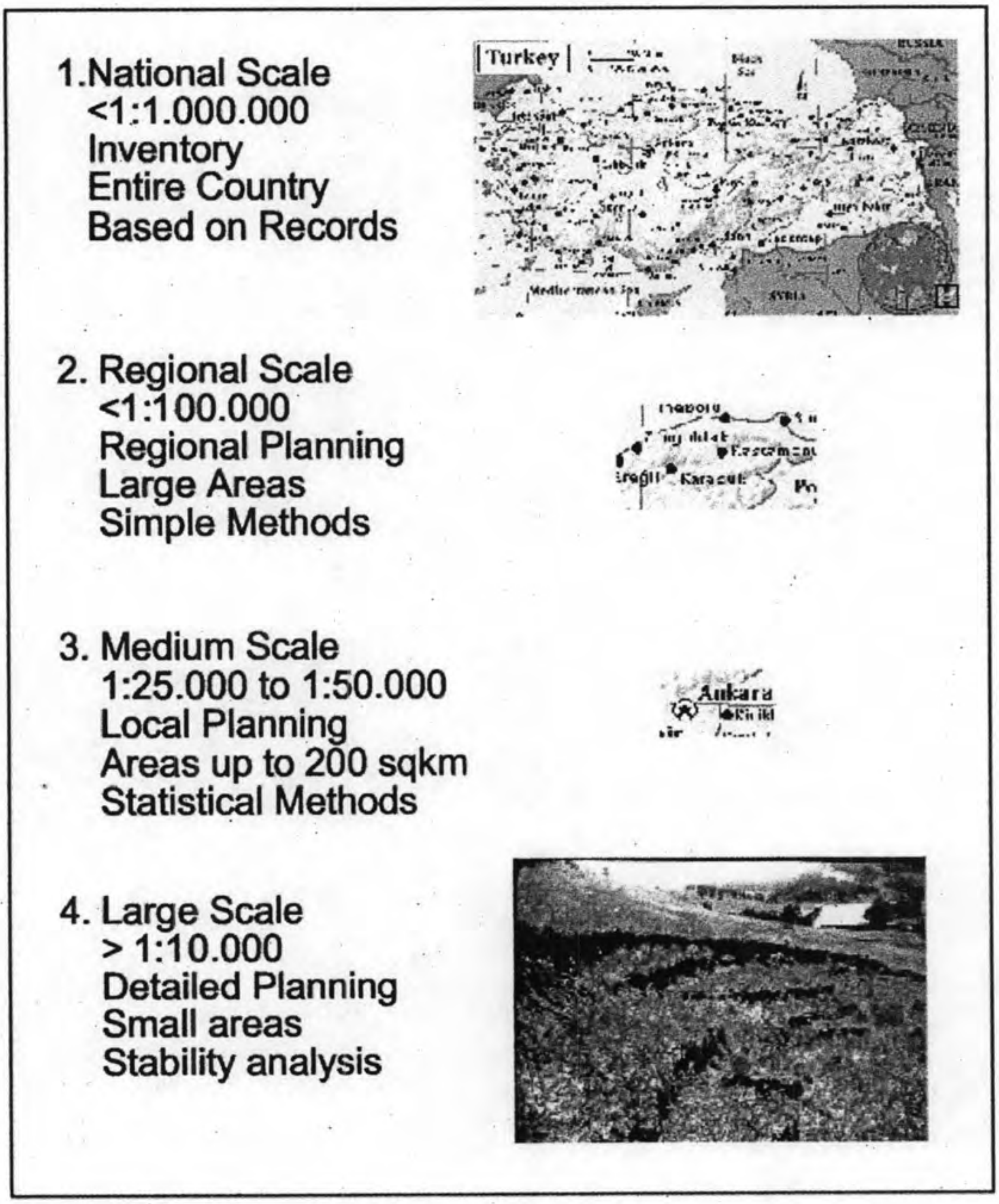


Figure 2.15 Scale of analysis and minor.