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INTERNATIONAL CENTRE
FOR SCIENCE AND HIGH TECHNOLOGY

Training Manual

***Introduction to Geographic Information Systems
for Industrial Development***

Version 1.0, September 2000



UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Vienna, 2000

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Numbers appearing in square brackets in the text refer to notes at the end of each chapter, under "references".

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Foreword

The strategy adopted in the formulation of the International Centre for Science and High Technology (ICS) Work Programme is to promote a policy of sustainable development which takes into account the industrial capacity of developing and emerging countries as well as environmental issues. This in line with the conclusions emerging from the 1992 Rio Conference, Agenda 21, which resulted from that conference, and ensuing international forums, and in particular with the recommendations of the Italian Ministry of Foreign Affairs and of the United Nations Industrial Development Organization (UNIDO).

In particular, pollution prevention and technologies based on renewable resources have been taken into consideration when formulating subprogrammes that propose intervention within industrial cycles rather than “end-of-pipe” solutions. This approach is applied to the majority of ICS Subprogrammes carried out under three main technical areas:

- Pure and Applied Chemistry
- Earth, Environmental and Marine Sciences and Technologies
- High Technology and New Materials

Some activities, still based on *post factum* interventions—e.g., bioremediation, waste water treatment and recycling of plastic materials—are planned in terms of their relevance in addressing environmental problems.

Alongside these activities a programme that provides support tools for technology transfer management is based at UNIDO Headquarters in Vienna. It focuses on technology and environmental management, business alliances, technology and competitiveness, services for research and development centre, benchmarking and needs assessment.

The ultimate goal of ICS strategy is to benefit developing countries and countries with economies in transition through technology transfer, institutional capacity building and development of human resources. Each of the ICS activities is tailored to the objectives of individual beneficiaries, focusing on the industrial conditions of the targeted countries.

To support all ICS activities, information system tools are being developed to expand and enhance in-house capacity and expertise. These tools include the Best Available Technologies Economically Viable (BATEV) database; software and mathematical models for simulation of industrial processes and chemical compounds; and software and mathematical models for “image engineering”.

These tools are valuable in training technical experts from developing countries as well as providing diagnostic services in support of project formulation. Known as decision-support systems (DSS), they aid in pre-assessment of technological, economic and ecological viability of projects.

In particular, geographic information systems (GIS) are taking on increasing importance for planners and decision makers concerned with problem domains that include spatial dimensions such as natural resources, environmental management, urban and regional development planning, agricultural assessment, and industrial site survey

and optimization. The use of GIS together with remote sensing, process simulation and dedicated expert systems represents the final goal of the strategy of ICS.

This manual presents an introduction to GIS for use in industrial development. The application of GIS and its use in combination with remote sensing are illustrated by examples of environmental information and decision-support systems. These include case-study demonstrations on urban land-use classification and on multi-criteria evaluation for industrial siting.

All ICS activities relating to the subject of this training package are closely coordinated with ongoing or planned UNIDO programmes in line with its newly revised strategy, and are jointly undertaken with the relevant branches at UNIDO Headquarters.

UNIDO-ICS joint projects follow UNIDO procedure for project development, funding and implementation.

We look forward to working with you, and to receiving your comments on this training package.

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1

Introduction to geographic information systems for industrial development

E. Feoli and M. Ghribi

1

Introduction to geographic information systems for industrial development*

In the industrialized world, new methods and theories for environmental assessment and analysis are in a phase of expansion. These focus on the combined application of decision support systems and expert systems with geographic information systems and remote sensing input and output, bringing a massive expansion in the analytical capabilities available today in the field of applied environmental research and pollution prevention.

This training package is a contribution to those new environmental methods and theories. It has been developed within the Decision Support Systems (DSS) Subprogramme, which supports the diffusion, integrated use and effective application of the GIS instruments and methods, and increased cooperation with developing countries. This means presenting a common “interface” and approach to tackling problems through networking and technology transfer. Activities include training in new techniques and demonstrations of practical case studies that have been developed at the local level or taking into consideration conditions at the local level and, in addition, channels are being established for sharing results, knowledge, standards and methodologies. Projects are then being developed in close cooperation with national counterparts. One goal is the enhancement of existing investment. Apart from acquiring knowledge in computer applications for integration of geographic information systems, decision support systems, remote sensing and image engineering, beneficiaries (local authorities and decision makers) will be made aware of the need to develop shared information resources. To date, high costs and inaccessibility of resources have been a major hindrance to environmental scientists, planning offices and decision makers.

The DSS Subprogramme links to the coastal zone management (CZM) Subprogramme by introducing GIS tools for landscape assessment in coastal areas. Both Subprogrammes have the objective, in line with general ICS strategies, of technology transfer to developing countries to improve their capacity building. The DSS Subprogramme is more oriented to the transfer of technological tools of the decision domain while the CZM Subprogramme allows the application of these tools to coastal zone management.

1.1. General objective of the DSS Subprogramme

The DSS Subprogramme highlights the decision-making process at the policy/regulatory level in developing countries related to the formulation and implementation of national or sub-national (area-wide) policies, strategies and action plans for sustainable industrial development. Its main objectives are:

- To introduce GIS concepts, allowing collaboration between technicians and industrial planners;

*This chapter was prepared by E. Feoli and M. Ghribi, Area of Earth, Environmental and Marine Sciences and Technologies, ICS-UNIDO.

- ❑ To develop regional projects with a focus on the impact of industrial development on peri-urban areas and on environmental plans for pollution control;
- ❑ To strengthen research in environmental sciences;
- ❑ To enhance a dynamic training network in integrated environmental applications;
- ❑ To promote regional cooperation.

1.2. Objectives of the training package

This training package is the first of several and allows for building other similar packages. It has been designed for training, educational needs and scientific information.

The immediate objectives are:

- ❑ To foster the formulation of projects suitable for applying technologies of the decision domain (GIS, image processing, image engineering, remote sensing, decision support systems, artificial intelligence techniques etc.) to support the industrial development of developing countries;
- ❑ To promote the creation of small enterprises that will assist small and medium enterprises (SMEs) to use environmental management system technologies and to assist planners and decision makers in environmental impact assessment and risk assessment and management of industrial areas;
- ❑ To develop a link between GIS technology and technology databases (e.g., BATEV), especially those in use at UNIDO.

1.3. Target clients

In general, GIS technology is applied in numerous fields such as forestry, agriculture, marine science, market research, public health, facilities management, habitat assessment, environmental science, cartography, geology, business, engineering and government.

GIS users include engineers, technologists, technicians, business people, entrepreneurs, researchers, database managers and information specialists. GIS technology is also applied by coordinators and technicians for municipal services, police forces and fire services, and by those in the fields of natural resources and telecommunications.

The target clients for the training package are analysts and institutions with clearly defined responsibilities for supporting the decision-making process of regulatory agencies and policy makers at national (area-wide) levels. These may include governmental agencies (e.g., ministries of industry, planning, or environment), industrial associations, chambers of commerce, academic institutions and consultants working in direct contact with decision makers.

1.4. Decision domain and sustainable development

The targeted decision domain relates to the design and implementation of policy and regulatory mechanisms addressing the following topics:

1.4.1. *National or regional development*

This includes spatial and structural industrial development planning and its typical activities such as:

- Siting, environmental impact assessment
- Zoning, environmental quality objectives
- Planning clusters of industries
- Infrastructure planning
- Cross-sector coordination

1.4.2. *Pollution prevention*

This focuses on incentives and regulation at the enterprise level to promote:

- Technology innovation, implementation of International Organization for Standardization (ISO) standards
- Cleaner production (reducing waste and pollutants at the source, energy saving etc)
- Pollution control and waste treatment (end-of-pipe/stack), monitoring techniques and monitoring systems

1.4.3. *Industrial risk*

The control and management of:

- Toxic waste and hazardous substances
- Chemical safety
- Risk assessment and emergency planning

1.5. Technological tools

Technological tools for use in the decision domain for sustainable industrial development include geographic information systems, decision support systems, process simulation, expert systems and remote sensing. Developing countries have requested training courses in these topics. Application of these tools must be implemented in specific research and development (R and D) projects. At ICS, a considerable amount of GIS software is available and can be used in R and D projects. However, for this training package a set of software with wide diffusion has been chosen that has a relatively low cost and is already used by other United Nations organizations, namely IDRISI for raster-based GIS applications, and ArcView for vector data models.

The training package is divided into two sections. The first section explains the theoretical concepts of GIS and its application and the second section introduces the use of GIS with a set of exercises and case study demonstrations. The ICS-GIS group is also interested in working with Multi-fold Ground-Penetrating Radar (GPR). To learn more about this technology, please refer to the appendix.

Finally, a CD-ROM containing the authors' contributions will be developed and inserted with the whole package.

2

The GIS data model and raster-based GIS applications

E. Feoli and M. Ghribi

2

The GIS data model and raster-based GIS applications*

2.1. Objectives

This section of the manual aims to assist the student:

- To understand the nature of the GIS data model
- To recognize technical raster and vector data issues
- To identify raster-based GIS applications

2.2. Handling spatial data with GIS

There are three approaches to handling spatial data with GIS. They are the:

- Raster model
- Vector model (points, lines, polygons)
- Object-oriented model (objects stored in linked tables)

2.3. Representation of features in GIS

Geographic information systems provide a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data from the real world for a particular set of purposes. They differ according to the data model that is used to store databases. The GIS is based on its ability to combine many data sets and display them in a common framework as thematic maps.

To obtain thematic maps the GIS may have internal software tools for database and data analysis and image processing, or may be easily interfaced with external software. There are many geographic information systems on the market, in both the commercial and public domains. Depending on how they have been designed [1], they can answer the following:

- Location.* Determine what exists at a particular location (using points, lines, polygons, or a buffer area around any such feature);
- Spatial identification.* Find locations where certain conditions are satisfied. This will include the logical (Boolean) or arithmetic combination of multiple data layers (overlay analysis);
- Trends.* Find the differences within an area over time or along spatial dimensions;

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- ❑ *Patterns.* Correlate different attributes and calculate similarity between patches, fractals, landscape indices etc.
- ❑ *Modelling.* Answer “What if” questions.

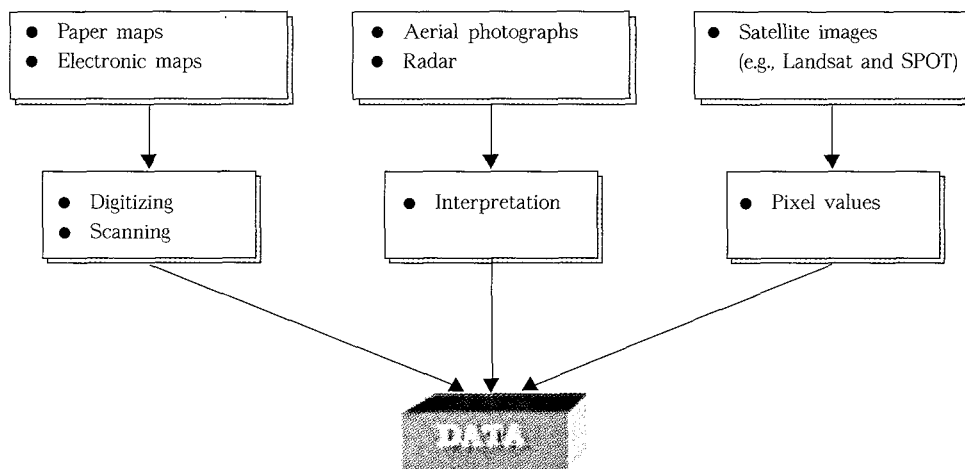
Analysis in GIS is based on the map paradigm; for maps of inherently static objects analysis is based on map overlays using Boolean expressions. To answer more complex questions, one needs to combine (static) geographic data layers with dynamic and spatially distributed models. The most common data storage formats are “raster” and “vector” data structures [2].

Later we will examine each data structure in detail and comment on the advantages and disadvantages of each. Most discussions now are focused on which data structure is more appropriate for an application. This has grown from the realization that both data structures are useful and in turn has led to research into methods for combining the data structures.

2.4. Where do data come from?

A geographic information system is a set of computer tools designed to efficiently capture, store, update, manipulate, analyse, and display all forms of geographically referenced information [3]. A GIS typically links data from different sets, using geo-referencing, i.e., spatial coordinates, as a common key between different databases as illustrated in figure 2.1:

Figure 2.1. Sources of data used in GIS



2.4.1. Data integration, transformation and analysis

The main procedures for data integration, transformation and analysis are:

- ❑ Overlay of maps (Landsat Thematic Mapper)
- ❑ Distance analysis (planning of infrastructure)
- ❑ Neighbourhood analysis (water run-off models)
- ❑ Spatial filtering (smoothing of data)
- ❑ Interpolation (inverse distance)
- ❑ Principal component analysis of map layers
- ❑ Correlation between map layers
- ❑ Clustering of pixel values

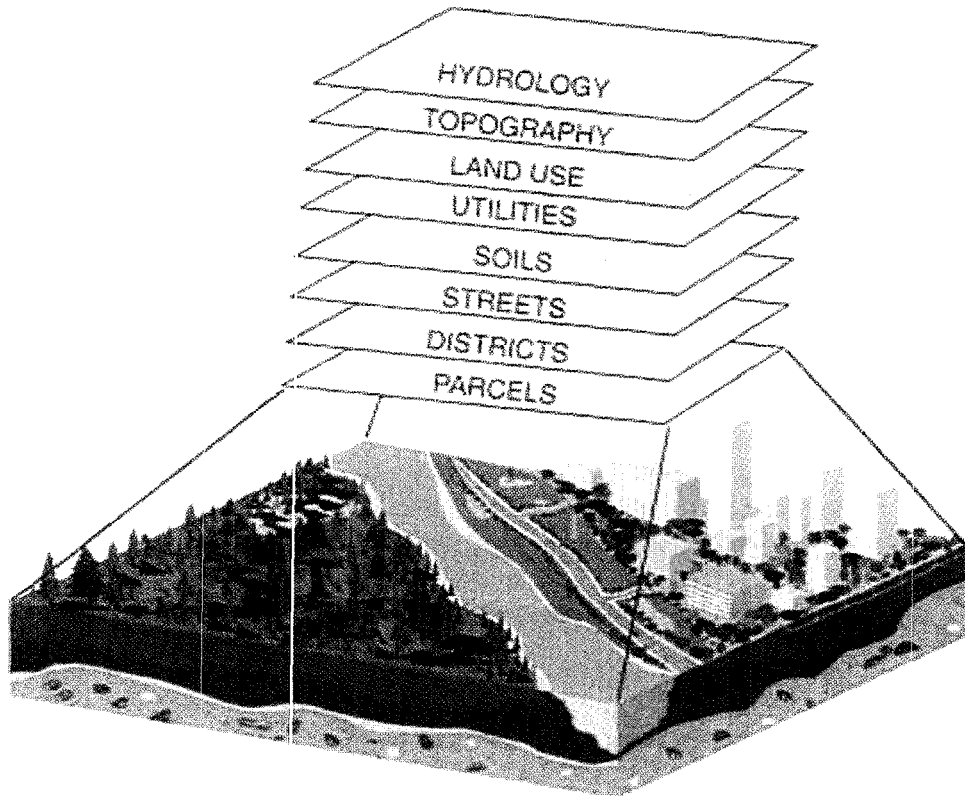
2.4.2. Errors in GIS sources

Errors in GIS result from data input, digitizing, interpretation and conversion of raster data to vector data and vice versa.

2.5. Cartographic model of GIS

In a layer-based GIS, the data for a geographic region can be visualized as layers of a map. The term "cartographic model" is used to describe a set of data (database) describing selected characteristics of each location within a bounded geographic area in the form of map-like layers (see figure 2.2).

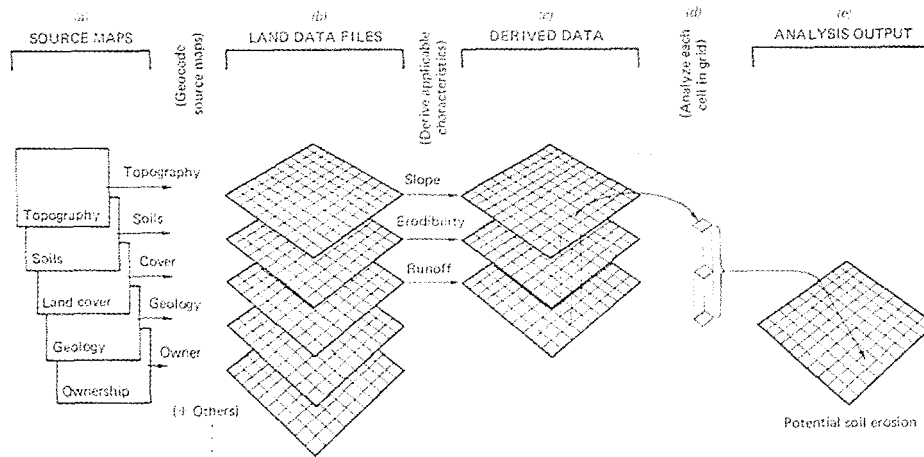
Figure 2.2. A GIS cartographic layer model in which an aspect of reality or parameter is represented by each layer [2]



A map layer is a set of data describing a characteristic of each location within a bounded geographic area. The nomenclature used may vary from one system to another but the principle is the same. The map layer is essentially a parametric approach to representing the real world in a GIS database. One item of data is available for each location within a single layer and multiple items of information require multiple layers.

One of the most important benefits of a GIS is the ability to spatially interrelate multiple types of information stemming from a range of sources. This concept is illustrated in figure 2.3, which shows a GIS study for soil erosion in a watershed [4].

Figure 2.3. GIS analysis procedure for studying potential soil erosion [4]



Key:

- (a) Source maps that have been geo-coded cell-by-cell
- (b) A series of land data files or layers
- (c) Sources of derived data that can be interrelated by the analyst
- (d) Analysis of each cell
- (e) Output analysis

2.6. Raster file structure

Raster data represent geographic features and variation as image files [5]. Each image consists of a defined number of rows and columns thus forming cells or pixels. These units are stored as a sequence of numbers (byte, integer or real number) representing values such as vegetation class codes, reflectance numbers, landscape patches, or z-values (e.g. altitude) in a digital elevation model (DEM).

2.6.1. Structure

A grid (5 columns, 4 rows) is a special type of raster where the value stored is a record in a table that stores additional descriptive information for the cells (i.e., legend) as shown below:

	0	1	2	3	4
0	22	22	18	18	18
1	15	15	18	16	16
2	15	15	18	16	16
3	15	12	12	12	12

Values may represent some code for landscape categories. In the simplest format "ASCII" the cell values and its categories are stored one in each line:

16	Industrial Area
12	Water
15	Commercial Zone
16	Parks
18	Agriculture
22	Residential sites

To summarize, a raster data model has the following characteristics:

- The model consists of rows and columns of cells (array)
- Area of cell equals spatial resolution
- Value for each cell records type of object or condition
- Cells do not correspond to spatial entities in the real world
- Cells are considered homogeneous units

2.6.2. Definitions

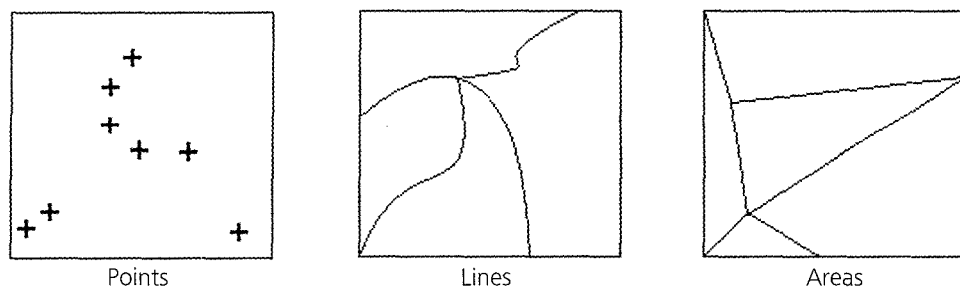
Pixel. The smallest indivisible element that makes up an image. In raster processing, data are represented spatially on a matrix of grid cells, called pixels, which are assigned values for image characteristics.

Resolution. A measure of the accuracy or detail of graphic display, expressed as dots per inch, pixels per line, lines per millimeter etc.

Spatial resolution. The accuracy associated with the capture of ground information as reproduced in digital format or graphic display.

2.7. Vector file structure

Vector data represent geographic features and variation as points, lines or area objects that specify locations or boundaries, and store information about the objects. The attributes are stored with a traditional database management software program. The elements or components of the spatial data in vector-based GIS are constructed from the graphic primitives, as shown below:



Point features. These could be used to represent the position of an industrial plant, a soil sample location, a meteorological station or the corner of a land parcel. In GIS, points are also important as they mark the position where two lines intersect (e.g., cross of two rivers).

Line features. These comprise two or more points and consequently have a length but no area. Lines are used to represent features such as roads, rivers and boundaries.

Area features. These features comprise a series of one or more lines. They have both area and perimeter length. Areas represent features such as soil types, vegetation and land ownership parcels.

2.8. Storing data types

Apart from describing objects by points, lines and polygons, it is also necessary to specify the location by mapping the earth surface onto a flat, Cartesian coordinate x, y system, where each point is recorded as a single (x, y) location. Lines are recorded as series of ordered x, y coordinates and areas are defined by an ordered set of coordinates that define their boundary.

Unfortunately the Cartesian coordinate system is only suitable for objects that require uniform units such as meters. When geographic features are presented on a map they have to be projected mathematically from a spherical globe onto a flat map. The only problem with projection is distortion, such as stretching and shifting. The most popular projections are Universal Transverse Mercator (UTM), Lambert Conic Conformal (LCC) and Albert Conic Equal-Area (ACEA). Latitude and longitude, which measure features in degrees from the earth's centre rather than at the earth's surface, are not considered a map projection coordinate system [6].

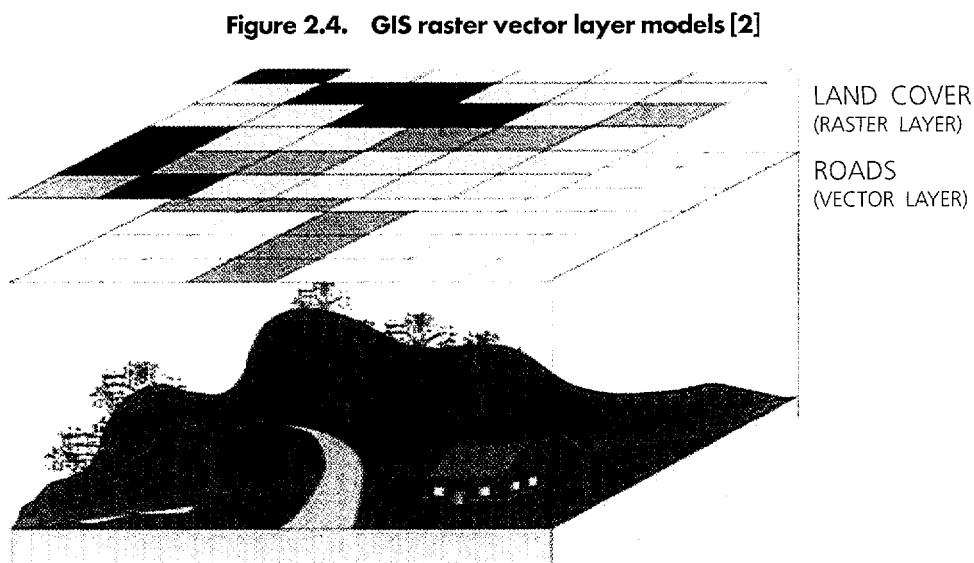
In summary, vector data model precisely position features in space and are constructed using the following elements:

- Points, nodes (single x, y coordinate pair)
- Lines, arcs (series of x, y coordinate pairs)
- Area, polygons (area as closed loop of x, y coordinate pairs).

2.9. Comparison of raster and vector models

Objects from the real world:

- Coordinate system: UTM, latitude-longitude etc.
- Attributes: Colour, pH, soil, vegetation etc.
- Topology: How objects are related



Raster Model

Advantages

- It is a simple data structure;
- Overlay operations are easily and efficiently implemented;
- High spatial variability is efficiently represented in a raster format;
- The raster format is more or less required for efficient manipulation and enhancement of digital images;
- Satellite data (a major data source) are in raster format.

Disadvantages

- The raster data structure is less compact; data compression techniques can often overcome this problem;
- Topological relationships are more difficult to represent;
- The output of graphics is less aesthetically pleasing because boundaries tend to have a blocky appearance rather than the smooth lines of hand-drawn maps. This can be overcome by using a very large number of cells, but may result in unacceptably large files.

Vector Model

Advantages

- It provides a more compact data structure than the raster model;
- It provides efficient encoding of topology, and, as a result, more efficient implementation of operations that require topological information, such as network analysis;
- The vector model is better suited to supporting graphics that closely approximate hand-drawn maps;
- It gives a good representation of the world, as we perceive it.

Disadvantages

- It is a more complex data structure than a simple raster;
- Overlay operations are more difficult to implement;
- The representation of high spatial variability is inefficient;
- Manipulation and enhancement of digital images can not be effectively done in the vector domain.

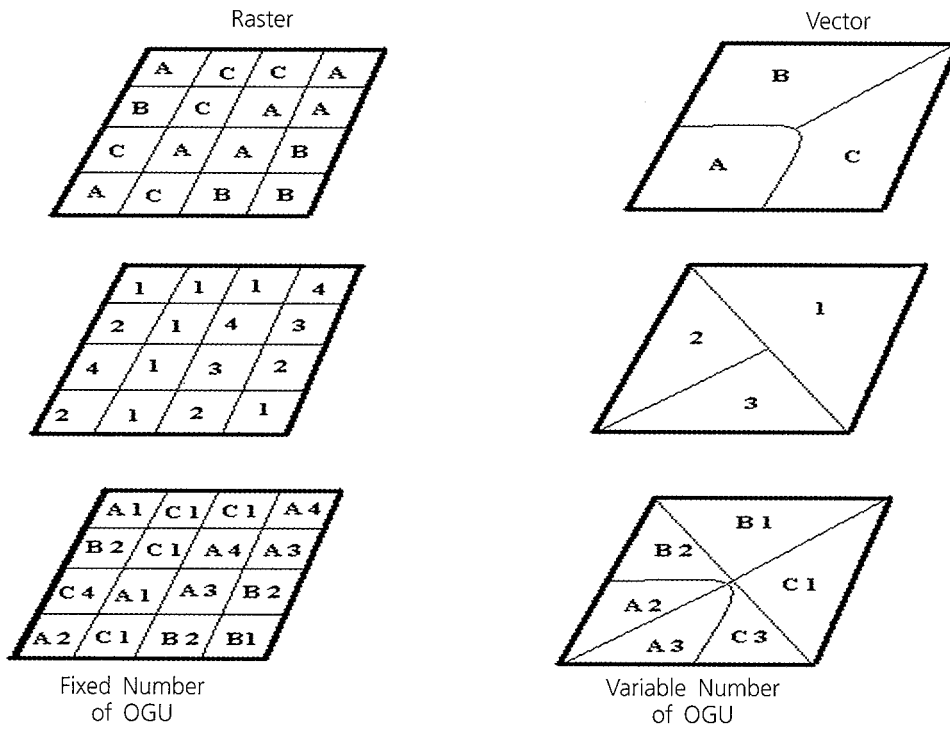
2.10. GIS tools and data analysis

Many GIS have internal data analysis and image processing functions that can calculate different pattern indices such as fragmentation, fractal, entropy, etc. [7]. With GIS tools such as IDRISI and GRASS, it is possible to treat remote sensing data coming from the LANDSAT programme of the United States, the French system (Système pour l'Observation de la Terre "SPOT"), the United States National Oceanographic and Atmospheric Administration (NOAA) and other sources by using the maximum likelihood algorithm and Fuzzy set theory.

GRASS also allows the use of sophisticated neural network algorithms [8; 9; 10]; however these GIS do not offer the possibility of treating ancillary data of specific operational geographic units (OGU). OGU are pixels, polygons and sets of pixels and polygons (illustrated in figure 2.5) and are used for hierarchical classifications and ordinations by methods such as cluster analysis and factor analysis [11] or fuzzy set theory [12]. These methods are still available only in external packages.

All modern GIS support convenient data import and export functions, and many packages are available for data analysis. However, with the exception of the "maximum likelihood" method, they rarely include methods of classification and ordination based on probability [13]. The advantages of using such functions derive from the fact that similarity between OGUs may be tested in a probabilistic way within the data sets representing the system under study. With probabilistic similarity functions, the similarity may be tested within and between time intervals. These functions, based on Goodall's probabilistic index [14], have been included in the information system developed by ICS-UNIDO [15], especially for applications in coastal zone management and for treating remote sensing data [16].

Figure 2.5. Operational geographic units (OGU)



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3

Topological overlay and mathematical operations with GIS

A. Altobelli, E. Feoli and M. Ghribi

3

Topological overlay and mathematical operations with GIS*

3.1. Overlay analysis

The overlay function can perform simple operations, such as laying a road map over a map of local wetlands, or more sophisticated operations, such as the Boolean approach to multiplying and adding map attributes of different values to determine averages and co-occurrences. GIS provides for the following arithmetic and Boolean operations:

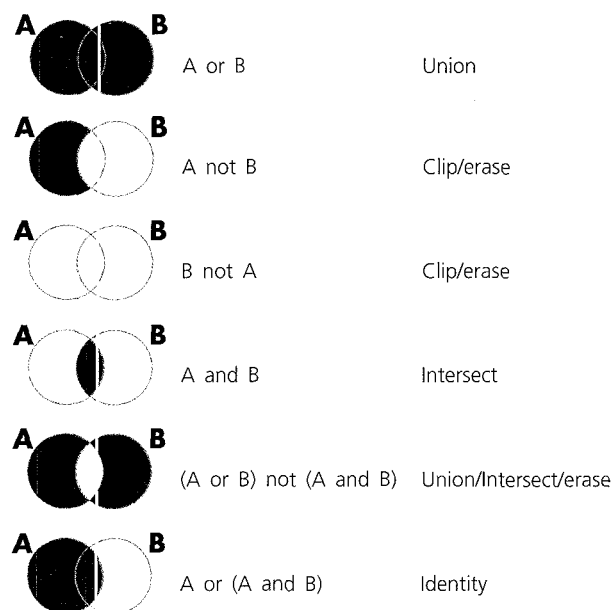
Arithmetic operations

- Addition
- Subtraction
- Division
- Multiplication

Logical (Boolean) operations (figure 3.1)

- Where conditions occur or do not occur together
- AND, OR, NOT etc.

Figure 3.1. Boolean logic operations

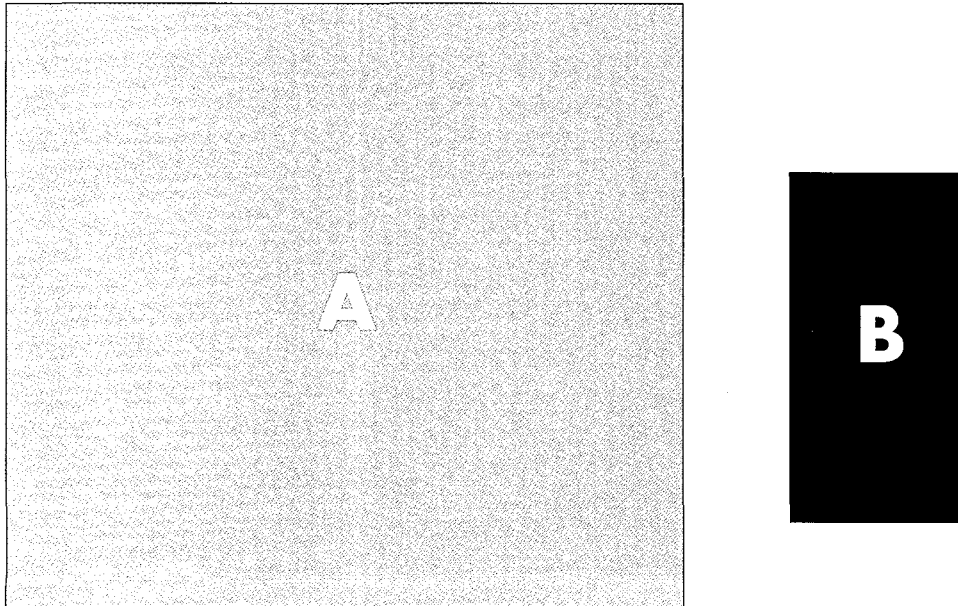


* This chapter was prepared by A. Altobelli, E. Feoli and M. Ghribi, Area of Earth, Environmental and Marine Sciences and Technologies, ICS-UNIDO.

The raster method has these limitations:

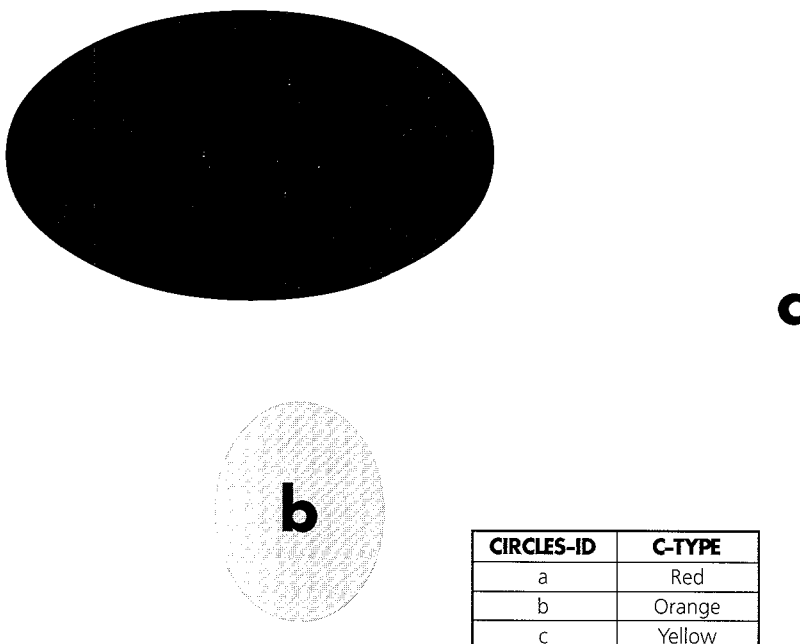
- ❑ Data storage requirements
- ❑ Overlay operations are performed on every cell
- ❑ Sparse data sets require as much processing as dense ones

Figure 3.2. Layer 1 (Squares)



SQUARES-ID	S-TYPE
A	Green
B	Blue

Figure 3.3. Layer 2 (Circles)



CIRCLES-ID	C-TYPE
a	Red
b	Orange
c	Yellow

Figure 3.4. Overlay logical operation

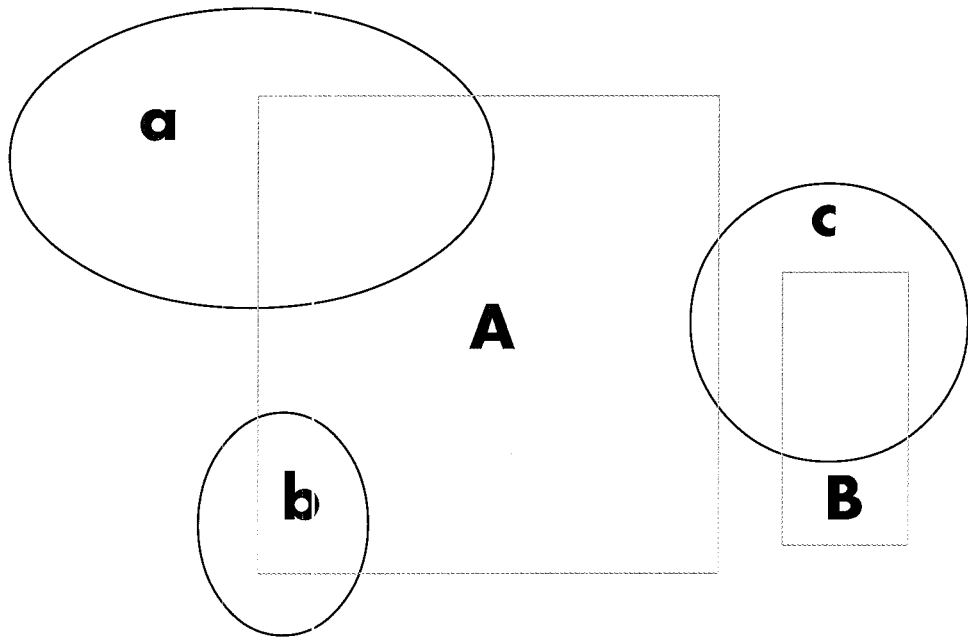
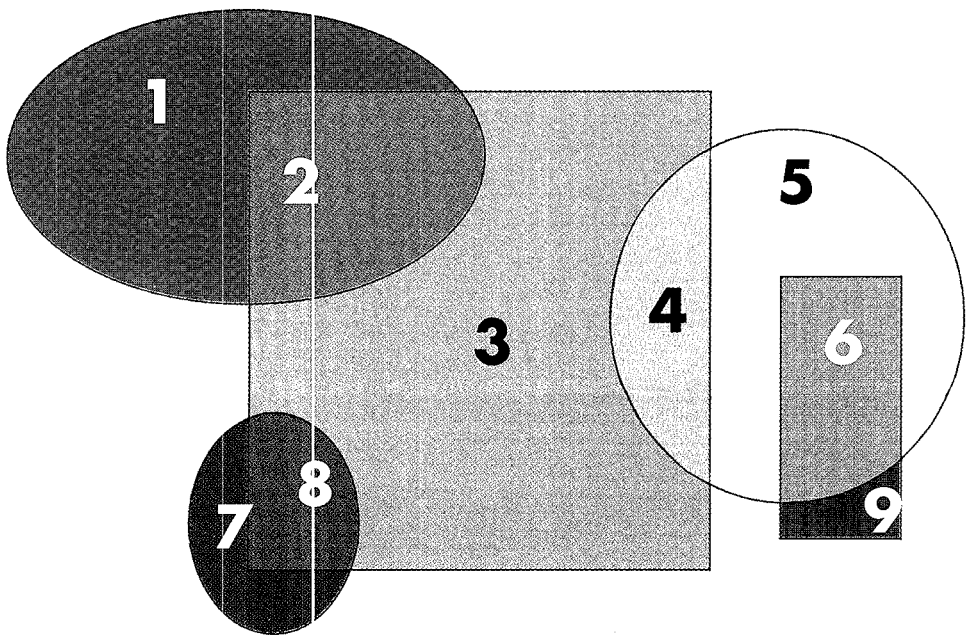
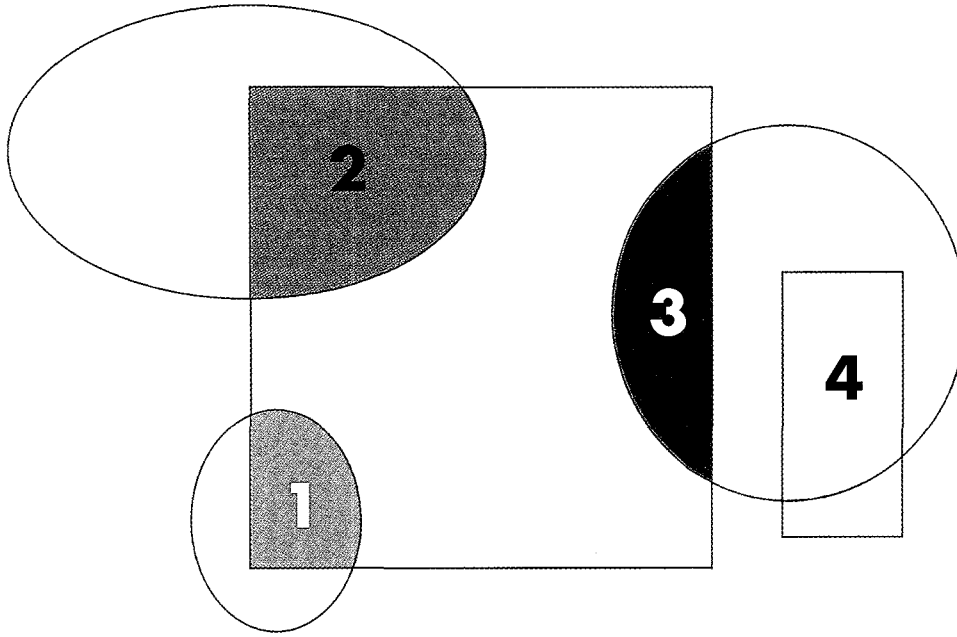


Figure 3.5. Union (layer 1 or layer 2)



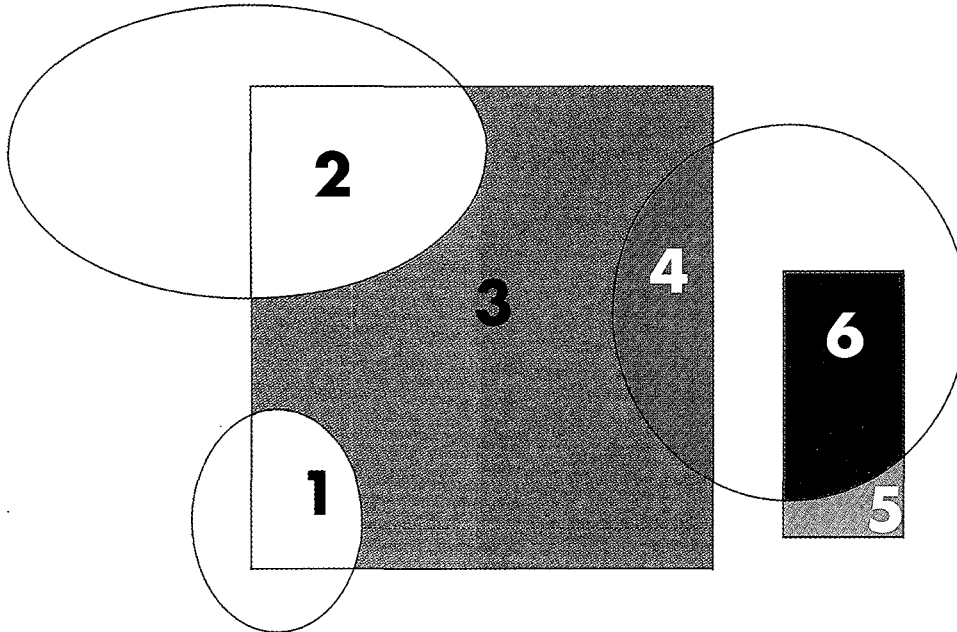
UNION-ID	U-TYPE	SQUARES-ID	S-TYPE	CIRCLES-ID	C-TYPE
2	Light blue	A	Green	a	Red
4	Sky blue	A	Green	c	Yellow
8	Brown	A	Green	b	Orange
3	Green	A	Green	.	.
6	Grey	B	Blue	b	Orange
9	Pink	B	Blue	.	.
1	Red	.	.	a	Red
5	Yellow	.	.	c	Yellow
7	Blue	.	.	b	Orange

Figure 3.6. Intersect (layer 1 and layer 2)



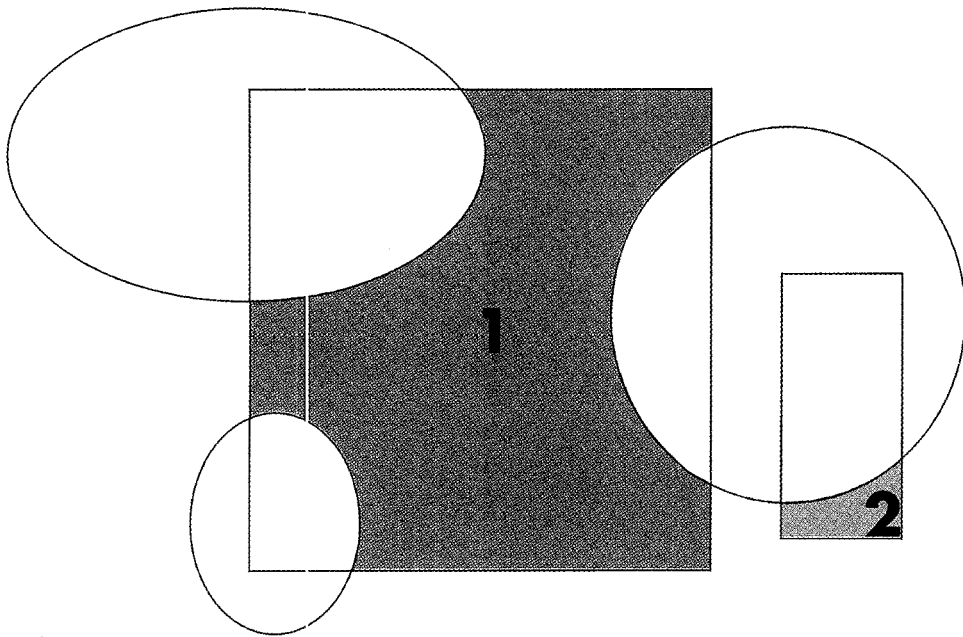
INTERSECT-ID	I-TYPE	SQUARES-ID	S-TYPE	CIRCLES-ID	C-TYPE
2	Light green	A	Green	a	Red
1	Blue	A	Green	b	Orange
3	Red	A	Green	c	Yellow
4	Yellow	B	Blue	c	Yellow

Figure 3.7. Identity (layer 1 or (layer 1 and layer 2))



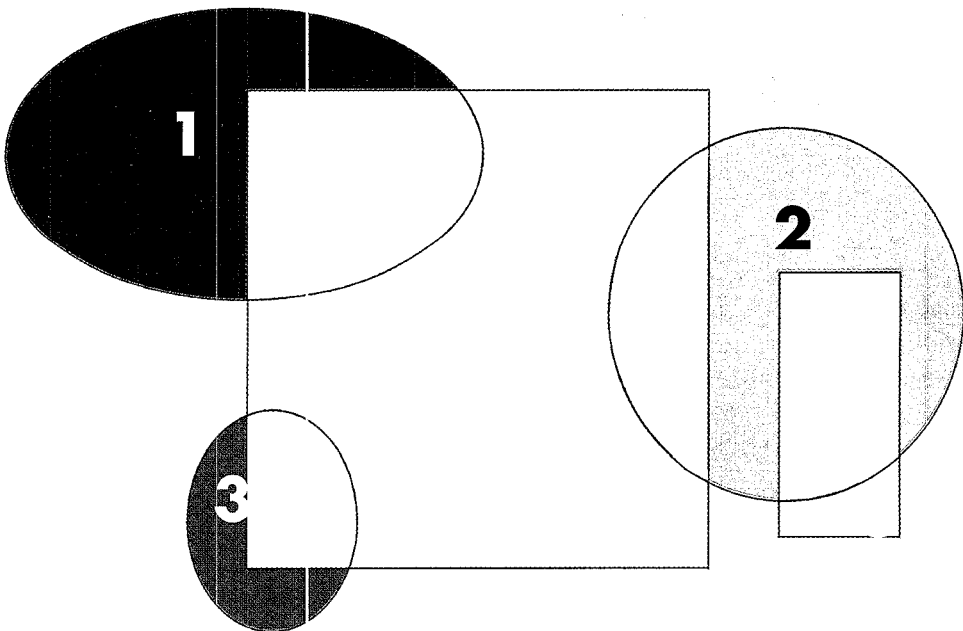
IDENTITY-ID	I-TYPE	SQUARES-ID	S-TYPE	CIRCLES-ID	C-TYPE
2	Yellow	A	Green	a	Red
3	Green	A	Green	.	.
4	Brown	A	Green	c	Yellow
1	Sky blue	A	Green	b	Orange
5	Blue	B	Blue	.	.
6	Red	B	Blue	c	Yellow

Figure 3.8. Erase (Layer 1 not Layer 2)



ERASE SQ-ID	E SQ-TYPE	SQUARES-ID	S-TYPE
1	Green	A	Green
2	Blue	B	Blue

Figure 3.9. Erase (Layer 2 not Layer 1)



ERASE CIRCLE-ID	E C-TYPE	CIRCLES-ID	C-TYPE
1	Red	a	Red
2	Green	c	Yellow
3	Blue	b	Orange

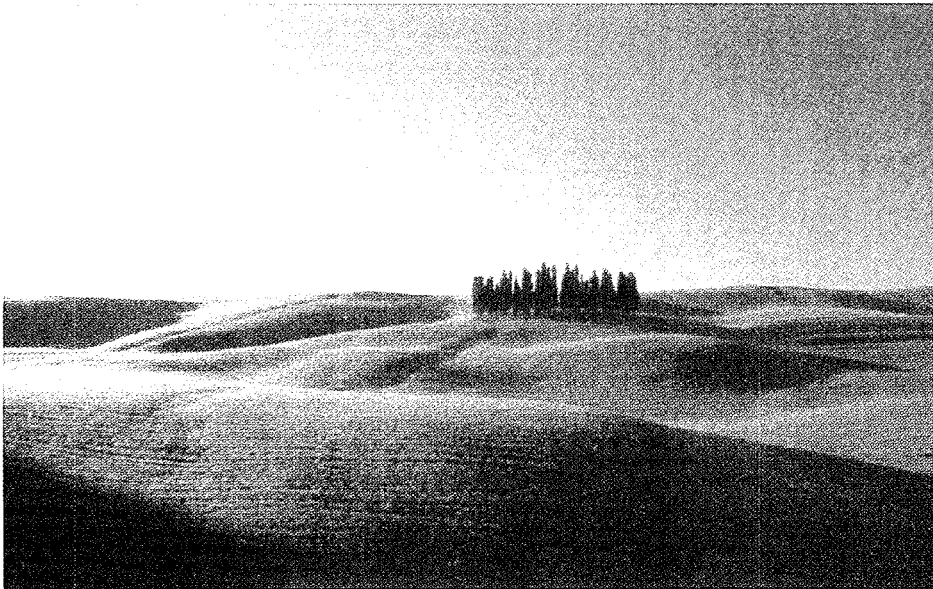
3.2. Spatial pattern indices

3.2.1. Landscape ecology

Forman and Godron [1] define landscape as a heterogeneous land area composed of a cluster of interacting ecosystems, or elements, that are repeated in a similar form throughout. The concept differs from the traditional ecosystem concept in that it focuses on groups of ecosystems and the interactions among them. Landscape ecology is the study of the spatial and temporal aspects of a landscape together with its flora, fauna and cultural components.

Terrestrial landscapes consist of mosaics of individual parcels or patches of different land cover types. In GIS, patches are defined as groups of spatially contiguous pixels assigned to the same attribute class.

Figure 3.10. Example of patch in Tuscany landscape



Landscape ecology focuses on three characteristics of landscape: structure, function and change [1]. Structure applies to the sizes, shapes, numbers and kinds of various patches and their arrangement in space (pattern). Function pertains to the interactions between patches of a landscape, that is, the flows of energy, materials and species. Change is related to the alterations in the structure and function of a landscape over time. Analysis of landscape structure is essential in order to conserve the communities and biological and cultural diversity [2].

3.2.2. Measures of landscape structure

The three most commonly used indices when analysing landscape structure are dominance, contagion and fractal dimension. Usually these indices are calculated for a sub-area of interest from a larger geographic region. These sub-areas can be static (e.g., administrative unit, regular grid) or dynamic (moving window). The dominance index [3], $0 \leq D \leq 1$, is given by:

$$\text{Dominance } (D) = H_{\max} - H$$

Where

$$H = \text{diversity} = -\sum P_i \ln(P_i)$$

$$H_{\max} = \text{maximum diversity} = \ln(n)$$

n = number of land classes

P_i = proportion occupied by class type i

As D approaches 1.0, the landscape tends to be dominated by a single class type. Dominance does not necessarily indicate diversity of the landscape [4]. For example, a landscape with two types of land cover, each with a 50% proportion, will have the same dominance value ($D = 0$) as one with ten types of land cover, each with a 10% proportion. The dominance index does not give a quantitative measurement of landscape pattern.

Example:

A	A	A	A
A	A	A	A
B	B	B	B
B	B	B	B

A	B	A	B
A	A	A	A
B	B	B	B
A	A	B	B

$$H_{\max} = \ln(2) = 0.693$$

$$H = -[2 * (8/16) * \ln(8/16)] = 0.693$$

$$(D) = 0$$

The contagion index has been used in ecosystem analysis to quantify the amount of clumping or aggregation of patches. It is also used as an indication of the degree of fragmentation of a landscape. It has been applied to relate the effects of contagion patterns on ecosystem processes such as habitat fragmentation, vegetation dispersal and animal movement [5].

The contagion index was first proposed by O'Neill et al [3]; Li and Reynolds [5] proposed a ratio estimator that is scaled to the interval [0,1], given by the equation

$$\text{Contagion index } (C) = 1 - E / E_{\max}$$

Where

$$E_{\max} = -\sum (1/n^2) \ln(1/n^2) = 2 \ln(n)$$

n^2 = number of possible attribute adjacencies

(For example, if the map has $n = 2$ attribute classes, then there are four types of attribute adjacencies: AA, AB, BA, BB)

and,

$$E = -\sum Q_i \ln(Q_i)$$

$$Q_i = g_{ik} / \sum g_{ik}$$

g_{ik} = number of adjacencies (joins) between pixels of patch types i and k .

There are different ways of calculating contagion, for example, the adjacencies can be calculated in each of the four cardinal directions. As C approaches 1.0, the landscape tends to have larger patches.

The following example shows a calculation of the contagion index on a matrix with 3 land cover types:

A	A	A	B	B
A	A	A	B	B
A	A	A	B	B
C	C	C	C	C
C	C	C	C	C

Adjacencies

	A	B	C
A	24	3	3
B	3	14	2
C	3	2	26

Total adjacencies = 80

$$E = -[(24/80) * \ln(24/80) + 4 * (3/80) * \ln(3/80) + 2 * (2/80) * \ln(2/80) + (14/80) * \ln(14/80) + (26/80) * \ln(26/80)] = 1.708445$$

$$(C) = 1 - (1.708445/2.197225) = 0.2224533$$

3.2.2.1. Patch-per-unit area index

An alternative landscape index for quantifying landscape fragmentation, known as the patch-per-unit area (PPU) index, was proposed by Frohn [4] because there are many situations where the contagion index does not measure contagion (an example is presented below).

$$\text{Patch-per-unit area (PPU)} = m / (n * \lambda)$$

Where

m = total number of patches for a land cover type

n = total number of pixels in the landscape

λ = scaling constant equal to the area of a pixel

Example

A	A	A	B	B
A	A	A	B	B
A	A	A	B	B
C	C	C	C	C
C	C	C	C	C

A	A	A	B	C
A	A	A	C	B
A	A	A	B	C
B	C	B	C	B
C	B	C	B	C

The first grid contains three attribute classes that are clumped into three patches. The second grid contains the same three attribute classes that there are fragmented into 17 patches. According to the contagion index, the first grid should have a higher value than the second because it is more fragmented. However, the value derived by the contagion index on the first grid is 0.22 and the value for the second is 0.42. The values for PPU, on the other hand, are 0.12 (PPU=3/25) for the first grid and 0.68 (PPU=17/25) for the second, so this index is more useful.

3.2.3. Features of fractal figures

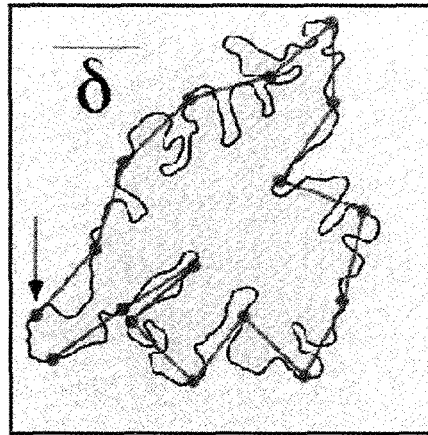
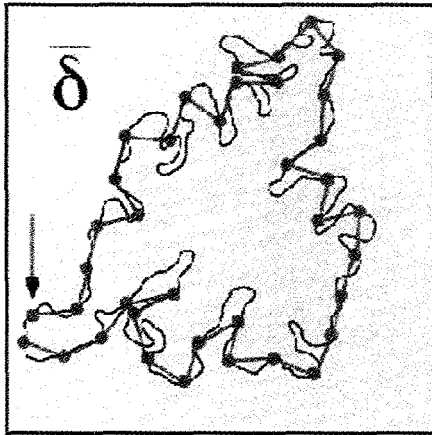
“Fractal” is a general term for figures or phenomena that have no characteristic length, are similar and have non-integer dimension. Geometric shapes have characteristic length, such as the radius or circumference of a circle and the edge or diagonal of a square. Fractal figures are unique in that they cannot be measured with a single characteristic length, because fractal figures hold self-similarity, i.e. their shape does not change even when observed under a different scale. This feature is also called scale-invariance.

Dimensions are essential in both Euclidean and fractal geometry for representing characteristics such as area and perimeter length. For example, when the area of a disk ($=\pi r^2 = \pi r^d$) is calculated, the radius is squared because the disk is a two-dimensional set of points (i.e., $d=2$). A point has a topological dimension of 0, a boundary has a dimension of 1, a surface has a dimension of 2, and a solid has a dimension of 3.

Although the geometrical interpretation of the exponent is often taken for granted, the implications of non-integer exponents are at the crux of fractal geometry [6]. The fractal dimension of a linear feature such as a coastline can be any value between 1 and 2, depending on its complexity. Similarly, for a surface, the fractal dimension value lies between 2 and 3 and reflects the overall characteristics of the surface. When applied to remote sensing data the fractal dimension represents the complexity of the image.

3.2.3.1. Dividers (compass) method of measurement

The dividers (compass) method is used to measure the fractal dimension of a curve, as in the length of a coastline on a geographic map. In practice the length of coast on maps is measured by moving a set of dividers of fixed length (δ) along the coastline. The result is that the smaller the δ value the longer the coastline, because it is possible to measure in greater detail, as shown in the illustration below. The conclusion is that total length L_δ is dependent on the measuring scale (δ). For Euclidean objects, L_δ is independent of δ ; for fractal objects, L_δ increases as δ decreases. Smaller features only become apparent at finer scales (self-similar coastline).



For fractals, length (L_δ) and measuring scale (δ) are related by the power-law:

$$L_\delta = K\delta^{1-D_f}$$

Fractal dimension (D_f) is estimated from the slope of $\ln(L_\delta) - \ln(\delta)$ plot:

$$\ln(L_\delta) = \ln(K) + (1-D_f) \ln\delta$$

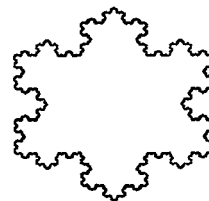
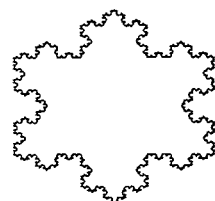
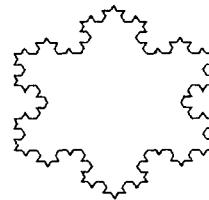
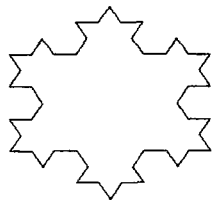
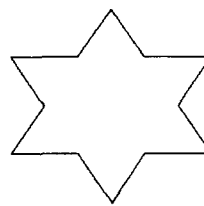
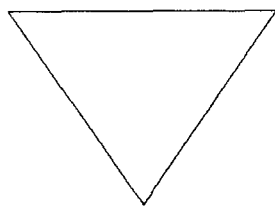
Where

$\ln(K)$ is the y-intercept.

Note that the measured length is independent of the measurement scale ($D_f=1$) for Euclidean (non-fractal) objects. For example, for the British coastline $D_f = 1.31$, while for Norway $D_f = 1.52$. The fractal dimension ($1 \leq D_f \leq 2$) in this case quantifies the "degree of complexity" of the coastline.

3.2.3.2. Koch Snowflake curve

Ideal fractal objects reveal exact copies of themselves with each scale change, which was introduced by Helga von Koch. It is "a rough but vigorous model of coastline", in Mandelbrot's words. A particularly interesting characteristic of the Koch Snowflake is its perimeter.



To construct a Koch curve, one begins with a triangle with sides of length l . At the middle of each side, a new triangle one-third the size is added, and so on, as illustrated in the patterns below. The length of the boundary is $3 \times 4/3 \times 4/3 \times 4/3 \dots \infty$. Yet the area remains less than the area of the circle drawn around the original triangle. Thus an infinite line surrounds a finite area. In the case of the Koch Snowflake the curve becomes four-thirds longer than the original curve every time it grows. In this case the fractal dimension is $1.26 (\ln 4 / \ln 3)$.

3.2.4. *Fractal dimension of a single landscape patch*

The basic relationship between patch area and perimeter as described in Peitgen and Saupe [7] is:

$$P \propto A^{D/2}$$

Where

A = area of the patch

P = perimeter of the patch

D = fractal dimension

When the landscape is grid-based, consisting of square cells, the previous equation can be modified:

$$P = K * A^{D/2}$$

Where K is the constant of proportionality between area and perimeter, in the case of square cells $K=4$, and the equation is given by

$$D = 2 * \ln(P/4) / \ln(A).$$

When the landscape contains a patch, which is represented by a single cell, the area is equal to one and the equation yields an infinite result. Because a single cell represents the simplest shape possible, $D = 1.0$ by definition.

3.2.5. *Fractal dimension of a landscape*

The calculation of the fractal dimension of landscape involves three steps. First, the landscape is divided into contiguous patches of the same attribute class (e.g., land cover). Second, the log of the patch perimeter (y) is regressed against the log of the patch area (x) for all patches in a landscape. Third, an estimate of the complexity of the shape is given by 2.0 times the slope ($D/2$) of regression [8]. Larger values indicate that landscape patches have a complex shape.

3.2.6. *A new landscape index for quantifying patch shape complexity*

Frohn [4] proposed a new index for the raster data as an alternative to fractal dimension, known as "square-pixel" (SqP). This index, which normalizes the ratio of perimeter and area to a value between 0 (for squares) and 1 (maximum perimeter deviation from that of a perfect square), is given as

$$SqP = 1 - (4 * A^{1/2} / P)$$

Where A is the total area of all pixels and P is the total perimeter of all pixels in the landscape for a land cover type.

3.2.7. A fractal method to estimate the roughness of a remotely sensed image

When computing fractal dimension, a remotely sensed image is considered a three-dimensional surface, and its complexity is expressed in terms of its variability over the space. Similar to a natural surface, such as hilly terrain or a flat plain, this complexity is a function of the vertical variability of pixel values. Hilly terrain has more changes in elevation than a flat plain, so it represents a more complex surface. This complexity function can be expressed by fractal dimension D and is a quantitative measure of the "roughness" of surface [9.]

One method used for calculating the fractal dimension of an image is the triangular prism method [10,11]. A window (9 x 9 pixels) is moved over the image, and for each pixel the surface area is computed at four different resolutions (squares).

This method takes elevation values at the centre of pixels located at the corners of a square and calculates the average. A vertical line in the square centre pixel takes this average as its z value. This creates a prism with four triangular facets. The areas of these facets are calculated with a trigonometric formula "Heron's formula" and then summed to represent the surface area of this particular square.

Heron's formula is

$$\text{Area} = [S * (S-a) * (S-b) * (S-c)]^{1/2}$$

Where

$$S = \text{the semi-perimeter} = (a+b+c)/2$$

a , b and c are the sides of triangle

The surface area is calculated within the moving window for four squares size: 1 per 1, 2 per 2, 4 per 4, and 8 per 8 pixels.

The logarithm of the total surface areas, which is computed using these different measuring resolutions, is plotted against the logarithm of the measuring units (number of cells). The fractal dimension (D) is then calculated by performing regression on these two variables and imputing the resulting slope of the regression in the equation

$$D = 2.0 - B$$

Where

$$B = \text{the slope of the regression.}$$

B is expected to be a negative value since the total surface area measured decreases with increasing step size; thus the result D should range between 2.0 and 3.0.

A general trend of D computations is that homogeneous areas yield low estimates of D and, as the heterogeneity of the image increases, D also increases.

The above method is applied to images derived from the Normalized Difference Vegetation Index (NDVI) to examine the spatial complexity of the landscape, particularly green vegetation distribution, while various mathematical combinations of satellite bands have been found to be sensitive indicators of the presence and condition of green vegetation. NDVI is the most commonly used [12] and is defined by the equation:

$$NDVI = (Nir - Red)/(Nir + Red)$$

Where

Nir = near-infrared band

Red = red band

Clouds, water and snow have larger reflectance in the visible band than in the near-infrared band, so for these features NDVI is negative. Rock and bare soil have similar reflectance in those two bands and result in a vegetation index that is near zero. In scenes with vegetation, the NDVI ranges from 0.1 to 0.6; the higher values are associated with greater density and greenness of plant canopy.

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4

IDRISI program modules

Clark Labs

4

IDRISI program modules*

This chapter was written using the IDRISI for windows system. IDRISI for windows is a grid-based geographic information and image processing system developed by the graduate school of geography at Clark University.

4.1. Core modules

The core modules provide basic facilities for the manipulation of raster images.

4.1.1. Data entry

EDIT

A simple ASCII text editor for use in creating a variety of IDRISI data files. With values files, EDIT creates and maintains proper documentation files automatically.

INITIAL

Initializes a new image with a constant value.

INTERCON

Interpolates a surface from a set of contours by linear interpolation.

INTERPOL

Interpolates a surface from point data using either a weighted-distance or potential surface model.

LINERAS

Line-to-Raster conversion.

POINTRAS

Performs point-to-raster conversion.

POLYRAS

Carries polygon-to-raster conversion.

TOSCA

An independent universal digitizing module distributed with IDRISI.

UPDATE

Keyboard entry/update of image data.

4.1.2. Attribute data management

ASSIGN

Creates an image from an attribute-values file by assigning the data values contained in these files to the cells belonging to defined regions. ASSIGN can also be used to reclassify integer images.

*The description of IDRISI program modules included in this chapter was generated by Clark Labs, Clark University, Worcester, Massachusetts, USA: <http://www.clarklabs.org/03prod/idrisi.htm>

DBIDRIS

Used to import dBase files into IDRISI value files, and moves IDRISI value files back into dBase format.

EXTRACT

Creates an attribute-values file from an image by extracting a summary of data values found within defined regions. The summary (minimum, maximum, range, total, mean or standard deviation) may also be output as a table.

4.1.3. *Spatial data management*

CONCAT

Concatenates multiple images to produce a larger image.

CONTRACT

Reduces image resolution by pixel thinning or aggregation.

EXPAND

Increases image resolution by pixel duplication.

LINEGEN

Generalizes vector lines by point selection, low-pass filtering or tolerance-band selection.

POINTVEC

Produces a vector point file from raster image (a companion to POLYVEC).

POLYVEC

Performs raster-to-polygon conversion.

PROJECT

Undertakes conversions between reference systems for both vector and raster files. With raster images, a resampling is undertaken using either a nearest-neighbor or bilinear interpolation. Supported projections include the Mercator, Transverse Mercator, Lambert Conformal Conic and Plate Carree. By using reference system parameter files, a limitless number of reference system conversions can be undertaken. Full forward and backward transformations are accommodated using ellipsoidal formulas. PROJECT also incorporates the United States National Geodetic Survey's NADCON procedure for converting between NAD27 and NAD83 and the Molodensky transform equations for all other data. Over 200 reference system parameter files are supplied with the module, including all State Plane (SPC) systems for NAD27 and NAD83 and a complete set of UTM zones based on WGS84 for the northern and southern hemispheres. In addition, users can construct reference system parameter files for any system based on a supported projection.

RASLNVEC

Produces plotted-vector output from images.

RESAMPLE

Determines the data values for a rectangular grid by interpolation of the values in a different (and possibly warped) grid. Linear, quadratic and cubic mappings between the grids are provided, along with nearest-neighbor and bilinear interpolations. Vector files may also be transformed with this "rubber sheet" procedure.

SUBSET

Windows sub-images from groups of images.

TRANSPOS

Image transposition by row or column reversal, or by rotation.

WINDOW

Extracts a rectangular sub-image.

4.2

4.2. Geographic analysis modules

4.2.1. Database queries

AREA

Creates a new image by giving each output pixel the value of the area of the class to which the input pixel belonged. Output can also be produced as a table or an attribute values file in a range of measurement units.

OVERLAY

Undertakes pixel-wise addition, subtraction, multiplication, division and exponentiation of paired images. Maximum, minimum, normalized ratio and cover are also supported. On binary images, logical AND/OR operations are supported by means of the multiply and maximum operation. Other Boolean operations are supported through various binary image overlay combinations (see the Boolean logic diagram in chapter 3, figure 3.1).

PCLASS

Evaluates the probability that pixels exceed or are exceeded by a specified threshold using the stated root mean square (RMS) error or the data set and a normal probability distribution error model.

PERIM

Creates a new image by giving each output pixel the value of the perimeter of the class to which the input pixel belongs. Output can also be produced as a table or an attribute values file in a range of measurement units.

QUERY

Extracts pixels designated by an independent mask into a sequential file for subsequent statistical analysis.

RECLASS

Reclassifies pixels by equal intervals or user-defined schemes. RECLASS is commonly used as a database query routine by reclassifying images into Boolean maps of areas meeting the specified conditions.

4.2.2. Map algebra

SCALAR

Adds, subtracts, multiplies, divides and exponentiates pixels by a constant value.

TRANSFOR

Transforms the attributes of images such as log transformation, using any of 14 operations.

4.2.3. Distance operators

ALLOCATE

Performs spatial allocation using either DISTANCE or COST surfaces.

COST

Generates a distance/proximity surface where distance is measured as the least distance in moving over a friction surface.

DECOMP

Decomposes a force vector (as a magnitude and direction image pair) into x and y component images. Also takes x and y component images and produces a force-vector image pair.

DISTANCE

Calculates the distance/proximity of each pixel to the nearest of a set of target pixels.

DISPERSE

DISPERSE is a companion to VARCOST that calculates dispersion distances. The procedure is essentially the same as that of VARCOST except that the emphasis is on forces acting to disperse a body (e.g., a point-source contaminant spill) and the time taken to disperse it to a specified distance. DISPERSE is released as an experimental module in IDRISI and all users are invited to comment on their experiences with this procedure and provide suggestions for modifications.

PATHWAY

Finds the shortest path between one or more specified points and a destination specified as the lowest point on a COST surface.

RESULTAN

Computes the resultant force vector (as a magnitude and direction image pair) from two input force-vector/image pairs.

SPDIST

A companion to the DISTANCE module, SPDIST calculates spherical distances on the surface of the earth from designated features using spherical trigonometry.

THIESSEN

Produces Thiessen polygons (a Voronoi tessellation) about a set of irregularly distributed points.

VARCOST

This module is the equivalent of COST (specifically the COSTPUSH algorithm) except that it recognizes that frictions may have different strengths in different directions. Frictions are entered as force vectors described by a pair of images, a magnitude image and a direction image. VARCOST also allows the specification of an isotropic friction image for omni-directional elements.

4.2.4. *Context operators*

GROUP

Classifies pixels according to contiguous groups.

HNTRLAND

Determines the supply areas dominated by, or the hinterlands of, point demand centres.

SURFACE

Produces slope gradient and aspect images from a surface. Can also be used to create analytical hill shading.

VIEWSHED

Creates an image of all points visible from one or more viewpoints over a given surface.

WATRSHED

Determines the watersheds of one or more specified locations.

4.3. Decision support analysis modules

BAYES

Evaluates Bayes' theorem. Multiple evidence maps (such as that produced by PCLASS) are permitted as long as they are conditionally independent. Prior probabilities may be input in map form (and thus, like the evidence maps, may vary continuously over space). The user is also able to specify the confidence in the decision rule, i.e., the belief that the evidence supportive of the hypothesis is truly reflected in the evidence at hand, $p(e|e')$. Bayes is an extension to what is sometimes called a Bayesian Weight of Evidence approach.

ERRMAT

Produces an error matrix analysis of categorical map data compared to ground truth information. Tabulates error of omission and commission, marginal and total errors and selected confidence intervals. Per category Kappa Index of Agreement figures are also provided. This module is a substantial revision and replacement for CONFUSE.

FUZZY

Evaluates the fuzzy set membership values (possibilities) of data cells based on any of three membership functions: sigmoid, j-shaped and linear. Monotonically increasing, monotonically decreasing, symmetric and asymmetric variants are supported. Other fuzzy set operations such as CON (concentration), DIL (dilution), AND and OR are covered by the standard modules TRANSFOR and OVERLAY.

MCE

Computes a multi-criteria evaluation by means of weighted linear combination of factors, subsequently masked by a set of constraints. Factor uncertainty information is propagated to the result to compute the uncertainty in the suitability derived.

MDCHOICE

MDCHOICE is a multi-dimensional choice procedure that produces an output map indicating, for each cell, which of a series of input maps has the highest value. In cases where the input maps represent suitability for different objectives, the procedure provides one alternative to the multi-objective decision problem (although the MOLA procedure is preferable in most instances). In these cases, input maps should be standardized either with STANDARD or by means of the histogram equalization procedure in STRETCH.

MOLA

An iterative multi-objective land allocation routine. Input maps are ranked suitability maps such as would be produced by ranking (using RANK) the output from a multi-criteria evaluation (using MCE). The procedure uses a decision heuristic to resolve conflicts and is suitable for use with massive data sets.

RANK

Orders the cells in a raster image. Ties may optionally be resolved by using the rank order of a second image. Both primary and secondary ranks may be in ascending or descending order. The procedure is used extensively in optimization problems such as with RECLASS for single objective decisions and MOLA for multi-objective decisions.

STANDARD

Converts an image to standard scores.

WEIGHT

Computes a best-fit set of weights by calculation of the principal eigenvector of a pairwise reciprocal comparison matrix in which each factor in a multi-criteria evaluation is compared to every other factor. Information on consensus and procedures for resolving lack of consensus are provided.

5

ArcView program modules

ESRI-ArcView user guide

5

ArcView program modules*

ArcView is a product of the Environmental Systems Research Institute (ESRI). It is a desktop geographic information system for accessing, displaying, querying, analysing, and publishing data. It links traditional data analysis tools, such as spreadsheets and graphics, with maps for a completely integrated analysis system.

5.1. ArcView terminology

5.1.1. Project

A project is the file in which ArcView stores work. All related work can be stored in a single project, including tables, charts, spatial views of data, map layouts etc. A project is saved with an (*.apr) file extension. Thus, the file "tunis.apr" would store all material, such as maps and tables, related to that project. Each project has a window.

5.1.2. Project window

The project window is the small window to the left of the initial ArcView window. When ArcView is first opened, the title of the project window is "Untitled." After a project is saved, this window contains the project file's name (with an .apr extension). It lists all the components of the project, organized by type (Views, Tables, Charts etc.). This window can be used to add new components to a project or to open existing ones.

5.1.3. Table

A table is a data file that contains rows of information about items in a particular geographic category (such as hotels, cities, streets, counties, countries etc.), with each row representing a different item. Tables also have numerous columns, with each column representing a particular attribute (variable); for example, one column might represent pesticide used, another population size etc.

5.1.4. Theme

Theme is the ArcView term for map layer that contains both spatial and attribute data (the latter are in database tables). A theme is a file containing the graphic information required for drawing a set of geographic features together with information about those features. Themes are listed on the left side of the view window in the table of contents along with the legends that identify them on the map. Examples of themes are streets, buildings, cities, rivers, countries and railroads. Themes can cover geographic phenomena at any scale, from small gardens to the entire planet.

*The descriptions of ArcView program modules included in this chapter were generated by ESRI-ArcView user guide; <http://www.esri.com/software/arcview/>

5.1.5. View

A view is the interactive map used to display queries and to analyse data in ArcView. Several map layers, called “themes”, are normally displayed in a single view. There can be more than one view in a project. The name of each view will be listed in the project window.

5.2. Spatial Analyst

The ArcView Spatial Analyst evaluates spatial relationships in the data and provides functions ranging from viewing and querying data to creating an integrated custom application. It includes tools for single-layer raster analysis that can generate surfaces, analyse characteristics such as slope, or model drainage basins. There are also interactive tools for creating contours and histograms.

ArcView Spatial Analyst provides tools to do the following:

- Convert feature themes (point, line or polygon) to grid themes
- Create raster buffers based on distance or proximity from feature or grid themes
- Generate density maps from themes containing point features
- Create continuous surfaces from scattered point features
- Provide contour, slope and aspect maps and hill shades of these surfaces
- Conduct cell-based map analysis
- Perform Boolean queries and algebraic calculations on multiple-grid themes simultaneously
- Carry out neighbourhood and zone analysis
- Produce grid classification and displays

Unique to ArcView Spatial Analyst is the ability to work with raster-based data (including the ability to overlay, query and display multiple raster themes) as well as to conduct integrated raster-vector theme analysis. An example would be the aggregation of properties of a raster theme based on an overlaid vector theme.

ArcView Spatial Analyst is particularly well-suited to problems that require distance or other continuous surface modelling information to be considered as part of the analysis. For example, site suitability analysis often requires the combination of information about slope (information best represented as raster data) and the location of roads and property boundaries (information best represented as vector data) to arrive at the best location for a new facility. The ArcView Spatial Analyst can not only generate the appropriate surface representation of information from a variety of existing data sources, but it can also derive new information from the overlay of multiple theme types.

5.3. Network Analyst

The ArcView Network Analyst enables users to solve a variety of problems relating to geographic networks (i.e., streets, highways, rivers, pipelines, electric lines etc.) such as finding the most efficient travel route, generating travel directions, finding the closest facility or defining service areas based on travel time.

ArcView Network Analyst adds an integrated graphical user interface, which provides access to network modelling capabilities that will assist the user to perform the following tasks:

- To find the most direct path between two points
- To establish the optimum route between many points
- To locate the closest facility
- To conduct time series analysis

ArcView Network Analyst can also do point-to-point routing (known as mid-arc routing, as opposed to endpoint-to-endpoint routing) and can reference local landmarks when reporting route directions. The geographic network data can be based on Arc/Info coverage, shape files or computer-aided designs (CAD).

The ArcView Network Analyst also includes a suite of more advanced network analysis tools that can be accessed through Avenue software. Developers will be able to deliver very sophisticated network analysis applications based on these extended capabilities.

5.4. 3D Analyst

The ArcView 3D Analyst software provides two types of surface models and grids for modelling continuous data like terrain elevation or temperature gradient. The main operational modules are capable of:

- Creating and modifying surface models
- Creating three-dimensional file themes
- Simple editing of triangulated irregular networks (TINs)
- Planimetric display of surfaces

Unique features of ArcView 3D Analyst include support for triangulated irregular networks (TINs) and simple three-dimensional vector geometry, as well as interactive perspective viewing.

6

Getting started with IDRISI

M. Ghribi

6

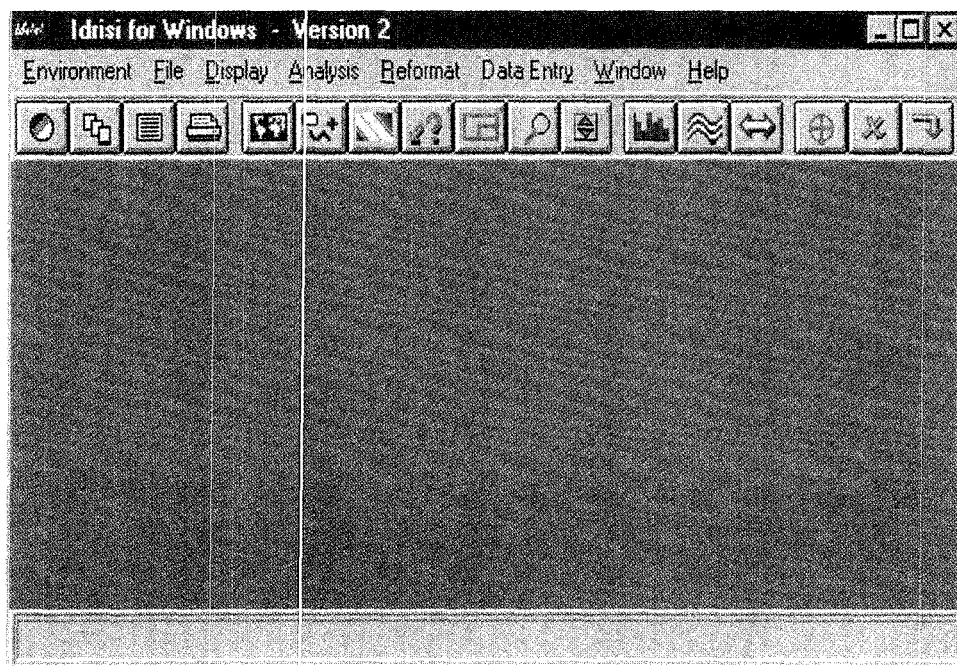
Getting started with IDRISI*

IDRISI for Windows consists of a main interface program (with a menu and toolbar system) and a collection of over 150 program modules that provide facilities for the input, display and analysis of geographic and remotely sensed data. These geographic data are described in the form of map layers.

6.1. Start IDRISI

From the Desktop, double-click on the IDRISI GIS Software Version 2 shortcut to start the program. After the start-up process, the application window appears (figure 6.1).

Figure 6.1. Application window for IDRISI



As soon as you start creating or using your own project, you should establish a working directory (figures 6.2 and 6.3). From the menu bar, choose **Environment**, and then **ENVIRON**.

The Operating Environment dialogue box will appear. Directories are shown on the right. Move to the `c:\ics\ghribi` directory by double-clicking each folder successively.

To open an existing project, click on **Display** in the menu bar and choose **DISPLAY Launcher** (figure 6.4).

*This chapter was prepared by M. Ghribi, Area of Earth, Environmental and Marine Sciences and Technologies, ICS-UNIDO.

Figure 6.2. Environment menu in IDRISI

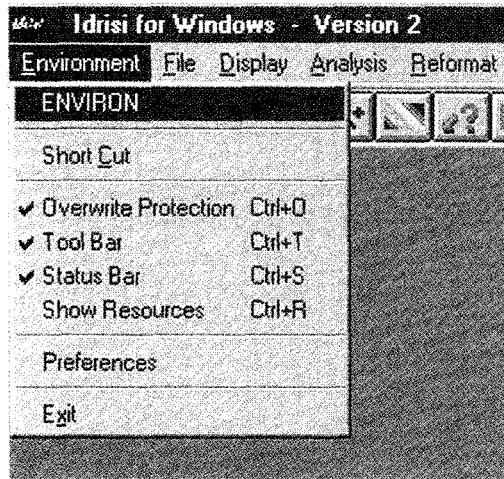


Figure 6.3. Establishing a working directory for projects

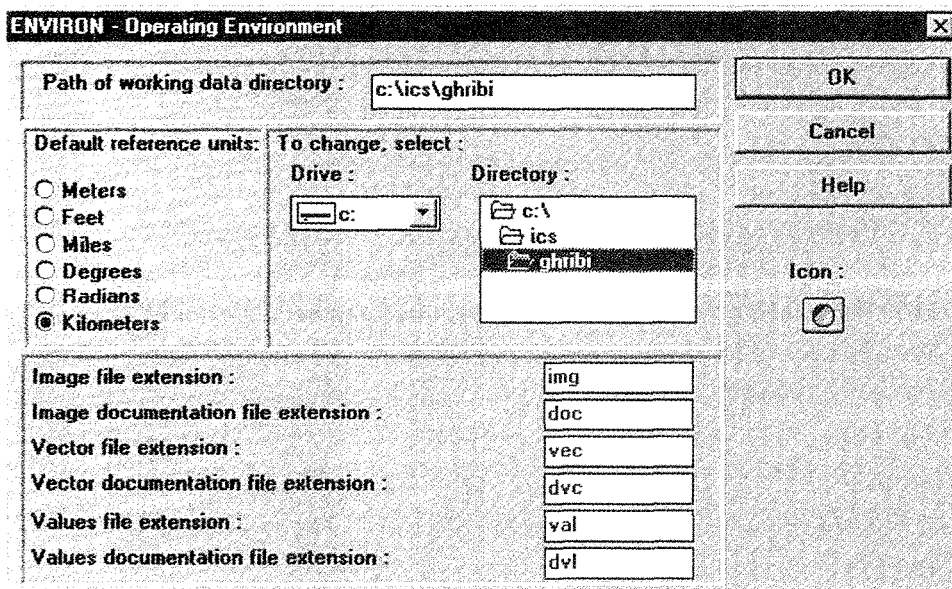
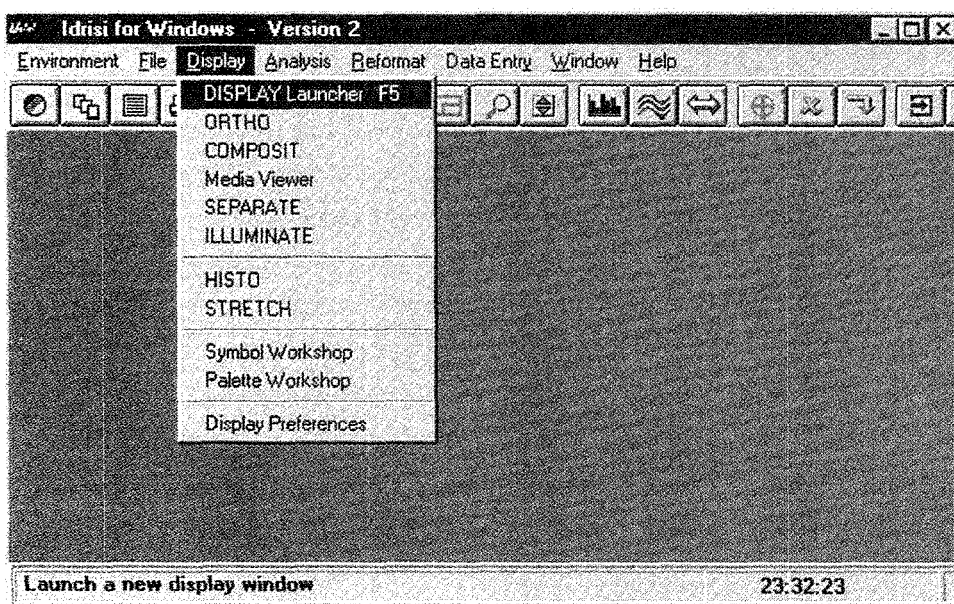


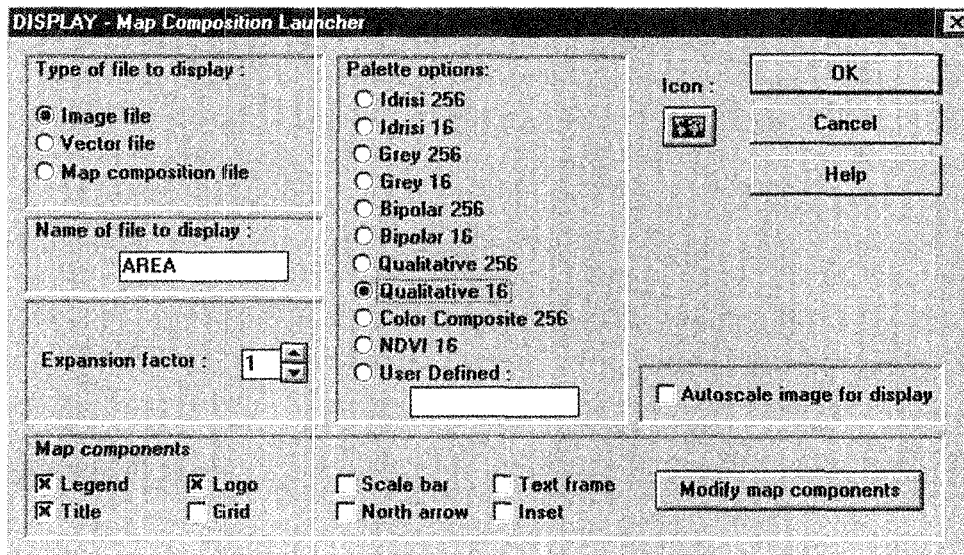
Figure 6.4. Opening an existing project with display launcher



6.2. Open an existing raster file and overlay vector files

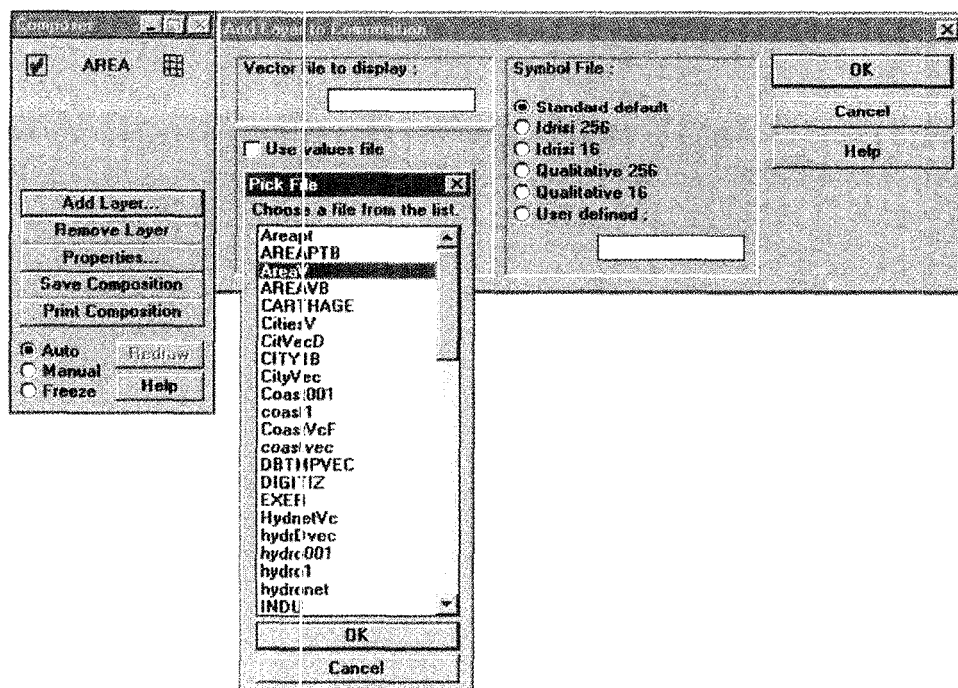
In the Display Map Composition Launcher dialogue box, double-click on the input image file box and choose **AREA**. Select the IDRISI palette file **QUAL16** and click the map components boxes to add the Title, Legend, Logo etc. To display the raster map layer click **OK** in the icon field (figure 6.5).

Figure 6.5. Opening a raster map layers



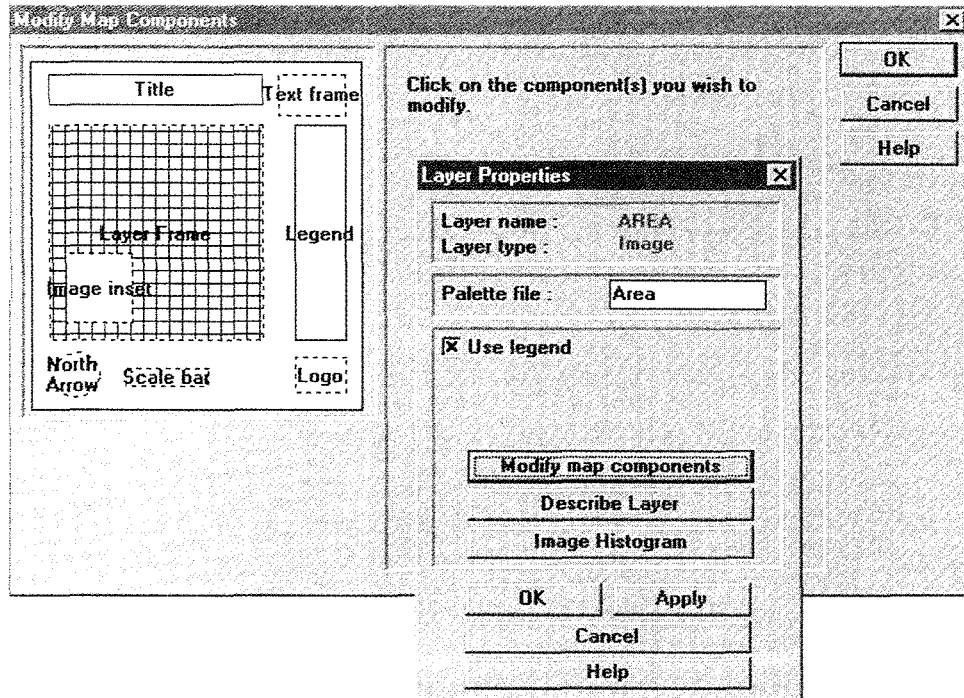
Once the raster map layer is displayed, go to the Composer dialogue box and press the **Add Layer** icon to add vector map layers. Double-click on the input file window and choose **AreaV**; accept the default symbol file. This will provide the administrative borders of the provinces of the study area used in this example (figure 6.6).

Figure 6.6. Use of composer dialogue box to add vector map layers



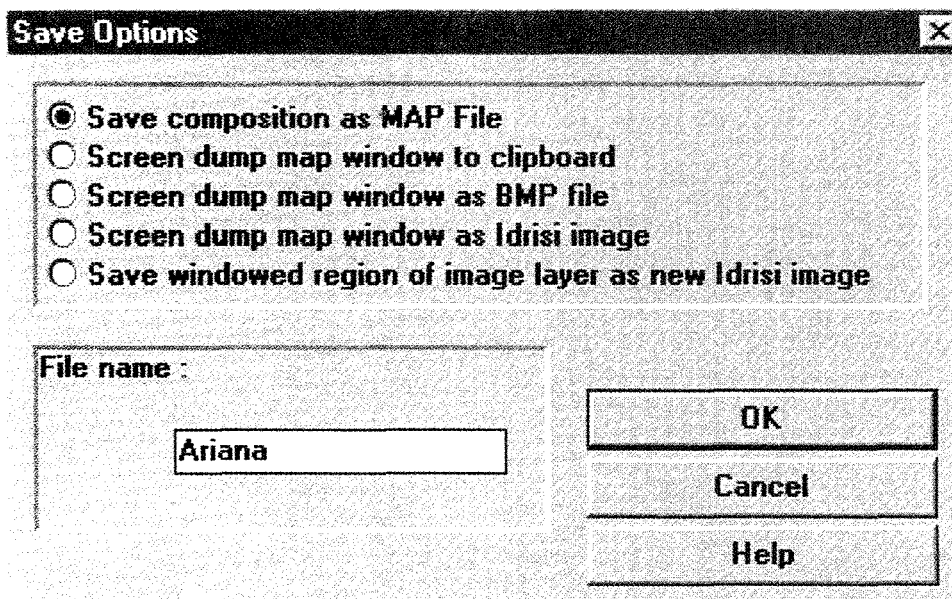
To add other components of your map, click **Properties** and press **Modify map components** in the Composer dialogue box and click on the component(s) you wish to modify. For each item selected, click the visible window and press **OK** (figure 6.7).

Figure 6.7. Modifying components of a raster map



Once you have finished selecting all map components, go to the **Composer** dialogue box, select **Save composition**, then **Save composition as MAP File** and give a file name to your final map composition (figure 6.8).

Figure 6.8. Saving final raster map composition



6.3. Exercise 1: Data extraction from the Internet

6.3.1. Purpose

This exercise emphasizes the utilities of the Worldwide Web as a source for data. It explains the steps involved in selecting the desired data with respect to a geographic system, and how to import it to GIS software.

6.3.2. Procedure

Using the Web navigator, access the following URL site:

<http://edcwww.cr.usgs.gov/landdaac/1KM/comp10d.html>

Select the following criteria for this exercise:

10-day composite period: **April 1-10, 1992**

Resolution: **1 km**

Latitude/Longitude geographic coordinates:

Northernmost Latitude: **38**

Westernmost Longitude: **9**

Southernmost Latitude: **36**

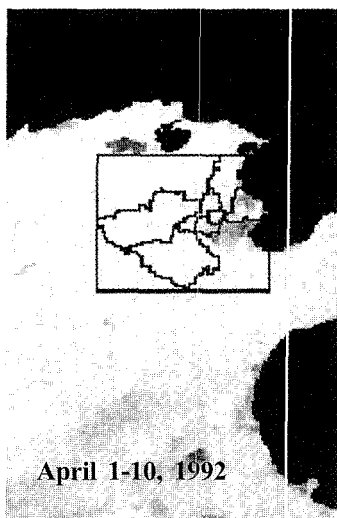
Easternmost Longitude: **11**

Bands to be retrieved: **NDVI**

Press the **Retrieve data** icon, and the research is launched. The output gives the size of the extracted image, specifying the number of lines (rows) and samples (columns).

Select **Retrieve data** again and the data will be downloaded.

Choose the directory corresponding with your IDRISI environment, in which you will save the downloaded data. Rename the image with an extension .img (for example, extract.img), in order to prepare its importation to IDRISI.



NOAA- AVHRR 10-day composite image, 1-km-Resolution.

Image size: 384 lines by 384 samples, 8-bit pixels

Actual coordinates:

Northernmost Latitude: 38.859705, line 4353

Southernmost Latitude: 35.415302, line 4736

Westernmost Longitude: 7.192014, sample 21377

Easternmost Longitude: 12.433991, sample 21760

Band: 6...NDVI

Run the IDRISI program and set up the environment (figure 6.2), which contains extract.img. Select **File>Document** (figure 6.9), double-click on the Input file window and select "extract.img". Fill in the document file with the corresponding properties of the extracted image. You can now display the image.

To view the extracted image, complete the document file according to the criterion corresponding to your study area (figure 6.10).

Figure 6.9. File document IDRISI window

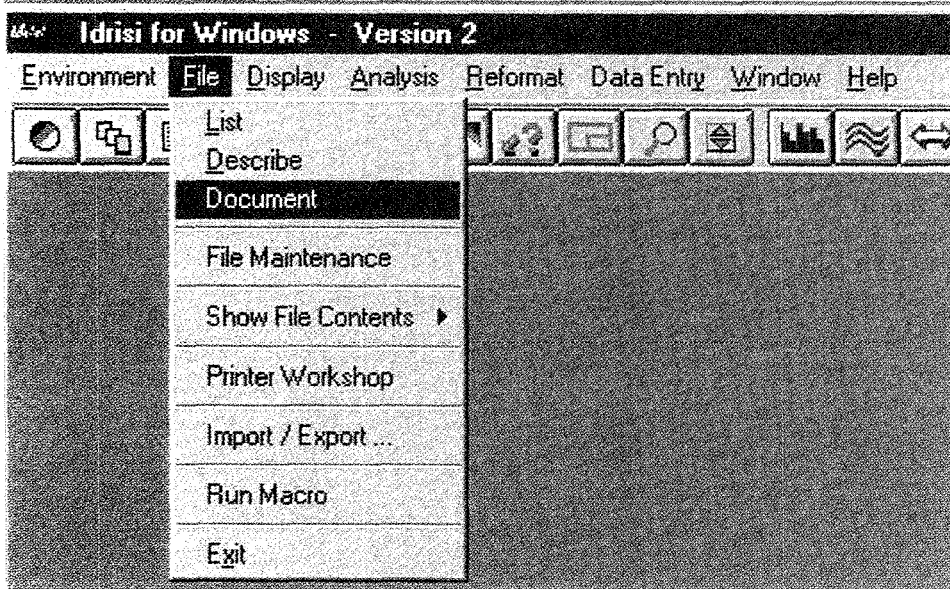
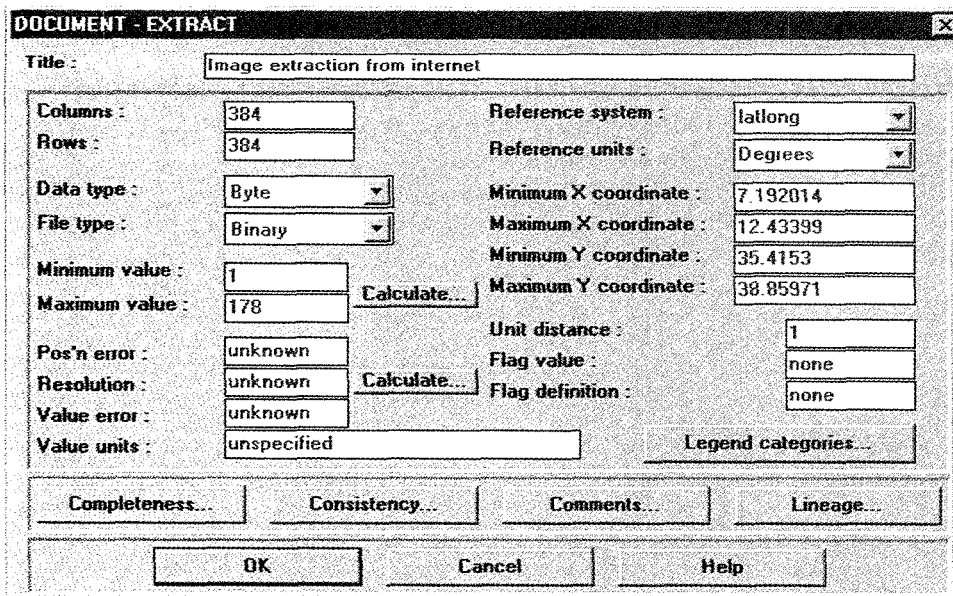


Figure 6.10. Document of the extracted image



6.3.3. Study area extraction

To illustrate IDRISI's windowing and geographic selection capabilities, this exercise shows how to selectively modify downloaded data in order to keep only the zone of interest.

To select the frame in which your study area is located, select **Reformat> WINDOW**. Specify the geographic coordinates (for example in this case latitude/longitude) and press **OK** (figure 6.11 and 6.12).

Figure 6.11. Extract a sub-image from a large image

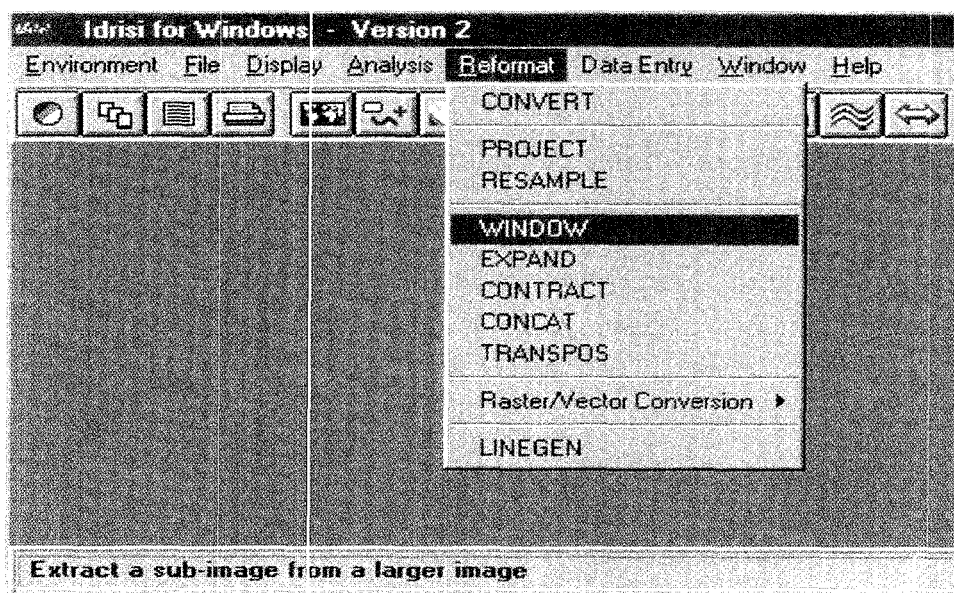
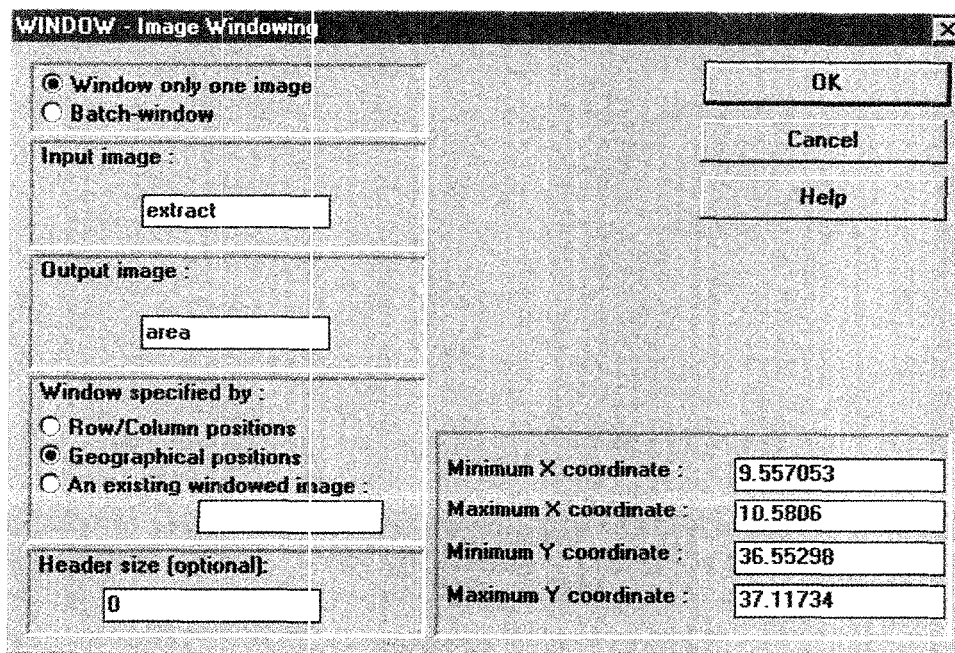


Figure 6.12. Image windowing



To select the irregular area of interest within the frame, choose **Analysis>Database query>RECLASS** (figure 6.13).

Double-click on the Input file window and select the raster file area; enter the output file name **arear**. Go to **Assign a new value of** and assign a new value **1** to all values from **1** to just less than **8** (figure 6.14).

Select **Analysis>Database Query>OVERLAY** (figure 6.15), Insert **arear.img** as a first image and **extract.img** as a second image. Choose the overlay option **First * Second**; choose the output file name **NDVI**. Enter a title for the overlay image (figure 6.16).

Figure 6.13. RECLASS IDRISI module window

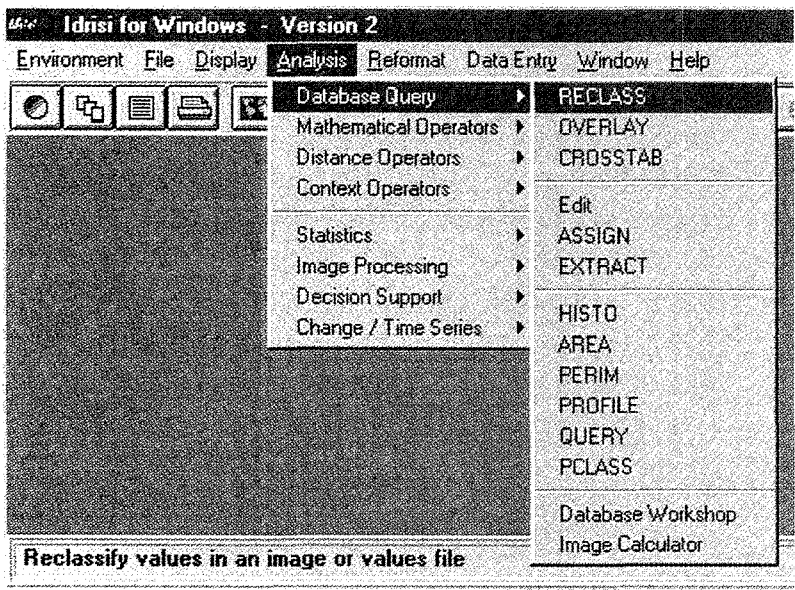


Figure 6.14. Area reclassification

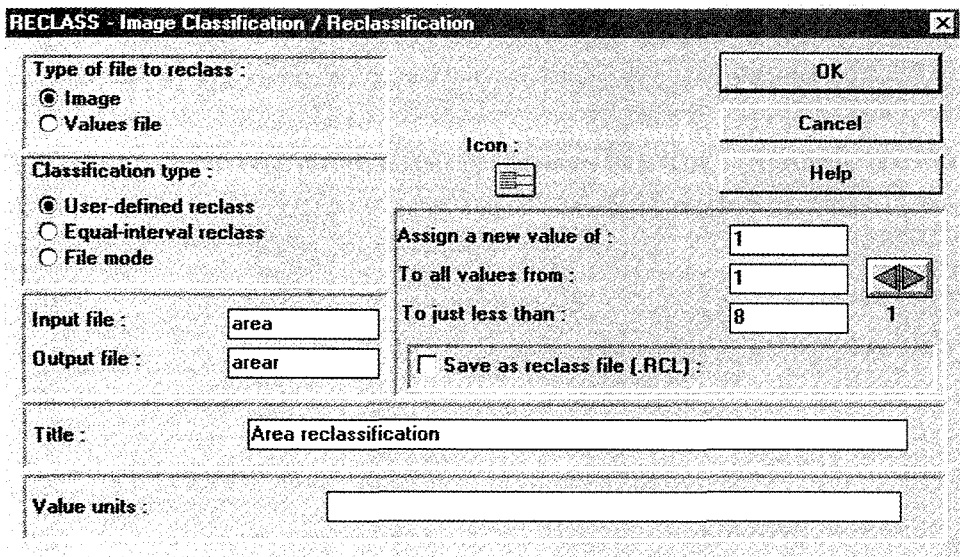


Figure 6.15. OVERLAY IDRISI module window

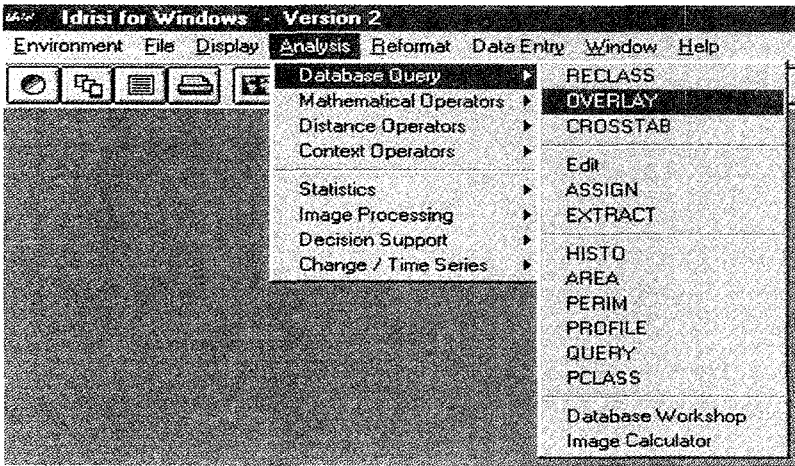
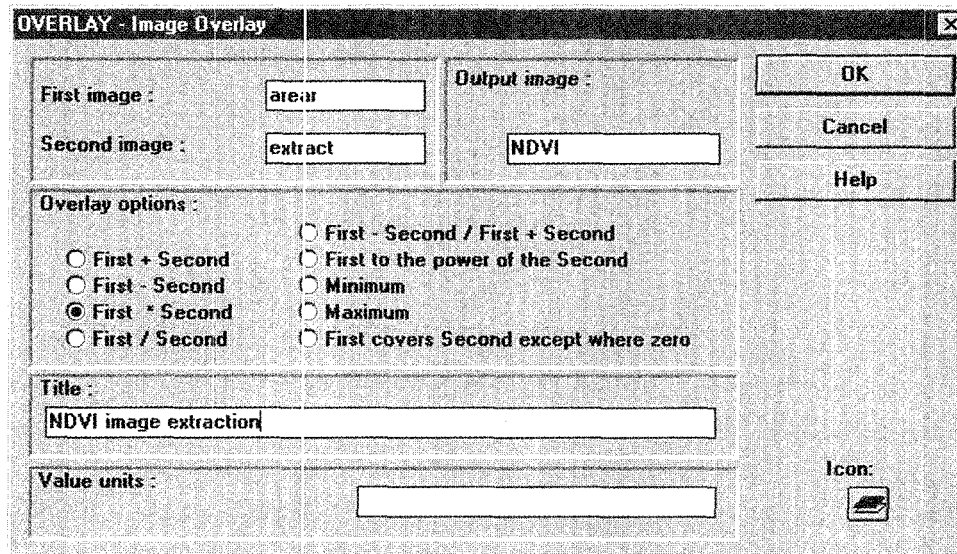
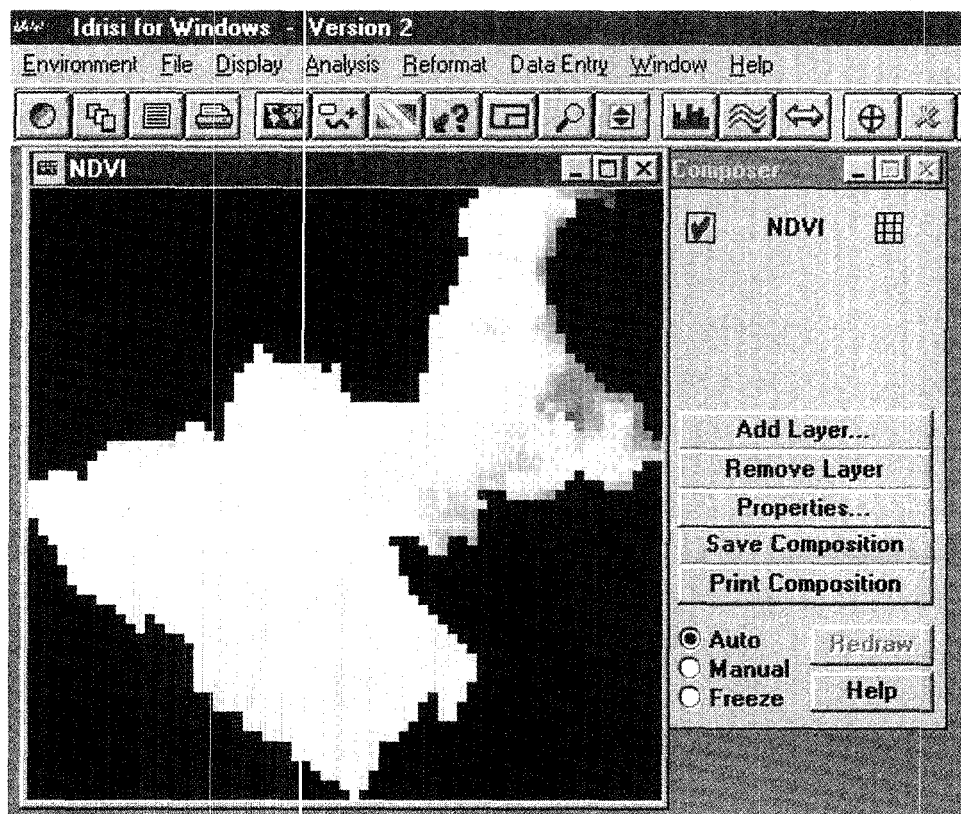


Figure 6.16. NDVI image extraction using OVERLAY IDRISI module



Click OK to see the final image overlay (figure 6.17).

Figure 6.17. NDVI final image



6.4. Exercise 2: Image processing

6.4.1. Purpose

This exercise will enable the participant to manipulate several mathematical expressions provided by the IDRISI software. In the following example, the average normalized difference vegetation index (NDVI) is calculated.

6.4.2. Procedure

Select **Analysis>Mathematical operators>Image calculator** (figure 6.18). In the **Expression to process** (figure 6.19), press **Insert image**, choose **10AV92OV**, and add the **+** sign, select **Insert image** again, insert **20AV92OV** and **+**; repeat the process and insert **30AV92OV**. Put the whole expression between parentheses, and divide by 3 to find the NDVI average of April 1992. Rename the output file **Avg1992**, and press **Process expression** to produce the final image (figure 6.20).

Figure 6.18. Image calculator IDRISI module window

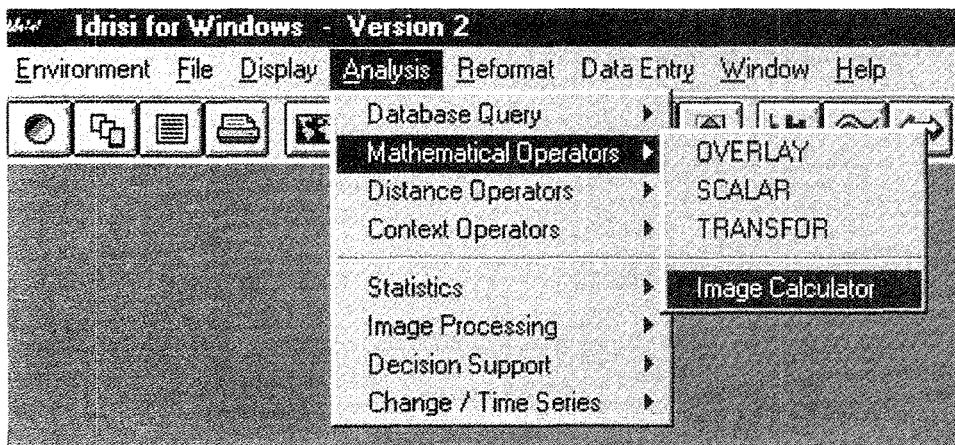
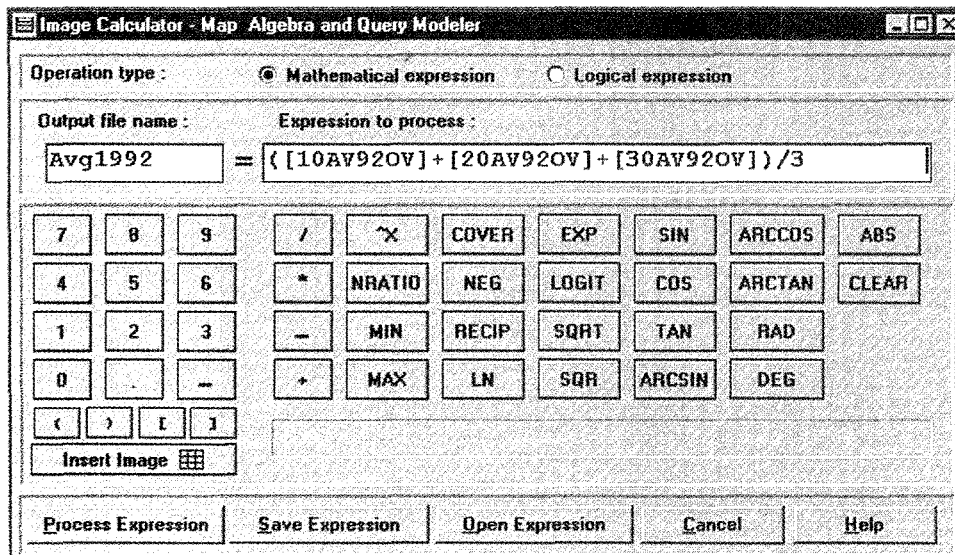
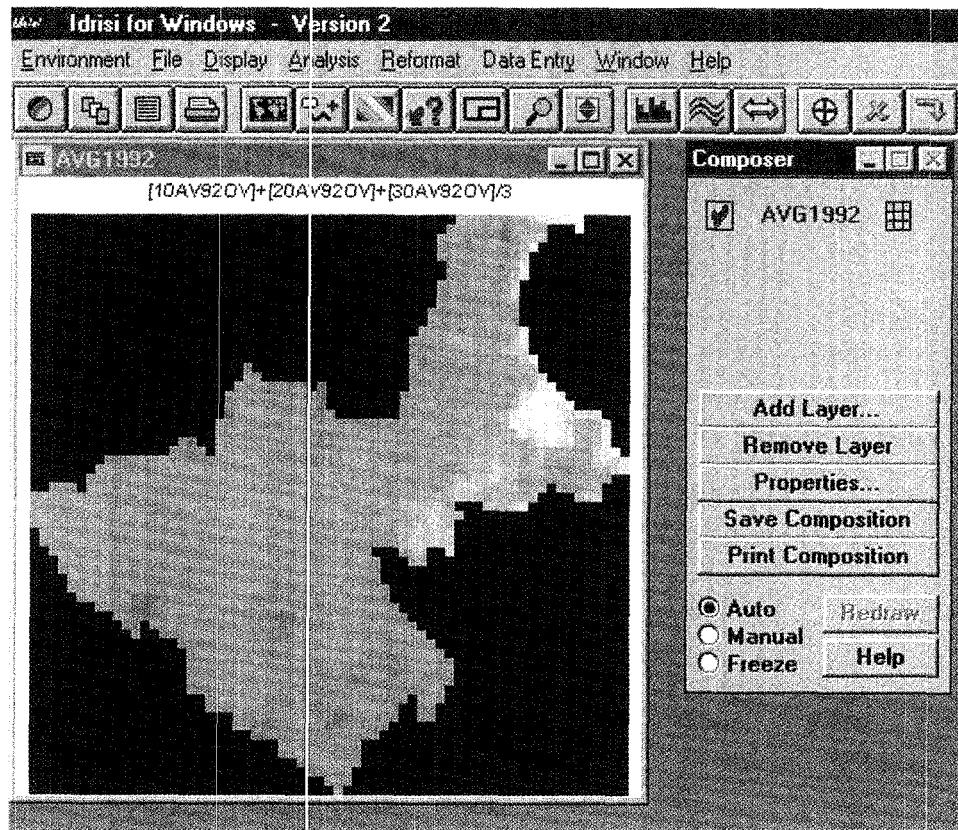


Figure 6.19. Average NDVI image using IDRISI image calculator



The average NDVI of April 1992 is calculated using the 10 day-average of 1-10 April 1992 (10AV92OV), the 10 day-average of 11-20 April (20AV92OV) and the 10 day-average of 21-30 April 1992 (30AV92OV).

Figure 6.20. Average NDVI image of April 1992



6.5. Exercise 3: Time-series analysis

6.5.1. Purpose

To measure the global changes over profiles of time, the vegetation dynamics of the Governorate of Ariana for the whole area by each industrial site was measured taking the normalized difference vegetation index (NDVI) as the numerical indicator.

6.5.2. Procedure

First, a time-series file is created where the files that will undergo a time series analysis are treated in chronological order.

Select **Data Entry>Edit**, click **time series file**, choose the file name **NDVI-MOD** and click **OK** (figure 6.21).

Select **avg1992**, **avg1993** and **avg1995** then press **Add** (figure 6.22).

Go to **Analysis>Change>Time-series>Profile** and click on the option **Over time series**. Maintain the default summary type **Mean**. Select the **Save as values file** and insert **profile** as the prefix for value files.

Insert **AREATOT** as the image defining the sample spots. Type **AVGNDVI** as the time series file to be taken into account when computing the NDVI change throughout the whole area and click **OK** (figure 6.23 and 6.24).

Figure 6.21. Edit file IDRISI module window

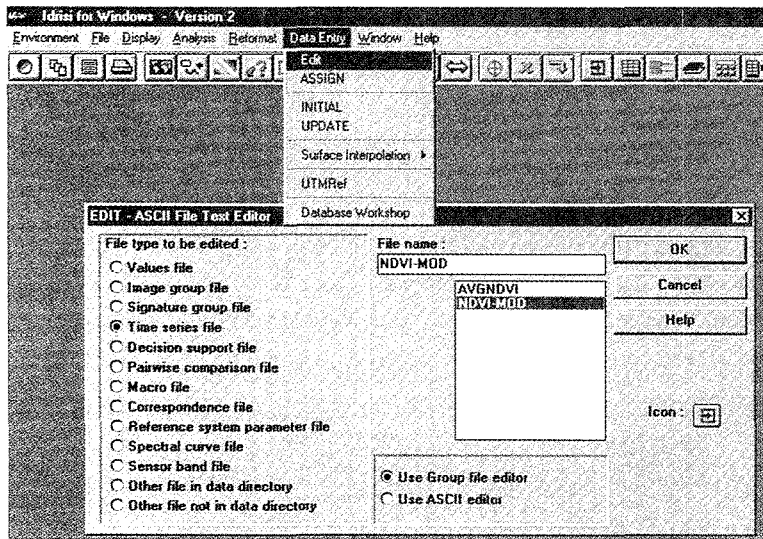


Figure 6.22. Editing time series file NDVI-MOD

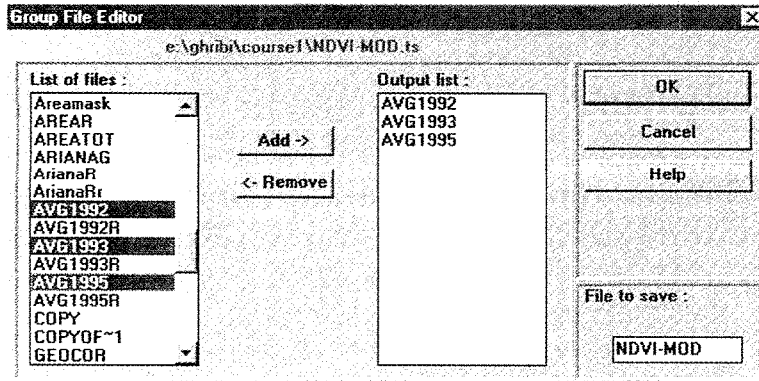


Figure 6.23. PROFILE IDRISI module window

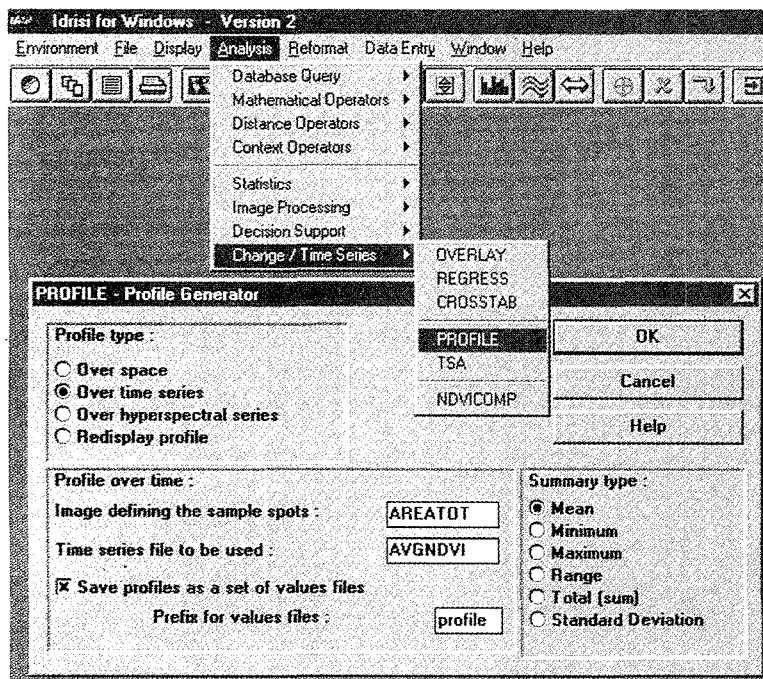
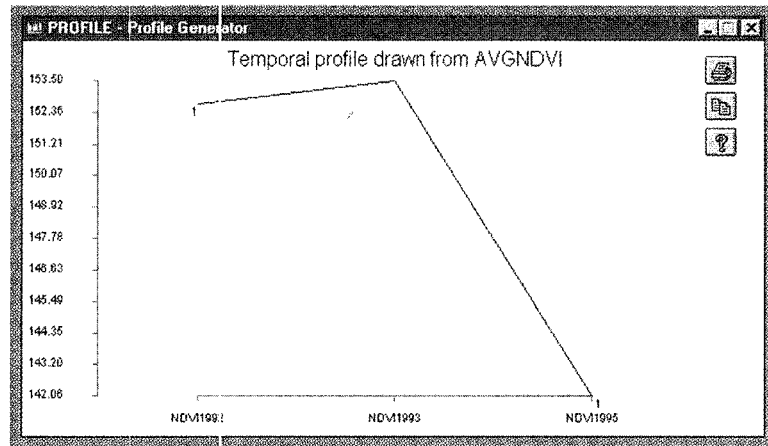


Figure 6.24. The NDVI change from 1992 to 1995 for the entire Governorate of Ariana



6.6. Exercise 4: Linear regression

6.6.1. Purpose

To demonstrate statistical function of the software, this exercise uses simple and multi-linear regressions to determine the correlation of NDVI, industrial manpower and rainfall.

6.6.2. Procedure for simple linear regression

Select **Analysis>Statistics>Regress**. Enter the image file name **LNNDVI** as the dependent variable and the image file name **LNLABOUR** as the independent variable and press **OK** to carry out the regression analysis (figures 6.25 and 6.26).

Figure 6.25. Simple linear regression analysis

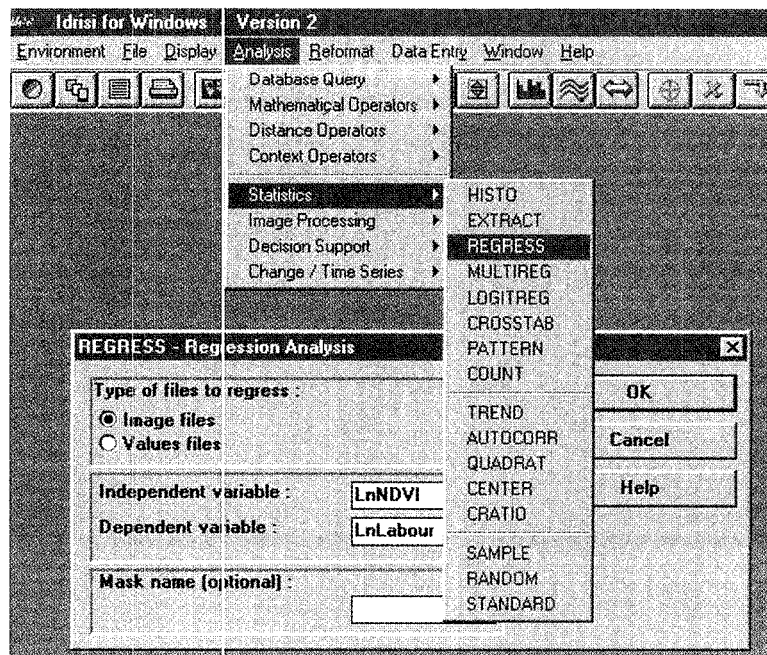
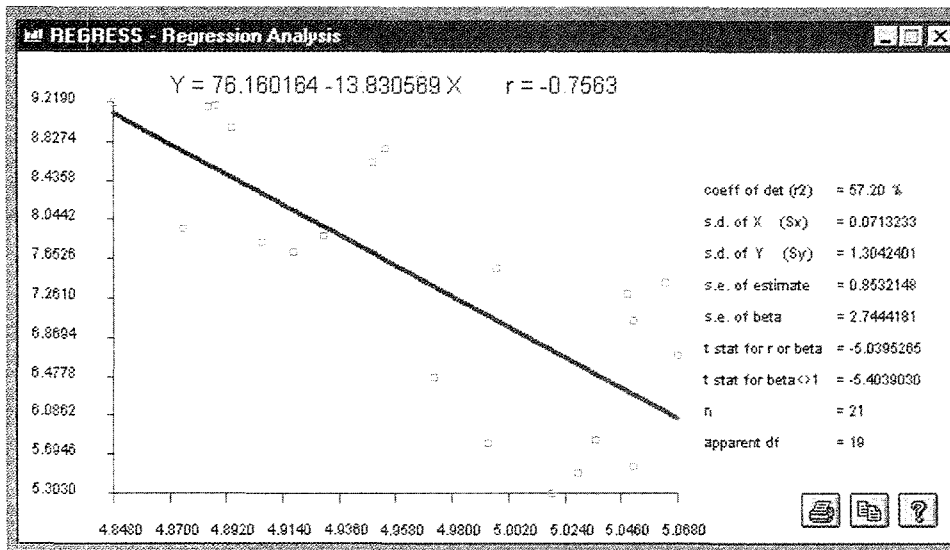


Figure 6.26. Simple linear regression analysis curve, where X is the natural logarithm of the number of employees (labour) and Y is the natural logarithm of the average normalized difference vegetation index (NDVI)



6.6.3. Interpretation

To establish a statistical correlation between the industrial development and the NDVI change, the NDVI average values were extracted and the number of employees was calculated for each province of the Governorate of Ariana (7 main residential sites) and for the same period (April 1992, April 1993 and April 1995). This gives 2 different matrices for each variable (NDVI and Labour) containing 21 samples ($n=21$) represented by the green boxes in the figure 6.26.

The simple linear regression equation is:

$$\text{Ln(NDVI)} = 76.160164 - 13.830569 [\text{Ln(Labour)}]$$

There is a negative correlation between the NDVI and the number of employees, as shown by the equation above with a coefficient of correlation $r^2 = 0.572$.

The increase of industrial activities occurs with an increase in the number of industrial plants. This, in turn, leads to the establishment of urban settlements. As a result the biomass and productivity of the green cover diminishes. Based on the direct and indirect effects of industry, NDVI will automatically decline.

6.7. Exercise 5: Multi-linear regression

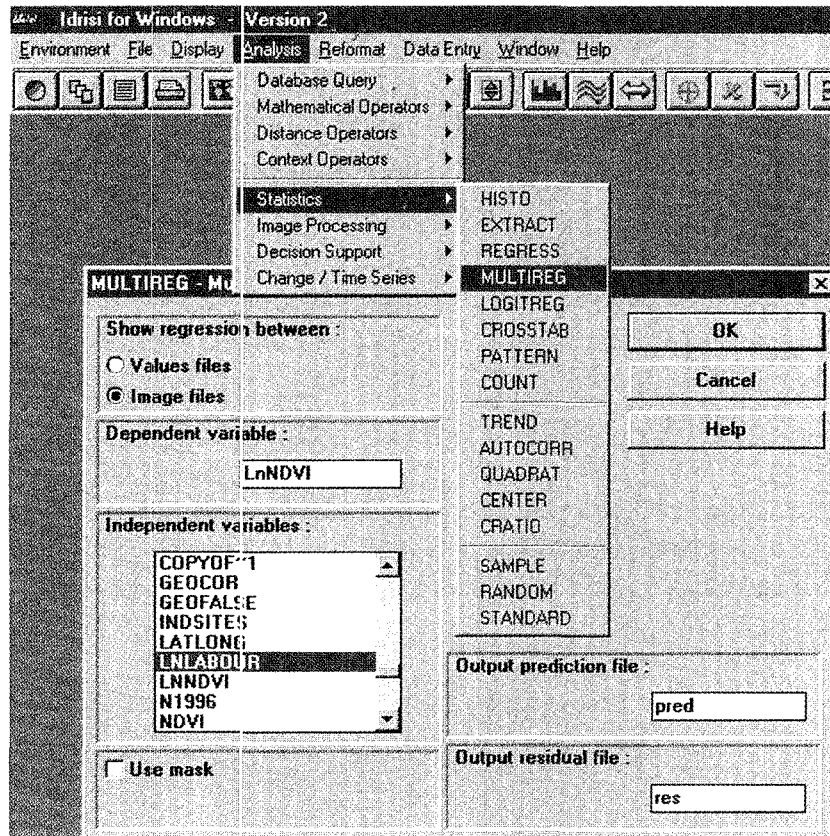
6.7.1. Purpose

In this exercise a multi-linear regression is conducted where NDVI is the dependent factor and labour and rainfall are independent factors. A square-root transformation has already been done for rainfall to bring its values to the same numerical range of Ln(NDVI) and Ln(Labour).

6.7.2. Procedure

Select **Analysis>Statistics>MULTIREG**. As a dependent variable, enter **LnNDVI**, select **LNLABOUR** (labour) and **sqrt** (rainfall) as independent variables. Choose **pred** as an output prediction file and **res** as an output residual file (figure 6.27).

Figure 6.27. Multi-regression IDRISI module window



6.7.3. Results and interpretations

Regression equation:

$$\text{Ln}(\text{NDVI}) = 5.1066 - 0.0366 [\text{Ln}(\text{Labour})] + 0.0183 [\text{SORT}(\text{Rainfall})]$$

Regression statistics:

Apparent R = 0.805019 Apparent R square = 0.648056

Adjusted R = 0.793431 Adjusted R square = 0.629533

F (2, 18) = 16.572279

Analysis of variance (ANOVA) regression table

Source	Apparent degrees of freedom	Sum of squares	Mean square
Regression	2	0.07	0.03
Residual	18	0.04	0.00
Total	20	0.11	

Individual regression coefficients

	Coefficient	t_test (18)
Intercept	5.106647	49.169075
Labour	-0.036593	-4.562873
rainfall	0.018338	1.971741

According to the regression equation, NDVI is more negatively correlated with industry than positively correlated with rainfall.

$$\begin{aligned} F(2, 18)_{\text{statistical}} &= 3.55 \\ F(2, 18)_{\text{calculated}} &= 16.572 \\ F(2, 18)_{\text{statistical}} &< F(2, 18)_{\text{calculated}} \end{aligned}$$

Hence the regression model between NDVI as an independent factor, and both industrial manpower and rainfall is very significant.

For the partial correlation, the student test $t_{18 \text{ theoretical}}$ is equal to 2.101. At the level of 5% confidence it is greater than $t_{\text{test}}(18) = -4.562873$, which means that the industry is significantly correlated with NDVI, whereas rainfall is not statistically correlated with NDVI.

In conclusion, the NDVI is positively correlated with rainfall and negatively correlated with industrial manpower. In fact, the rain affects green biomass cover depending on the season and the bio-climatic level. On the other hand, industrial manpower has both a direct and an indirect negative influence on the vegetation cover. Its direct effect is shown in the establishment of factories to the detriment of the green cover. Its indirect effect is due to rural migration by those seeking employment, resulting in the establishment of new urban settlements.

7

Getting started with ArcView

M. Ferneti and M. Dragan

7

Getting started with ArcView*

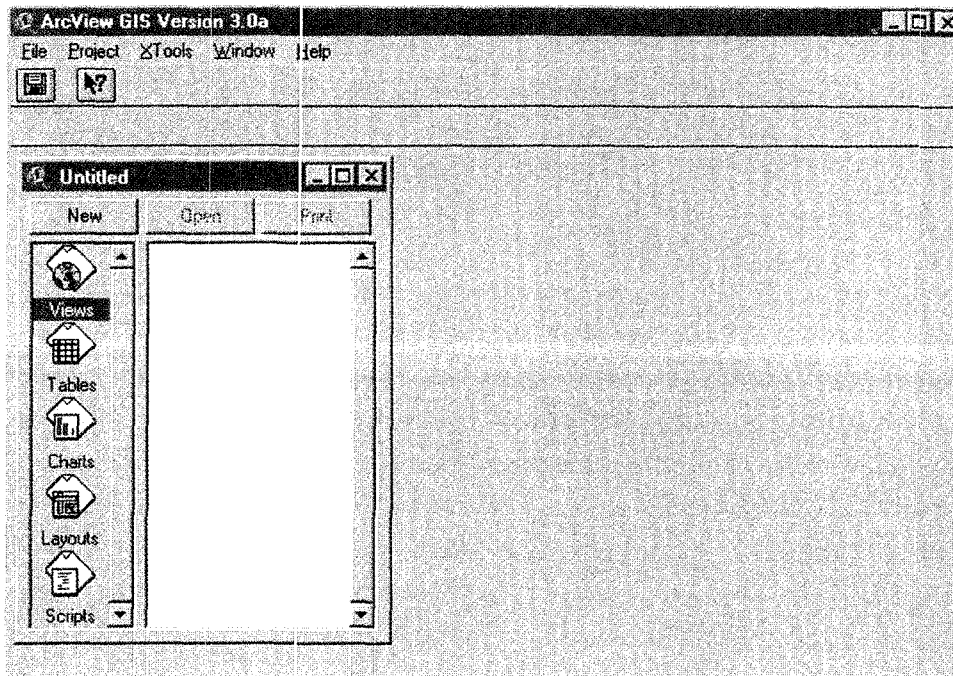
This chapter contains some exercises using ArcView GIS (a leading desktop geographic information system software). It includes data input and integration, land use destination using global positioning system (GPS) data, geo-referencing raster images and performing spatial analysis.

7.1. Step 1: Start ArcView

From the Desktop, double-click on the ArcView GIS Version 3.0a shortcut to start the program.

After the start-up process, you are presented with the application window that contains an untitled window, which in ArcView is referred to as the “project window” (figure 7.1).

Figure 7.1. ArcView project window

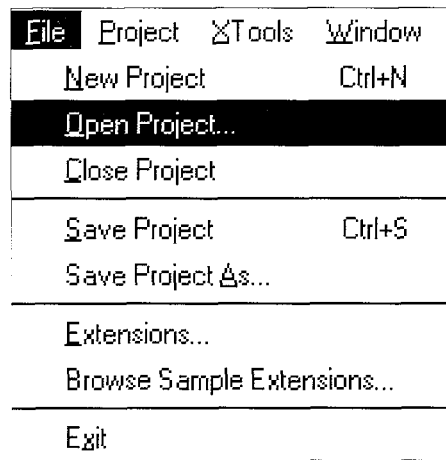


As soon as you begin to create your own project, the Project window will list all the documents (including views, tables, charts, layouts and scripts) that are included in the project.

*This chapter was prepared by M. Ferneti and M. Dragan, Area of Earth, Environmental and Marine Sciences and Technologies, ICS-UNIDO.

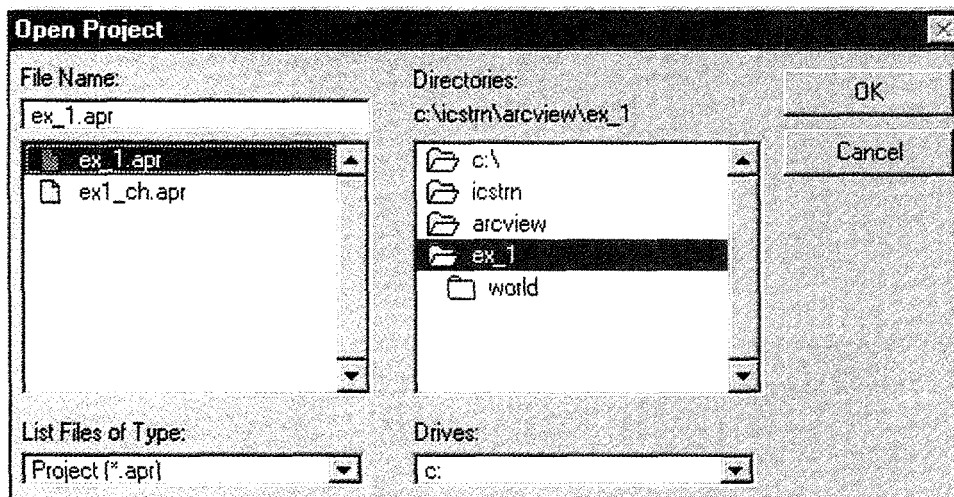
7.2. Step 2: Open an existing project and display views and tables

From the File menu, choose Open Project.



The Open Project dialogue box appears. The directories are shown on the right. The ArcView project files within each directory are shown on the left. On the right side of the pop-up window is the Directories list. Move to the c:\icstrn\arcview\ex_1 directory by double-clicking each folder successively (figure 7.2).

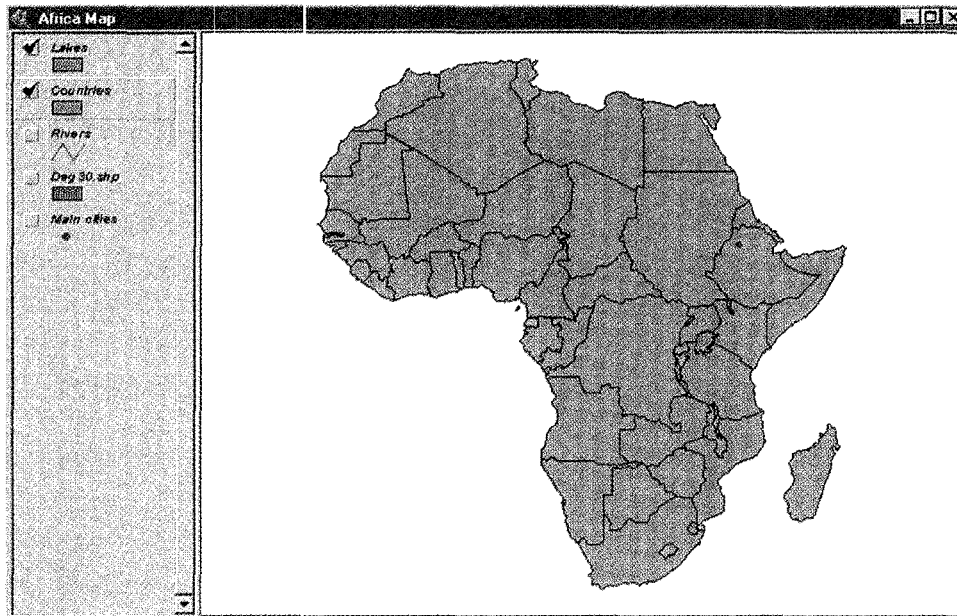
Figure 7.2. ArcView window for opening a project



To open the project, click on **ex_1.apr** in the File Name list, and then click **OK**. When the project opens you will see the Project window containing two views, named Africa Map and World Map. Double-click the view named **World Map** to open it.

The view opens with a map of the world that we will modify later in the exercise. We will now have a closer look at the African continent. First, close the World Map window by selecting **Close** from the **File** menu. From the project window, click on **Africa Map** and choose **Open**. The view opens (figure 7.3.)

Figure 7.3. Project view window



7.2.1. Theme operations

7.2.1.1. Turning themes on and off

In order to display a theme in the view dialog box you must click on its check box.



When a theme is turned on, ArcView draws it in the map display area. When a theme is turned off, ArcView does not draw the theme. Turning the theme off affects the display only, it does not delete the feature from the theme. A theme does not have to be turned on to perform operations on it.

7.2.1.2. Making a theme active

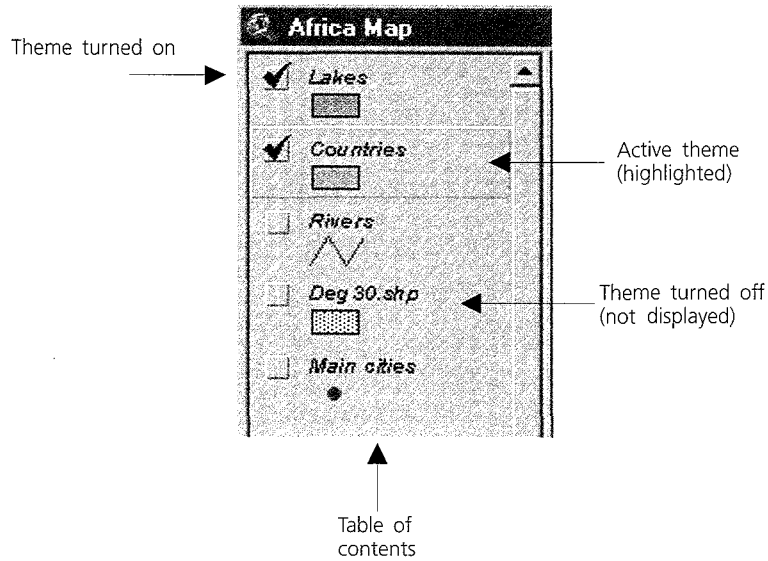
To make a theme active click on its name in the table of contents. When a theme is active, it is highlighted in the table of contents, which means that it is available to perform operations (figure 7.4). Many operations *only* work on active themes.

7.2.1.3. Display order

ArcView draws the themes sequentially from the bottom of the table of contents. To change the order in which a theme is drawn, place the cursor over the theme, hold down the mouse button and drag the theme to a new position (up or down) in the table of contents.

Notice that in figure 7.4 the Lakes and Countries themes are checked in the table of contents and are visible in the view while Deg30, rivers and main cities are not checked. Click on the check box by the Deg30 theme to turn the theme on. Then click on the check box to display the Rivers theme.

Figure 7.4. Activating a theme in the table of contents

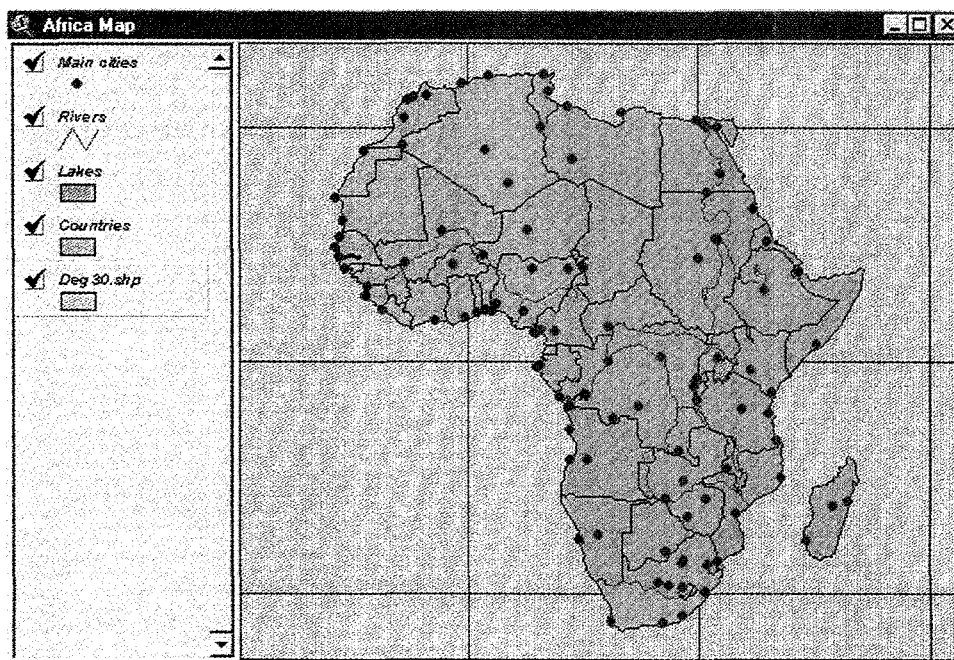


The theme is displayed in the view, but it is immediately obscured by the Lakes and Countries themes. A line or point theme must be on top of a polygon theme in the table of contents in order to be visible. In the table of contents, place the cursor on the Rivers theme. Click and drag the theme to the top of the table of contents and release the mouse button.

The display order changes and all the themes are now visible. Repeat the same procedure for the point theme representing Main cities after clicking on its check box.

Change the display order and turn the themes on and off to become familiar with the theme display. Determine the correct sequence of themes in order to see all the features.

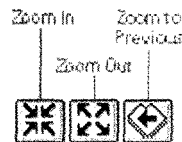
Figure 7.5. View dialogue box showing different features



7.3. Step 3: Navigation basics in the view dialogue box

ArcView provides tools to zoom in and out, while in the view dialogue box. The view toolbar has the following options:

With these **Zoom in** and **Zoom out** buttons the display is zoomed in or out by a factor of two, centered on the original display. **Zoom to Previous** allows the view to be redrawn to its previous extent.



These buttons are in the view tool bar:



The two zoom buttons on the left give more control over the extent of the zoomed area.

Click on the **Zoom In** button to make it active.



Click and drag to draw a rectangle in the view, and release the mouse button. The view redraws to the extent of the selected area.

To focus on another part of the theme, shift the view with the **Pan** tool.



Click on a point in view and drag the cursor to focus on another area. Experiment with these buttons to get familiar with the zooming options.

When you have finished, make Countries the active theme by clicking on its check box.

Click on the **Zoom to Active Theme(s)** button.



7.4. Step 4: Get information about features

Once you are familiar with the zoom and pan tools, zoom the east African region, where we will retrieve information about the features.

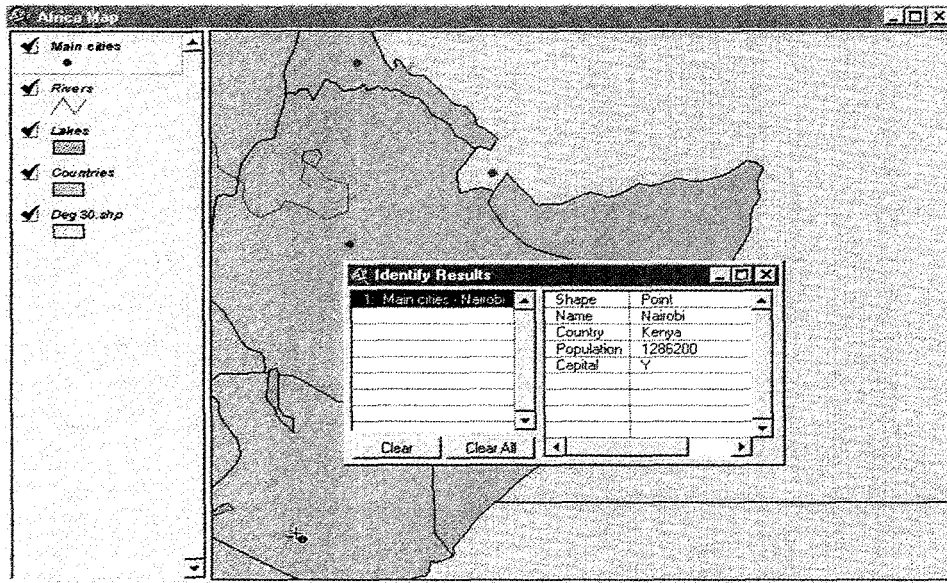
Verify that the Main cities theme is the active by clicking on its name in the table of contents.

Click the **Identify** tool.



The cursor changes to cross hairs. Click on any city to identify it. The Identify Results dialogue box appears which displays the information taken from the attribute table of the Main cities theme (figure 7.6). Click on another city to experiment further. To complete this experience, close the Identify Results window.

Figure 7.6. View dialogue box showing the attribute table



Another way to get information about features is to select them in the view and then examine their records in the theme table. When you select a feature in view, you also select the corresponding record in the Theme Attributes table. There are several ways to select features in view. One quick way is to use the **Find** button.

In the view of table of contents, click on the Countries theme to activate it. Select **Find** in the menu bar.



In the Attributes dialogue box, which is displayed in the Find Text box, type **Guinea** and click **OK**. ArcView searches for the attribute in the table and when a match is found the feature is highlighted and centered in the view.

In order to get back to east Africa, click the **Zoom to Previous** button.



Another way to select features, which allows multiple selections, is the **Select Feature** tool. Click on the button in the toolbar in order to make it active.

Put the cursor anywhere in view, then click and drag to make a rectangle. When you release the mouse button, any countries that are included wholly or partially in the rectangle will be selected in view.

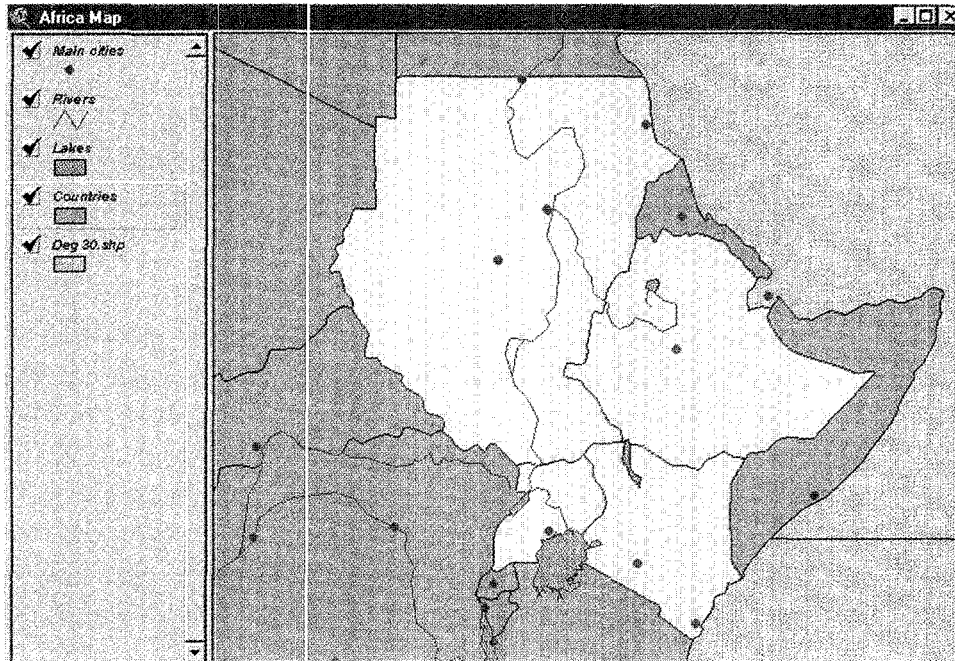


7.5. Step 5: Working with tables

Having selected certain features, it is now possible to look at their attributes. Open the attribute theme table for the Countries theme. Click the **Open Theme Table** button.



Figure 7.7. View dialogue box showing the way to select features



The Attributes of Countries theme table is displayed (figure 7.8). The records highlighted in yellow match the selected features in view. It is probably necessary to use the side scroll bar to move around the table to see all the selected records. To see all the selected records together click the **Promote** button.



The selected records move to the top of the table. The scroll bar at the bottom of the table allows you to see all the remaining fields.

Figure 7.8. Selection of attributes

Shape	Area	Perimeter	Y104	Y104.ct	Abbreviation	Pop. (est)	P. per 1000
Polygon	180,570	78,949	36	37	Zaire	CG	48548531
Polygon	309,543	67,082	143	144	Sudan	SU	32669687
Polygon	10,775	22,044	145	146	Eritrea	ER	4631752
Polygon	52,996	44,749	147	148	Ethiopia	ET	75512339
Polygon	52,121	47,524	153	154	Somalia	SO	8537248
Polygon	48,345	32,422	156	157	Kenya	KE	34482815
Polygon	19,451	19,435	157	158	Uganda	UG	24227621
Polygon	23,654	26,242	8	9	W Sahara	WI	89
Polygon	106,039	58,724	12	13	Mali	ML	11162646
Polygon	100,329	47,731	14	15	Niger	NG	10385903
Polygon	106,511	49,184	15	16	Chad	CD	7296271
Polygon	22,892	23,841	26	27	Burkina Faso	BF	11614948
Polygon	51,442	38,226	30	31	Cent Af Rep	CT	4067031
Polygon	5,652	9,409	31	32	Sierra Leone	SL	5235062
Polygon	7,411	13,640	35	36	Liberia	LI	3364399
Polygon	76,955	37,974	37	38	Tanzania	TZ	37193962

Click **Select None** in the tool bar to unselect all the selected records in the table as well as the related features in view.

Another common operation is sorting the table according to the values of a certain field.



For example, you might want to sort the countries in order of projected population, from the largest to the smallest. From the Attributes of Countries table, click on the Projected Population field name to highlight it, then click the **Sort Descending** button.



Highlight another field sort in ascending order.



Sorting works on both numerical and alphabetical fields and the result is kept only while the table is open. When you close the table the order is restored according to the internal indexing system adopted by the program. Sorting is useful for visualization purposes and does not change the original structure of the table. When you have finished experimenting, close the theme attributes table.

To see the entire map of Africa, with the view window active, click on the **Zoom to Active Theme(s)** button.

7.6. Step 6: Querying data

In Step 4, we used the **Find** button to select a feature according to its attribute value (for example, the name of a country). This approach allows you to select only one feature for each search. Another powerful tool is the **Query Builder** icon. It allows you to select more than one feature at a time based on a logical expression (logical query). Make Countries the active theme. From the toolbar, click on the **Query builder** icon.



The Query Builder dialogue window (figure 7.9) lists the fields in the theme's attribute table (countries, in this case) on the left. In the lower part of the window, you can build a logical expression by either clicking on fields, operators and values or simply by typing it in. For this exercise select all the countries according to life expectancy.

From the Fields list, double-click the Life expectancy field to enter **[Life_exp]** into the expression. From the Operators field, click ">" (greater than).

From the Values field, scroll down the list and select one of the available values by double-clicking it. As you can see, the choice is from a range of decimal figures.

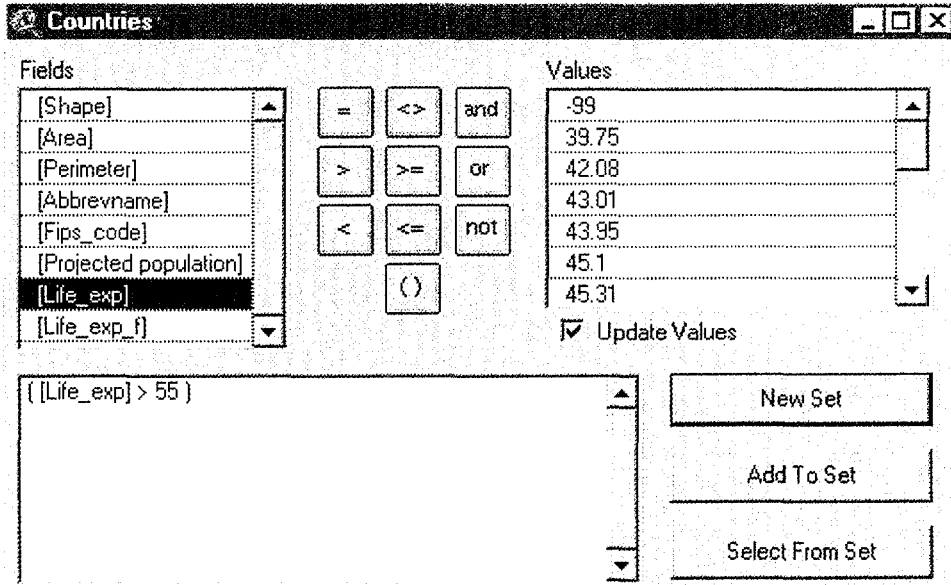
To execute the expression, click **New Set**. ArcView executes the query, and features that match the criteria are highlighted on your map. Close the dialogue window to see the results more clearly.

Repeat the selection in order to specify an integer value of your choice. For example, build a query to select all the countries with life expectancy that is greater than 55 years.

Start the Query Builder and type the following expression:

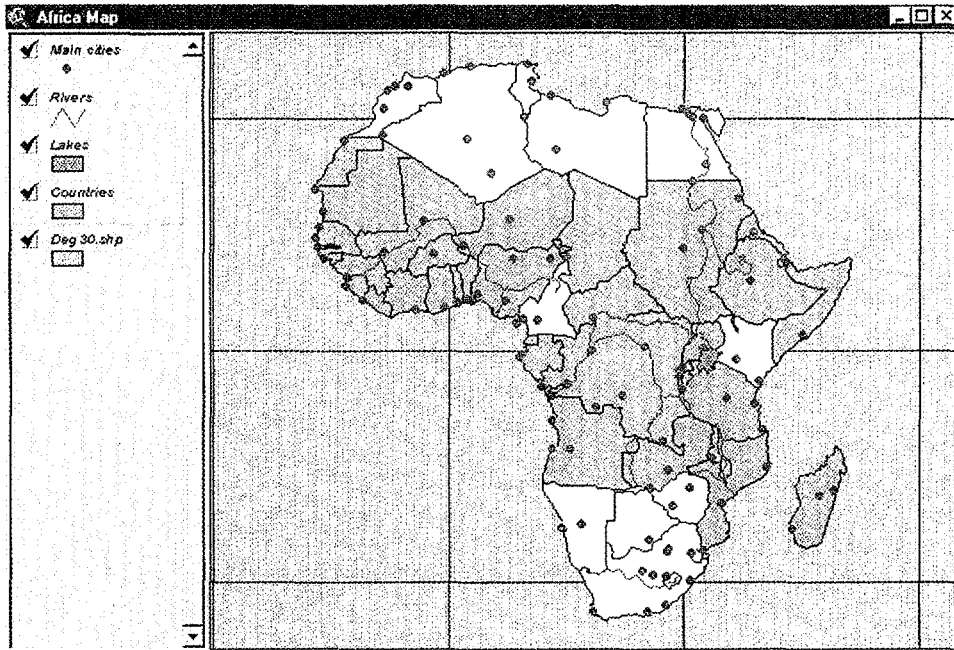
```
([Life_exp] > 55 )
```

Figure 7.9. Query builder dialogue window



To execute the expression click **New Set**. This operation unselects the previously selected features to let the query work on the whole new data set. The result is shown in figure 7.10.

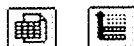
Figure 7.10. View dialogue box showing life expectancy distribution



To see the life expectancy values for each selected country, you can either use the **Identify** tool in the view and click over the countries,



or click **Open Theme Table** and use the **Promote** button.



Once you have finished, return to the Africa Map view and click **Clear Selected Features** to unselect all the features.



7.7. Step 7: Refining your query

In Step 6 you used ArcView Query Builder to select a set of features in a theme on your map. You can also use the Query Builder to refine a set of features with any of the selection methods available in ArcView. Query Builder can widen your selection and add the features specified in your query expression to an existing set of selected features (**Add to Set** option), or apply the query expression only to those features that have already been selected (**Select from Set** option). This exercise uses the latter option.

First, we will use the **Select feature** tool in the view to create a subset of features. Click on **Select Feature** button and select all the countries in the southern African region.

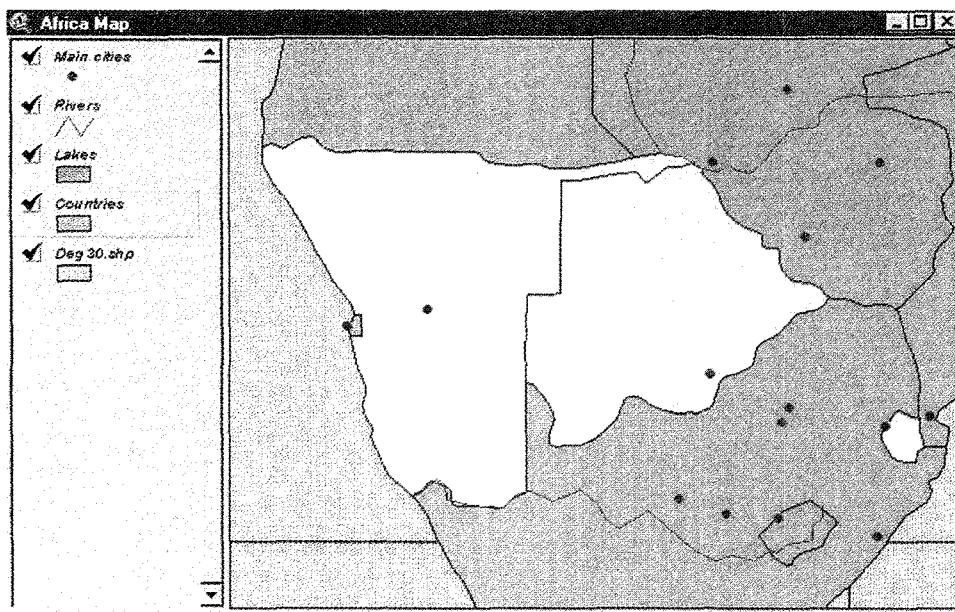


Click on the **Query Builder** button again. In the Query Builder dialogue box, build an expression selecting those countries with a projected population that is less than or equal to 2,000,000:

([Projected population] <= 2000000)

In order to apply this query only to the countries you have previously selected, click on the **Select from Set** button. In your map, only three countries will remain highlighted: Namibia, Botswana and Swaziland. To look more closely at the selected polygons, use the **Zoom In** button (figure 7.11).

Figure 7.11. Select and unselect features



Once you have finished, return to the Africa Map view and click on the **Clear Selected Features** button to unselect all the features.



7.8. Step 8: Getting data into ArcView

So far, you have worked with the view already containing the feature themes. You can add more themes to a view and save the modified project for future use. In this exercise you will add a point theme representing the major cities in the world and a line theme representing the main rivers.

First, close the Africa Map view.

Double-click on the World Map view to open it.

Click on the **Add Theme** button to add a theme to the view.



The Add Theme dialogue box is displayed. The directories appear in the scrolling list on the right and spatial data sources are in the scrolling list on the left.

Navigate to c:\icstrn\arcview\ex_1\world.

On the left side, you can see all the Feature Data Source files that are available.

Click on **Lakes.shp** to highlight it. Click **OK**.

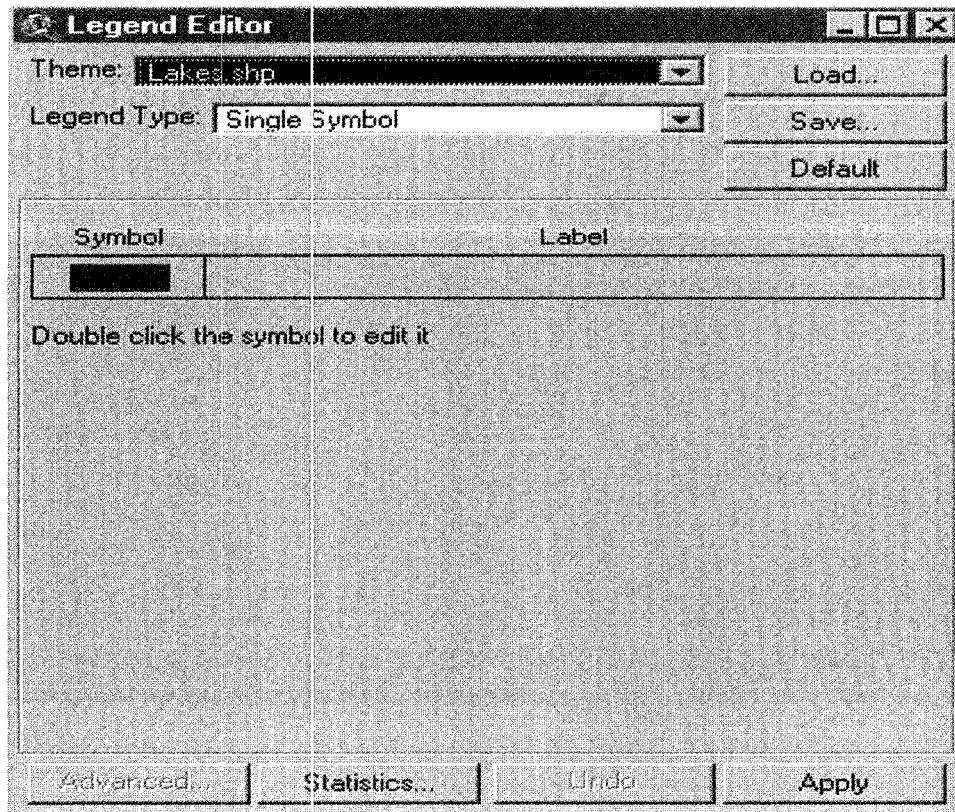
ArcView adds shapefile as a theme. In the view's table of contents, click on the **Lakes.shp** and click the check box to draw the theme.

Repeat the same steps to add two more themes.

Click the **Add Theme** button and select **Cities.shp**. Click **OK**. Then click on its check box to draw in this theme. Repeat the same procedure to add the Rivers.shp theme. Change the order of the themes to make them all visible in the view.

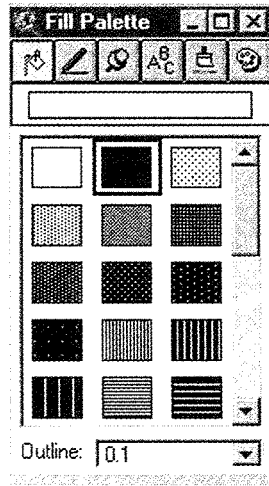
When you add a theme to a view, ArcView assigns a randomly selected colour to all features. If you want to change the default colour, you can use the Legend Editor (figure 7.12). To open the Legend Editor, double-click on the Lakes.shp theme in the Table of Contents. The Legend Editor is displayed.

Figure 7.12. Legend editor window for changing symbol properties



To change the Symbol properties for the Lakes theme, double-click on the **Symbol** rectangle. The Fill Palette is displayed. With this tool you can change the colour, fill pattern, font style, line symbol and point symbol used to represent the features in the view.

Figure 7.13. Fill palette window for changing colour palette



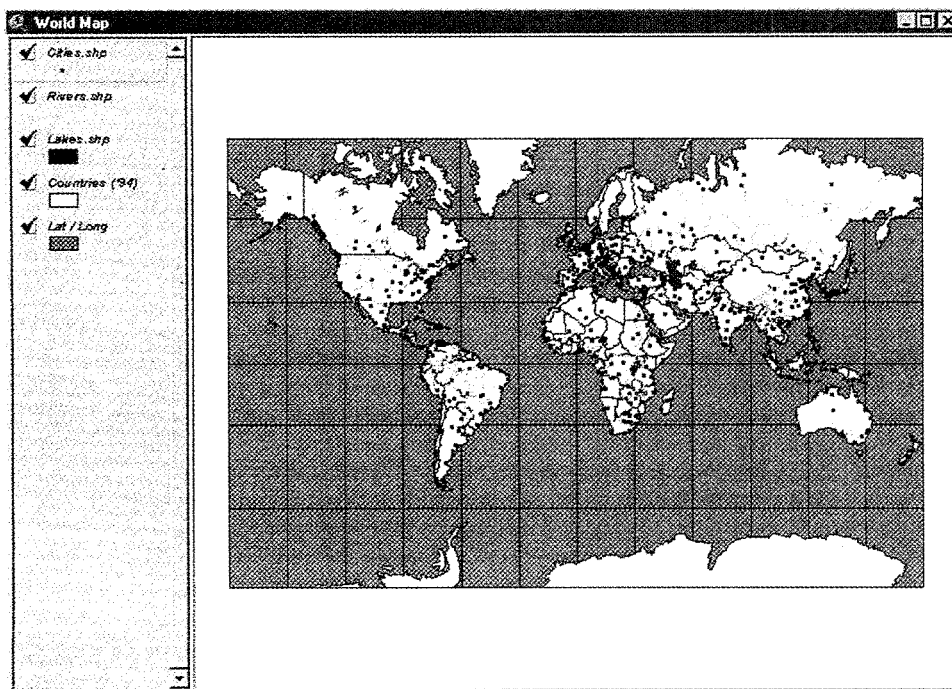
Click the **Colour Palette** button at the top of the Fill Palette box (figure 7.13) to switch to the Colour Palette.



Choose an appropriate colour to represent the Lakes in your map by clicking on the colour; close the Colour Palette. To apply your changes click **Apply** in the Legend Editor and close it. ArcView redraws the theme according to the new settings.

You can now experiment with changing the colours used to represent the Rivers and Main cities themes (figure 7.14).

Figure 7.14. View dialogue box showing the world map

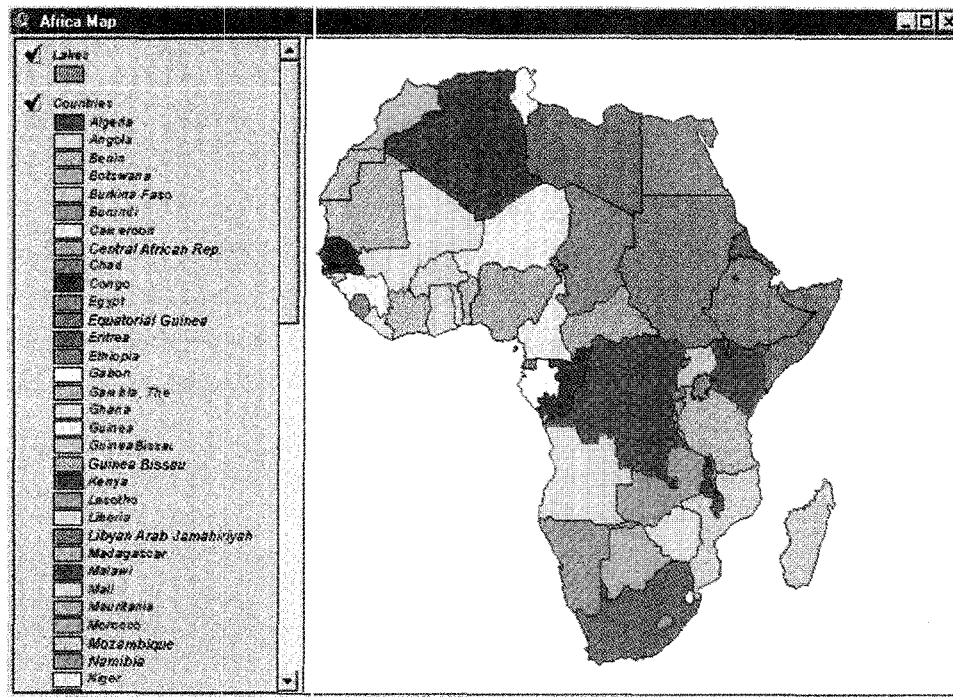


Next, we will use the Legend Editor to symbolize the African countries according to their names. Close the World Map view and open the Africa Map.

Double-click on Countries name to display the Legend Editor. From the Legend Editor click on the Legend Type field and choose **Unique value** from the available options. The Legend Editor now displays a Values Field scroll down list. Click on it and select **Name** as the field on which you want to base the classification. Click **Apply** and close the Legend Editor.

We have now classified our theme according to the unique values of a field of its attribute table (the Name field). We have also applied a colour to symbolize the result. This is just one way you can classify your features according to their values in ArcView.

Figure 7.15. View dialogue box showing the map of Africa



When you have finished, close the view and choose **File** and **Close Project**. If you want to save changes, choose **Yes** when prompted.

7.9. Exercises

7.9.1. Exercise 1: Labelling features

In the directory `c:\icstrn\arcview\ex_1`, open the `ex1_ch.apr` project from the File menu.

Make Countries the active theme.

Select a group of countries (six or seven is enough) with the **Select Features** button. (Tip: If you want to narrow or widen the selected set after the selection.) Shift-Click over the countries you want to exclude or add from the selection. Choose **Zoom In** to select.

From the menu bar, select **Theme > Auto Label** and press **OK** to accept the default settings. The selected countries are labelled by name. The font of the labels is the default size and it may be too large if we have many features to label. We can change the font size using the Font Palette (figure 7.16).

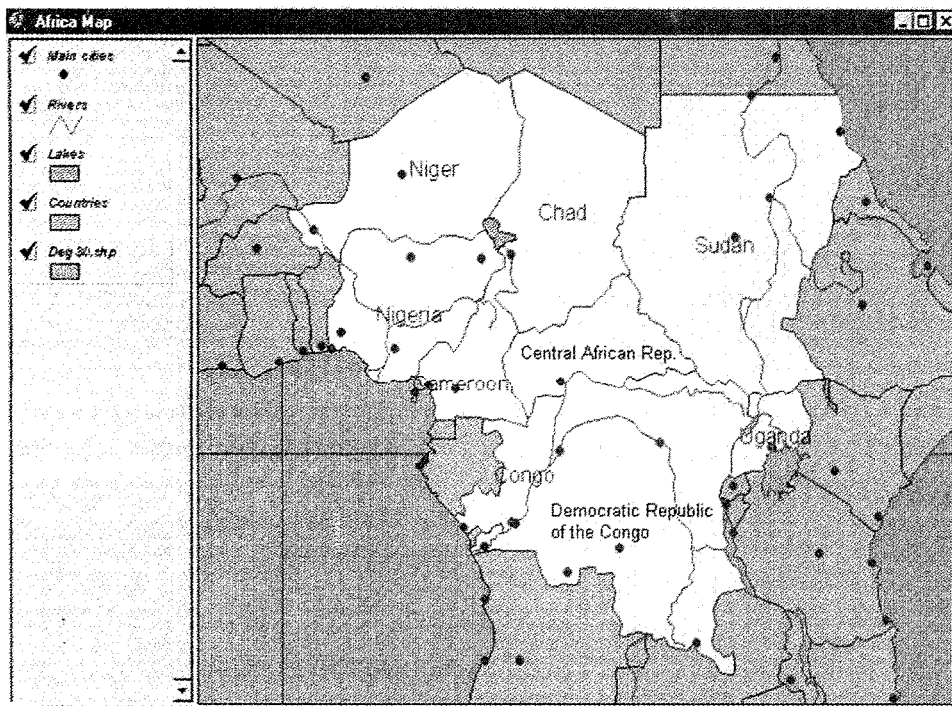
First, remove all the labels from the view by selecting **Remove Labels** from the Theme menu.

Select **Show Symbol Window** from the Window menu. In the Symbol window select **Font Palette**.



Change the font size. Close the Symbol window and repeat the **Auto Label** command.

Figure 7.16. Changing font palette from the Symbol window



7.9.2. Exercise 2: Create a chart with the selected data

Open the Countries theme table and press the **Promote** button to bring the selected fields to the top.

From the Menu, choose **Table** and then **Chart**.

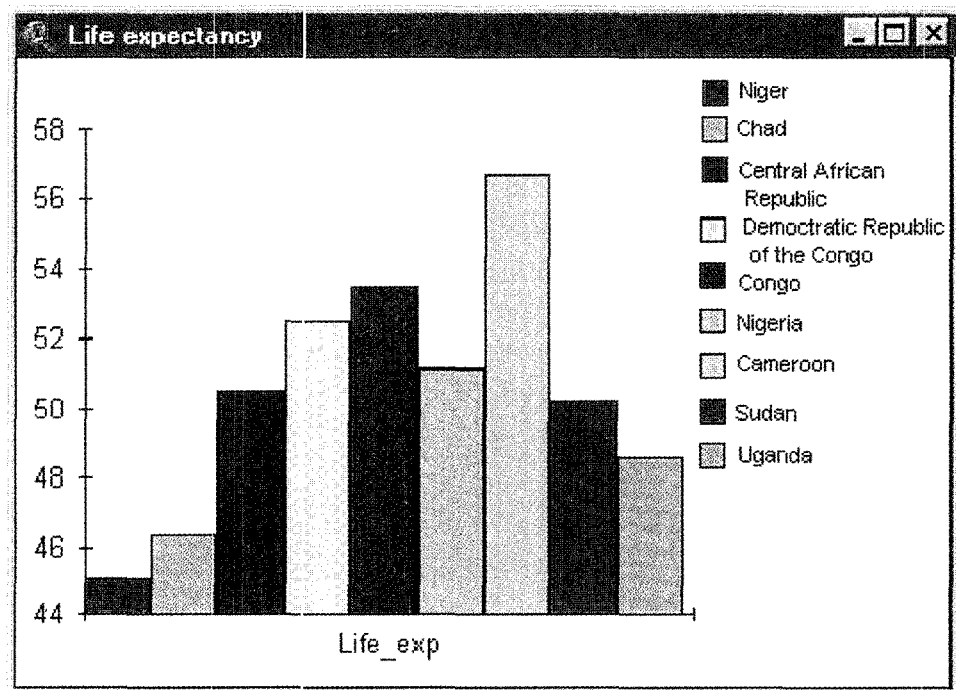
In the Chart Properties dialogue window, rename the chart **Life Expectancy**.

In the Fields list, scroll down and highlight **Life_exp** and click the **Add** button. **Life_exp** is shown in the Groups list on the right.

Under the Label series, choose the **Name** field. Click **OK**.

Move the cursor into the Chart window (figure 7.17). You will see the Identify cross-hairs symbol. Click on any bar in the chart. The corresponding field will flash in the attribute table, the polygon will flash in the view and the Identify Results window will open. Arrange the windows by moving and resizing them in order to see the highlighted field in every window.

Figure 7.17. Chart window



7.9.3. Exercise 3: Create a layout

Make the view the active window. Choose from the menu bar **View** then **Layout**.

The template manager window will pop up. Choose the Landscape default template and click **OK**.

Resize the layout window to its full extent. Every object in the view can be resized and arranged in the template. To change size and position, single-click on the object. The cursor will change to cross-hairs and four black squares will appear at the corners of the object. Click and drag in the middle of the object to change its position, or move one of the squares to modify the dimensions.

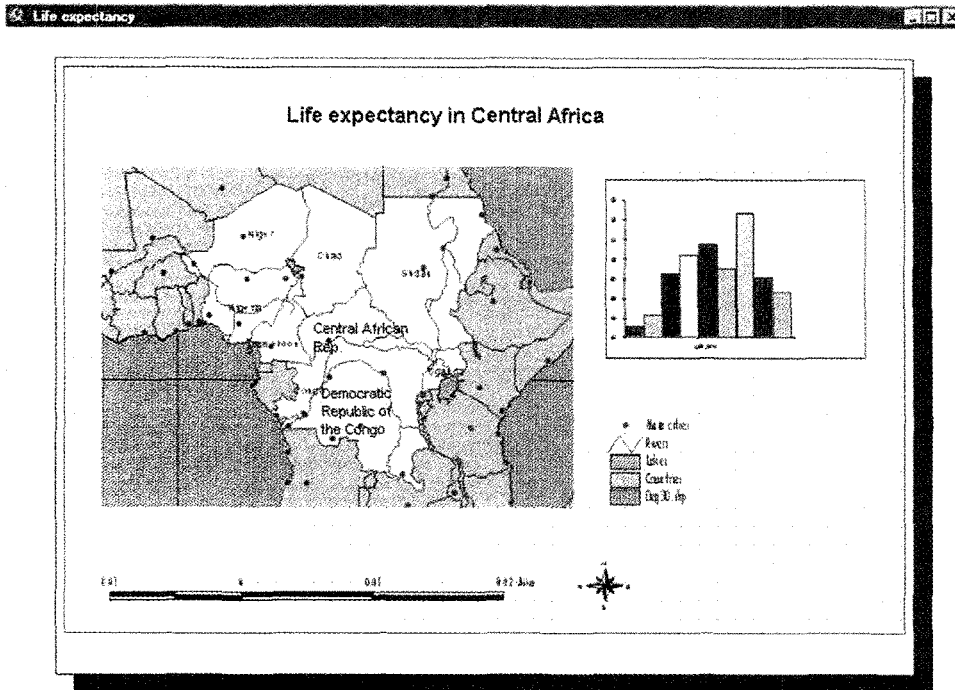
To add a chart to the layout, go to the button bar, click, and hold on the last button. In the resulting scroll down menu, choose the **Chart** icon to add a chart frame. The cursor changes to a cross. In an empty area of the layout window, click and drag the square where the chart will be displayed.

The Chart Frame Properties window is displayed. Select the chart you created in Exercise 2 and click **OK**. Notice that the Chart should be open in order to be displayed in the layout template. If you previously closed the Chart window, go to the Project window, click on **Chart** and open it again. Go back to the Layout window.

Resize and reposition the view (i.e., the north symbol, the chart and the legend) as if you were preparing this map composition for printing (see figure 7.18). Double-click on the title and change it in the Text Properties dialogue window.

You can use the zoom controls in the menu and button bar to see different display possibilities. When you have finished, select **Close Project** and save the changes.

Figure 7.18. Life expectancy in Central Africa



7.9.4. Exercise 4: Create your own project

Create a new project by selecting **File>New Project**. Save it with a name of your choice.

Create a new view and add all the available themes from the `c:\icstrn\arcview\ex_1\world` directory:

- cities
- cntry94
- lakes
- rivers
- world30

Arrange the themes in the table of contents to make them all visible. Select the colour of the themes.

Zoom in on the Mediterranean Sea area. Select all the countries that border the Mediterranean Sea and zoom to the selected features.

Build a query to select all the cities in Italy and label them. Check attributes of the selected cities in the Attribute table. Create a chart representing the population of the selected cities.

7.10. Data input and integration

GPS, which stands for Global Positioning System, is the only system today able to show you your exact position on the Earth anytime, in any weather, anywhere. GPS satellites, 24 in all, orbit at 11,000 nautical miles above the Earth and are continuously monitored by ground stations located worldwide. The satellites transmit signals that can be detected by anyone with a GPS receiver. Using the receiver, you can determine your location with great precision.

7.10.1. Step 1: Modifying the global positioning system (GPS) log file

From the Desktop, double-click on the Explorer shortcut to start this program.

Navigate to the c:\icstrn\arcview\datass folder. In the file list on the right hand side, double-click on **GPSDATA.TXT**. The text editor will show the raw data file.

Press **Enter** to insert a blank row on the first line of the file. Move up to the blank row and type:

East, north, height

Do not press **Enter** after typing this text. The beginning of the file must look like this:

```
East, North, Height
13.40404600, 45.68185850, 0.57
13.40418667, 45.68191033, 2.17
13.40433167, 45.68196133, 4.07
13.40447583, 45.68201600, 5.60
13.40461850, 45.68207450, 6.72
13.40476400, 45.68213183, 8.16
```

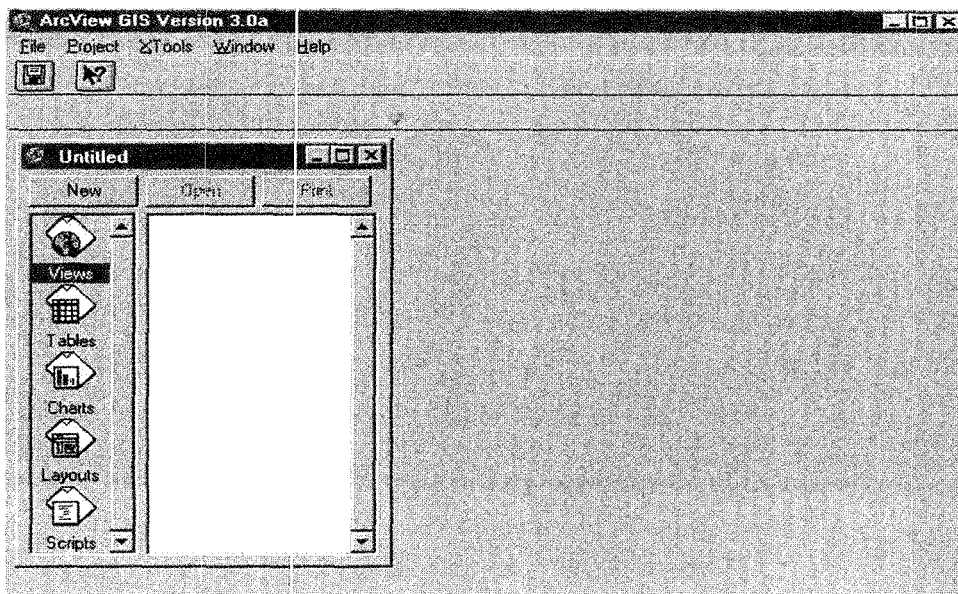
Close the window and select **YES** to save the changes. Now the Global Positioning System data can be imported into GIS.

7.10.2. Step 2: Importing data in ArcView

From the Desktop, double click on the ArcView GIS version 3.0a shortcut to start the program.

After the start-up process, you are presented with the application window that contains an untitled window, which is referred to as the Project window in ArcView (figure 7.19).

Figure 7.19. Arc View application window



First, we will add to our project the table that contains the GPS data. In the Project window select **Tables** and then click **Add**.

In the Add Table dialogue window, click on **List File** and scroll-down the menu and set it to Delimited text (*.txt).

In c:\icstrn\arcview\datass, select the file **gpsdata.txt** and click **OK**. The GPS data are imported into a new table that appears in figure 7.20.

Figure 7.20. Table dialogue box

<i>East</i>	<i>North</i>	<i>Height</i>
45.68185850	13.40404600	0.57
45.68191033	13.40418667	2.17
45.68196133	13.40433167	4.07
45.68201600	13.40447583	5.60
45.68207450	13.40461850	6.72
45.68213183	13.40476400	8.16
45.68214967	13.40494750	17.26
45.68220000	13.40510150	20.20
45.68227117	13.40523767	19.24
45.68233400	13.40538250	20.02
45.68240017	13.40552567	20.18
45.68246400	13.40567217	20.91
45.68252700	13.40582067	21.94
45.68259250	13.40596850	22.56
45.68266017	13.40611417	22.62
45.68272550	13.40625950	22.96
45.68278950	13.40640183	22.89
45.68285283	13.40654017	22.96

Notice that the field names are the ones that you just added to the raw data file. You can now close the table.

We will now create a new view with backdrop layers over which we will display our GPS data later in the exercise.

7.10.3. Step 3: Displaying Arc/Info coverage in ArcView

The layers we are going to use are derived from the Digital Chart of the World. They are stored in Arc/Info format and the information has a maximum detail of 1:1,000,000. To create a new view, first click on **View** icon in the Project window.

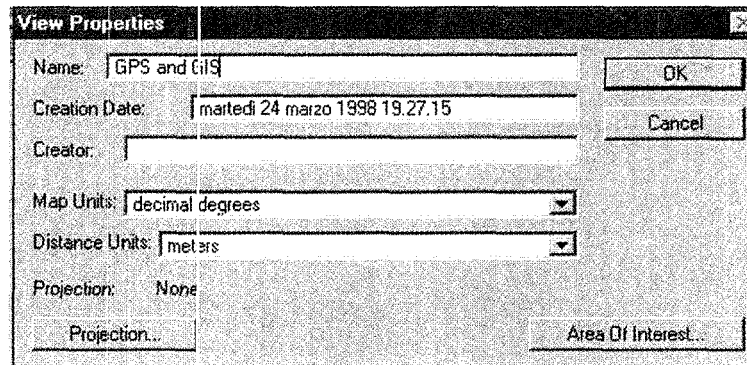
Then, click **New** and view 1 opens.

We will now change the properties of the current view before adding the themes to it. From the View menu, select **Properties** (see figure 7.21). The View Properties dialogue is displayed. Change the Name of the view to **GPS and GIS**.

Under Map Units, click the scroll-down menu and select decimal degrees; under Distance Units, ensure that meters is the defined unit.

Click **OK** to apply the settings to your view.

Figure 7.21. View properties dialogue box



We can now begin adding our themes to the view. Click the **Add Theme** button.



The Add Theme dialogue box is displayed. Directories appear in the right scrolling list and spatial data sources in the left scrolling list. In c:\icstrn\arcview\datass you can see the feature data sources that are available.

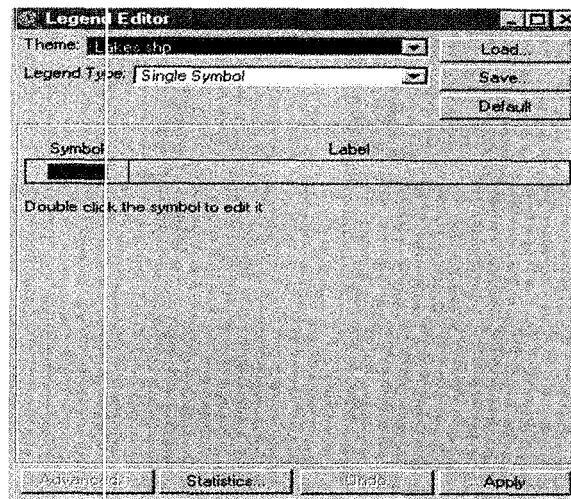
The icons on the left represent the Arc/Info coverage derived from the Digital Chart of the World. Single click over the **Hynet** icon. Three different feature types become available: polygon, arc and labelpoint. Click **Polygon** and press **OK**.

In the view, draw the theme by a Click on the following icon.



We will use a previously created legend to display this theme. Open the Legend Editor by double clicking on the **Hynet** theme from the table of contents. The Legend Editor is displayed (figure 7.22).

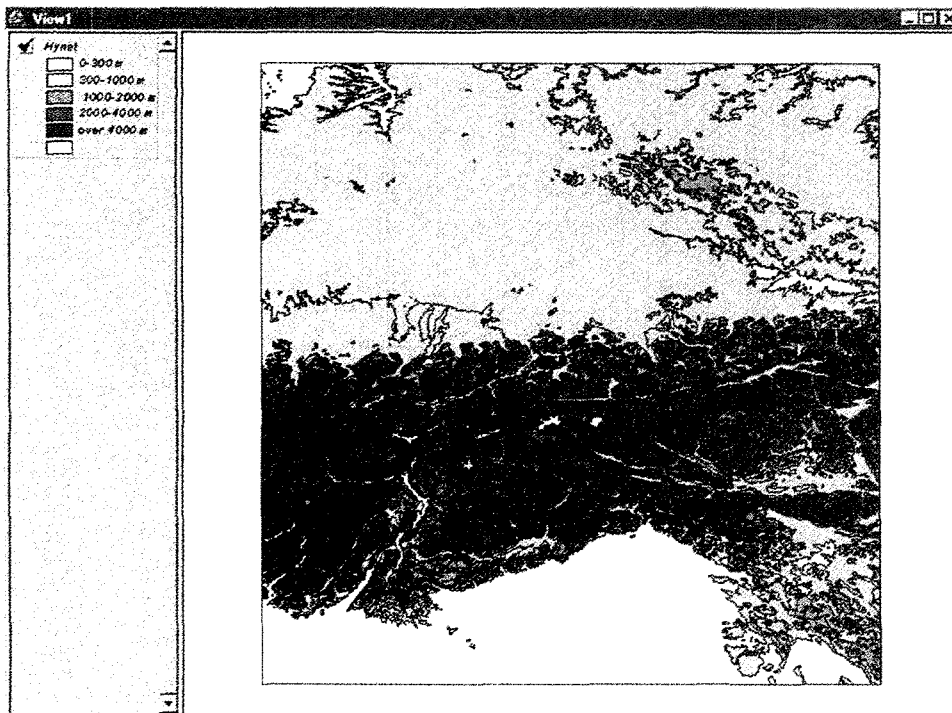
Figure 7.22. Legend editor dialogue box



Click on the **Load** button and in the Load Legend dialogue box select **hynet.avl**. Press **OK** once then **OK** again in the subsequent dialogue box.

In the Legend Editor, you now have the six classes of altitude with their labels. Click the **Apply** button and close the Legend Editor. The theme is now classified according to the altitude information in the theme attributes table (figure 7.23).

Figure 7.23. Classification of altitude according to the theme attributes table



We can now add the theme depicting the political boundaries. Click again on the **Add Theme** button.



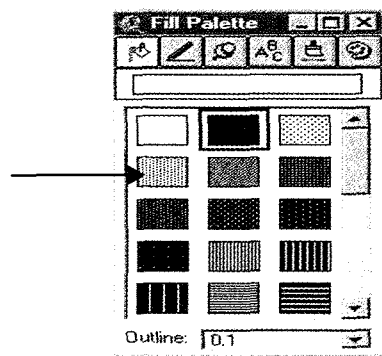
Select the **Ponet** folder. Click the **Polygon** option and press **OK**.

Draw the theme (this will hide the **Hynet** cover, but we will alter the fill properties in order to see them both). Double-click the **Ponet** theme name to launch the Legend Editor.

From the Legend Editor choose **Unique** value for Legend Type. In the **Values** field select **Popytype**, which indicates that you want the unique values contained in that field of the attributes table.

Two rectangular boxes will appear. Double-click on the first to open the Fill Palette window. Select the blank box in the upper left corner of the box (figure 7.24) to draw only the outline of this polygon. Close the Fill Palette window.

Figure 7.24. Fill Palette dialogue box



Double-click on the second rectangular symbol box. Click the **Colour Palette** button at the top of the Fill Palette to switch to the Colour Palette.



Change the colour to light blue.

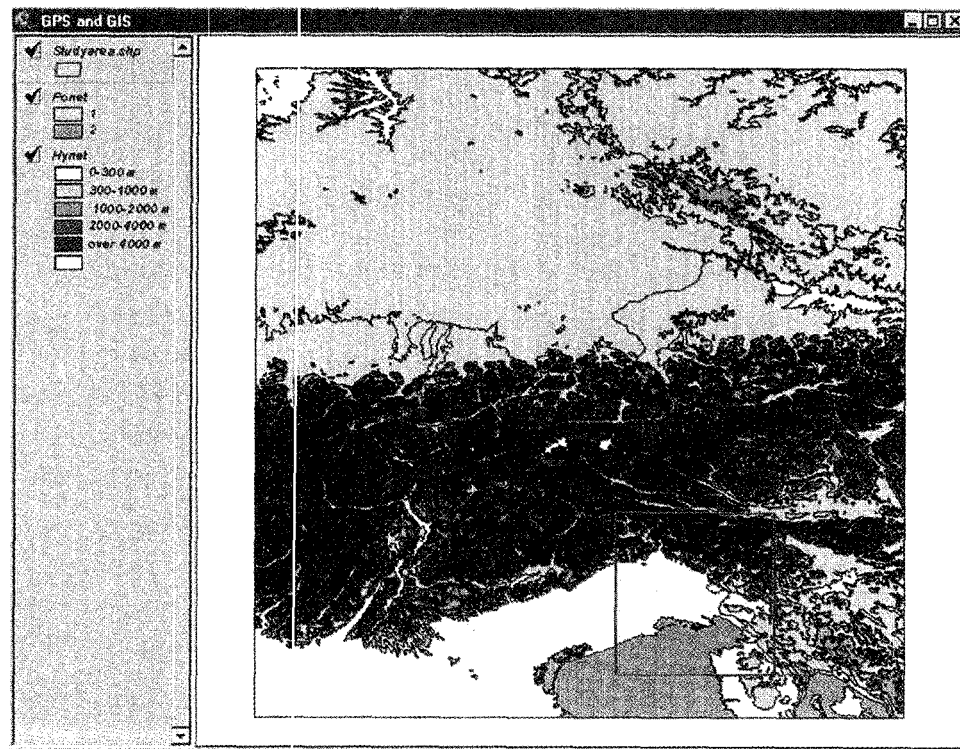
In the Legend Editor click **Apply** and close the Legend Editor. Now you can see both themes again, the blue colour represents bodies of water.

We will now add one more theme, which is a square polygon in the northern Adriatic Sea region. Add to the view the theme named **Studyarea.shp**. Display the view and start the Legend Editor.

In the Fill Palette window select the blank box to display only the outline of the polygon. Close the Fill Palette window.

Select **Apply** and close the Legend Editor.

Figure 7.25. Study area selection



Make study area the active theme by clicking on the check box. Click the **Zoom to Active Theme(s)** button.



The View is now centered in the Gulf of Trieste area. At this point, we are going to display the theme containing the main cities and the road network. Click the **Add theme** button and select the **Pppoint** folder with the point option feature type.

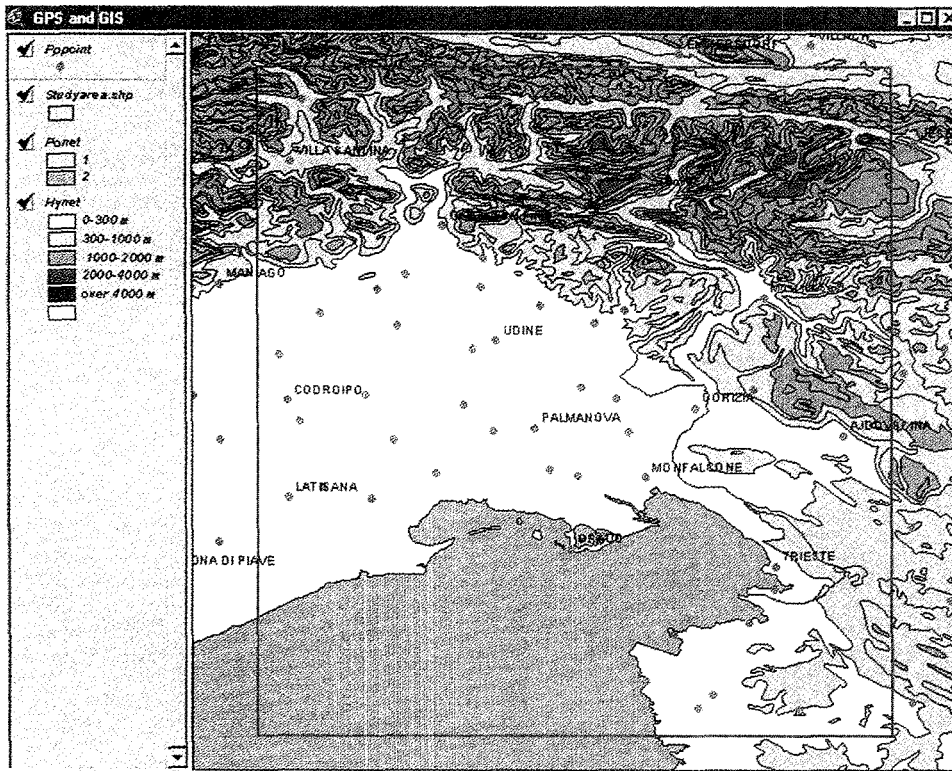
Launch the Legend Editor. Double-click on the **Symbol** and change its colour to black using the Colour Palette.

Select the **Font Palette** button and set the font size to 7.



From the Menu bar choose **Theme**. Select **Auto Label** and press **OK** to accept the default settings. This will identify cities by name.

Figure 7.26. Study area extraction



7.10.4. Step 4: Saving work in a project file

In order to save the changes made so far to this untitled project you should save it and give it a name. Click on the **Save** button.



Choose a name for your project and press **OK**.

You can save the changes made to your project file at any time. Remember, however, that when you save your project you are just creating a text file that contains the references to the spatial and attribute source data on your hard drive (or elsewhere), and the definitions of how these data have to be represented and linked for that particular project. No data duplication or modification occurs when you are saving your project file.

7.10.5. Step 5: Joining tables

In the first compact disc in the Digital Chart of the World series there is a subdirectory called Utilities\Metadata that contains attribute information concerning the coverage in ASCII text file format. In order to classify the themes according to this information we have to join the theme attributes table and the external tables. We will do this for the theme representing the road network. From the Project Window select the **Tables** icon and click **Add**. We will first add the external text file. Select **rdln.txt** and click **OK**.

The table has two fields: Rdlntype is the key field for joining the data and Type.desc is the field that carries the information about the road type. *Do not* close the table window. Select **View**.

We will now add the features for the road network. Click the **Add Theme** button and select the **Rdline** folder. Select **Arc** as the feature option this time.

Display the theme and click on its name to make it the active theme.
Click the **Open Theme Table** button to see the theme attributes table.



Figure 7.27. Attributes table

Attributes of Rdline									
Shape	Fnode	Tnode	Lpoly	Rpoly	Length	Rdline	Rdline_id	RdlnType	F
PolyLine	99	108	0	0	0.554406	127	4060	2	
PolyLine	108	109	0	0	0.031016	128	4148	2	
PolyLine	110	109	0	0	0.007960	129	4483	2	
PolyLine	108	110	0	0	0.032698	130	4140	2	
PolyLine	111	99	0	0	0.084889	131	4062	2	
PolyLine	103	111	0	0	0.086279	132	4061	2	
PolyLine	97	112	0	0	0.223186	133	3526	1	
PolyLine	112	113	0	0	0.014523	134	3359	1	
PolyLine	115	107	0	0	0.085935	135	3526	1	
PolyLine	115	107	0	0	0.080117	136	3577	2	
PolyLine	109	114	0	0	0.380971	137	4148	2	
PolyLine	116	106	0	0	0.109707	138	3020	1	
PolyLine	116	105	0	0	0.132650	139	3104	2	
PolyLine	117	83	0	0	0.780110	140	3578	2	
PolyLine	98	117	0	0	0.267757	141	3579	2	
PolyLine	118	102	0	0	0.302181	142	3018	2	
PolyLine	104	118	0	0	0.269849	143	3327	2	
PolyLine	113	119	0	0	0.024360	144	3359	2	

Figure 7.27 shows a typical Arc/Info attributes table; the first seven fields from the left carry the topological information. The fields to the right of Rdline_id are user-defined and carry attributes of the cover containing all attributes.

In order to join the two tables you first must select the key field (i.e., rdln.txt) in the source table.

Without closing any windows make **rdln.txt** the active window (be careful not to select any records in the table). Single-click on the **RdlnType** field name. The name will be highlighted.

Now make Attributes of Rdline the active window and repeat the selection of the RdlnType field name. The name is highlighted also in this table.

Now it is possible to join the two tables. Click the **Join** button.



In the Attributes of Rdline table you now also have the Type.Desc field. **Close** the Attributes table.

Notice that the two original files have not been changed, and only the parameters that define the join operation can be saved. Click on the **Save Project** button to record the join operation.

Each time you open this project, the join operation will be executed during the initialization procedure.

We can now use this information to classify the theme according to the road type. From the View, double-click on **Rdline** to launch the Legend Editor.

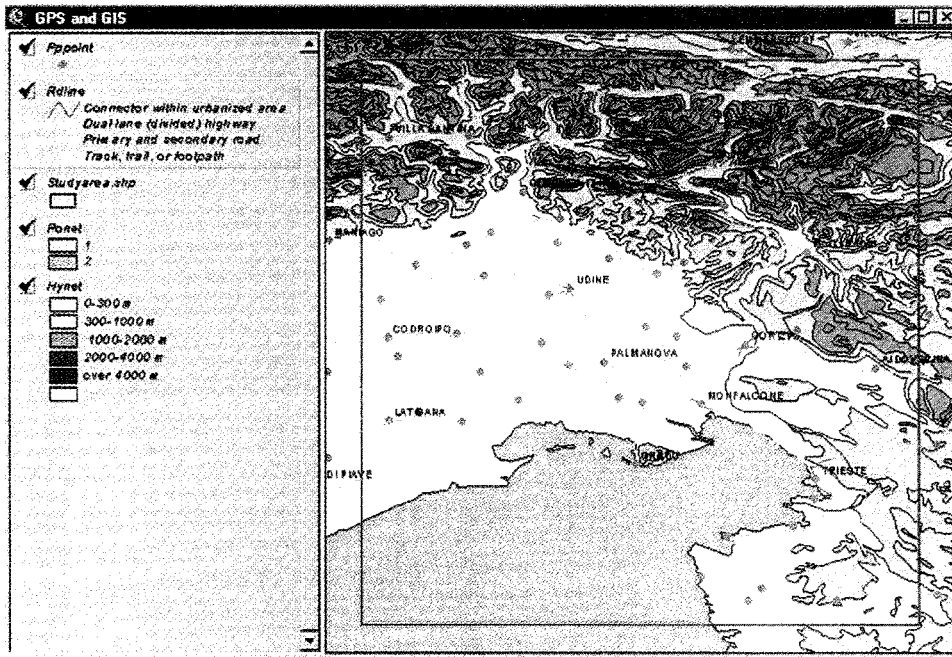
Under Legend Type, choose **Unique** value.

In the Values field, scroll down to select **Type.Desc** (which is the field we have just joined).

To change colours you may double click each symbol and change the colour using the Colour Palette, or select one of the predefined palettes in the Colour Scheme scroll-down menu.

Once you have changed the colours, click **Apply**. Close the Legend Editor and you will be able to see the classified cover (features) in the view window (figure 7.28).

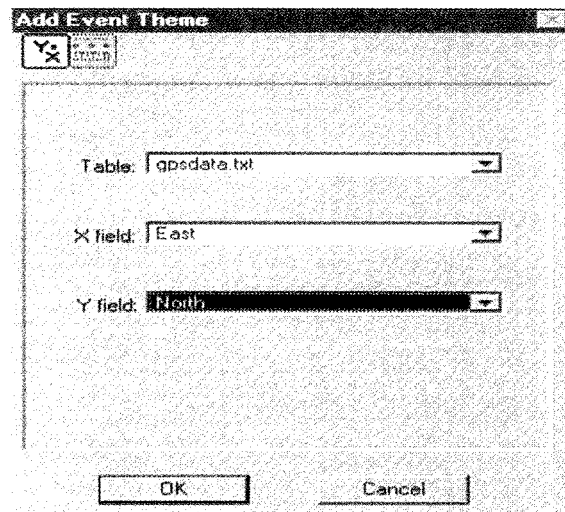
Figure 7.28. Classification of features according to the road type



7.10.6. Step 6: Creating an event theme with the GPS data

Now that the thematic background has been prepared, we want to see where the GPS points that were collected in the field survey are located on the map. With the view active, select **Add Event Theme** in the view menu.

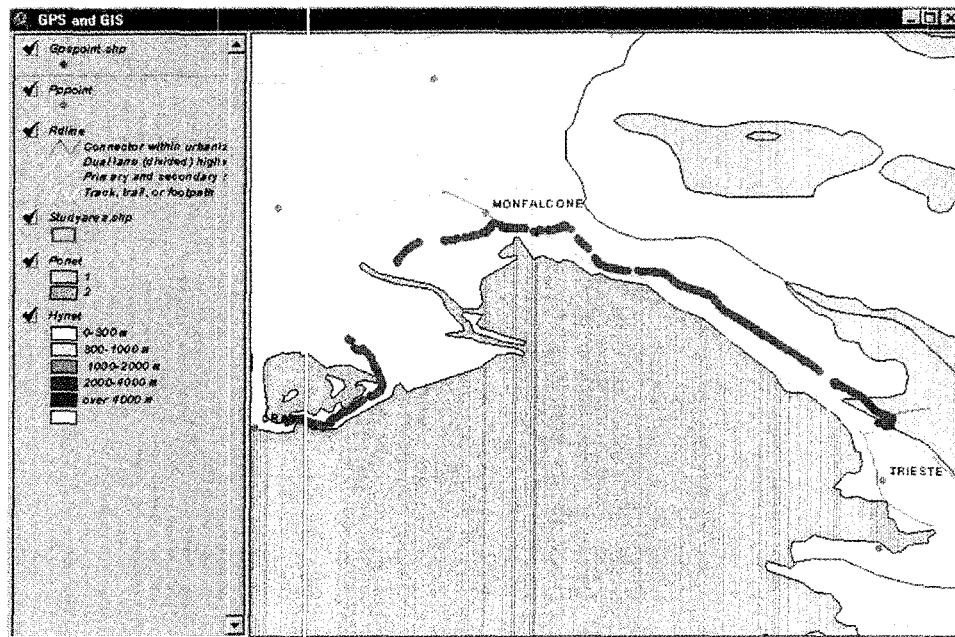
Figure 7.29. Add Event Theme dialogue box



Specify **gpsdata.txt** as the Table containing the information. Select **East** as the X field and **North** as the Y field (figure 7.29). Click **OK**.

Display the resulting theme (Gpsdata.txt) (figure 7.30). If you wish to change the colour of the points, use the Legend Editor, and then use the **Zoom to Active Theme** button to display the theme.

Figure 7.30. Displaying the resulting theme



We have not yet created a Point theme for ArcView. We have only created a representation of a series of coordinates with the height attribute. In order to make Point theme we must convert it to a Shapefile, which is the native format of information storage for ArcView.

With Gpsdata.txt the active theme, select **Convert to Shapefile** from the Theme menu.

Give it a name (e.g., GPSpoint). Click **OK** and **Accept** to add this theme to the view.

We can now remove Gpsdata.txt from our view and keep only the Shapefile theme.

Make Gpsdata.txt the active theme and select **Delete Themes** from the Edit menu. Confirm your choice.

If you want to see the height information of the points, use **Zoom In** and use **Identify** buttons to retrieve the altitude information from the attributes table.



You can now save the changes to the project.

You have successfully completed the integration of GPS and GIS data and created a project that will display your field survey information on a thematic background.

7.11. Land use destination using GPS data

In order to determine the land use destination of a study area, we will analyse the polygon theme and we will associate all GPS data of the area with other features.

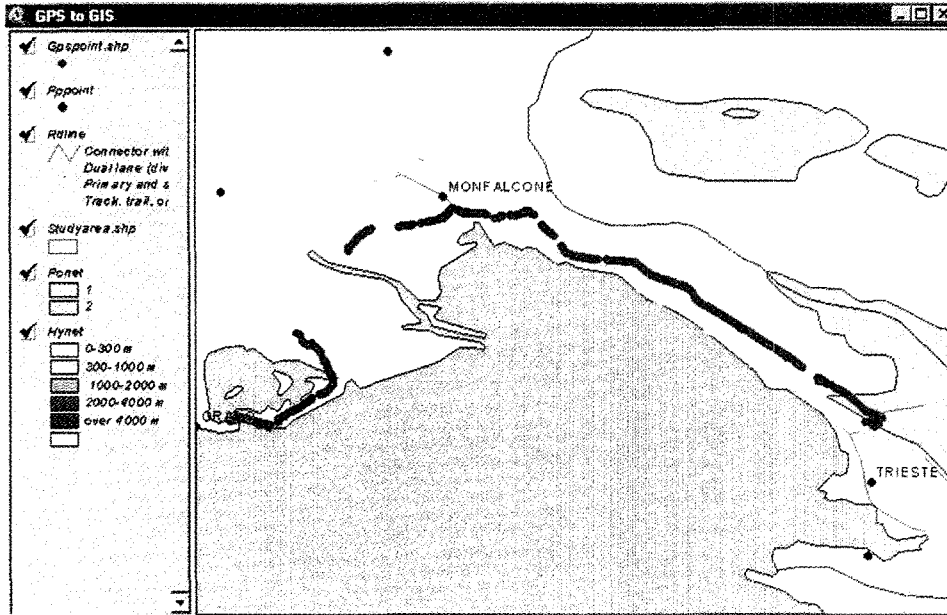
7.11.1. Step 1: Open the project and set the study area

From the Desktop, double-click on the ArcView GIS version 3.0a shortcut to start the program.

After the start-up process, navigate to the c:\icstrn\arcview\datass\land folder and open the Project named **zoning.apr**.

Open the view named **GPS to GIS** in the Project window (figure 7.31).

Figure 7.31. GPS to GIS project window



We now must add the polygon theme that we want to analyse in order to determine its land-use destination in terms of the spatial relationships with other features. Click on the **Add Theme** button to add the Landuse.shp theme to the view.



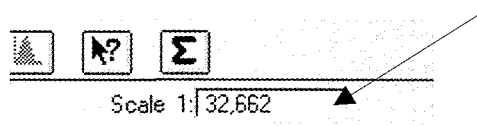
Display the theme, and make it active by clicking on its name.

Use the **Zoom to Active Theme(s)** button to zoom in on the area of interest.



The automatic zoom does not allow you to see the features around the Landuse polygon. You can use **Scale** to zoom out and see a larger area.

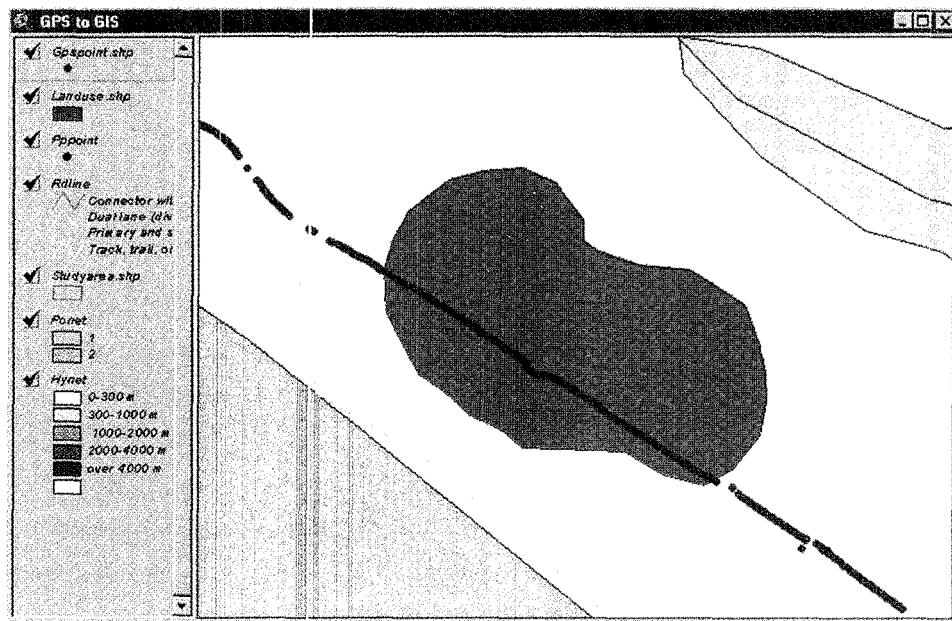
The Scale indicator is in the upper-right corner of the ArcView interface. It shows the scale of representation, which was selected earlier when we assigned view properties (to decimal degrees). To view a large area, change the value of the scale by typing **50,000** in the Scale box. The view redraws to a smaller scale.



Use the Legend Editor if you want to change the colour of the polygon.

Before starting the spatial operations, we will arrange the themes so that we can see the GPS points displayed on top of the Landuse polygon (figure 7.32). From the table of contents of the view, click on **Gpspoint** and drag it to the top.

Figure 7.32. Display of GPS points on the land use polygon



7.11.2. Step 2: Buffering the GPS points

The GPS waypoints that were collected and imported into GIS represent the route of a highway that intersects the area of interest. According to a simulated land-use planning criterion, we will propose that the portion of the area that is in a range of 200 m from the highway will be destined for general commercial district use. The remaining portion will be classified as an industrial district area.

In order to distinguish these two different areas, we will make use of the spatial analysis capabilities of ArcView. First, we will create a Buffer Polygon theme around the GPS waypoints. We will then overlay the Buffer theme and the Landuse theme and create a theme with the two different areas.

Finally we will modify the attributes table of the new theme and use the link operation to select the polygons according to their destination. We must then load the Xtools extension that will provide the spatial analysis tools that we need.

Make the Project window the active window.

Select **Extensions** from the File menu. Click the check-box next to Xtools Extension and press **OK**. The Xtools Extension is now working. Go back to the view.

First, we need to select the points to buffer. They should only include those points that fall in the Landuse theme. This selection is performed with a theme-on-theme selection.

Make gpspoint.shp the active theme. From the Theme menu choose **Select by Theme**.

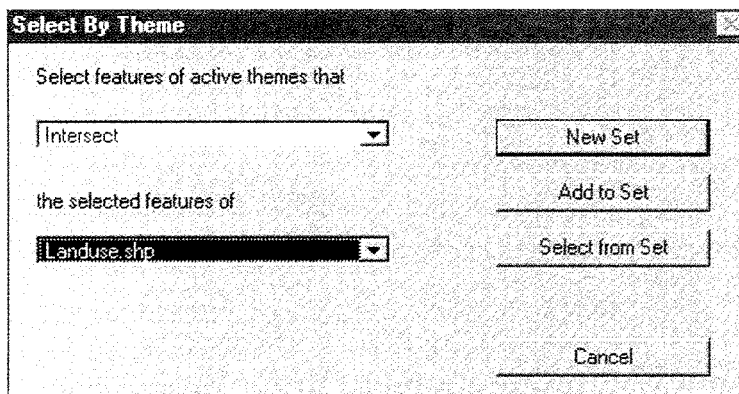
There are several types of theme selections. In this case, however, we will select only the features in the gpspoint theme that intersect with the Landuse.shp and that represent our area of interest. Use the scroll-down button to specify the correct selection option (**Intersect**) as well as the theme you are going to use for the selection (figure 7.33). Press **New Set**.

In the view you will see that only the points over the Landuse theme are highlighted in yellow. This means that they have been selected.

Now that we have the selected set, we can buffer these points.

We are now going to create a buffer of 200 m around the selected points using the Xtools Extension. From the view window, open the Xtools menu and choose **Buffer Selected Features**.

Figure 7.33. Selection of features of active theme

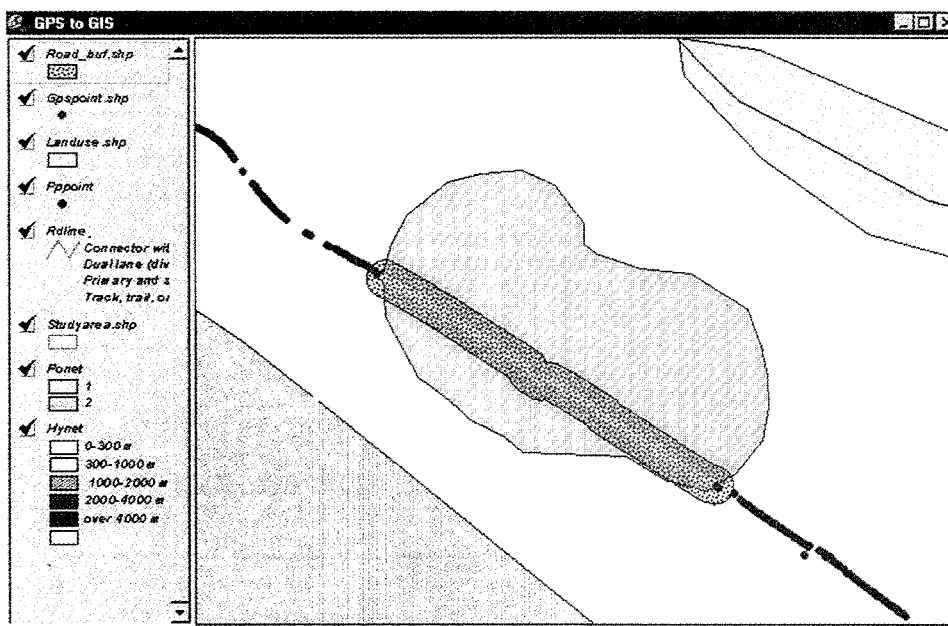


As successive dialogue windows appear, use the scroll-down lists to select the correct following options for each choice:

- | | |
|------------------|------------------------|
| Buffer units | meters |
| In theme | gpspoint.shp |
| Out theme | enter road_buf |
| Buffer input | buffer distance |
| Buffer distance | 200 |
| Output structure | contiguous |

Click in the view and then click on the **road_buf** check box to display it (figure 7.34).

Figure 7.34. Display of roads



Click **Save** button to save the changes made so far to the project.



7.11.3. Step 3: Topological overlay

You will notice in the view that the road buffer extends outside the border of the Landuse polygon. We will therefore overlay these two themes with the identity option.

The identity option creates a new theme by overlaying two sets of features. The output theme contains all of the input features and only those portions of the identity theme that overlap the input theme.

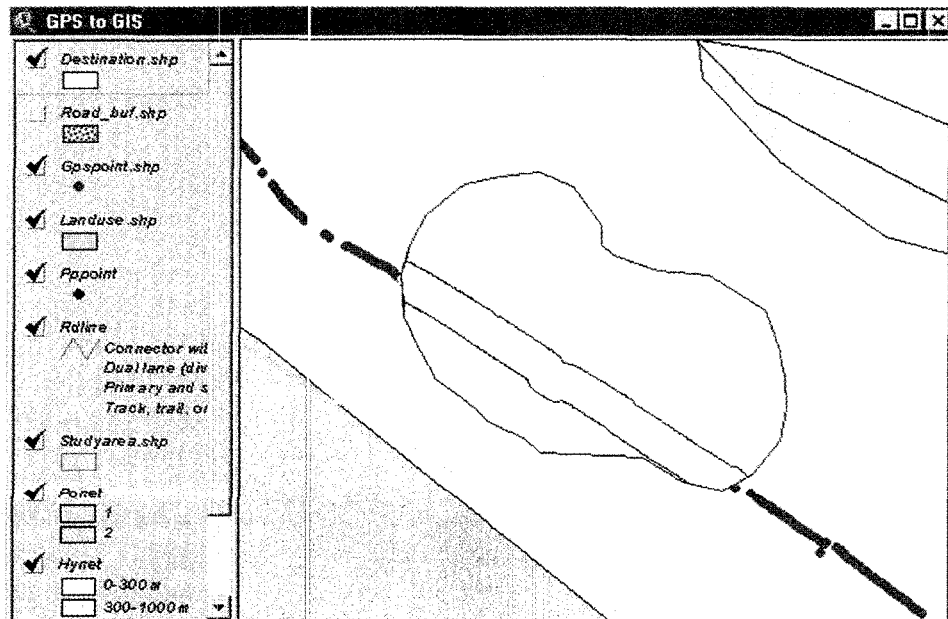
Make Landuse.shp the active theme.

In the View, choose **Identity** from the Xtools menu. As successive dialogue windows appear, use the scroll-down lists to select the following options for each choice:

Input theme	Landuse.shp
Fields for output	select Zoneid and OK
Select Identity theme	road_buf.shp
Fields for output	select Buf_id and OK
Name new theme	Destination

The overlay is performed and the theme is added to the view at the bottom of the list. Click on the new theme and drag it to the top of the list; release the mouse button to display the theme (figure 7.35).

Figure 7.35. Overlay of theme



To see the attributes table of the resulting theme, make Destination the active theme. Click on the **Open Table** button.



The second field on the left is the **ID**, which is the unique identifier of the two resulting polygons. Click on the first row and look into the view to see which of the polygons is highlighted. Repeat the same step for the second row of the table.

Use the table to determine what the correct Land_code values are for the two land use destinations. Make a note of these values as you will need them later.

The table in figure 7.36 describes the general commercial district for the area near the highway and the industrial district for the area at least 200 m away from the highway.

Figure 7.36. Table showing the correct Land_code values for the land use-destinations

<i>Land_code</i>	<i>Destination</i>
1	Administrative & Professional
2	Educational District
3	General Commercial District
4	Highway Commercial District
5	Industrial District
6	Light Industrial District
7	Multiple Family Residential District
8	Multiple Family Residential District
9	Open Land District
10	Transitional

We will now add a field to the attributes table of the Destination theme in order to store the Land_code ID. Make the attributes table of the Destination theme active. Unselect any selected record by clicking over the **Unselect** button:



Choose **Start Editing** from the Table menu. Select **Add Field** from the Edit menu. Change the name of the field to **Land_code** and press **OK**.

In the tool bar click on the **Edit** button, and then click on the blank record in the Land_code field.



Using the table in figure 7.36, type in the Land_code that you noted previously and press **Enter**. Type in the code for the second record and press **Enter**.

Choose **Stop Editing** from the Table menu and save the changes.

7.11.4. Step 4: Linking tables

We will now link the theme's attribute table with an external table that describes the land-use destinations.

In the external table file, add the description of the land-use destination follow the same steps used to assign the Land_code identifier.

From the Project window select the **Tables** icon and click **Add**.

Browse to find c:\icstrn\arcview\datass\land

Select **landcode.dbf** and click **OK**.

The table has two fields. The Land_code field is the essential field for linking the data and Destination. This field carries the information about the road type. *Do not* close the Table window. Click on the view.

Make Destination the active theme. Click on the **Open Theme Table** button to view the theme attributes table.



In order to link the two tables you first must select the key field in the source table (i.e., landcode.dbf). Without closing any windows, make landcode.dbf the active window (be careful not to select any records in the table).

Single-click on the Land_code field name. The name should be highlighted.

Make Attributes of Destination the active window and repeat the selection of the Land_code field name. The name is also highlighted in this table.

It is now possible to link the two tables. From the Table menu select **Link**. Click on the **Save Project** button to record the link.

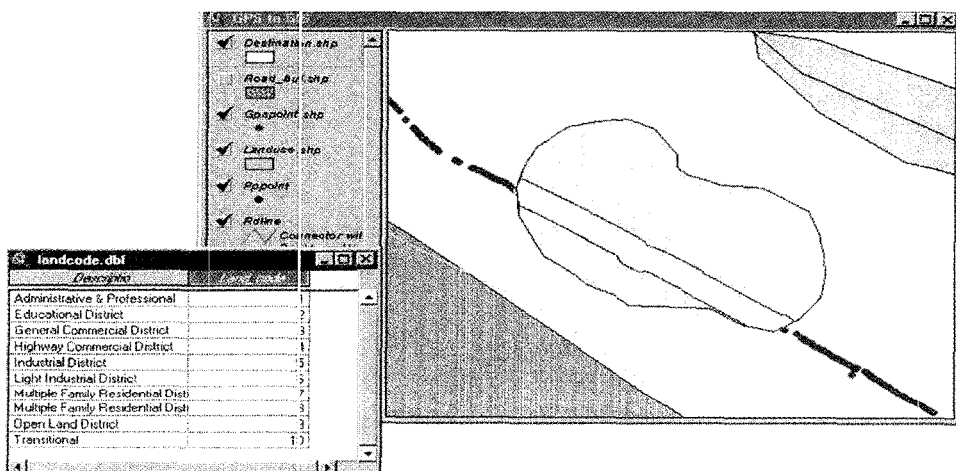
Now that the tables are linked you can use the **Select Feature** button in the view to highlight one of the Destination polygons (figure 7.37).



Select Feature icon

This will select the corresponding records in both the attributes table and in the landcov.dbf table.

Figure 7.37. Highlighting one of the destination polygons using linked table



7.12. Georeferencing raster images

Satellite imagery that has been georeferenced can be purchased, but you should consider georeferencing it yourself, for these reasons:

- Better results can be achieved in reducing the positional error of an application;
- The image georegistration, through resampling, transforms the original image and introduces spatial distortion. This entails performing an additional operation after the spectral transformations (Principal Component Analysis, indices) and classifications have been executed.

An image can be registered without coordinates if the coordinates of certain features are correct and if they can be identified on your map as well as on the following:

- A paper map
- The ground, using traditional methods or a global positioning system
- A digital vector map
- An image that has already been georeferenced

IDRISI creates a correspondence file (a simple ASCII file) for georeference operations that has the following structure:

```
npoints
Xunref      Yunref      Xref  Yref
Xunref1     Yunref1     Xref1 Yref1
Xunref2     Yunref2     Xref2 Yref2
Xunref3     Yunref3     Xref3 Yref3
...
```

Xunref and Yunref are the false coordinates of a feature in the image to be georeferenced. Xref and Yref are the coordinates of the features in the real world, and npoints represents the number of correspondence points. IDRISI uses an equation to register and transforms the image into a new one. The following steps explain this operation.

Start IDRISI from the Desktop. The graphical user interface is displayed.

From the environment menu choose ENVIRON. Change the path of working data directory to c:\icstrn\idrisi\georef and select **OK**.

From the Display menu, select **Display Preferences** and check that the option to display the output of analytical modules is set to "on". Double-click the quantitative palette input box. Select **Complig** and click **OK**. Do the same for the qualitative palette and for the default palette. This will provide the results or images of any modules that are displayed with a colour composite scale palette unless another palette is specified. If necessary, unselect both the Use Extended Cursor Inquiry and the Show Legend. Close the Display Preferences window.

From the Display menu choose **Display Launcher** or click on in the toolbar. The map composition launcher dialogue is displayed.



Select **tar4** to be displayed with the grey256 palette, autoscaling and an expansion factor of 1. This display is a near-infrared band, produced from a set of images of a mountain area about 150 km north of Trieste (figure 7.38). Click **OK**.

Now run **Describe** from the File menu.

Select **tar4** from the list. You will see the image specifications (figure 7.39). It has 301 columns, 301 rows and no coordinate system is specified. The minimum and maximum x and y values have been typed during an import procedure and for convenience have been given according to the number of rows and columns.

Close the Describe window.

Move the mouse on to the image and look at the coordinates displayed in the status bar. Columns (c) and X coordinates (x) match; however the rows (r) and Y coordinates (y) do not. This occurs because the origin of the rows and the columns is displayed in the upper left-hand corner while the origin of the x, y reference system is in the lower right-hand corner.

Now try to identify these features. Since the image is not that clear (figure 7.40), enhance it by creating a colour composite called tar234 with tarR2, tar3, tar4 and with a percent saturation of 2.5 (**DISPLAY, COMPOSIT**). (See figure 7.41.)

Figure 7.38. Landsat Thematic Mapper (Band 4)

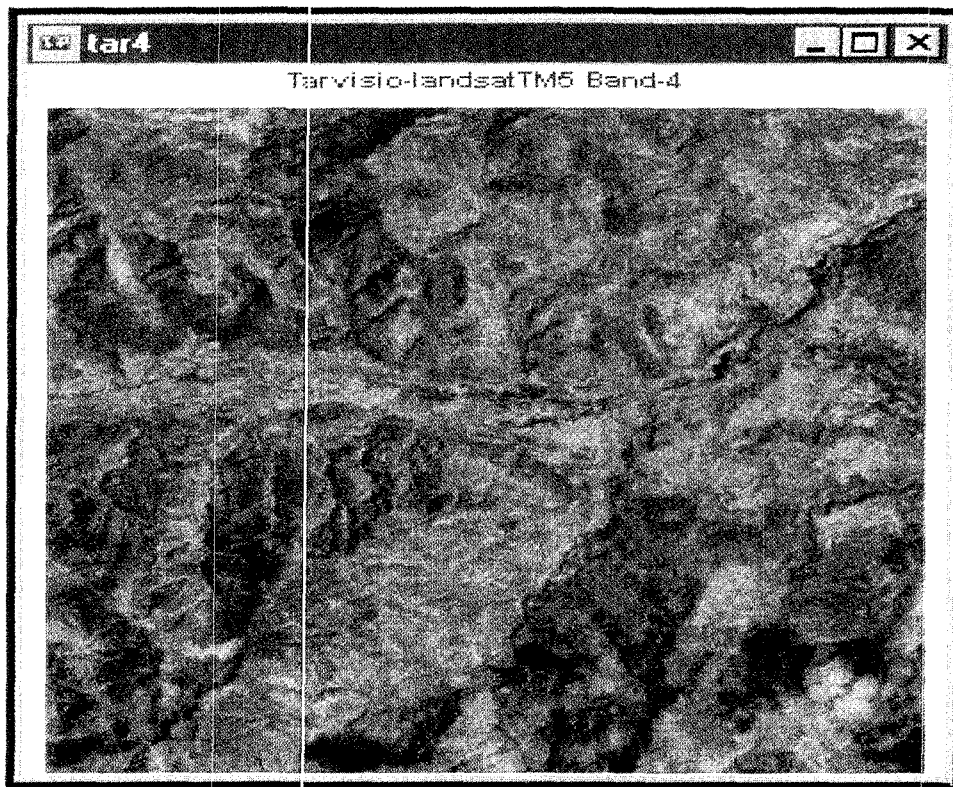
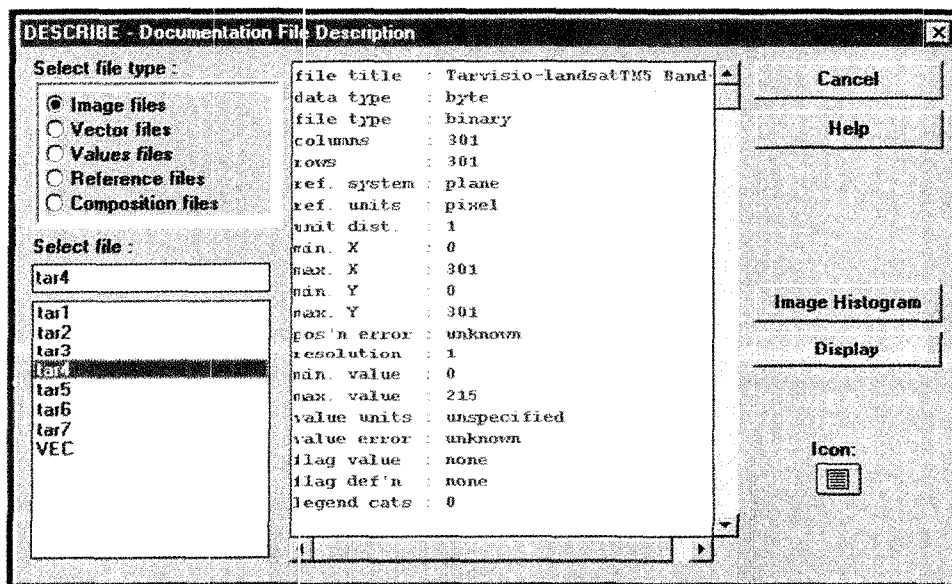


Figure 7.39. Documentation file description



Close tar4.

Start the **Display Launcher** from the Display menu and select **Vector** as the type of file to be displayed. Select **RIVERS** for both the input and palette files. Check the scale bar box, check the north arrow box and the grid box. Another window will be displayed. In the increment X and increment y input boxes type **1000** to have a grid spacing of 1 km on the vector map that you are going to display (figure 7.42). Click **OK**. Click **OK** on the Display Launcher window. You will have to wait for the map to be displayed.

Figure 7.40. Image enhancement

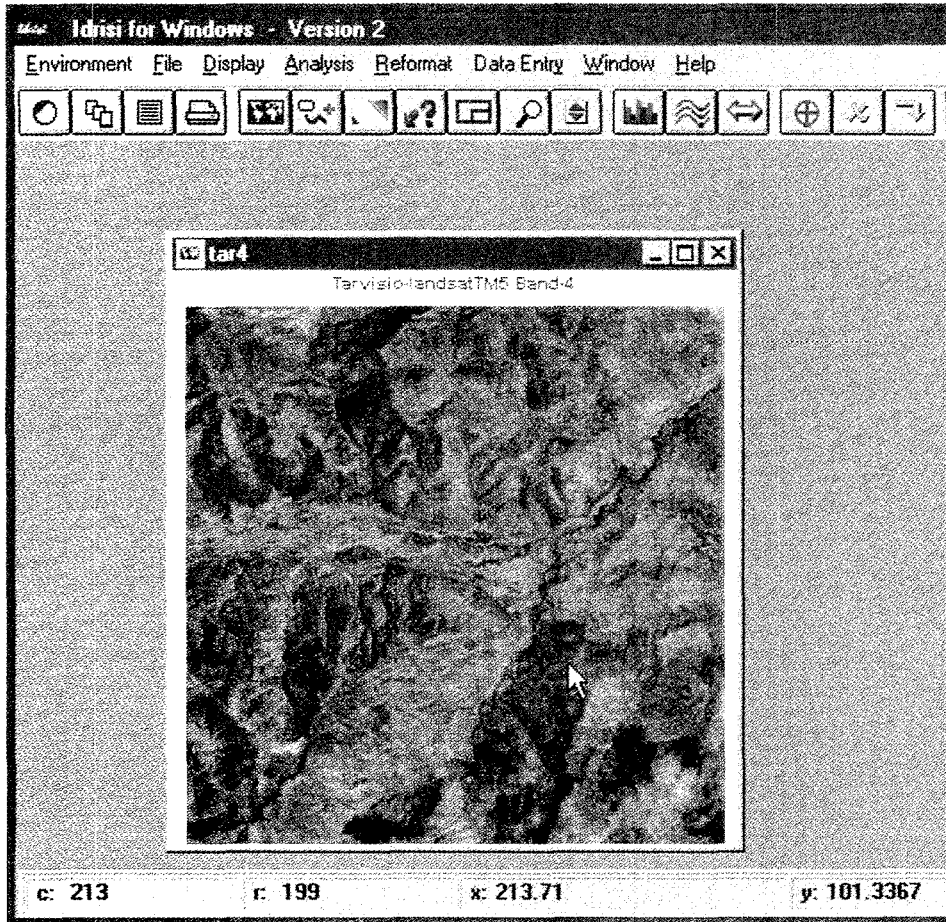


Figure 7.41. Landsat TM image (composite bands 234)

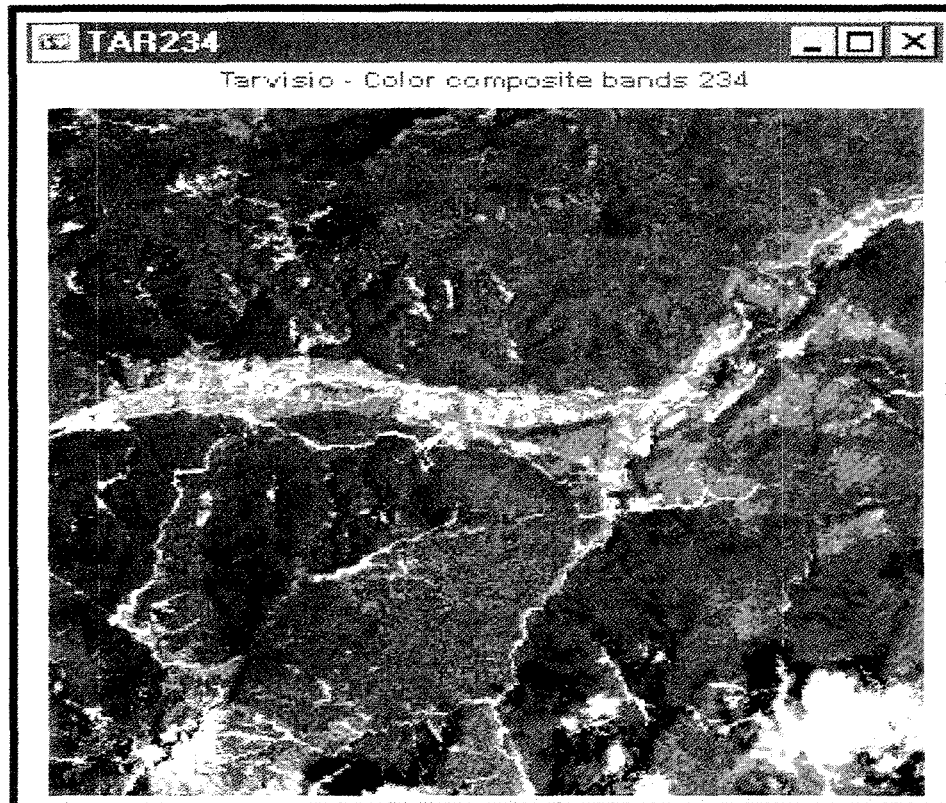
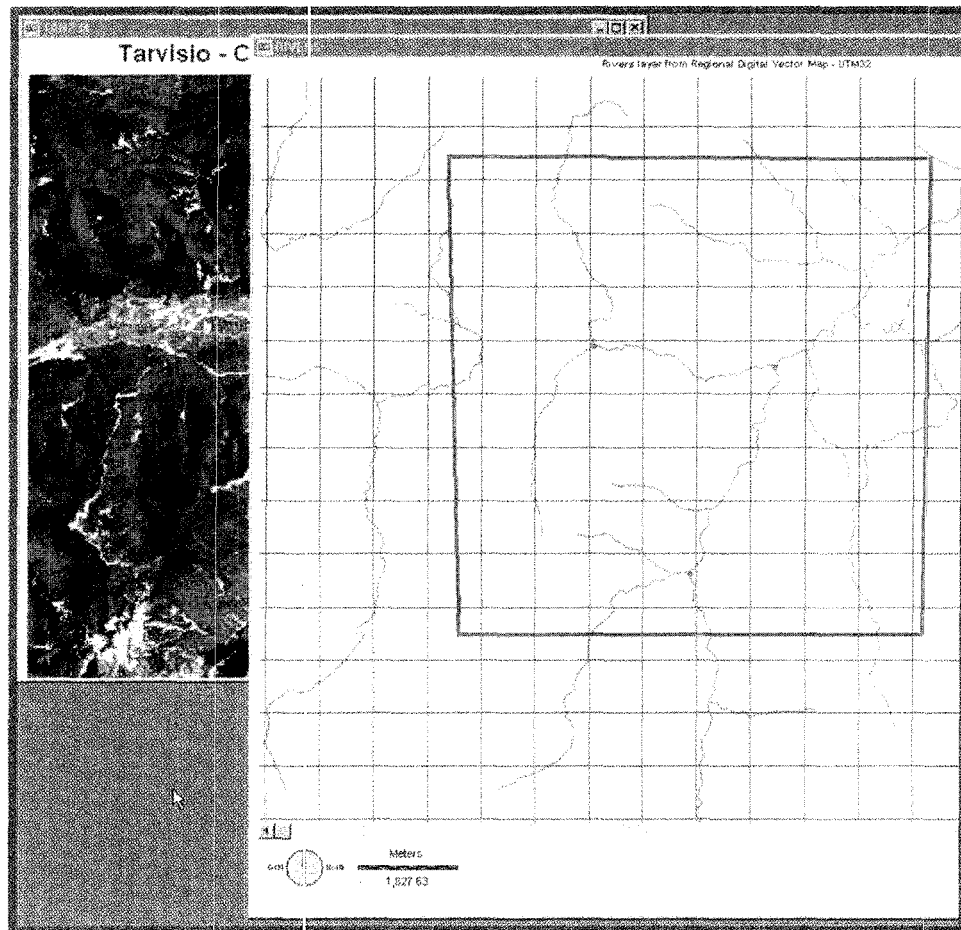


Figure 7.42. Identification of the watershed



In order to georegister the map, you should find the points that are common to the image (TAR234) and to the digital map of the rivers projected in UTM-32 that you have just displayed. As we have a digital layer of rivers, we can use river intersections as control points.

Focus on the Rivers map. Select **Add Layer** in the Composer window.

In the Input box, double-click and select **AREA**. In the Symbol File Input box, select **AREA** again. Click **OK**. Image TAR234 shows the rivers and approximates our study area (see figure 7.41).

Create a correspondence file using DATA ENTRY/EDIT or clicking on the



From the ASCII file text editor window, select the Correspondence file as the file type to be edited.

Select **CORRES** in the right-hand window and click **OK**. You will see the file structure as previously described. A number of ground control points (four, as specified in the first row) have been inserted.

Identify the river intersections in both the image and the rivers maps. Add points to the Correspondence file by clicking inside the window and typing (as if typing in a common text editor).

If you are not successful, try the operation again. Without closing the text editor, focus on the rivers map and select **Add Layer** in the Composer window. Try to find good points for the image registration.

In the Input box double-click and select **REFER**. Accept all defaults and click **OK**. You will see a set of three points corresponding to the three river intersections that are also visible in the TAR234 image. These are additional points to add to include in the correspondence file.

There are two ways to improve your view of the TAR234:

- Click once on the **Zoom** button and once on a point in the image to magnify by a factor of 2. To go back, click again on the **Zoom** button on the tool bar and then click on the image with the right mouse button,



or,

- Click once on the **Window** button on the tool bar and draw a window around the point to be magnified. To restore to the original size, click the **Window** button again and click on the image with the right mouse button.

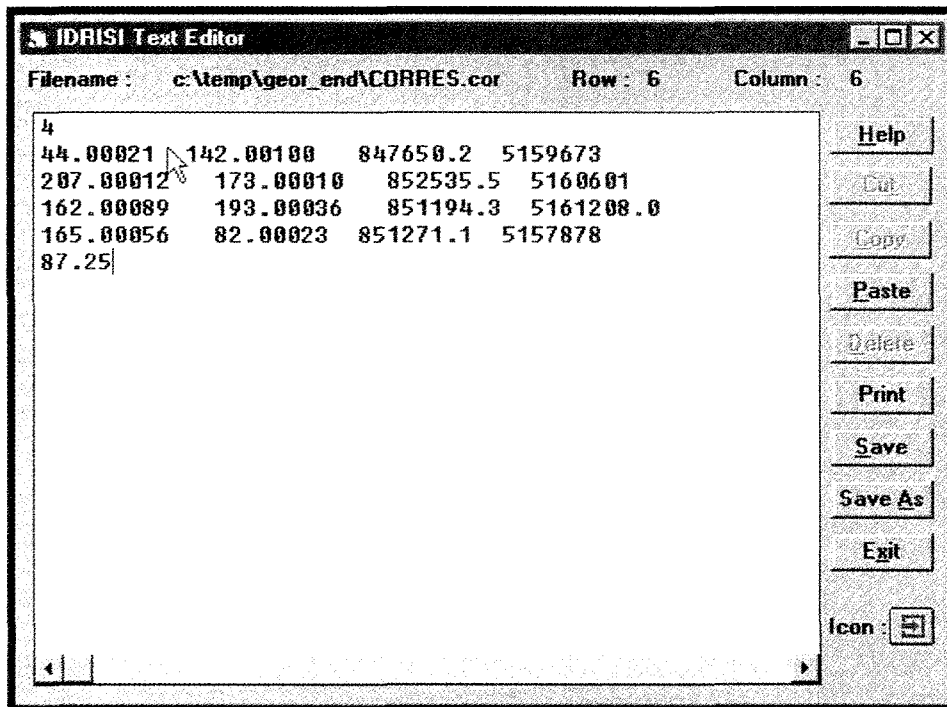


It is difficult to determine a precise position for river intersections in the TM234 image because of the coarse cell resolution (there is a 30 metre resolution of the ground details on pictures received from the Landsat satellite). As can be seen, resampling is a very time-consuming and exacting task.

Identify the river intersections (points) on the TM234 image. For each of the river intersections, do the following and note the results on a piece of paper:

- Focus on TAR234 and record the *x* and *y* coordinates that you can read in the status bar;
- Focus on RIVERS and record the corresponding *x* and *y* coordinates that you can read in the status bar (e.g., X_TAR234, Y_TAR234, X_RIVERS, Y_RIVERS).

Figure 7.43. IDRISI text editor window

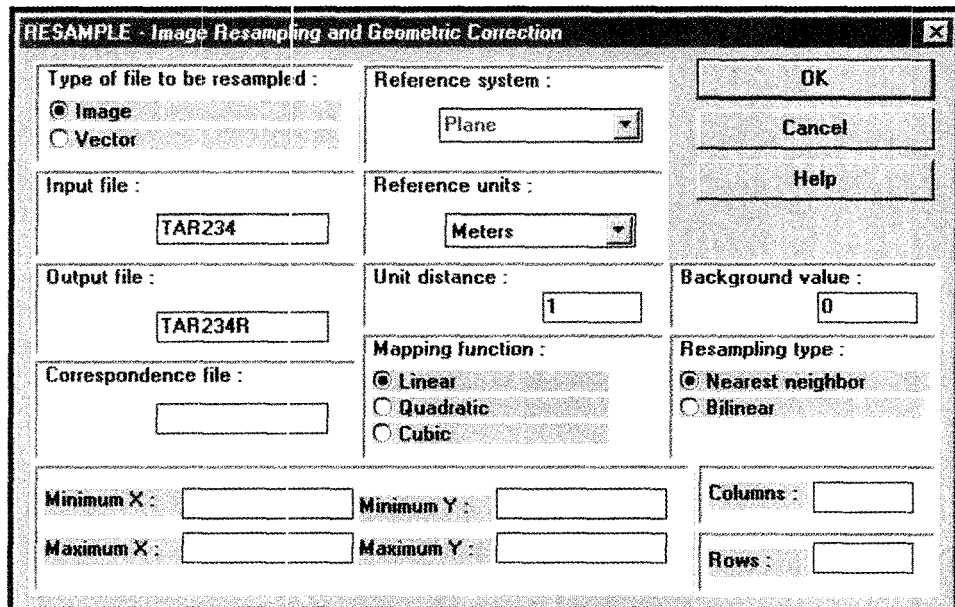


Once you have done this, go back to the IDRISI text editor window (figure 7.43) and start modifying the correspondence file by adding 3 rows with *xold*, *yold*, *xnew*, *ynew* (each of the 3 new points should be separated by the TAB key). In the first row change the total number of control points from 4 to 7.

Click **Save** and **Close** the Text Editor window.

You now must resample the image according to your control points. From the REFORMAT menu start RESAMPLE.

Figure 7.44. Image resampling and geometric correction



Select TAR234 as the input file, type **TAR234R** in the output file input box (figure 7.44).

In the Correspondence file input box select or type **CORRES**, which is the control points file you have just finished editing.

Since you need other information (i.e., the minimum and maximum x and y for the new resampled image and the new reference system) select **DESCRIBE** from the File menu to read the documentation about the files. Select Vector files as the file type (figure 7.45).

From the Select file list, choose **AREA** which is the vector file delimiting the study area (figure 7.45). Review the descriptions in the window:

- Record the reference system and the reference units;
- Record min X, max X, min Y, max Y.

Select **Cancel**. In the Resample window (figure 7.46) select the reference system, the reference units and type in the values for min X, max X, min Y, max Y.

In both columns and rows type **300**. Using the calculator on the Windows desktop, calculate whether the cell resolution is 30 m (the resolution of Landsat images) in both x and y directions by dividing $(x_{max} - x_{min})/300$ and $(y_{max} - y_{min})/300$.

Accept all defaults and click **OK** in the Resample window. You will see the Resample window with the global residual positional error (the RMS root mean square), and the error for each control point, calculated through the best-fit equation. This represents the probability that a mapped position will vary from the true location. According to United States national map accuracy standards, the RMS should be less than half the resolution of the input image. According to the input image units, it should be less than 0.5.

Figure 7.45. Document file description

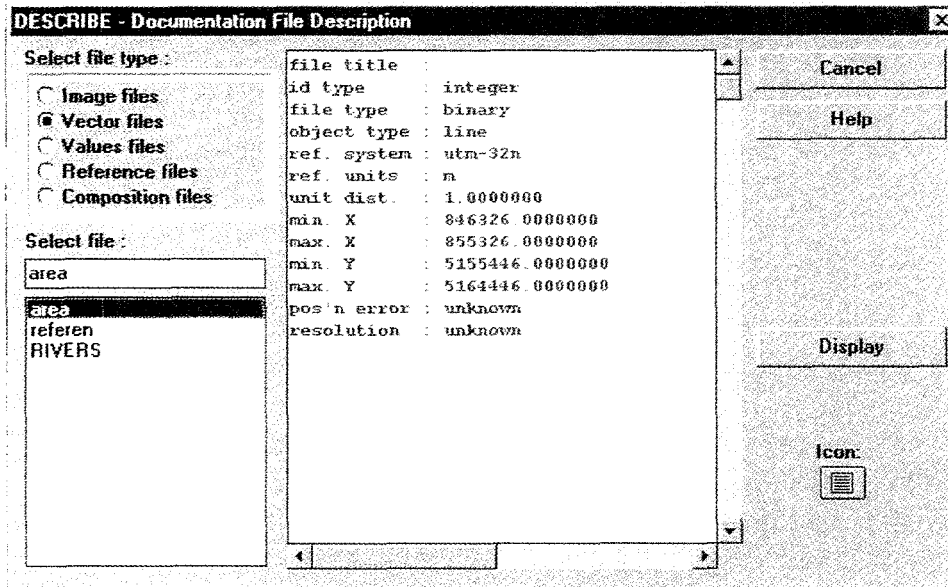
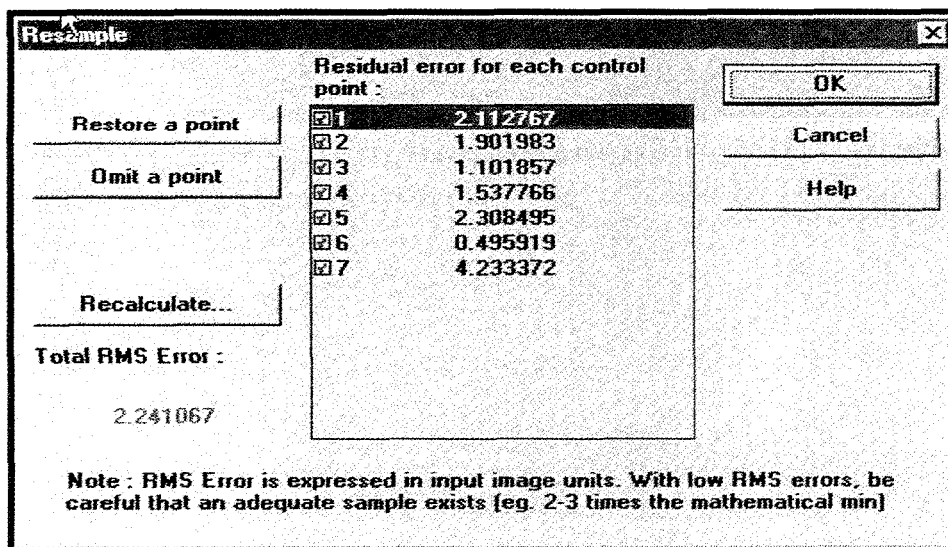


Figure 7.46. Resampling residual error (RMS)



To familiarize yourself with the calculations for the residual error, select a point in the Resample window with a high RMS error and click on **Omit a point** and then on **Recalculate**. See if the total RMS error decreases. Select the point again and click on **Restore a point** and **Recalculate**.

Even if the error is greater than 0.5, click **OK**. The resampling process starts and the new georeferenced image will be displayed. You will also see a text report on the transformation. Focus on this window and click on the **Save** button to save these results. Accept results1.txt as a file name and click **OK**. Close the Results window. This file should be stored together with the image to give information about its positional accuracy.

Close all windows except for the TAR234 resampled window.

To display the digital map with rivers again, start the Display Launcher from the Display menu and select Vector as the type of file to display.

Select RIVERS from the Input file and the Palette file. Check the Scale bar box, the North arrow box and the grid box; another window will be displayed. In the increment X and increment y input boxes type **1000** to have a grid spacing of 1 km on the Vector map that you are going to display. Click **OK**.

Select **OK** in the Display launcher window. Wait until the map is displayed.

Select **Add Layer** in the Composer window.

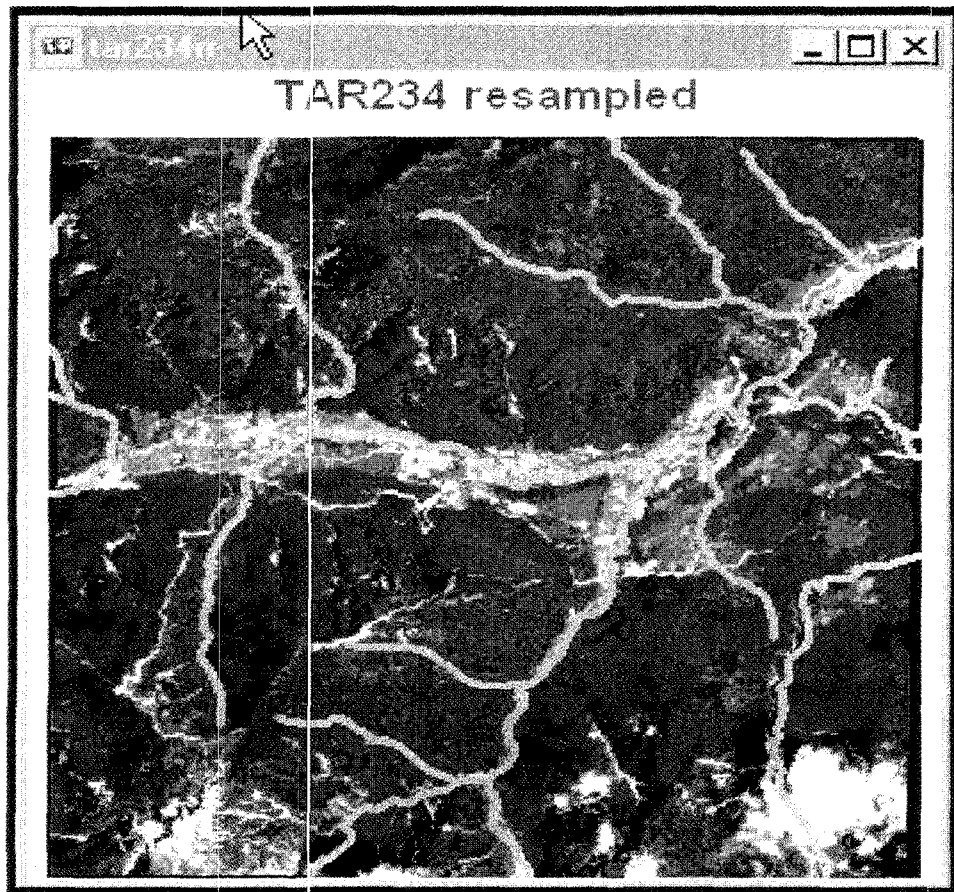
Superimpose the study area on the map. In the Input box, double-click and select **AREA**. In the Symbol File input box select **AREA** again. Click **OK**.

We will now visually verify the georeferenced points by displaying the rivers over the image. Focus on TAR234 resampled and click on **Add Layer** in the Composer window.

Select RIVERS as the Vector file to display and RIVERS as the Symbol file. Click **OK**. The rivers will be displayed over the new georeferenced image (figure 7.47).

Compare the image and the map.

Figure 7.47. Rivers overlay on the georeferenced image



7.13. Siting project for performing spatial analysis in ArcView

From the Desktop, double-click on the ArcView shortcut to start the program.

Navigate to the folder `c:/icstrn/arcview/siting` and open the Project named `siting.apr`.

Open the View named Data implementation from the Project window. Together with the windows of the available digital information, the administrative boundaries are drawn.

From the table of contents, display in the View the following themes:

Infra_33n
Infra_33s

These line themes represent the road network and the main infrastructures. Due to the tiling system, we must first derive a new theme that contains all the features of both themes. This can be accomplished with the Merge function. The result of this operation is represented by the theme named Infra_merge.shp. Turn on the theme Infra_merge.shp to see the result.

The analysis will be conducted only in a part of the administrative district; you can see the study area by displaying the theme named Area.shp. Display Area.shp. This is the same extent that you have previously used to display the digital terrain model within IDRISI. We now have to use this window to select the infrastructures that fall within this area of interest.

We will use the polygon to define the extent of the study area in order to clip the infrastructure theme and create a new line theme that contains only the infrastructures present in the area of interest. Select **Clip with Polygon(s)** from the Xtools menu.

Select the following options in the successive dialogue windows that will appear (use the scroll-down lists to select the correct option for each choice):

Input theme	Infra_merge.shp
Clip theme	Area.shp
Name new theme	Infraclip

At the bottom of the table of contents, the theme is displayed. Click and drag the theme to the top of the list.

Display the theme and press **Zoom** to Active Theme.

In order to save the changes made so far to the project, click on the **Save** button.



Once you have completed this phase, you can close the view. In the Project window open the view named Industrial siting. In the View, you will find the following themes displayed:

- Area
- Infrastructure (which you created with the clip)
- Rivers (derived with the same procedure as the infrastructures theme)
- Sites (representing the possible lots we have to select)



We will now load the results of the analysis performed by IDRISI. Use the **Add Theme** button to load c:\icstrn\arcview\siting\ALTITUDE.SHP.

Display the theme, and make it active by clicking on its name.

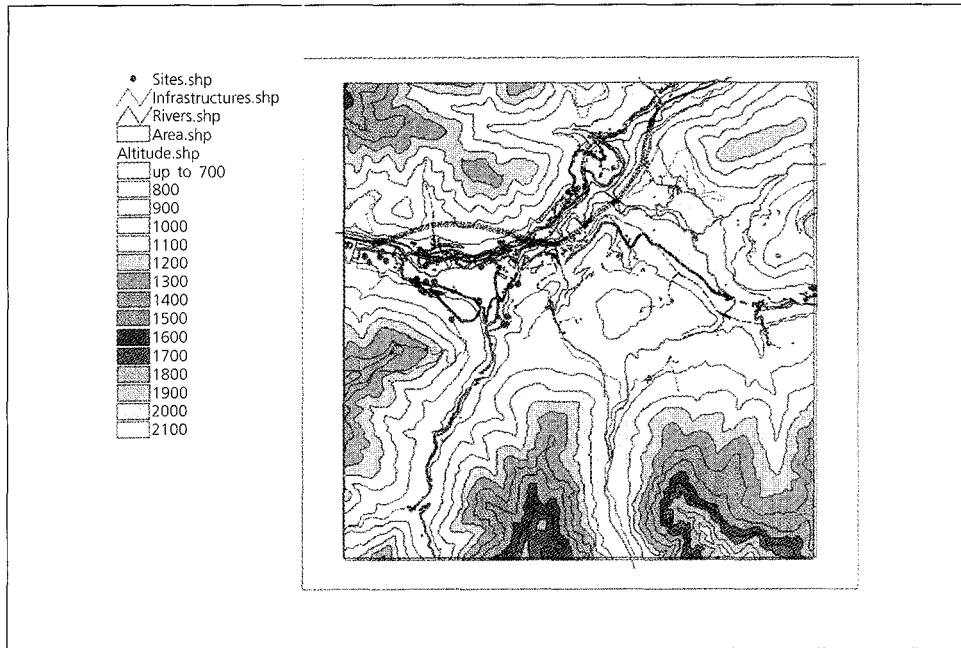
Double-click the name to start the Legend Editor and load the already prepared legend named altitude.avl. Click **OK** twice and then **Apply**. Close the Legend Editor.

From the Theme menu choose **Show/Hide Legend**.

Arrange the themes in order to see the infrastructure and rivers displayed over the Digital Terrain Model (figure 7.48).

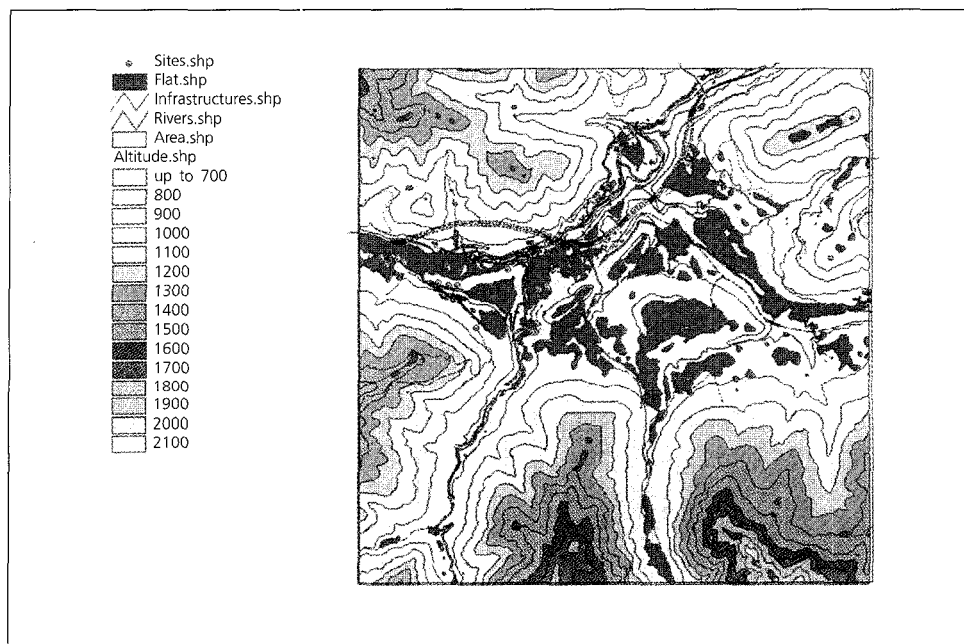
Use the **Add Theme** button to load c:\icstrn\arcview\siting\FLAT.SHP, which is the map of the slope.

Figure 7.48. Infrastructure and rivers displayed over the Digital Terrain Model



Use the Legend Editor to give the map a colour of your choice and to display the theme (figure 7.49).

Figure 7.49. Infrastructure and rivers displayed



According to the requirements for our potential sites, we know that:

- The slope of the lot cannot be greater than 15%;
- The lot should be in an altitude range of between 700 and 900 above sea level.

We will now extract from the two themes only those areas that meet both requirements.

Make Altitude the active theme and start the Query Builder.

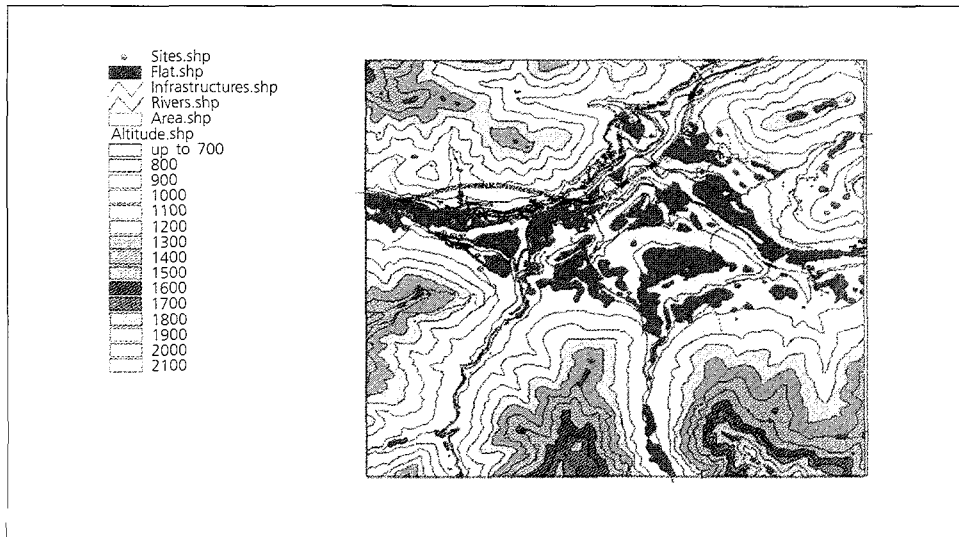


In the Query Builder dialogue window, type in the following expression:

([Quota] <= 900)

Press **New Set** to execute the expression and close the dialogue window. The areas highlighted in yellow satisfy the expression (figure 7.50).

Figure 7.50. Pre-selection of area to highlight according to their altitude



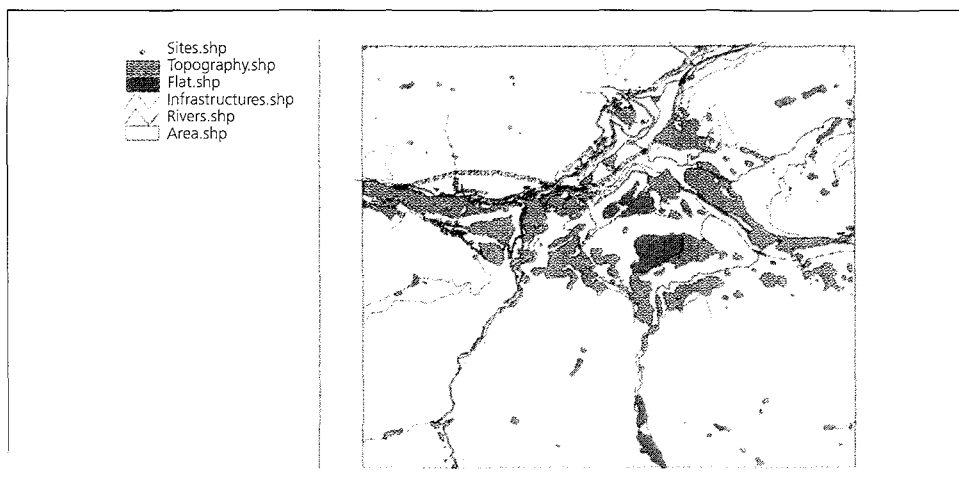
We can now perform a clip between the Flat and Altitude themes in order to extract only the areas in the altitude range with a slope that is acceptable for the siting. **Select Clip with Polygon(s)** from the Xtools menu.

Select the following options in the successive dialogue windows that will appear (use the scroll-down lists to select the correct option for each choice):

Input theme	Altitude.shp
Clip theme	Flat.shp
Name new theme	Topography

Drag the theme to the top and display it (figure 7.51).

Figure 7.51. Display of the new theme



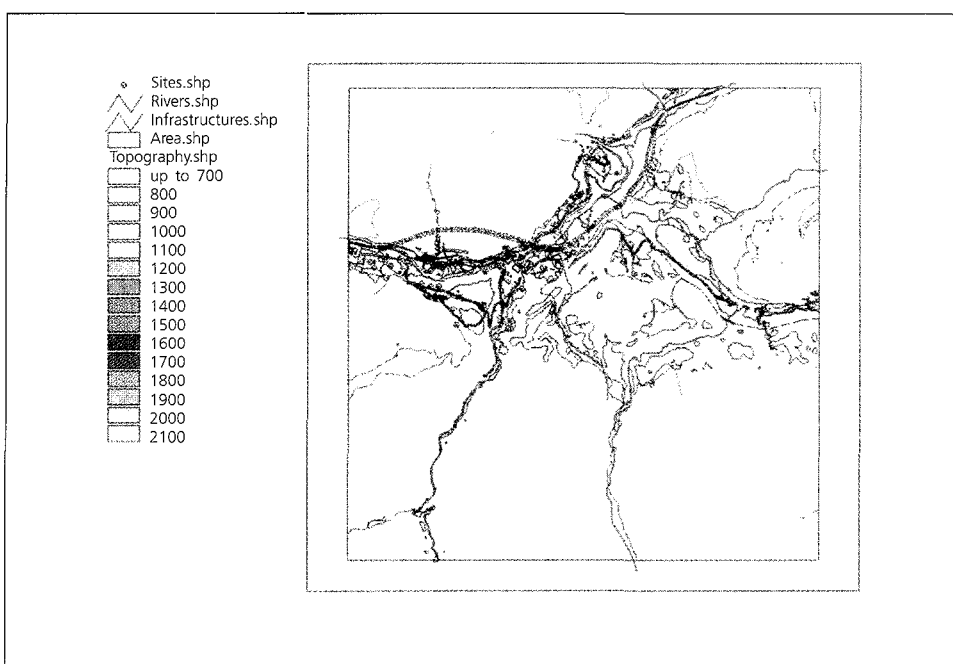
Turn off the Altitude and Flat themes and drag their names to the bottom of the list since we will not need them during the successive analyses.

We now will classify the Topography layer according to the altitude information. Start the Legend Editor.

Set Legend type to **Unique Value** and the Values field to **Quota**.

Select **Apply** and close the Legend Editor. The first criterion map for the site selection is now ready (figure 7.52).

Figure 7.52. New theme with complete legend



We can now prepare the map that meets the Land-use type criterion.

The lot must be included as one of the following Land Uses: Urban Areas, Crop Patches or Bare Ground. We now must load the land-cover map in the view and join the table containing the description of the land-cover types. We will then build a query to select only the required classes.

Add the Landcover.shp theme to the view and display it.

In the Project window select the **Tables** icon and click **Add**.

Browse to the directory c:\icstrn\arcview\siting.

Select **land_code.dbf** and click **OK**.

The table has two fields. Corine_id is the necessary field for linking the data and the description, the second field carries the information about the land-cover type. *Do not* close the table window or click on the view.

Make Landcover.shp the active theme.

Click the **Open Theme Table** button to look at the Theme Attributes table.



The Land_code field is at the right side of the table. Without closing any windows make land_code.dbf the active window (be careful not to select any records in the table).

Single-click on the **Corine_id** field name. The name should be highlighted.

Now make Attributes of Landcover.shp the active window and select the Land_code field name. This name will also be highlighted in this table. It is now possible to link the two tables (notice that the join procedure works even if the essential fields have different names).

Press the **Join** button.



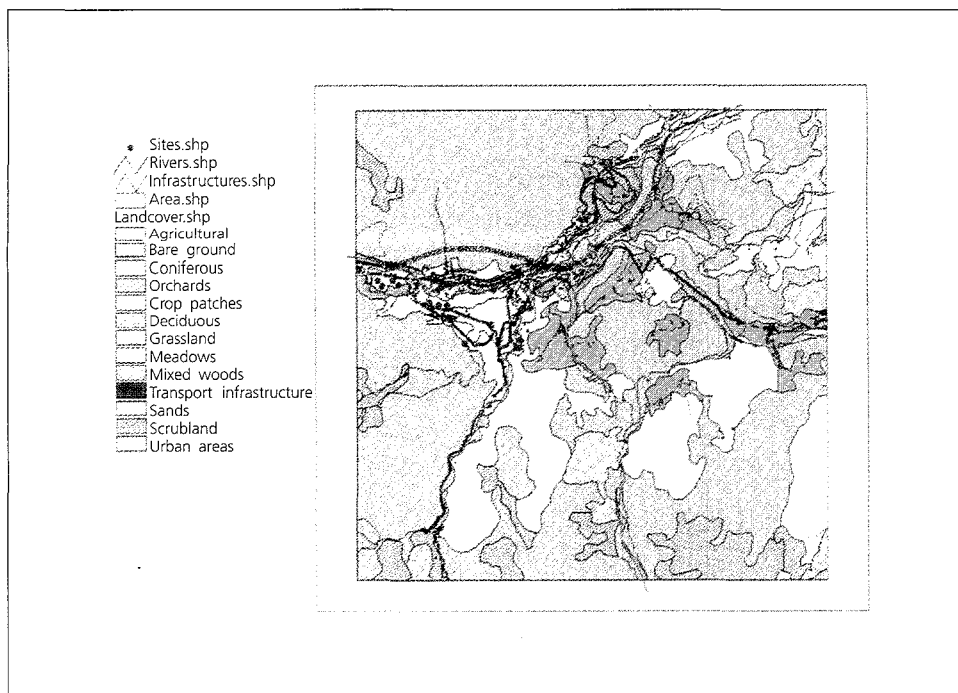
Close the Attributes table.

This information can now be used to classify the theme according to the land-use type. In the table of contents, double-click on **Landcover** to launch the Legend Editor.

A legend file named landcover.avl already exists, so just choose **Load**.

Press **OK** twice, select **Apply** and then close the Legend Editor. The resulting map is shown in figure 7.53.

Figure 7.53. Land cover with detailed legend



Now we can select the land-use polygons according to their descriptive information.

Make Landcover the active theme and start the Query Builder.

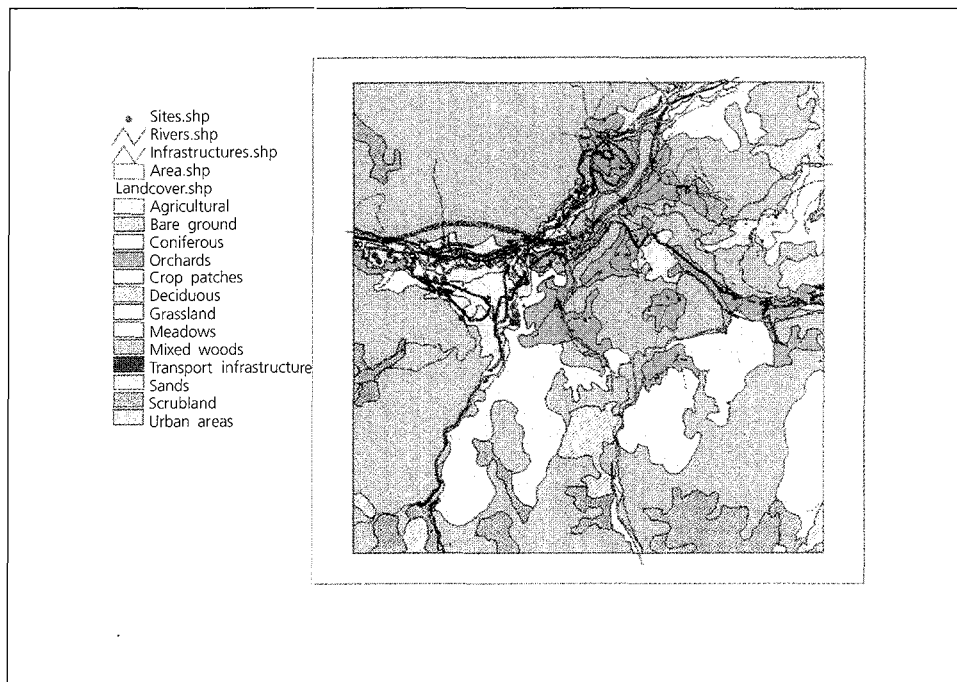


In the Query Builder dialogue window, type in one of the following expressions:

([Description] = Crop patches) or ([Description] = Bare ground) or ([Description] = Urban areas)

Press **New Set** to execute the expression and close the Query Builder dialogue window. The resulting map is shown in figure 7.54.

Figure 7.54. Selection of land use polygons according to their descriptive information



The next step is to use the topography layer and to intersect it with the selected land-cover polygons we have just highlighted. Notice that this time we are using Intersect and not Clip, as we want the new theme to contain both the altitude and the land-type information.

In the View, choose **Intersect Themes** from the Xtools menu.

Select the following options in the successive dialogue windows that will appear (use the scroll-down lists to select the correct option for each choice):

Input theme	Landcover.shp
Fields for output	select Corine>Description >OK
Select Intersect theme	Topography.shp
Fields for output	select Quota >OK
Name new theme	Landsuit

Drag the theme to the top of the list and display it (figure 7.55).

Open the Attribute Table to ensure that both the altitude information and the land-cover types are present. Close the table.

Start the Legend Editor and set Legend type to **Unique Value** and the Value field to **Description**.

Colour the two symbols bright red and pink.

Click on **Apply** and then close the Legend Editor.

In the resulting screen (figure 7.56) you will see the areas that meet both topographic and land-cover type parameters.

Notice that during the last intersect the bare ground land type was excluded from the suitable areas because it did not meet the altitude-slope parameters.

Turn off the Topography and Landcover themes and drag them to the bottom of the table of contents.

Now use the Infrastructure theme to exclude the lots that are too close to existing residential buildings according to the criterion "the lot has to be at least 100 m away from residential areas". Make Infrastructure the active theme.

Figure 7.55. Land suitability

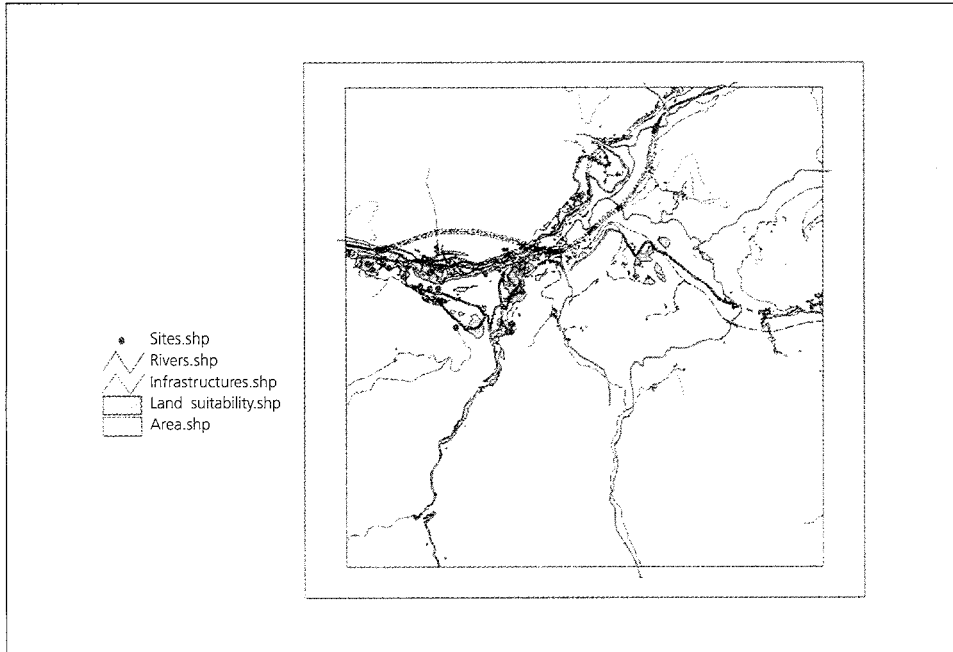
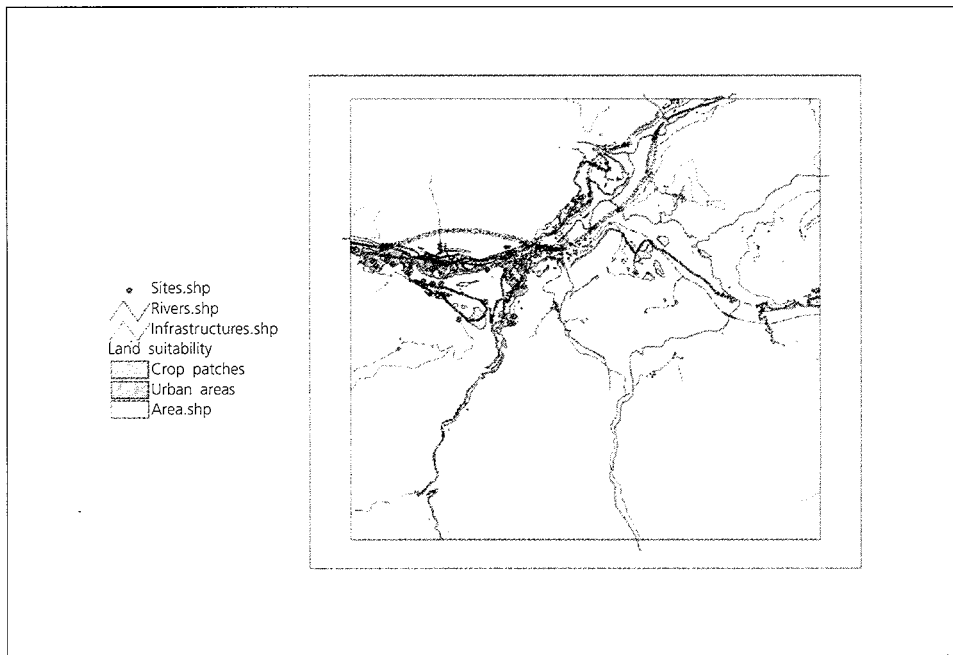


Figure 7.56. Areas that meet both topographic and land cover type parameters



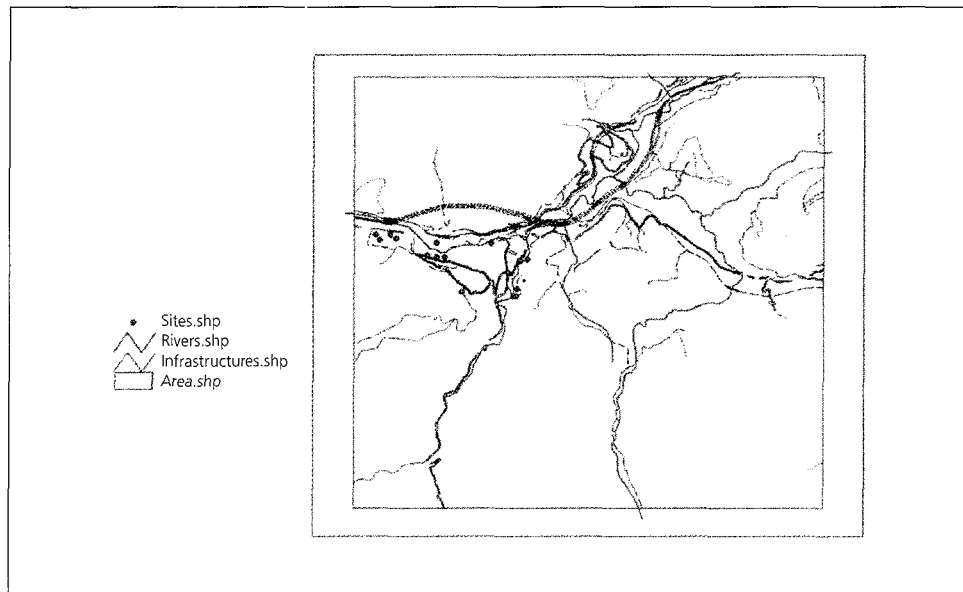
Start the Query Builder and type in one of the following expressions:



`([Type] = buildings) or ([Type] = residential)`

Close the Query Builder to see the result (figure 7.57).

Figure 7.57. Use of the infrastructure theme to exclude the lots that are too close to existing residential sites



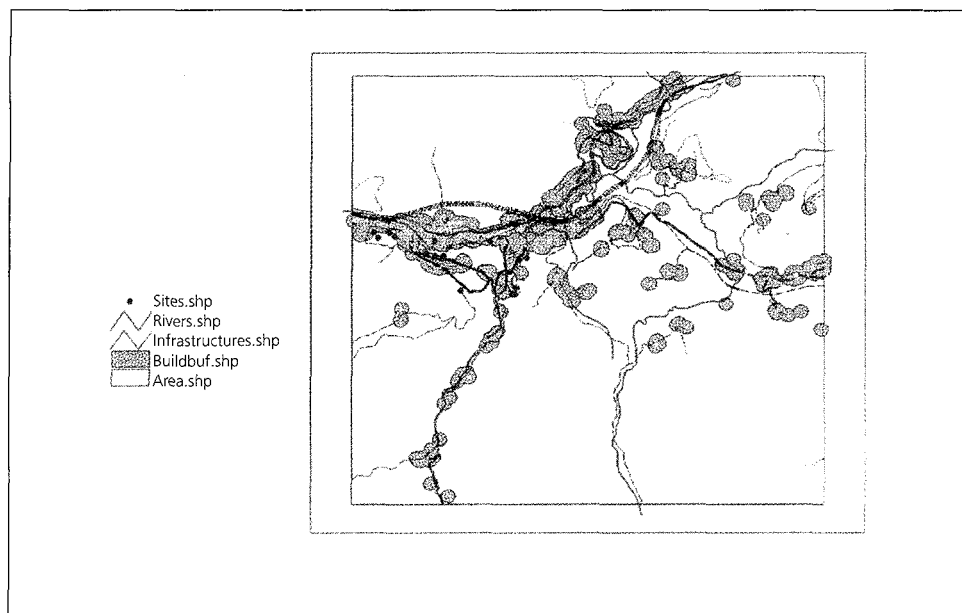
We can now create a buffer area around the selected features. In the view, choose **Buffer selected features** from the Xtools menu.

Select the following options in the successive dialogue windows that will appear (use the scroll-down lists to select the correct option for each choice):

Buffer units	meters
In theme	Infrastructures.shp
Out theme	enter build_buf
Buffer input	buffer distance
Buffer distance	100
Line buffer options	Line
Output structure	contiguous

Click on the View of the build_buf check-box to display it (figure 7.58).

Figure 7.58. Creation of buffer areas



In order to save the changes made so far to the project, click the **Save** button.



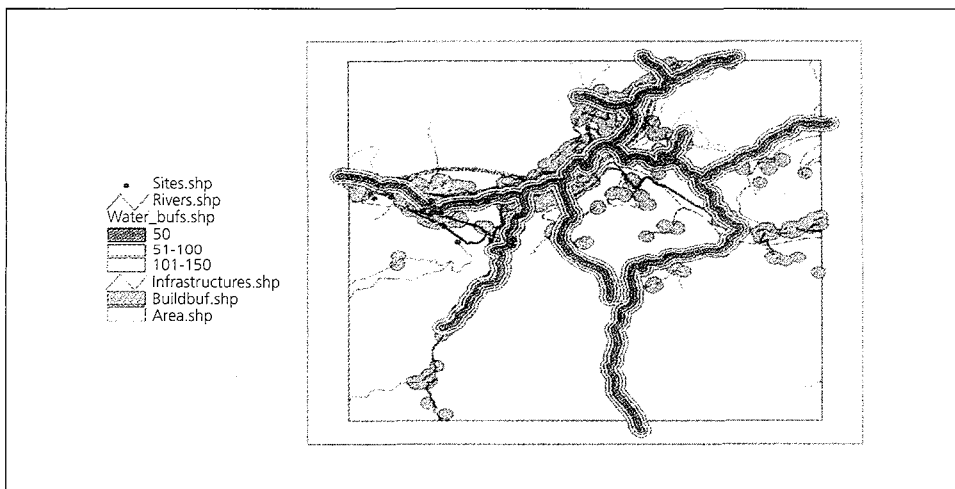
Now we must add the previously created buffer for the water proximity factor according to the criterion “priority has to be given to those lots that are closer to water sources, and in any case the plant cannot be sited more than 150 m away from water”. Click on the View and use the **Add theme** button for water_bufs.

Display the theme and start the Legend Editor to classify the theme with graduated colour. Set the value field to Distance and choose the colour ramp named Blue-green monochromatic. Then use the label button to invert the colour scale; click **Apply** and close the Legend Editor.



Drag the Rivers theme to the top in order to view it over the buffer and **Zoom In** to see the buffers better (figure 7.59).

Figure 7.59. Overlay of rivers theme



We can now start the site selection analysis by combining all the criteria that our sites have to meet.

In the table of contents, arrange the themes in the following order from top to bottom:

- Sites
- Infrastructures
- Rivers
- Landsuit
- Build_buf
- Water_bufs

Turn off all the other themes.

The resulting map is shown in figure 7.60.

Make **Sites** the active theme.

From the Theme menu choose **Select by theme**.

Specify that you want to select the lots that intersect the theme containing the buffer area around the buildings (Build_buf) (figure 7.61) and press **New Set**.

Now open the Attributes theme table for Sites.

Press the **Switch selection** button:



Figure 7.60. Site selection analysis

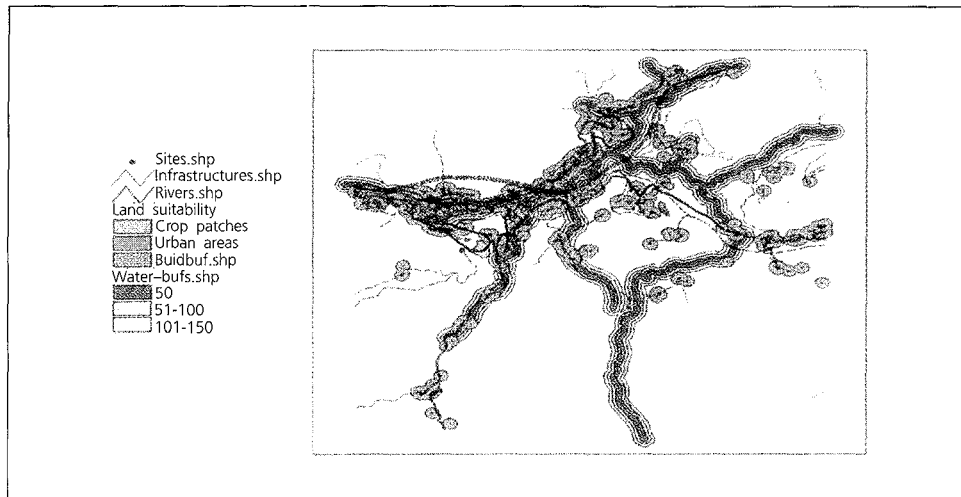
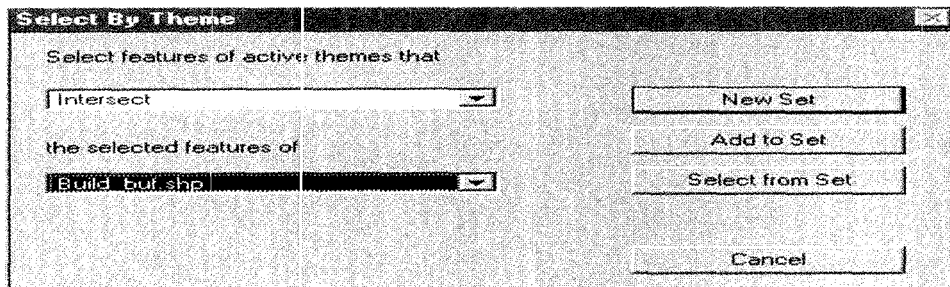
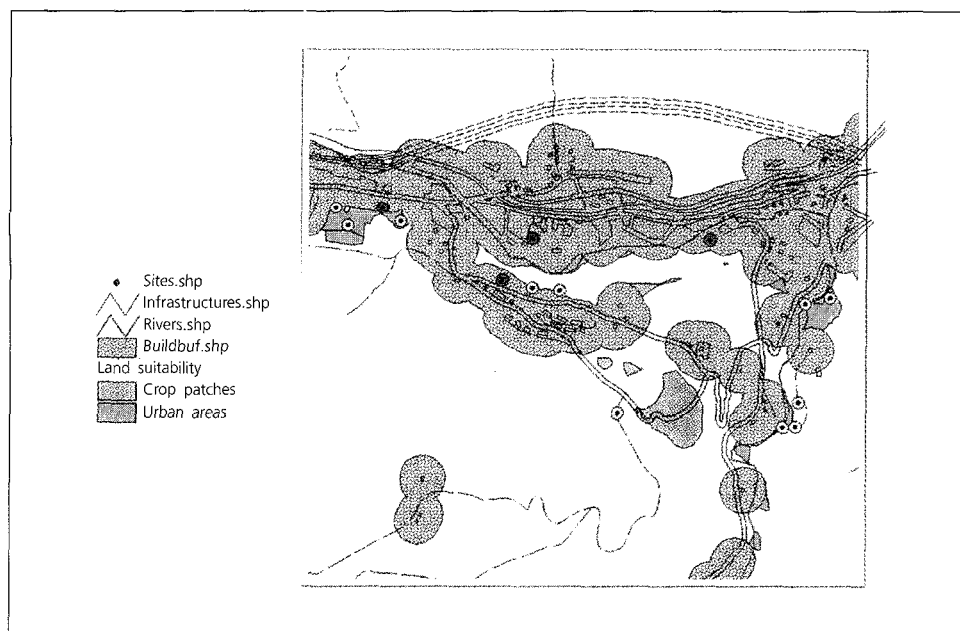


Figure 7.61. Selection of features of active theme



Close the table. This process has allowed us to select the lots that are outside the 100 m buffer zone around residential buildings (figure 7.62).

Figure 7.62. Selection of lots out of a 100m buffer zone



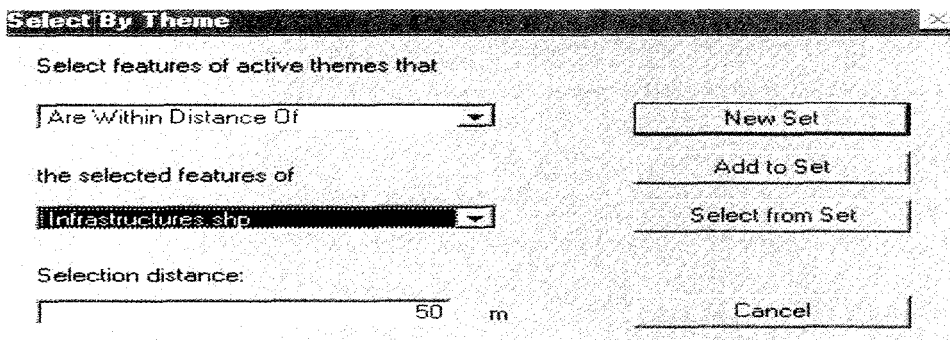
Now we must select the lots that are within 50 m of the road network. Make Infrastructures the active theme.

Run the Query Builder and type in quotes:

([Dxf_layer] = "E*")

Press **New set** and close the Query Builder. Make Sites the active theme again. From the Theme menu choose **Select by Theme**.

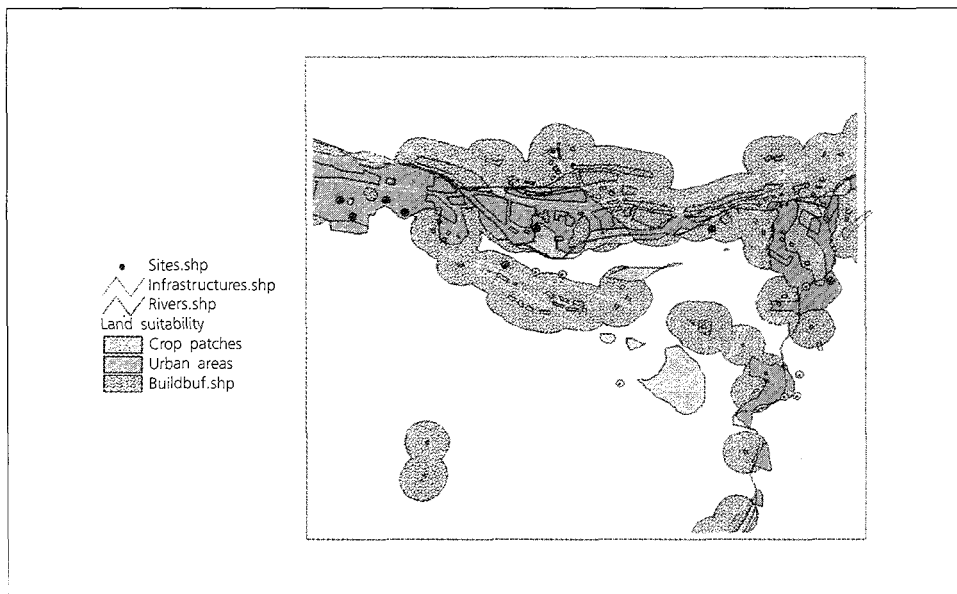
Figure 7.63. Selection of the features of active theme according to the buffer distance



Specify the parameters (as shown in figure 7.63). Since we have already selected some of the lots in the Sites attributes table, we can choose the **Select from Set** option to narrow the selection.

Again, open the Attributes table to ensure that other lots have been excluded; close the table. The map shown in figure 7.64 appears.

Figure 7.64. Excluding other lots



We are now going to perform a spatial join operation in order to verify which of the remaining lots satisfy the last two criteria, i.e., the proximity to water and topographical characteristics.

Open the Landsuit.shp theme attributes table and click on the **Shape** field.

Open the Sites.shp theme attributes table and click again on the **Shape** field.

Press the **Join** button.

In the attributes table you will find that only those lots with a suitable land-cover type receive the attributes from the Landsuit cover attributes table. All the other fields are left blank, which means that these lots do not satisfy the criteria and will be discarded. We will use this process to find lots that meet the criteria for water proximity.

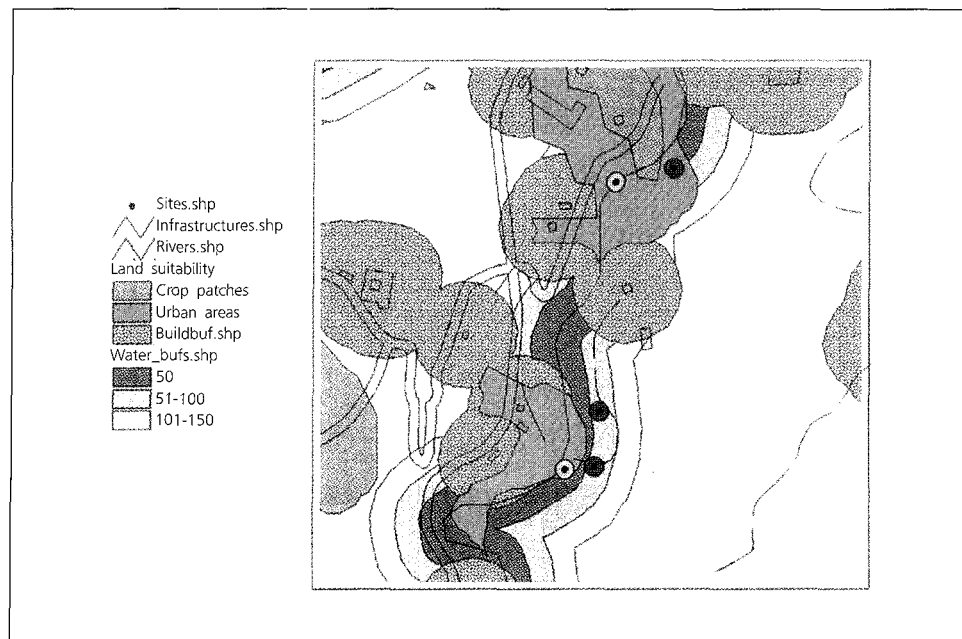
Open the Water_buf's.shp theme attribute table and click on the Shape field.
 Open the Sites.shp theme attribute table and click again on the Shape field.
 Press the **Join** button.

Examine the Sites attributes table (figure 7.65). From the table that contained 15 possible sites, only 2 remain that meet all the criteria we have defined. These are shown in yellow in figure 7.66.

Figure 7.65. Table of attributes where only 2 sites remained having met all criteria we have defined

Attributes of Sites.shp							
	Area	Area	Description	Distance	Quota	N	Distance
Point	100	100.0		100		2	100
Point	20	450.0		100		2	100
Point	80	700.0		100		2	100
Point	76	650.0					
Point	58	670.0	Urban areas		800.000000		
Point	99	2000.0	Urban areas		800.000000		
Point	49	400.0		150		3	150
Point	69	870.0		100		2	100
Point	65	870.0	Urban areas	50	800.000000	1	50
Point	47	650.0	Urban areas	50	800.000000	1	50
Point	101	1540.0	Urban areas	50	800.000000	1	50
Point	130	1420.0	Urban areas		800.000000		
Point	96	1450.0	Urban areas		800.000000		
Point	150	1900.0	Crop patches	150	800.000000	3	150
Point	200	3400.0		100		2	100

Figure 7.66. Remaining sites that meet the criteria

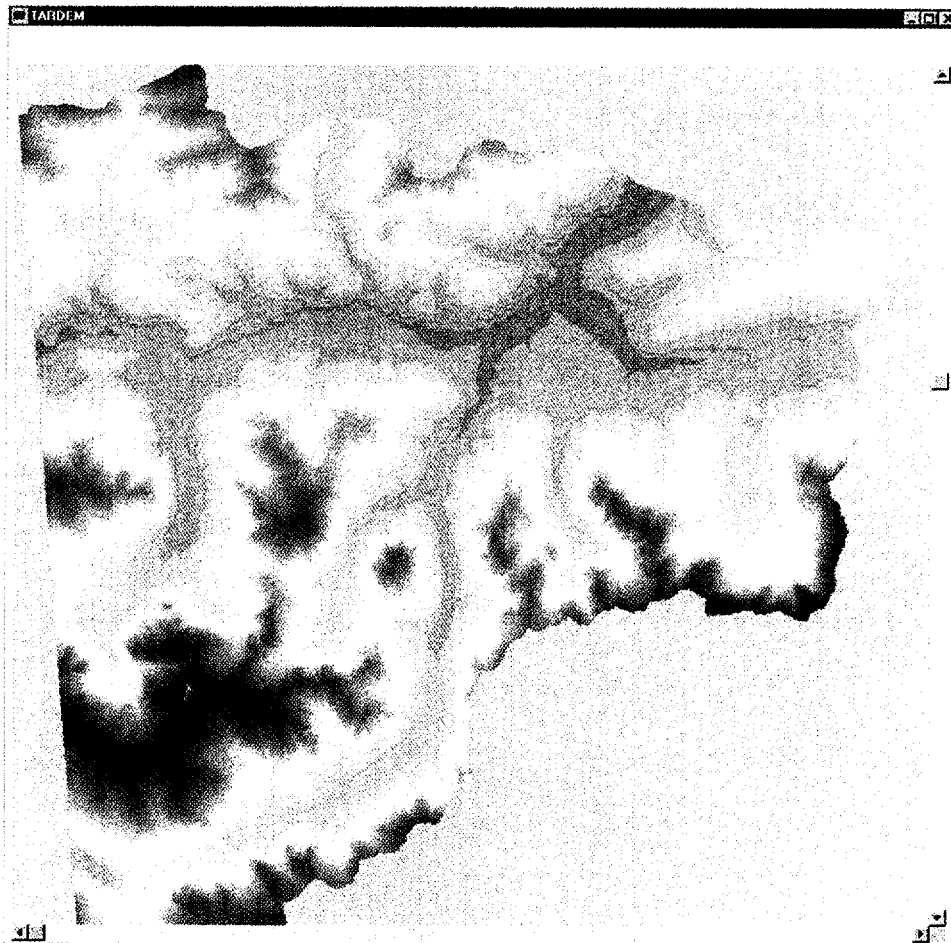


7.14. Siting project for performing surface analysis in IDRISI

In Display/Display preferences unselect the Use extended cursor inquiry and select QUAL256 as the qualitative palette, QUANT256 as the quantitative and ALTI as the default palette. In the map defaults verify that both **Title** and **Legend** are checked.

From the Display, run Display Launcher. The name of file to display should be TARDEM. Double-click in the input box and then **OK**. A digital raster elevation model that was obtained through the interpolation of scattered elevation points from a digital map will be displayed (figure 7.67).

Figure 7.67. A digital raster elevation model that was obtained through the interpolation of scattered elevation points from a digital map



From the Composer window, click on **Add Layer**.

To display Area as a vector file, select **Area** as the symbol file. Our study area will be superimposed to the elevation model.

As you can see, we are interested in a small area. To avoid consuming processor time, we will extract a sub-image from the digital elevation model before performing our surface analysis. Run **Window** from the **Reformat** menu (figure 7.68).

In the input image text box select or type **TARDEM**.

In the output image text box type **TARWIN**.

Select the option to specify a window by the geographic positions.

Obtain the minimum and maximum x and y coordinates to type into the 4 input boxes by either:

- Focusing on the image window and pointing the cursor in the proximity of the corners of the study area superimposed by TARDEM and looking at the x and y values in the status bar. The obtained values that have been rounded to the nearest hundred can be used, or
- Run **Describe** from the **File** menu. Select **Vector files** as the file type and click once on **AREA** to read its document file. Note the minimum and maximum coordinates, rounded to the nearest hundred, in the four coordinate boxes of the Image windowing window.

Click **Cancel** on the Documentation file description window.

Accept all other defaults and click **OK**. The image will be displayed (figure 7.69).

Figure 7.68. Image windowing

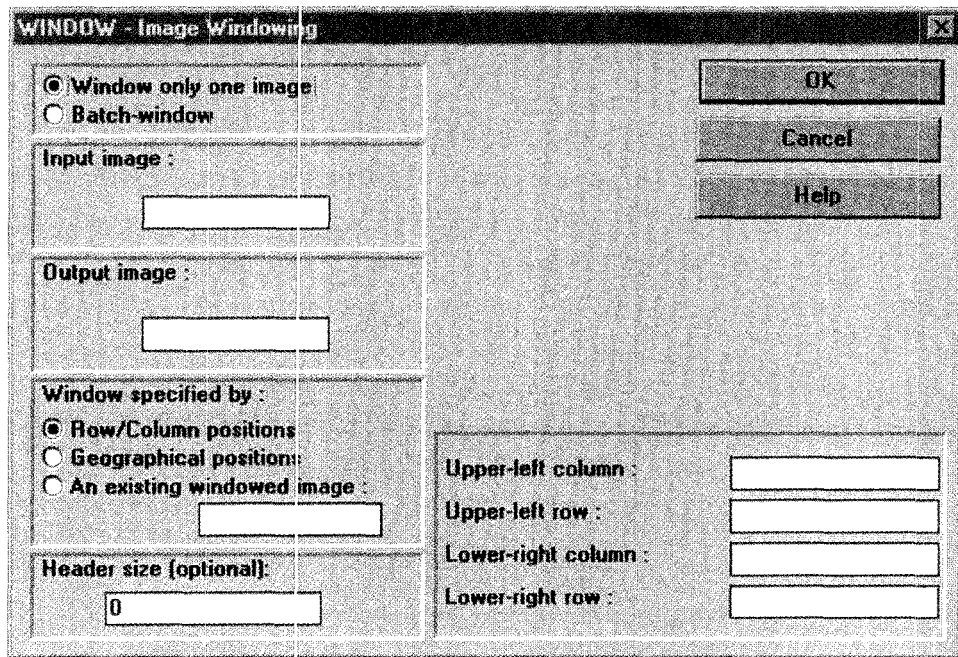
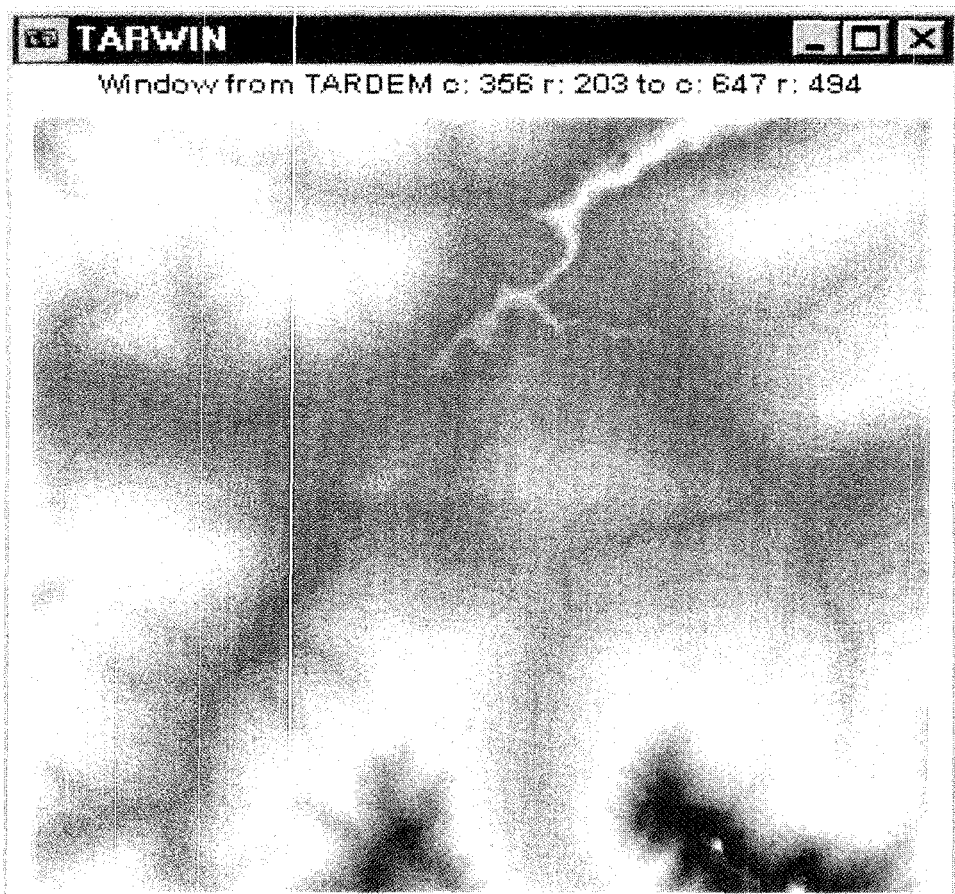


Figure 7.69. Window from the TARDEM image



In the Composer window, click on Properties.

In the Layer properties window double-click on the palette file box to select ALTI as the palette file and click OK. The new digital elevation model (DEM) has the correct combination of colours.

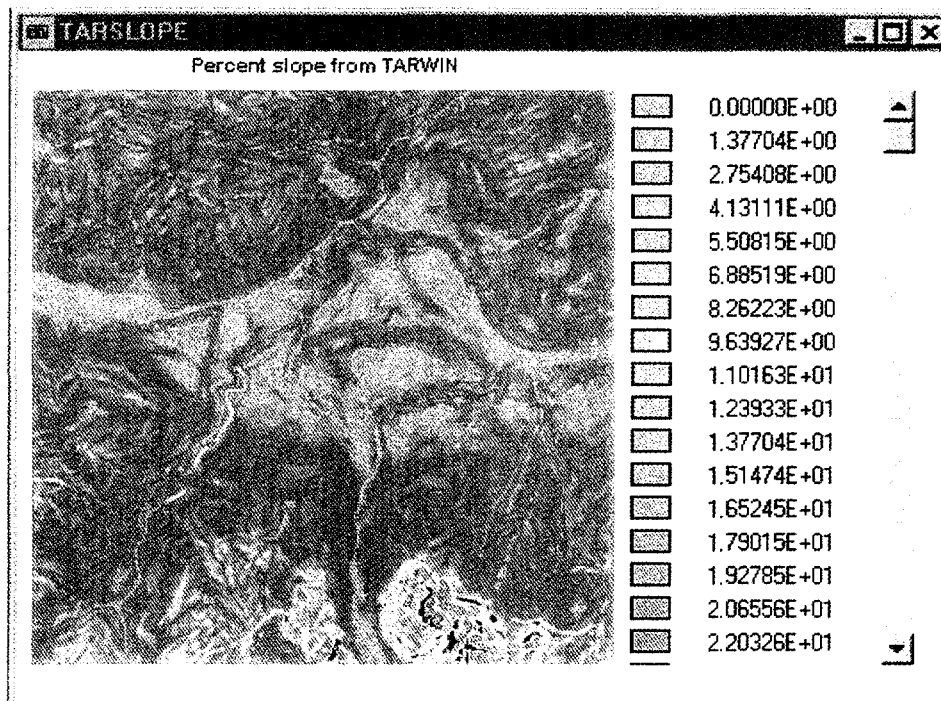
Now you can begin performing the surface analysis on the DEM to satisfy your project task. From the Analysis/Context operators menu, run SURFACE or click on



which is located on the toolbar.

Choose to calculate slope by selecting **TARWIN** as the input elevation model. Type **TARSLOPE** in the output slope image input box. Choose the option to calculate the slope as a percentage. As a conversion factor, type **1**. In the title input box type **Percent slope from TARWIN** and click **OK**. The map in figure 7.70 will appear.

Figure 7.70. Percent slope from the TARWIN image



In the Composer window, click on Properties.

In the Layer properties window, double-click on the palette file box to select Slope as the palette file and then check the Use legend box. Click **OK**.

The map of the slope has a legend; by using the scroll bar you can look at the range of values for the study area. The slope steepness ranges from grey to green to yellow to red.

Since we are interested in finding areas with a slope of less than 15 percent, we must reclassify the slope image in order to obtain a new image displaying suitable and non-suitable areas.

Click on the reclass button in the toolbar.



The image reclassification window (figure 7.71) is displayed.

In the Type of file to reclass, choose Image.

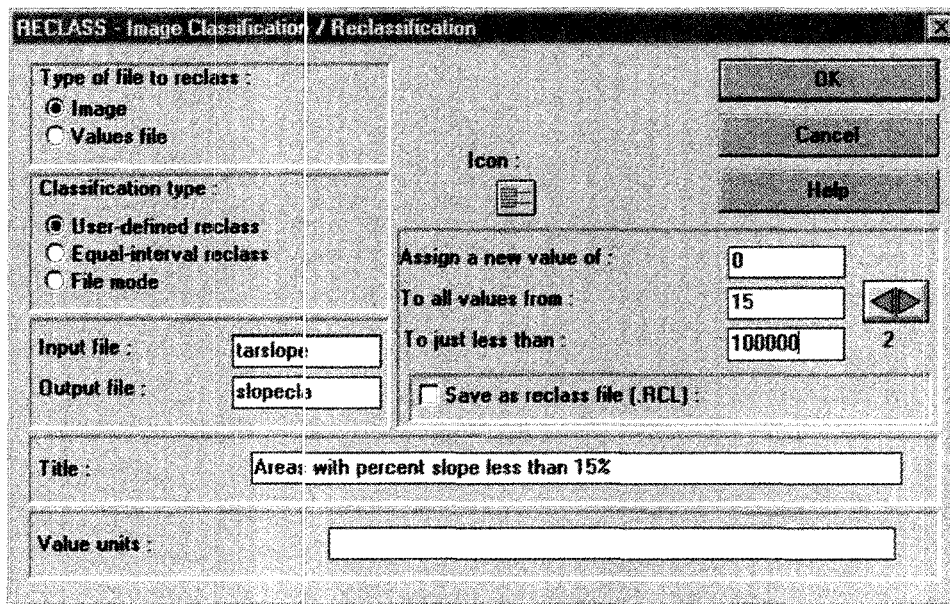
In the Classification type, choose User defined-reclass.

In the Input file, type or select **Tarslope**

In the Output file, type **Flat**.

In the title input box type **Areas with slope less than 15%**.

Figure 7.71. Image classification and reclassification IDRISI window



Now start assigning classes to values by filling the input boxes in the right part of the window. Assign a new value of **1** to all values from **0** to just less than **15**. Click on the right arrow to scroll to assign a new set of values.



Assign a new value of **0** to all values from **15** to just less than **100000** (greater than the image maximum to include all values).

Click **OK** and a new image will be displayed. The pixels in the image represent the flat areas with a slope of less than 15 percent and as you can see from the legend, they have a new value of 1.

We are now going to collect all the data in ArcView to take our final planning decisions. In order to do so we need to transform the raster polygons in Flat by:

- Converting them into a vector format
- Exporting them into the specific ArcView shapefile

Before converting our raster flat areas to a vector file, we will use a filter to remove very small areas considering only polygons that are of a significant size. From the Analysis/Image_processing/Enhancement menu, run Filter. The Filter window (figure 7.72) is displayed.

Select **Mode** as the type of filter. This will reassign values of one pixel according to the predominant value of its neighbours, thereby generalizing the image. In the input image input box type **Flat**. In the output image input box type **FLATFIL**. In the title box type **FLAT areas filtered with mode**. (See figure 7.73.)

In the Reformat/Raster-vector Conversion menu run Polyvec. You should normally enter **FLATFIL** as the input image and **FLATFIL** as the output vector file and exclude the background polygon that is identified by the value of 0 in the image (areas with a slope of more than 15 percent). However, we will not perform this operation now, since it takes about 15 minutes to do on a PC. The output of this module is already saved in your directory as FLATFIL and it is a vector file.

Display this vector file using the Display Launcher from the Display menu (figure 7.74).

Figure 7.72. Digital filtering using a moving Kernel window of 3 by 3 pixels

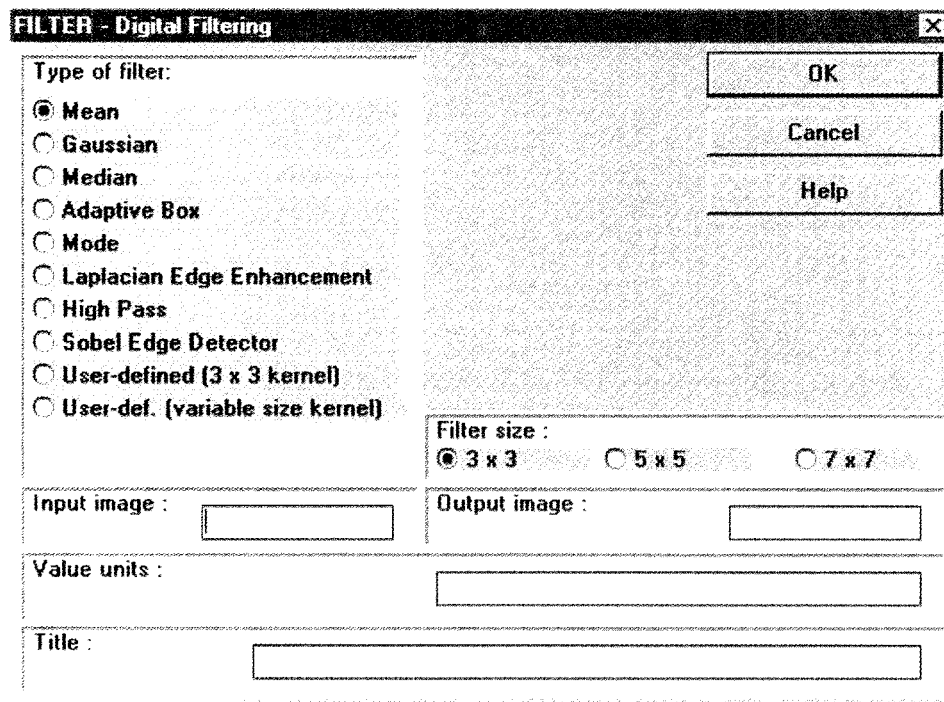


Figure 7.73. Raster flat areas

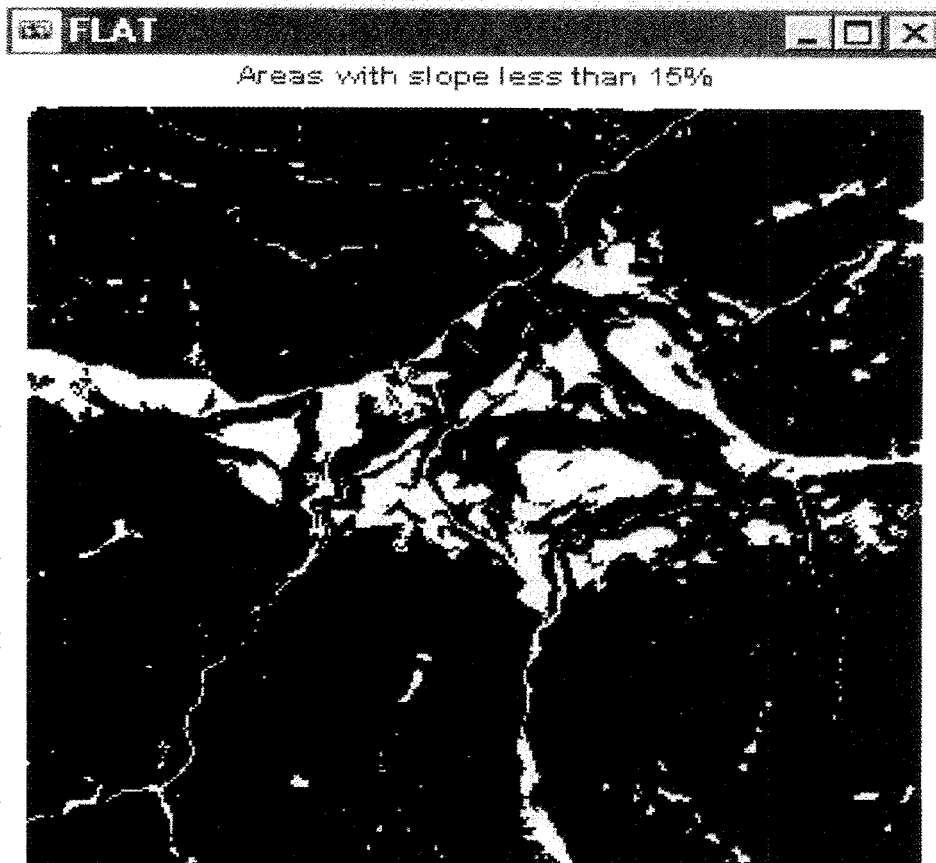
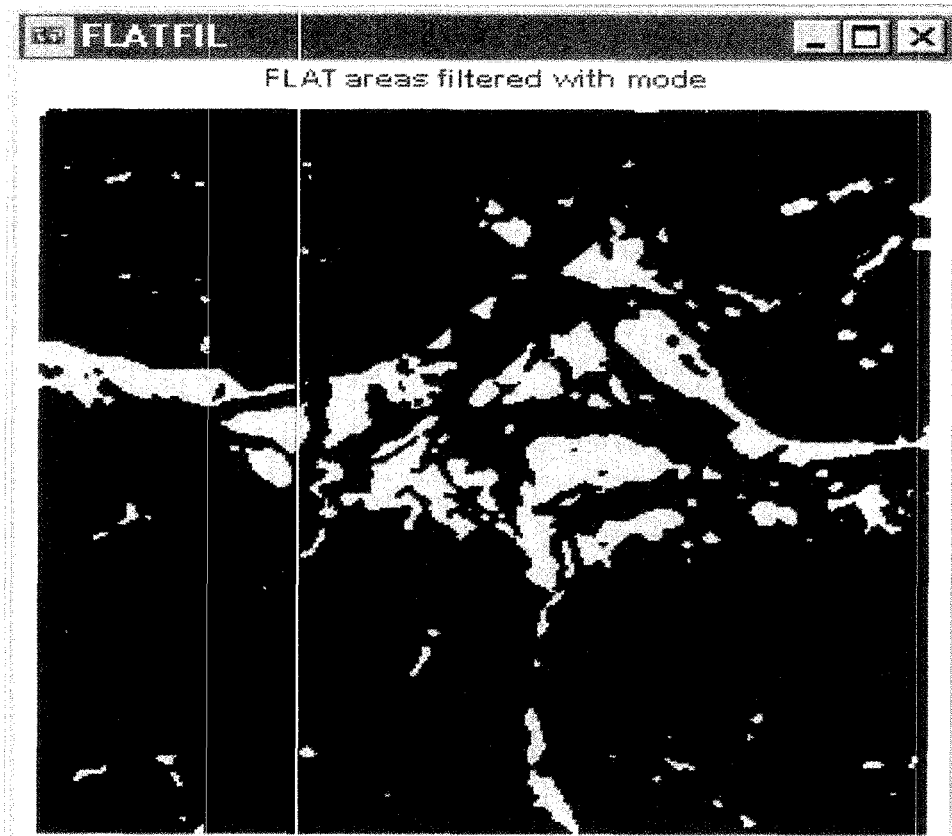
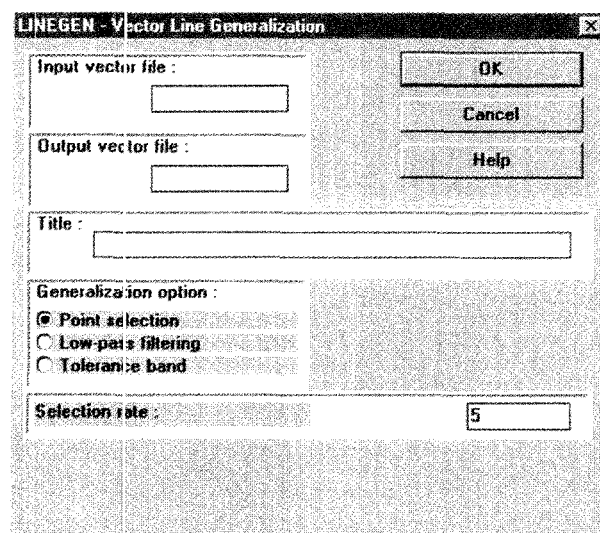


Figure 7.74. Raster flat areas using filter as image enhancement procedure



In this file the lines appear very jagged. So we will smooth it before exporting it to the ArcView format. Run Linegen from the Reformat menu (figure 7.75).

Figure 7.75. Vector line generalization



Select **FLATFIL** in the input file box; type **FLATGEN** in the output file box. Select Low-pass filtering and click **OK**.

A window showing the results of your smoothing is displayed. Close this window.

Now display the vector map you have just created. Run the Display Launcher and select Vector as the file type to display. In the input box select **FLATGEN**. Accept all the other defaults and click **OK**.

Now compare (visually) FLATFIL (figure 7.76) and FLATGEN (figure 7.77).

Figure 7.76. IDRISI to Arc View file export

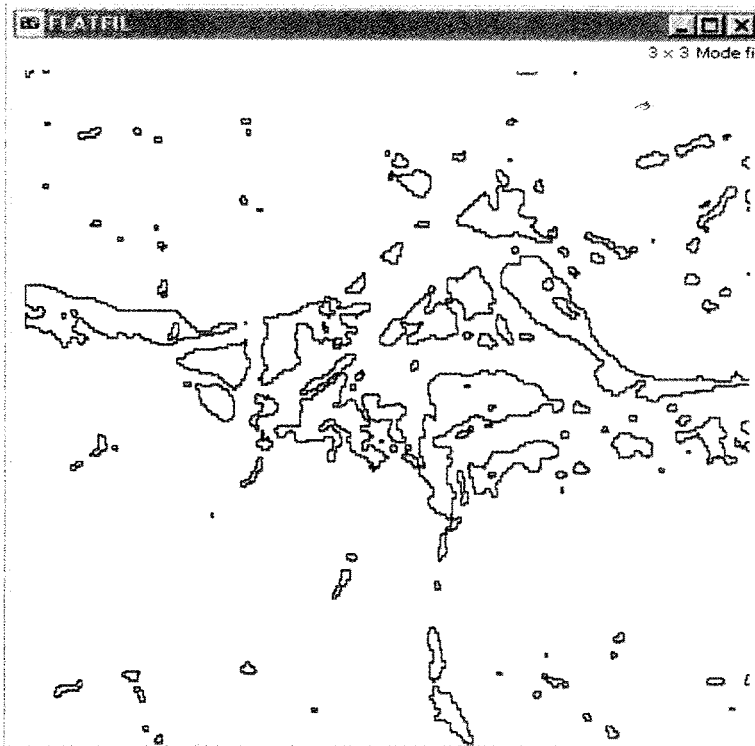
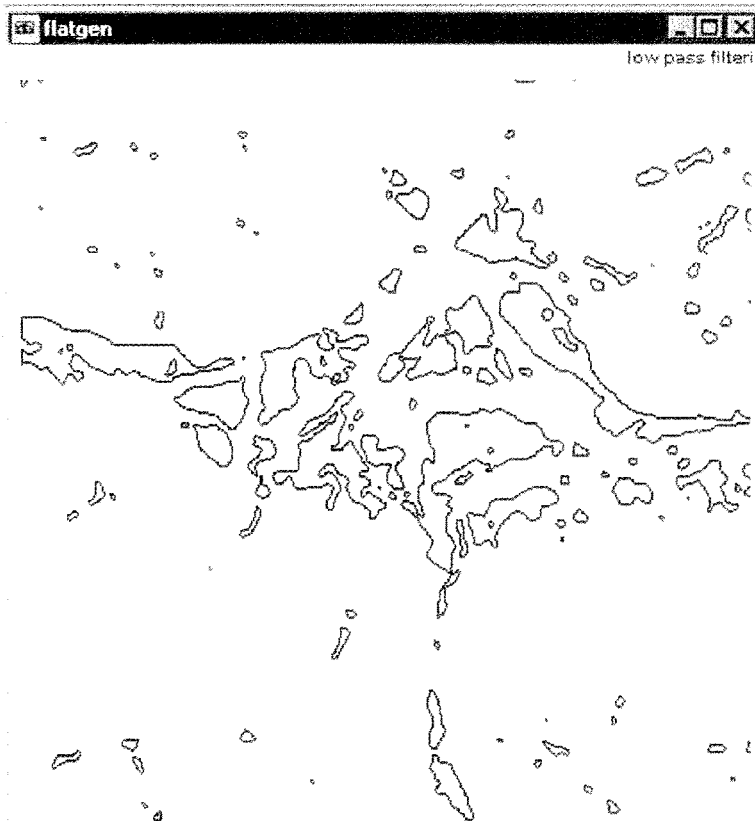


Figure 7.77. The file is ready to be included into an Arc View project



There is still one step prior to exporting to the ArcView format. Run Convert from the Reformat menu and choose a vector file type. In the input file box type **FLATGEN**, and in the output box type **FLATGE**. Accept all other defaults and click **OK**. You are now going to convert an integer ASCII vector file to an integer binary vector file.

From the FILE menu run Import/Export. From the IDRISI import/export utility Export/software-Specific Formats menu, run Shapeidr.

In the input IDRISI vector file select **FLATGE**. In the output shape file type **FLAT**.

Accept all other defaults and click **OK**. The file FLAT is now ready to be included into an ArcView project.

Having completed these steps, you should be able to perform other operations, including:

- A reclass on the Digital Terrain Model (TDM) to have a 100 m altitudinal belt
- A conversion to a vector polygon file of the altitudinal belt
- A generalization of the polylines
- An export to shapefile for ArcView

The maps resulting from these operations have been included in the ArcView project.

8

Case studies

8

Case studies

Landscape ecology analysis and urban land use classification in the Sebaou watershed, Algeria

A. Altobelli and L. Ourabia

Multi-criteria evaluation for industrial siting in the region of Tunis-Bizerte, Tunisia

M. Ghribi

Landscape analysis of degraded and degrading areas of Tigray, Ethiopia

A. Altobelli

Case study 1

Landscape ecology analysis and urban land use classification in the Sebaou watershed, Algeria*

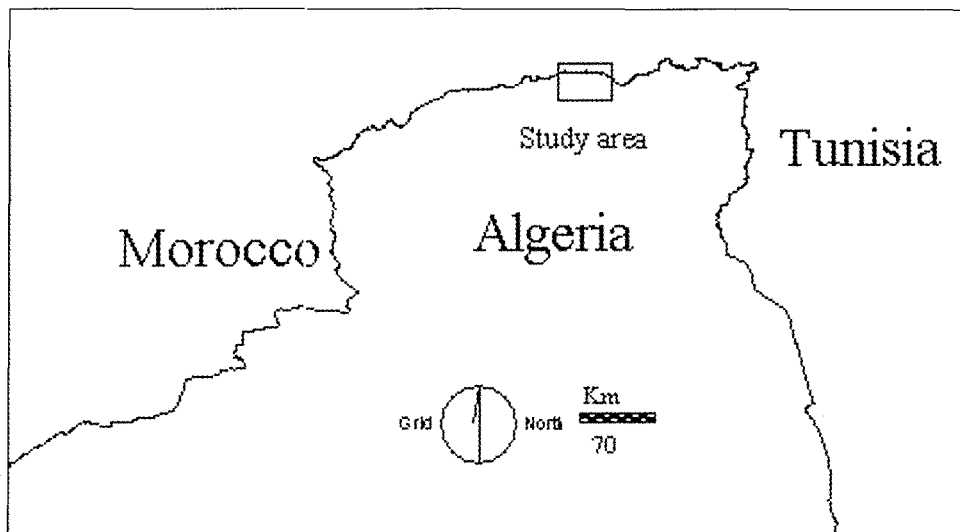
1. Introduction

Watershed deterioration is a common phenomenon in most parts of the world. A prime cause is the improper utilization of watershed resources, which is a severe problem in developing countries [1]. Vegetation loss and land degradation resulting from unsuitable agriculture practices is of particular importance in predominantly mountainous regions, such as north central Algeria. Monitoring changes in land cover is essential to improving watershed management.

Remote sensing is very useful in assessing the land cover of an area at a particular time and monitoring change over a given period [2, 3].

The test area selected for our study is a coastal watershed (the Sebaou watershed) located in north central Algeria (figure 1). The area of the watershed is about 2,460 km² and has an estimated population of 1,302,077, and population density of 457 inhabitants per km². It is bordered on the north-west by the Mediterranean Sea, on the north and north-east by a coastal mountain range and on the south and south east by the Djurdjura Mountains. It is 80 km east of Algiers, the national capital, and is considered a strategic basin for the water supply of several Governorates.

Figure 1. Location of the study area



*This case study was prepared by A. Altobelli and L. Ourabia, Area of Earth, Environmental and Marine Sciences and Technologies, ICS-UNIDO.

2. Landscape ecology analysis of remote sensing data

This part of the case study focuses on the calculation of three of the most commonly used landscape indices, namely:

- Dominance index
- Contagion index
- Fractal dimension index

2.1. Data extraction

Different types of images have been used—two land-cover images (supe92RR and supe98RR) and a grid image where geographic operation units (OGU) are presented. All analysis will be computed using these images. To display both of the land-cover images, use palette qualitative 256 and legend.

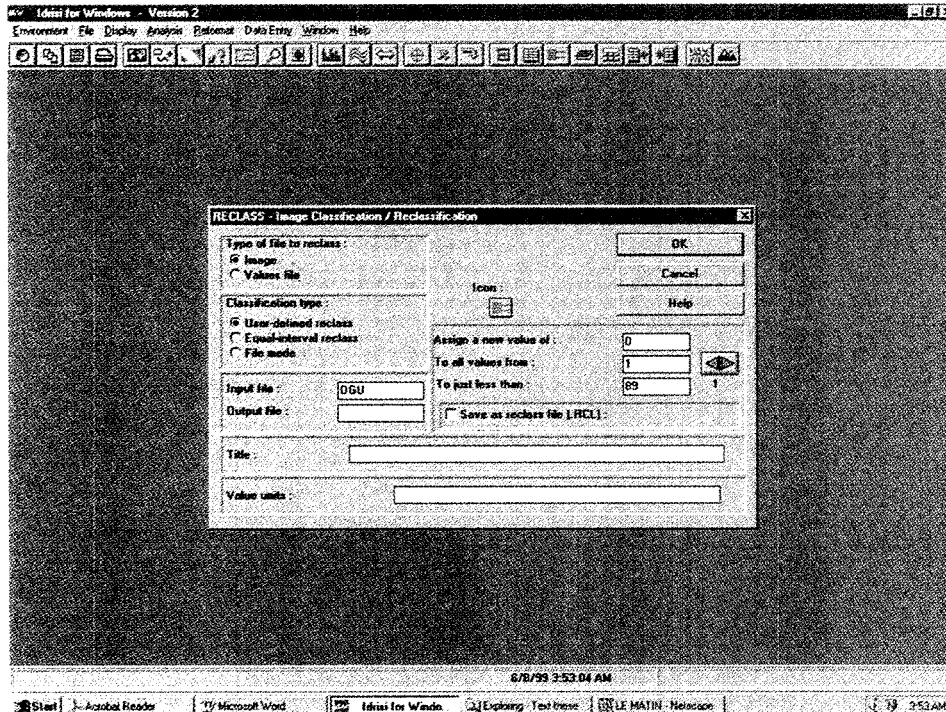
The first step in calculating the three indices is to isolate five OGU. The identifiers for the randomly selected OGU are 89, 108, 198, 185 and 80.

To isolate the OGU with identifier 89, select **Analysis Database Query>Reclass** (see figure 2) for Input file, enter OGU. Enter a name for the Output file.

Assign a new value of 0 to all values from 0 to just less than 89.

Press the arrow on the right side of the screen and assign a new value of 0 for all values from 89 to just less than 90. Press the arrow again and assign a new value of 0 to all values from 90 to 300. Press OK.

Figure 2. RECLASS IDRISI module window

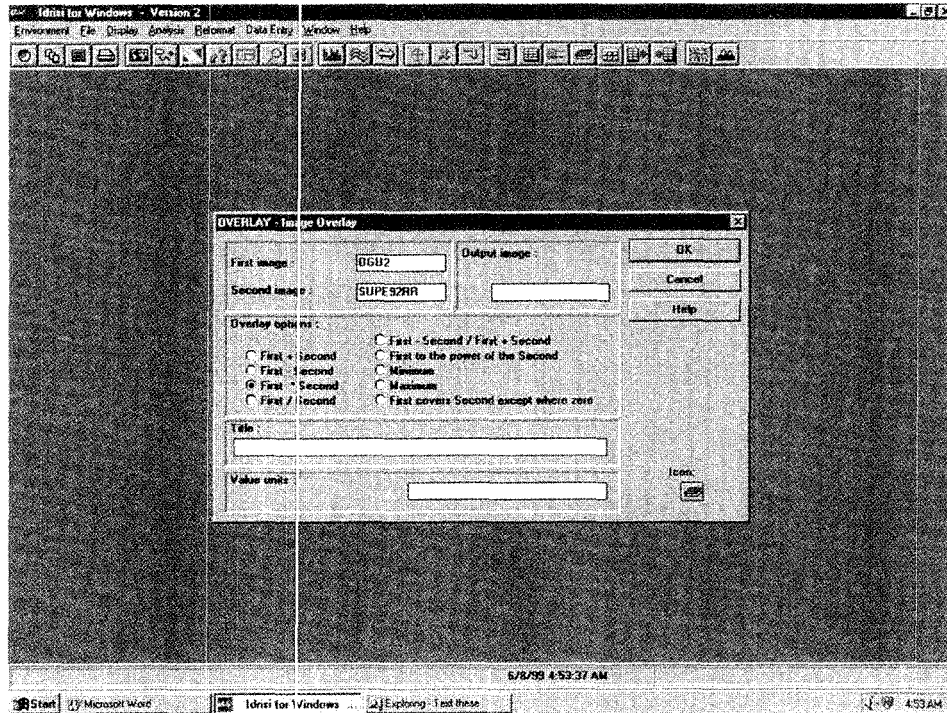


A Boolean image will be displayed where the OGU has a value of 1 and the remaining part a value of 0.

Repeat the same operation to isolate the OGU identifiers 108, 198, 185 and 80.

We will now isolate the land cover image of the OGU for both land-cover images (supe92RR and supe98RR). Select **Analysis>Database Query>Overlay** (see figure 3).

Figure 3. OVERLAY IDRISI module



Enter the following in the Overlay window:

First image: OGU 2

Second image: supe92RR

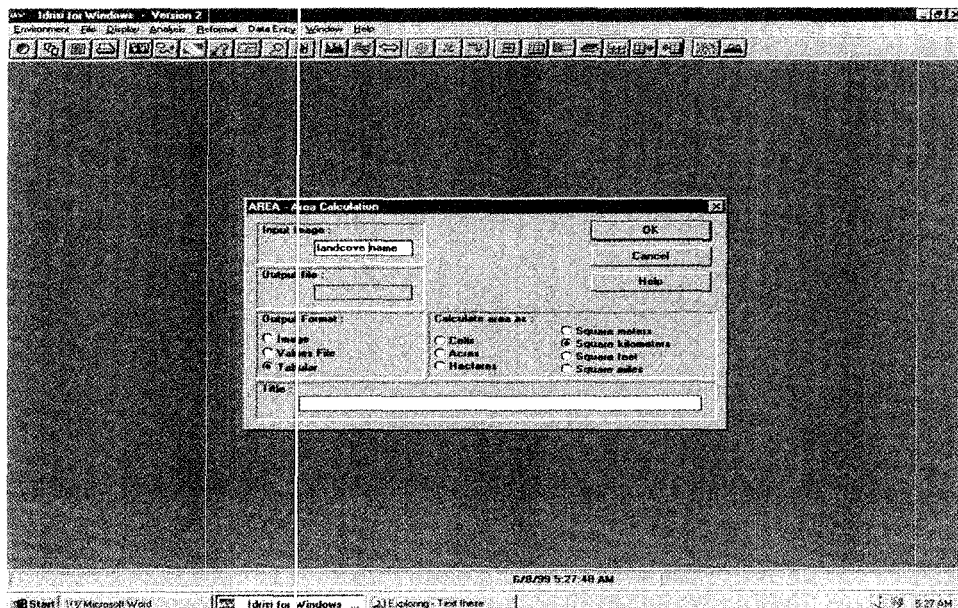
Overlay option: First*second

Press OK.

Follow the same procedure for all the OGU and for both land-cover images (supe92RR and supe98RR).

Select **Analysis>Database Query>Area** (figure 4) to calculate the area of each land-cover category. For the Input image enter the OGU with the correspondent land cover. For Output format select **Tabular** and for Calculate area as select **Square kilometers**.

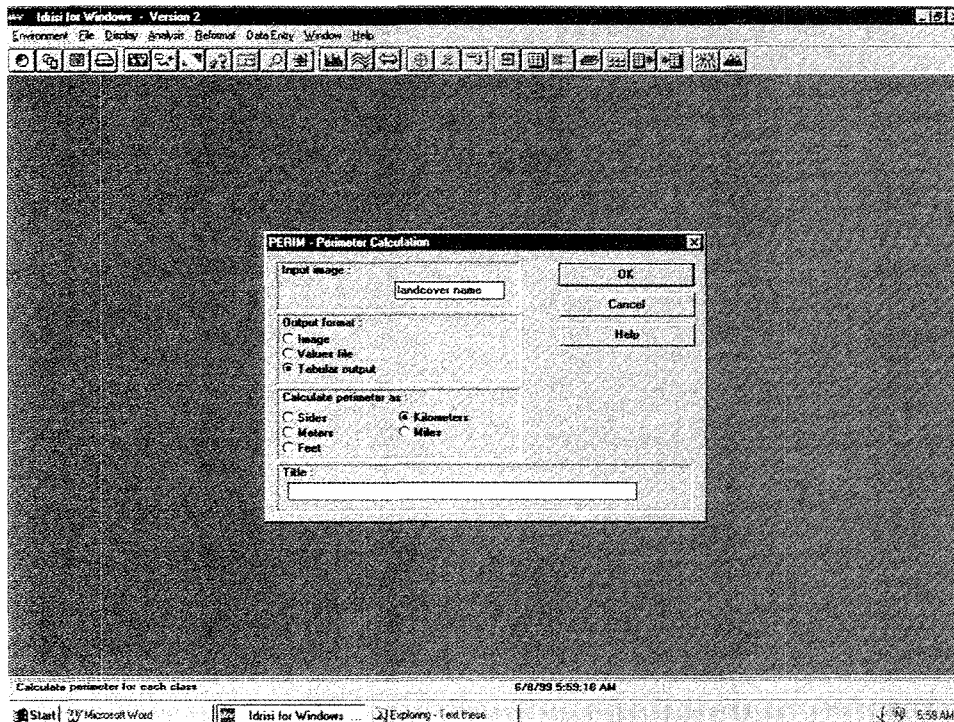
Figure 4. Area calculation IDRISI module



Select **Analysis>Database Query>PERIM** to calculate a perimeter for each land category type (figure 5).

For Input image enter the same OGU used to calculate area. For Output format enter **Tabular output**. Calculate the perimeter in kilometers.

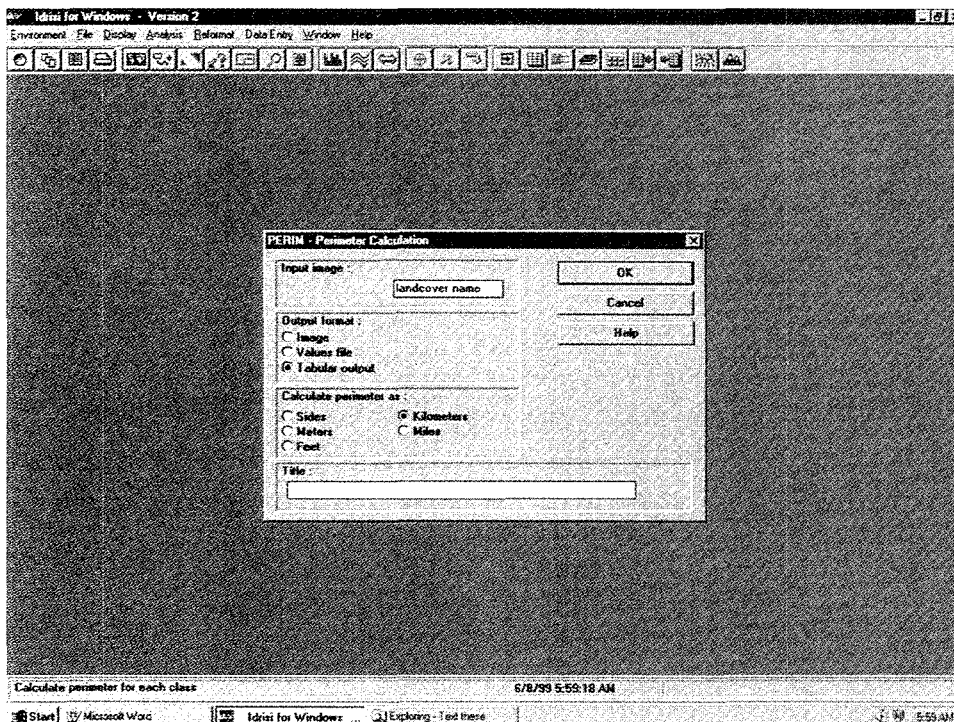
Figure 5. Perimeter calculation IDRISI module



Repeat this process to calculate the area and the perimeter of each land-category and for each OGU. Record the results in a table.

To determine the number of patches for each OGU select **Analysis>Context operators>Group** (see figure 6).

Figure 6. GROUP IDRISI module



For Input image enter the name of the corresponding OGU with land cover. Enter an appropriate name for Output image. Check the box for **Include diagonals**. Include a diagonal and Press **OK**.

For Input image enter the same OGU used to calculate area. For Output format enter **Tabular output**. Calculate the perimeter in kilometers.

Repeat the operation for all OGUs corresponding to both land-cover images.

In order to see the number of patches, check the maximum value for each grouped image in the Documentation file (figure 7).

Figure 7. Documentation file description IDRISI window



2.2. Data analysis

The three landscape indices were computed using the LAND program written in qbasic. To run this program, go to the qbasic directory and enter this command: **OBASIC LAND**.

Input the following for each OGU:

- Pixel resolution: 20 m².
- Number of classes: 5 (since we have five land-cover categories).
- Number of patches: 2159 (in 1992) and 2279 (in 1998), see table 3.
- Area for the 5 landscape categories (A1, A2, ... , A5).
- Perimeter of 5 landscape categories (P1, P2, ... , P5).

Press **Enter**, the values for the three indexes for the first OGU will be displayed. Follow the same procedure for the other OGUs.

The following tables (table 1, 2 and 3) contain data values obtained:

Table 1. Area of land-cover categories

	OGU2		OGU3		OGU4		OGU5		OGU6	
	1992	1998	1992	1998	1992	1998	1992	1998	1992	1998
Category 1	0.0316	0.002	0.4660	0.1940	1.6548	1.6244	0.5988	0.6296	0.9372	0.6924
Category 2	0.1596	0.0864	1.9284	1.8932	1.0356	0.7292	1.8604	1.4120	0.7820	1.0756
Category 3	0.8440	0.3104	1.3616	1.7784	0.9352	1.2004	1.2040	1.7996	1.7360	1.6120
Category 4	0.6052	2.7768	0.1416	0.0400	0.2412	0.2980	0.2212	0.0968	0.4796	0.4596
Category 5	2.3596	0.824	0.2280	0.0148	0.0560	0.0684	0.0756	0.0220	0.0252	0.1204

Table 2. Perimeter of land-cover categories

	OGU2		OGU3		OGU4		OGU5		OGU6	
	1992	1998	1992	1998	1992	1998	1992	1998	1992	1998
Category 1	3.679	0.36	37.920	20.68	67.400	70.440	44.200	43.400	55.760	51.4006
Category 2	15.320	12.00	74.000	132.998	70.440	80.640	76.200	115.119	49.360	106.319
Category 3	42.000	21.04	68.520	130.958	57.680	98.079	64.161	117.518	72.400	116.838
Category 4	42.920	75.440	19.16	5.239	29.2	22	28.24	9.28	54.040	32.3601
Category 5	48.160	57.640	2.5599	2.16	6.5199	9.07	4.7999	2.9199	3.559	12.84

Table 3. Number of patches in land-cover categories

	Number of patches 1992	Number of patches 1998
OGU2	286	257
OGU3	398	313
OGU4	515	664
OGU5	451	439
OGU6	509	606
Total	2159	2279

3. Urban land use classification

The following exercises will try to give you an overview of IDRISI capabilities and show you some ways of carrying out a specific analysis dealing with vegetation monitoring.

3.1. Exercise 1

Create a map displaying urban density.

The two main images that we will use for this exercise are the land-cover image (designated as *Clustw*, 12 classes representing land-cover) and administrative borders of the area (Communes, 10 communes). Use palette qualitative 256 to display both of them.

Isolate the communes situated along the main river (Sebaou valley). They are listed with the corresponding identifiers as follows: S. Daoud (63), Delys (65), Baghlia (64), Tadmait (30), S. Namman (66), DBK (29), T. Ouzou (26), T. Rached (37), Freha (56), Mekla (39).

To isolate these communes we will first create a value file where the commune identifiers will have a value of **1** and other identifiers have a value of **0**.

Access the File menu and select **Edit>Show File contents**, choose the value file *Valley1* and ensure that the communes listed above have a value of 1 and the others a value of 0 (figure 8). **Save** the file and exit.

From the Data Entry menu, select **Assign>Attribute Values Assignment**. For Future definition image, type *Communes*; for the Attribute value file enter *Valley1*; for the Output image, enter *comval* (see figure 9).

You should obtain a Boolean image in which the communes of the valley have a value of **1**.

Isolate the land-cover image of our study area (the buffer zone is the Sebaou valley).

From the Analysis menu select **Database Query>Overlay**.

Enter *comval* as the First image, *clustw* as the Second image and *cluswval* as the Output image. Select **first*second as** Overlay options (figure 10).

Figure 8. Value file representing the selected communes

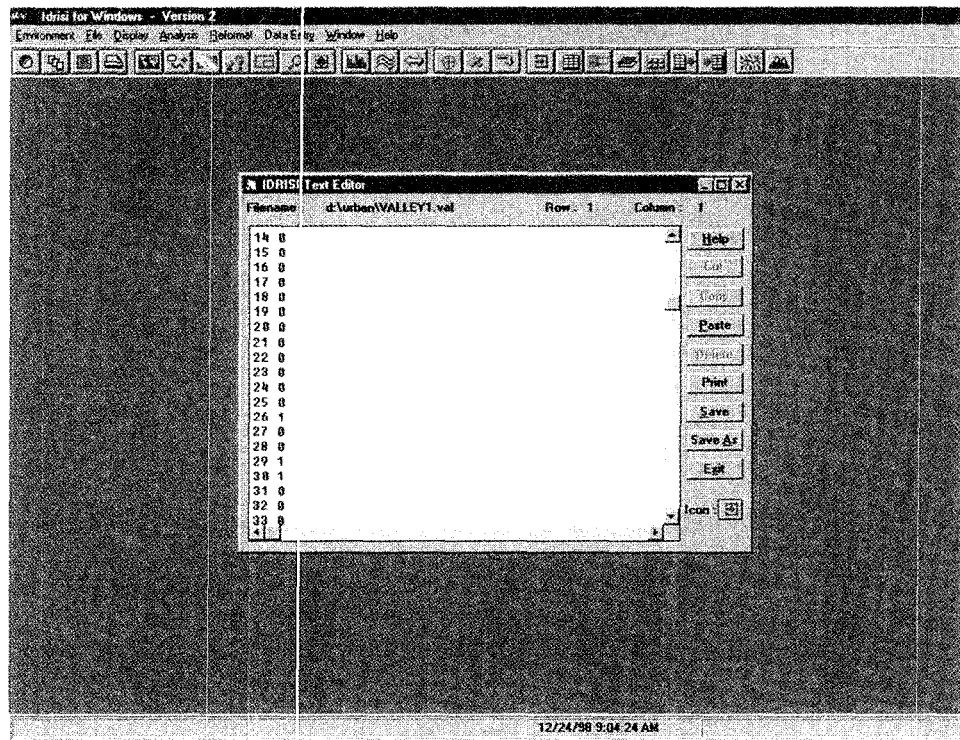
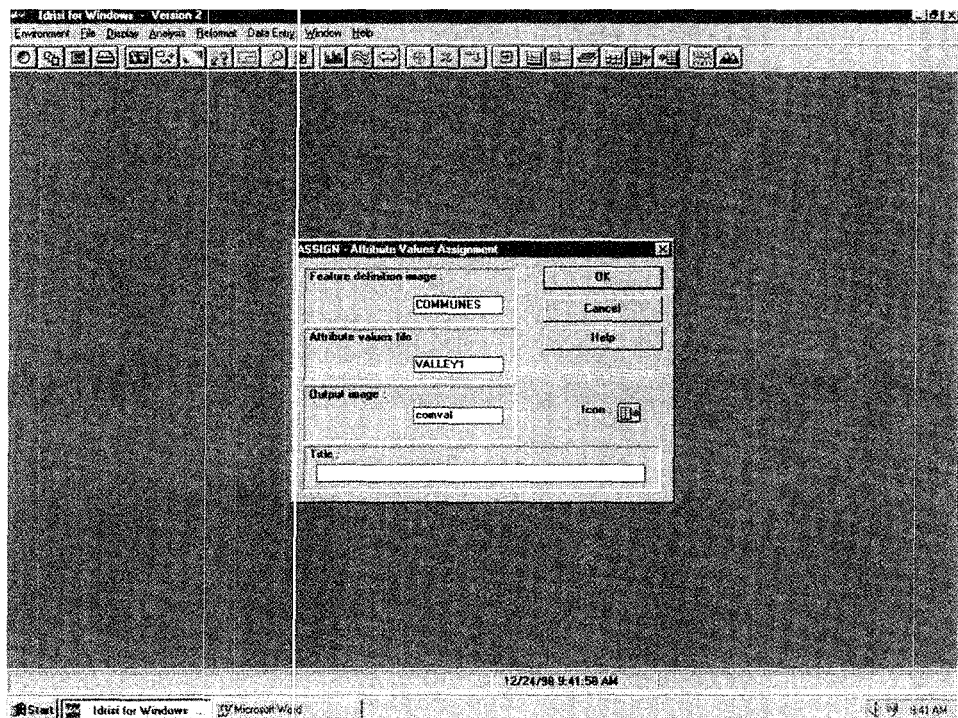


Figure 9. Elaboration of a Boolean image



Go to Display>Map Composition Launcher. For Type of file, select **Image file**; for Name of file to display, type *cluswval*. Select **Qualitative 256** for the Palette and check **Legend** under Map compositions (figure 11).

Figure 10. Overlay module to isolate the land-cover for the study area

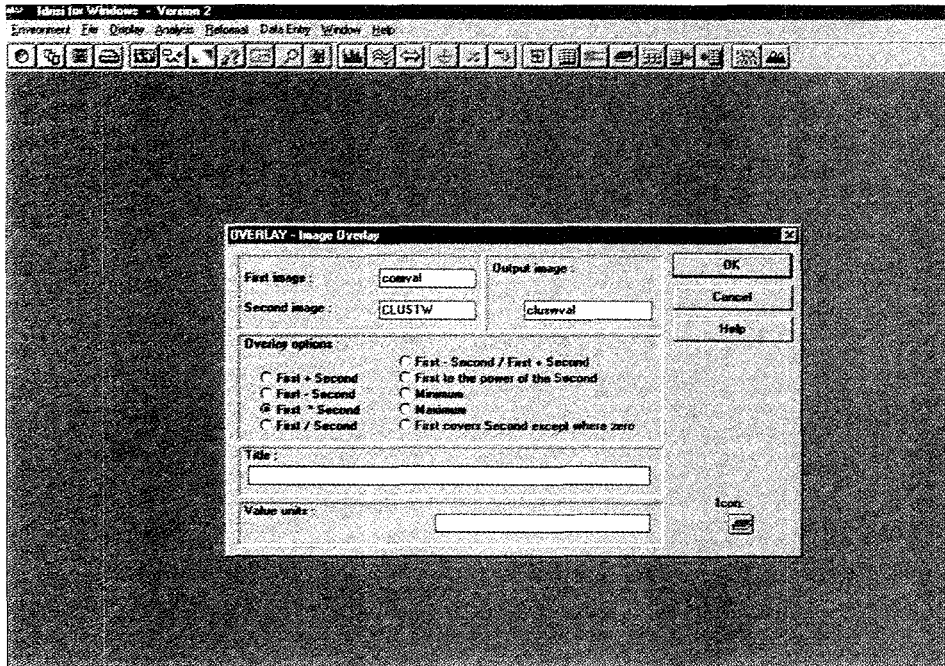
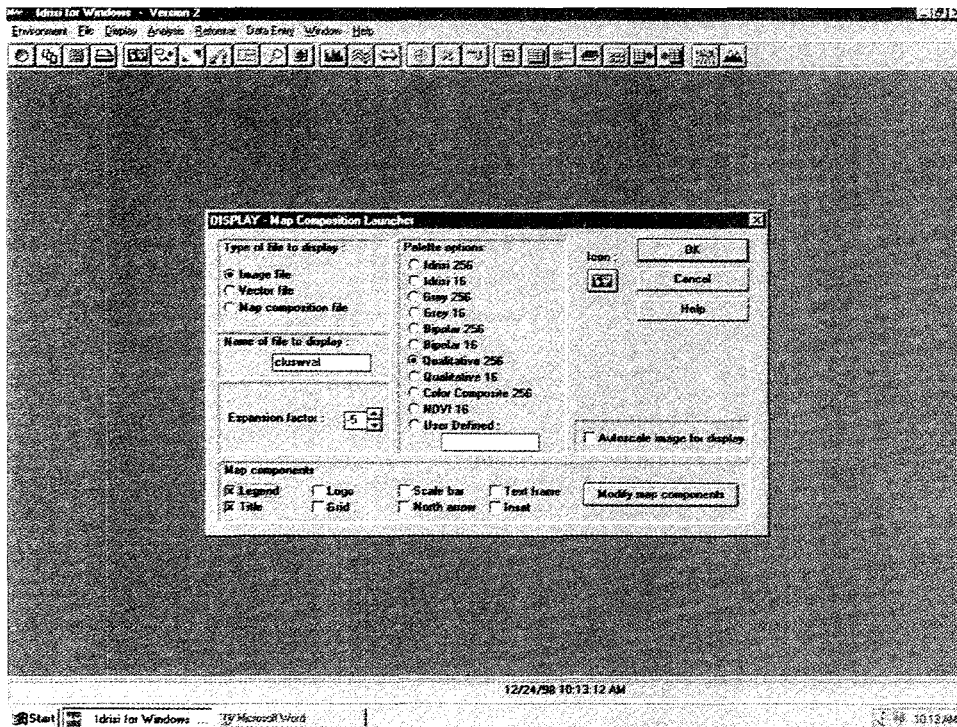


Figure 11. The display module for map composition launcher



Go to Composer (on the right side of the screen) >Add Layer>enter **City2** with Palette cities. Note that the urban categories present attribute No 10.

Go to the Analysis menu and select **Image processing>Transformation>Texture**.

Enter the following options (see figure 12):

Type of analysis: **Class frequency**

Input image: enter *cluswval*

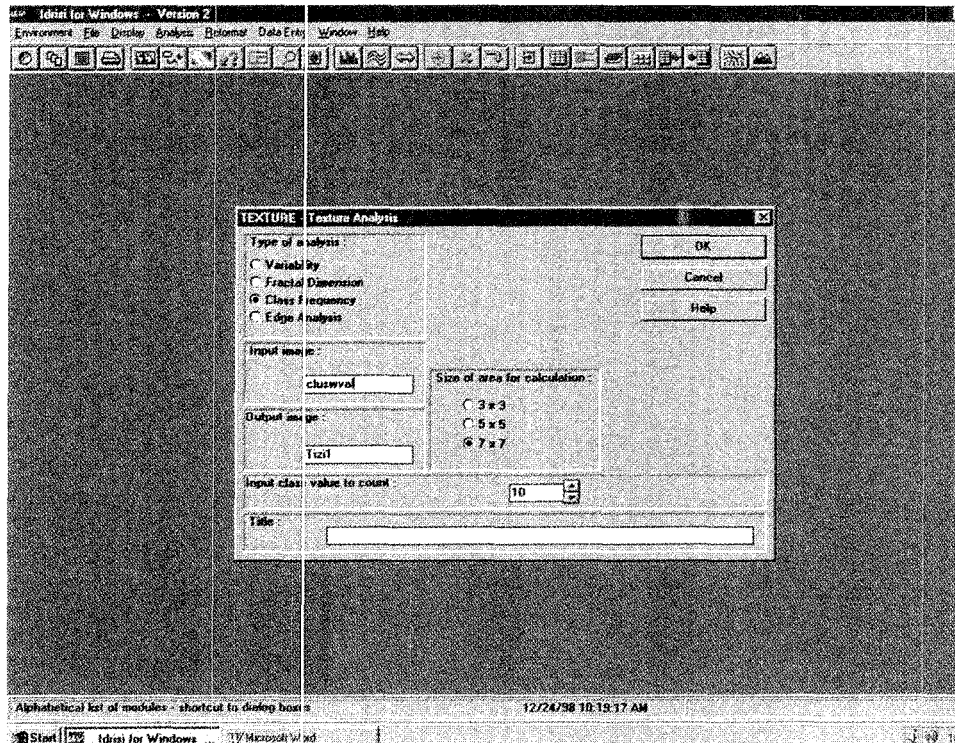
Output image: enter *Tizi1*

Size of area for calculation: select **7 x 7**

Input class value to count: **10** (it corresponds to the urban category).

Press **OK**.

Figure 12. Texture analysis to calculate the frequency of urban pixels



To create a map density value, open the Analysis menu and select **Mathematical operator>scalar**.

Enter the following information (see figure 13):

Input file: enter *Tizi1*

Output file: type *Tizi2*

Operation: **divide**

Scalar value: enter **37**

Press **OK**.

Display the output using **Quant 256** Palette option.

Go to the Display menu and select **Image Histogram** (see figure 14). Type *Tizi2* for the input image and **0.01** for the class width.

Select **Analysis>Database Query>Reclass** to classify the image *Tizi2* in three main categories defined from the histogram. Name the output image *Tizi3*.

The three categories of urban density are:

Class 1: Low urban density (from 0.01 to 0.30)

Class 2: Medium urban density (from 0.31 to 0.59)

Class 3: High urban density (from 0.60 to 1)

Figure 13. Urban density calculation using the module scalar

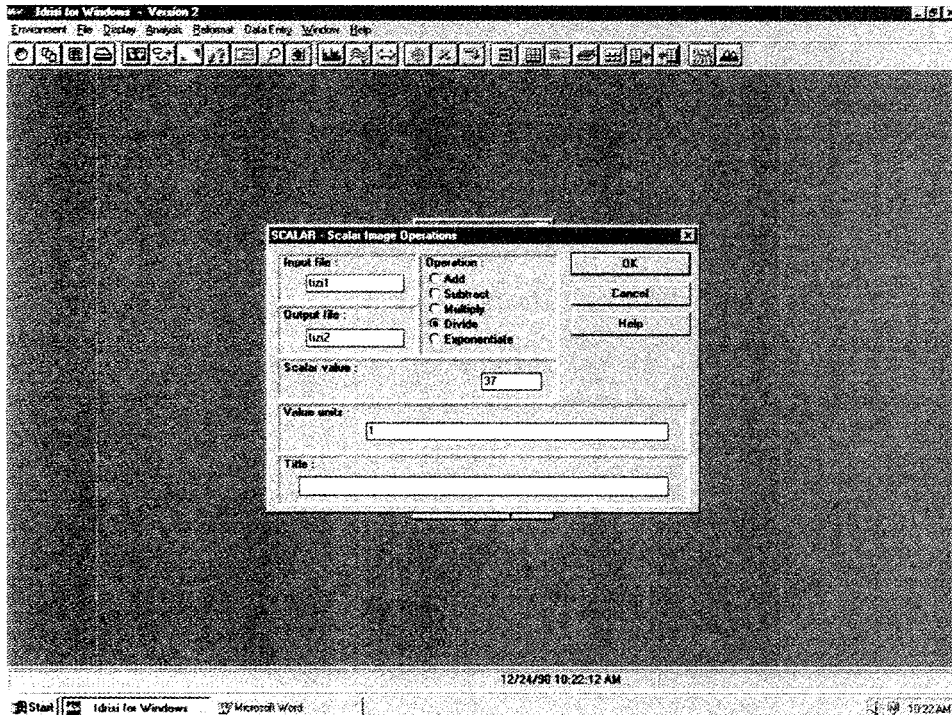
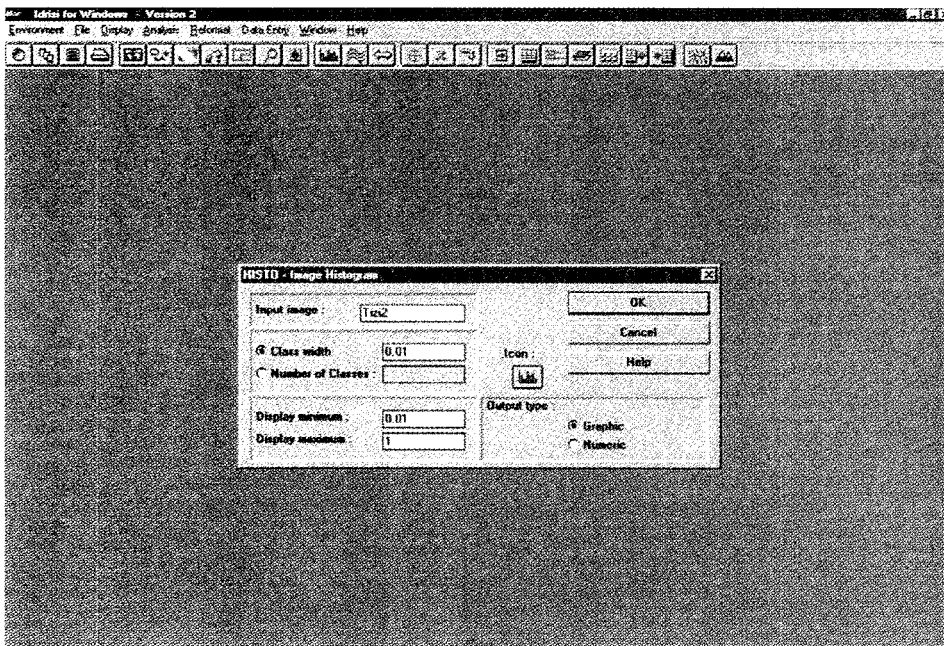


Figure 14. Image histogram module



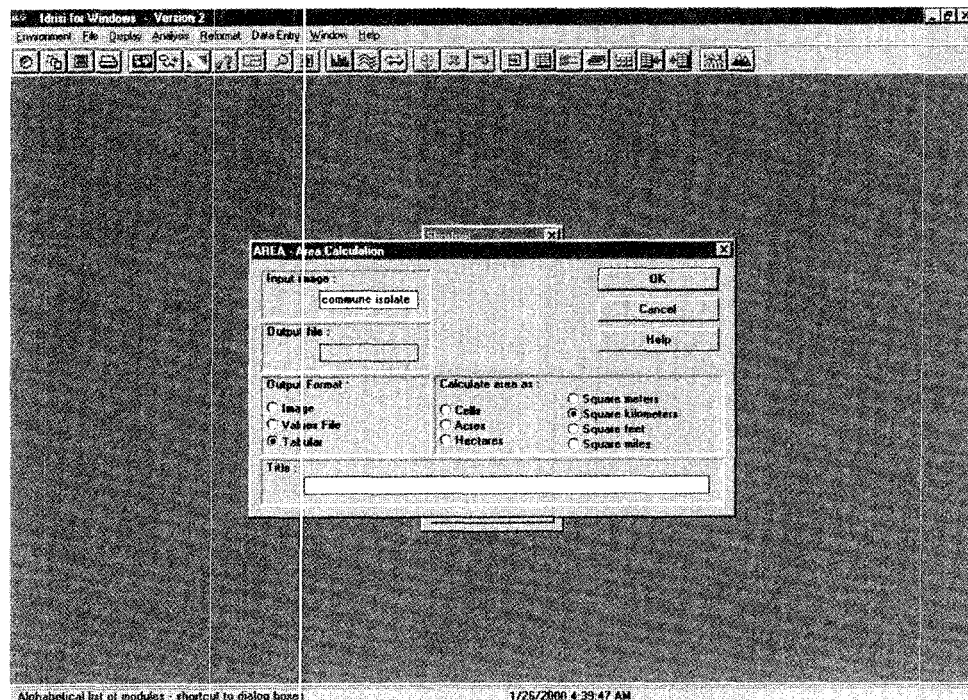
To display Tizi3 select **Urbanden** as the Palette option and add the following Vector files from the composer: **Limits, city2, city2'**. Save the result as a map composition file. Give it a name.

Create a second image to show the industrial area in the valley. For the Map Layer enter **Industry**, for the Text Layer enter **INDTXT**. Use the Urban density map as the base map with the Vector file: limits, industry and INDTXT. Save the result as a map composition file from composer.

Calculate the area of each category and each commune (one by one). Take as the transect the commune situated along the main river. You should then isolate commune by commune. Use the method explained at the beginning of this section to isolate the necessary communes.

To calculate the area select **Database query>Area** (see figure 15). For the Input image enter **Commune isolated**; for the Output format select **Tabular** and for Calculate the area as select **Square kilometers**.

Figure 15. Determining the areas of the communes



3.2. Exercise 2

Calculate the NDVI average.

In this exercise we will calculate the NDVI average for selected communes located along the Sebaou river. These communes are listed as follows with their corresponding identifiers: S. Daoud (63), Delys (65), Baghlia (64), Tadmait (30), S. Namman (66), DBK (29), T. Ouzou (26), T. Rached (37), Freha (56), Mekla (39).

In the Reclass module we will create a Boolean image where the urban categories will have a value of 0 and the non-urban area will have a value of 1.

For the input image enter **Tizi3**.

Name the output image **seba1**.

To obtain a NDVI image without the urban categories we should overlay the Boolean image **seba1** with **NDVIAW** (Pallet NDVI 256). Name the result **seba2**.

Select **Analysis>Database Query>Extract** to obtain the NDVI average for the corresponding images.

Enter the following (figure 16):

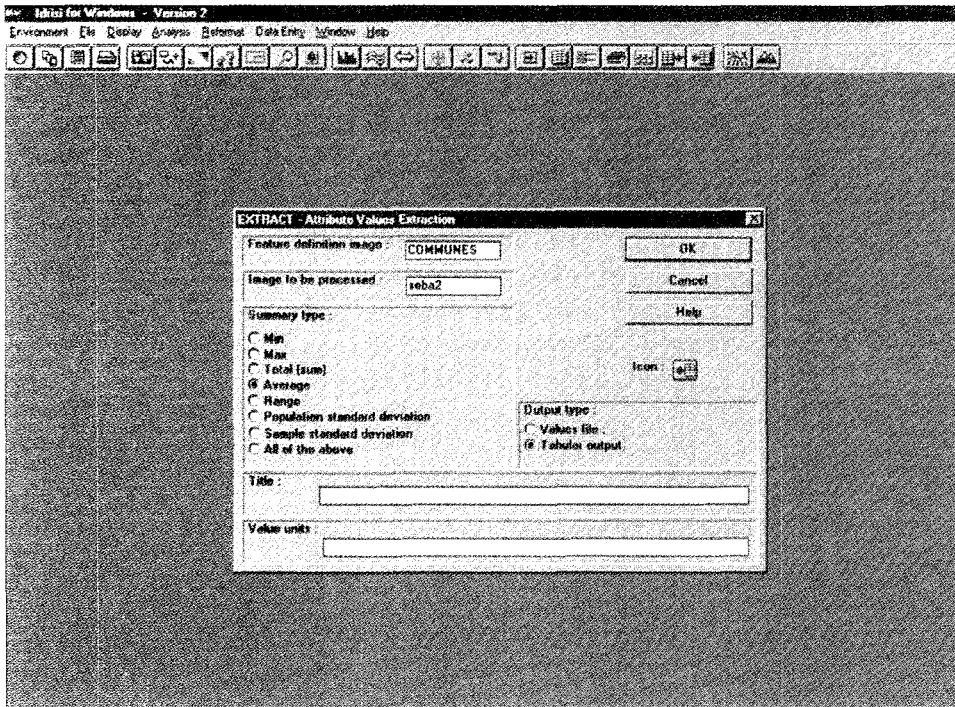
Future definition images: **Communes**

Image to be processed: **seba2**

Output type: **tabular**

Press **OK** and save as **extract.txt**.

Figure 16. Calculating the NDVI average for each commune

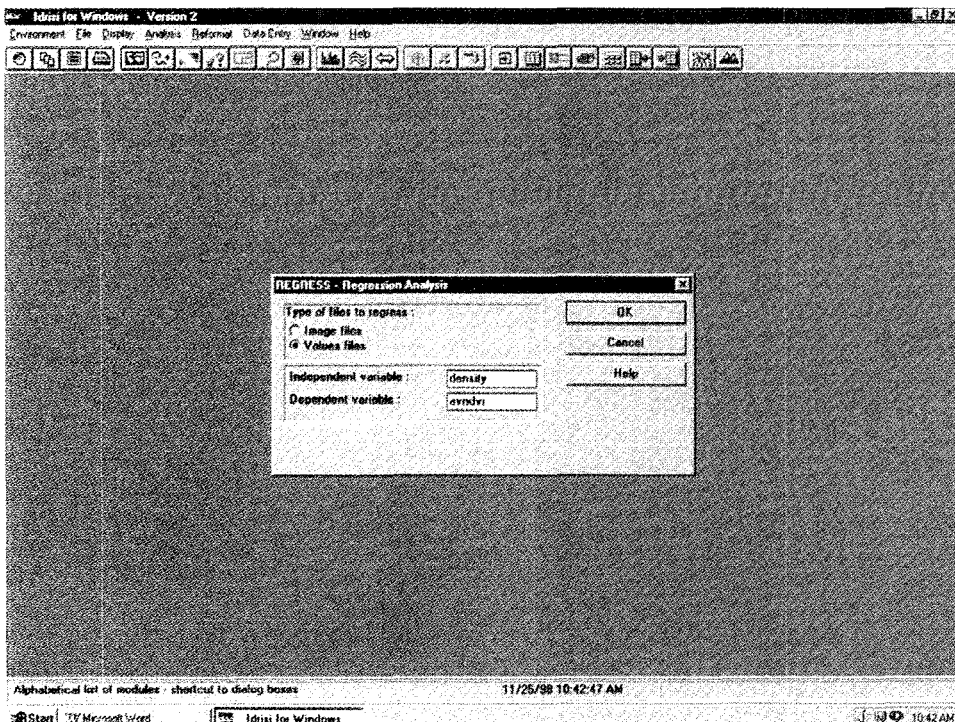


This process provides a series of values corresponding to the NDVI average for each commune of the Sebaou valley. You can either print or export these values to statistical package for further analysis.

3.3. Exercise 3

Find the relation between urban density and vegetation index NDVI.

Figure 17. Regression analysis between NDVI average and urban density



Calculate the NDVI average for the 37 categories corresponding to the urban density categories for the image Tizi1.

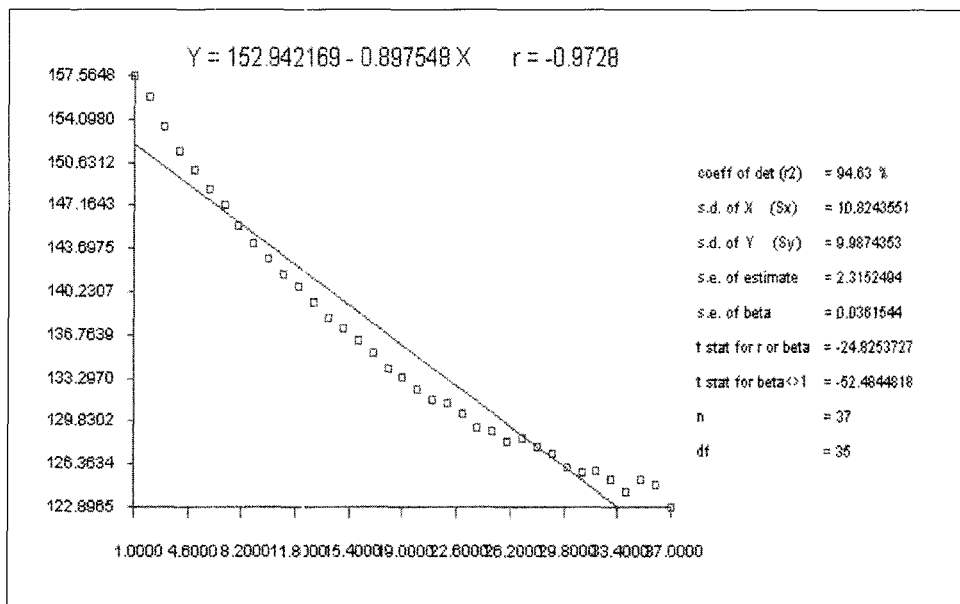
Use the module Extract but, instead of choosing Table for output, type **Table**, select **Values File**. Name the output file avndvi.

Use the Value File Density as an independent variable. (The Value File Density is available within the database created by the author.)

Now you have all the necessary data to conduct regression analysis (**Analysis>Statistics>Regression**) between the two value files. Use the density file as the independent variable and avndvi as the dependent variable (see figure 17).

The result should be as shown in figure 18.

Figure 18. Linear correlation between NDVI intensity and urban density



The correlation between the NDVI intensity and the urban density confirms a highly significant negative correlation between the two parameters with $R = -0.9728$.

4. References

1. Food and Agriculture Organization of the United Nations. Tropical Forestry Action Plan, Committee on Forest Development in the Tropic. Rome, 1985.
2. Lillesand T. M. and R. W. Kiefer. Remote Sensing and Image Interpretation. 2. ed. New York, John Wiley and Son, 1987.
3. Blackburn G. A. and E. J. Milton. An ecological survey of deciduous woodlands using airborne remote sensing and geographic information system (GIS). *Remote Sensing*, 18:9:1919-1935, 1997.

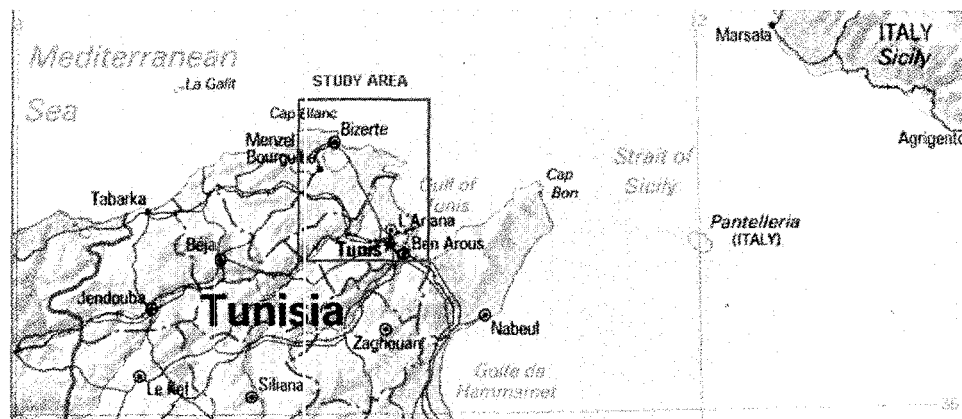
Case study 2

Multi-criteria evaluation for industrial siting in the region of Tunis-Bizerte, Tunisia*

1. Description of the study area

Human settlements in the Mediterranean basin have existed since ancient times and have had a profound impact in the flora and fauna of the region. Consequently the Mediterranean system offers a very interesting field for investigations on human impact [1]. The region of Tunis-Bizerte in Tunisia has been selected for study because it is typical of the Mediterranean environment. It is located on the coast of the Gulf of Tunis in north-eastern Tunisia (see figure 1).

Figure 1. Location of the study area



2. Purpose

The present exercise designs a suitability map depicting the sensitivity of the coastal areas of the region of Tunis-Bizerte to the establishment of industries. It consists of landscape evaluation for industrial siting and includes a GIS technology developed for the IDRISI geographic information system software.

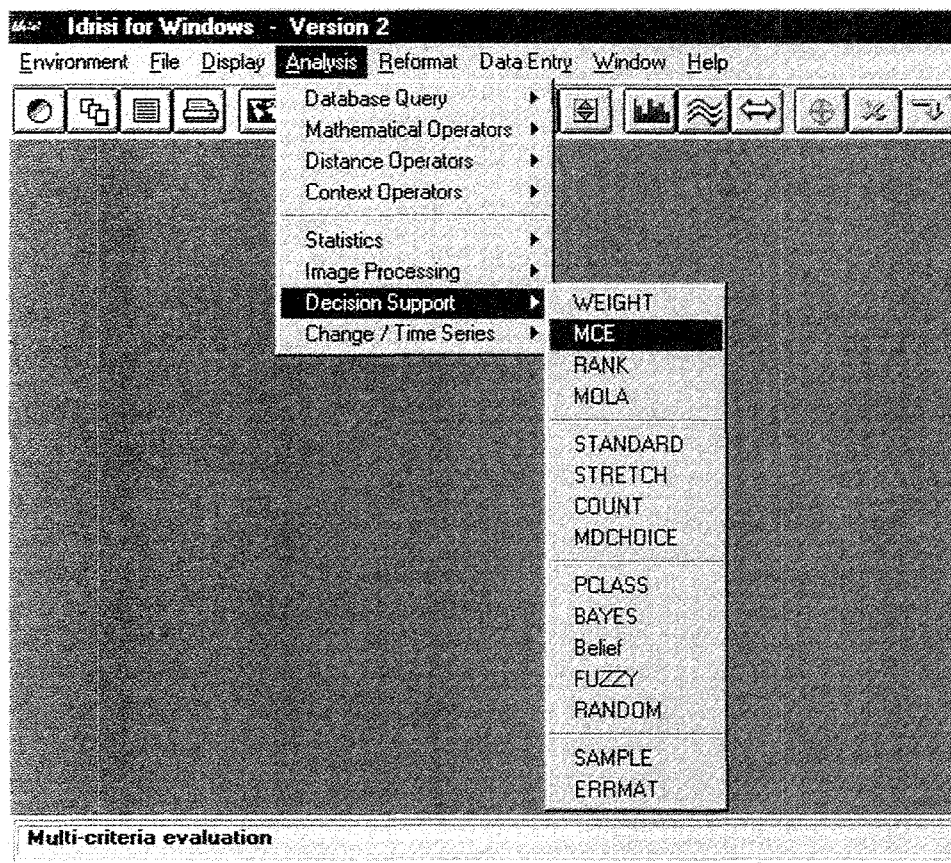
3. Procedure

Open IDRISI for windows [2] from your Desktop and select **Analysis>Decision Support>MCE** (see figure 2).

Multi-criteria evaluation (MCE) is a decision-support tool [3]. A decision is a choice between alternatives (such as alternative actions, land allocations etc.) [4]. In MCE, an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective.

*This case study was prepared by M. Ghribi, Area of Earth, Environmental and Marine Sciences and Technologies, ICS-UNIDO.

Figure 2. Multi-criteria evaluation IDRISI module window



A GIS-based methodology is integrated by using the Weight IDRISI module. The concept consists of inserting interactive effects of several contributing factors (table 1) and constraints that may contribute in enhancing or decreasing industrial susceptibility. The factors are raster images containing the target features from which distance is measured using the Distance IDRISI module (figure 3). The constraint, on the other hand, is used to exclude certain areas from consideration (such as water and reserved lands).

Table 1. Factors contributing to the change of industrial susceptibility

<i>Factors</i>	<i>File name</i>	<i>Description</i>
1	97UTMUD.img	Proximity to main urbanized areas
2	97UTMID.img	Proximity to main industrialized sites
3	97UTMRD.img	Proximity to main roads
4	97UTMWD.img	Proximity to water (sea, lakes and rivers)
5	97UTMFD.img	Proximity to protected forests and national parks
6	97UTMBD.img	Proximity to bare soils

Using the IDRISI MCE function, these criteria images were combined to form a single suitability map from which the final choice can be made. The output will consist of a certain number of categories, each reflecting its susceptibility to the installation of new industries and urban-area expansion.

In MCE, using a weighted-linear combination, weights are derived from a PAIRWISE comparison between factors. The comparisons concern the relative importance of two criteria in determining suitability.

Select **Analysis>Decision Support>WEIGHT**, select **use a previous PAIRWISE comparison file**, enter the file name **97UTMPW** and click the **Continue** icon (figures 4 and 5).

Figure 3. Distance IDRISI module window

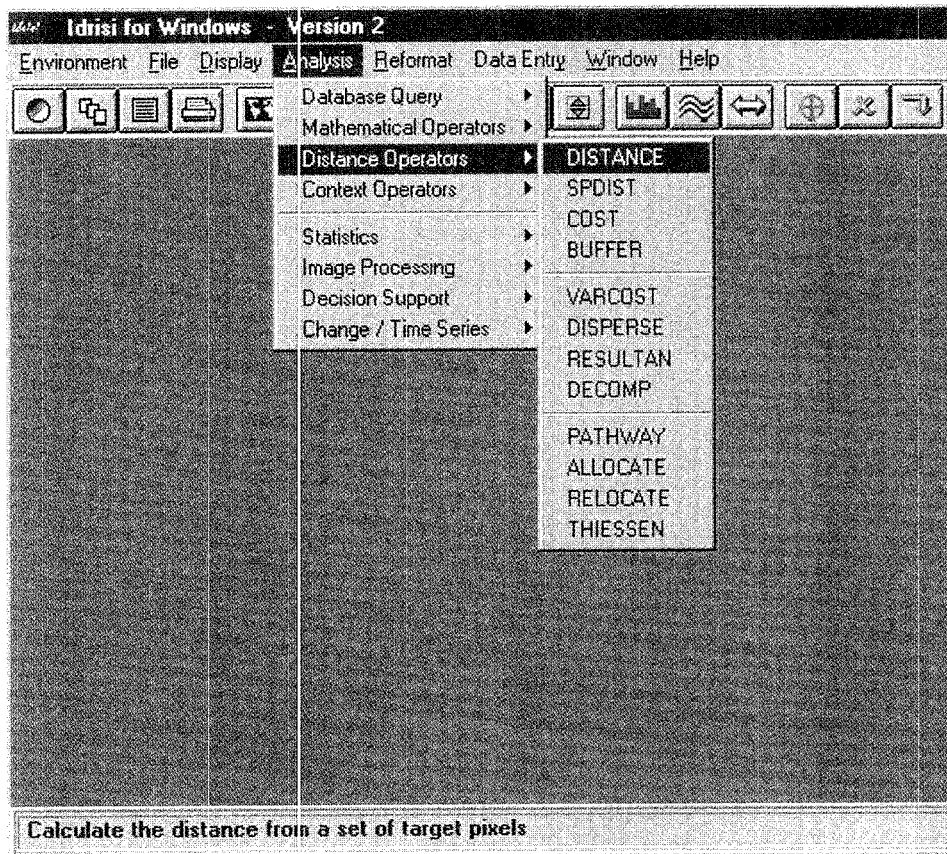


Figure 4. WEIGHT IDRISI module window

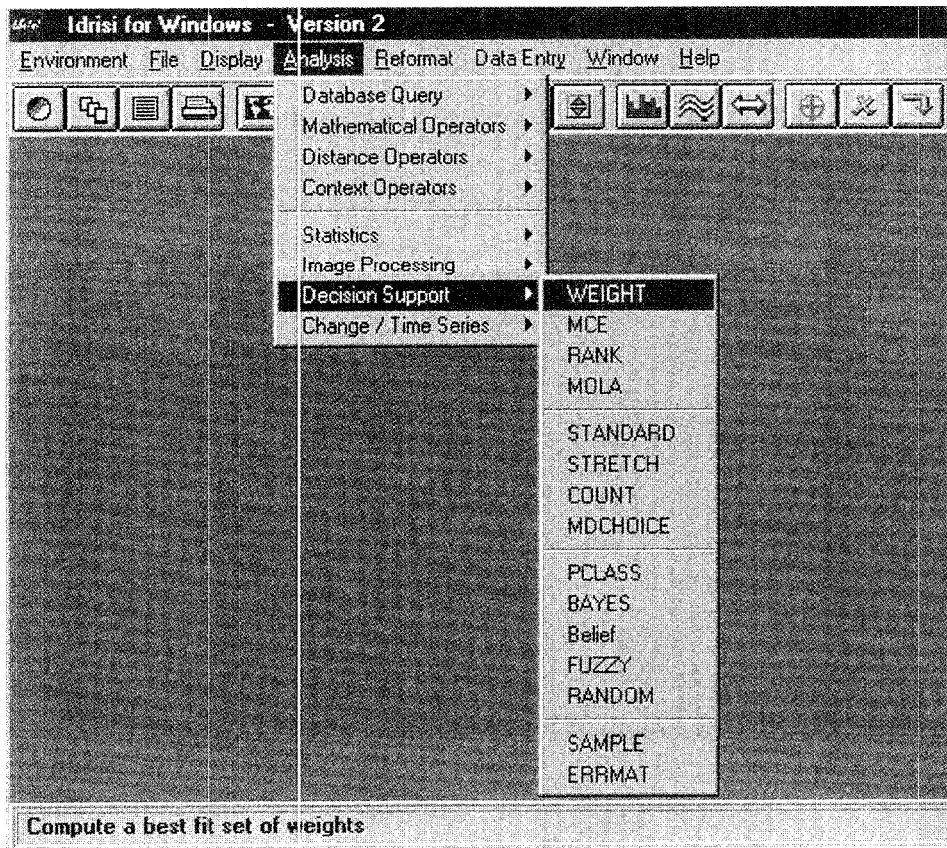
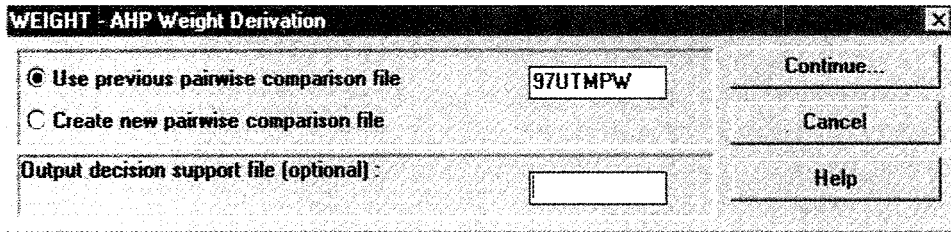


Figure 5. PAIRWISE comparison



The weights are developed by providing a series of pairwise comparisons of the relative importance of factors to the suitability of pixels for the objective being evaluated. Ratings are provided on a continuous nine-point scale from extremely less important to extremely more important (figure 6).

Select **Calculate weights** to produce the eigenvector of weights (figure 7).

The result is a set of factor weights used by a weighted-linear combination in the multi-criteria evaluation (figure 8).

Figure 6. Continuous nine-point scale for the pairwise comparison

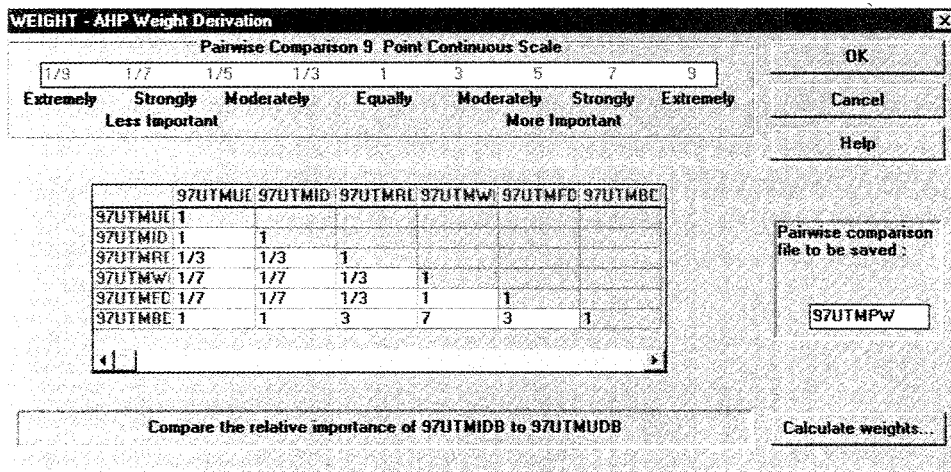


Figure 7. The eigenvector of weights generated from the pairwise comparison

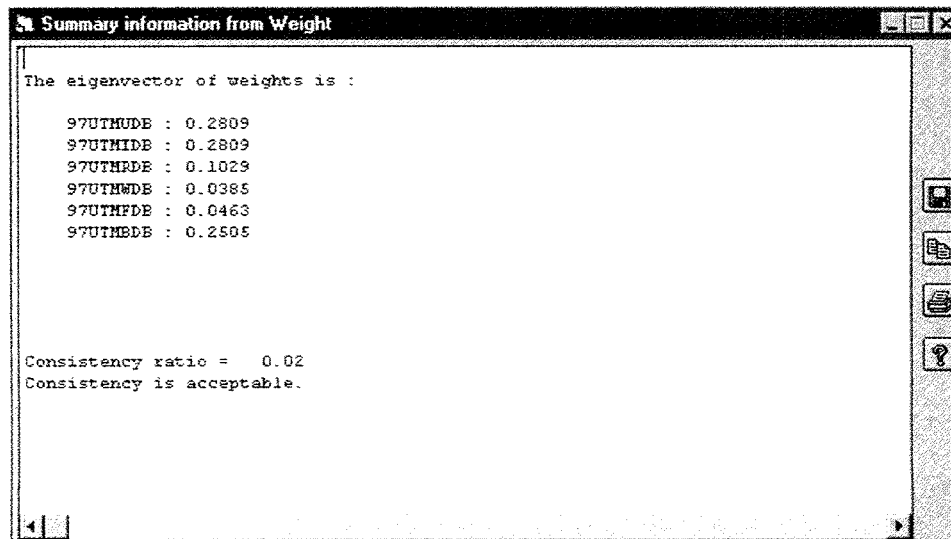
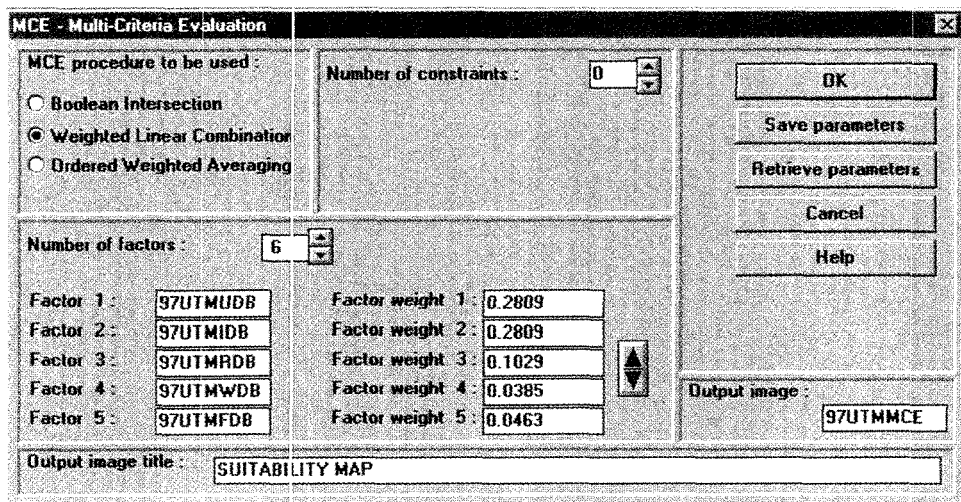


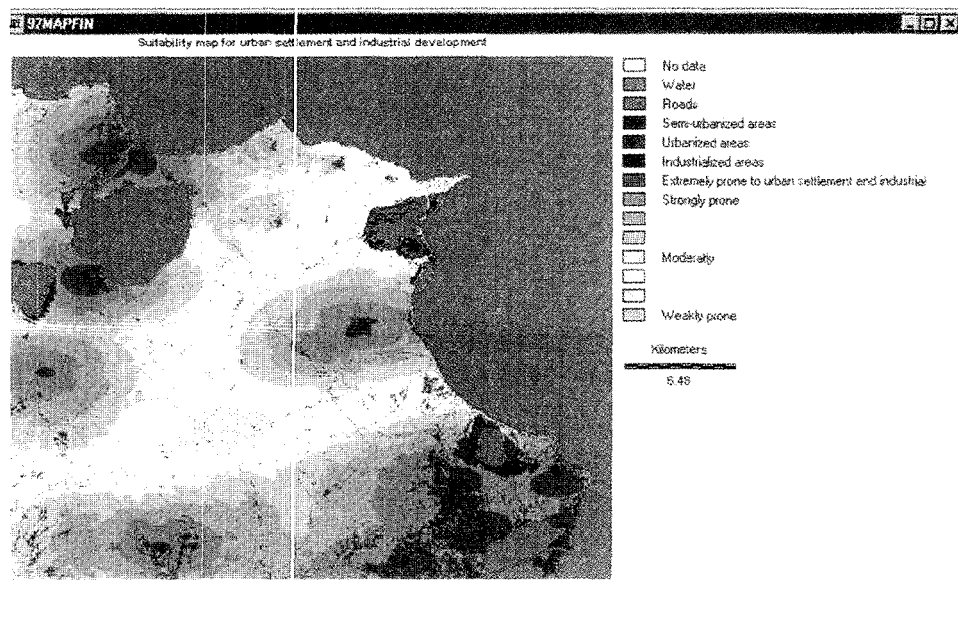
Figure 8. Multi-criteria analysis procedure



4. Industrial suitability map

The suitability map 97UTMMCE.img is used as a first raster layer for which we will overlay all the factor layers to get a final suitability map 97MAPFIN.img displayed with a palette file "97sui." (figure 9).

Figure 9. Suitability map for industrialization



5. Interpretation

The suitability map produced from a multi-criteria evaluation shows different degrees of susceptibility to new industrial plants. As shown in figure 9, the extremely prone areas are concentrated around the main existing industrial sites (Echarguia, Ariana,

Ettadhamen, Mannouba, Mateur, Menzel Bourguiba and Bizerte), in the urbanized areas and along the coast. Areas that are highly prone to industrial development are characterized by:

- Proximity to an existing industrial zone in which there is a high probability that infrastructure and an organized industrial system exist;
- Proximity to residential and commercial sites fulfilling the requirement for social activities. The availability of a large number of workers will satisfy labour requirements for industrial activities;
- Proximity to main roads and good connections with markets;
- Natural allocations (coast, rivers, lakes, slope etc.), which can represent an environmental constraint.

6. References

1. Food and Agriculture Organization of the United Nations. A framework for land evaluation. *Soils bulletin* (Rome) 32, 1976.
2. Idrisi for Windows user's guide. Clark Labs for Cartographic Technology and Geographic Analysis. Worcester, MA, United States of America, Clark University, 1997.
3. Eastman, J. R., W. Jin, P. A. K. Kyem and J. Toledano. Raster procedures for multi-criteria/multi-objective decisions. *Photogrammetric engineering and remote sensing*, 61:5:539-547, 1995.
4. Carver, S. J. Integrating multi-criteria evaluation with geographic information systems. *International journal of geographic information systems*, 5:3:321-339, 1991.

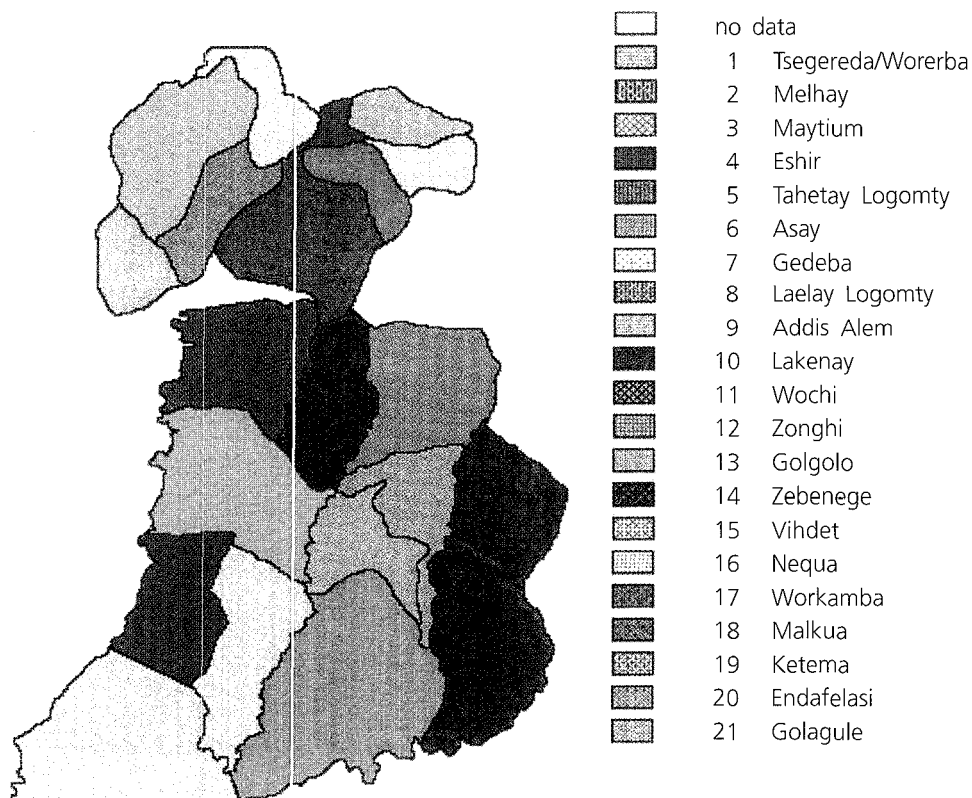
Case study 3

Landscape analysis of degraded and degrading areas of Tigray, Ethiopia*

1. Introduction

In this case study we will use two new indices of fragmentation and path shape complexity for the landscape ecology analysis of remotely sensed data. The traditional indices of contagion [1] and fractal dimension [2, 3] will be replaced by two new indices called patch-per-unit area (PPU) and square-pixel (SqP) [4]. These indices are independent of the variations of spatial resolution in remotely sensed data and are very sensitive to actual changes in the landscape pattern. They will be applied to each of the 21 *tabias* (administrative units, see map 1) of the Tigray region in northern Ethiopia in order to study the structure and distribution of the areas most exposed to the risk of soil erosion.

Map 1. Location of the *tabias* (administrative units) of the Tigray region in northern Ethiopia



*This case study was prepared by A. Altobelli, Area of Earth, Environmental and marine Sciences and Technologies, ICS-UNIDO.

A technique for the simulation of alternative land cover types (cropped lands into woodlands) will be applied in one area of industrial development, with the objective of reducing the risk of soil erosion.

Various data types of land cover will be stored and processed in the geographic information system using IDRISI 2.0 [5] and PCRaster softwares [6] for Windows 95 or NT. The land-cover map is produced by means of Landsat Thematic Mapper (TM) images with the support of a ground truth survey.

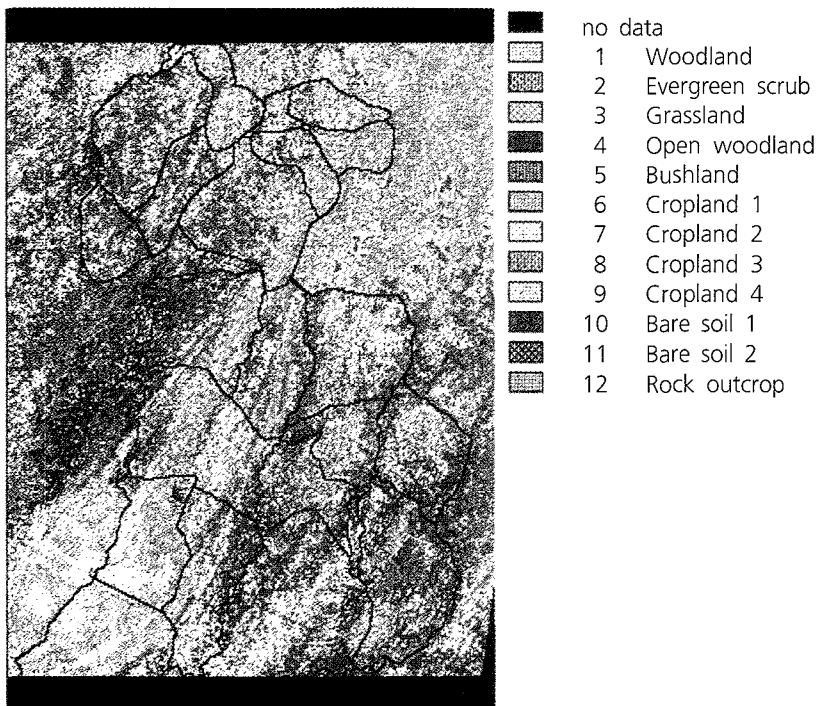
The data to be used are derived from the final report of a project funded by the European Union [7].

2. Land cover map

The classification of the Landsat TM images is performed using unsupervised and supervised techniques. The map obtained from the unsupervised classification is used to sample the training areas for the supervised method. The accuracy of the classification, evaluated by the mean of a confusion matrix, approaches 90 per cent. The land-cover classes for map 2 are as follows:

1. Woodland
2. Evergreen scrubland
3. Grassland
4. Open woodland
5. Bushland
6. Cropland 1 (tef)
7. Cropland 2 (wheat, barley)
8. Cropland 3 (sorghum, maize)
9. Cropland 4 (wooded cropland)
10. Bare soil 1
11. Bare soil 2
12. Rock outcrop

Map 2. Land-cover map obtained from a Landsat-TM satellite image



The bare soil 1 category is located in a karstic depression. The bare soil 2 category contains all the areas without or with very little (less than 5 per cent) vegetation cover and consists of ploughed lands or fallow lands on steep and stony hillsides. Further descriptions of the land-cover classes can be found in the final report on rehabilitation of degraded and degrading areas of Tigray, northern Ethiopia [7].

3. Potential soil erosion model map

The map that shows the potential soil erosion for the area is calculated using the following maps:

- Slope map
- K-factor map
- C-factor map

3.1. Slope map

The slope map is calculated from the digital elevation model (DEM) (map 3). Three classes of slopes, expressed as percentages, are defined:

<i>slope</i>	<i>slope.class</i>
0-10%	1 (mild erosion)
>10%-20%	2 (medium erosion)
>20%	3 (severe erosion)

The slope map with the three percentage classes is shown in map 4.

3.2. K-factor map

The K-factor map is obtained from the geomorphological unit map (map 5). The K values for each unit were estimated on the basis of the physical properties of the most characteristic soil types in the area (see table 1):

Table 1. Geomorphological units and corresponding K-factor values

<i>Geomorphological unit</i>	<i>K</i>	<i>Class</i>
Town	0.00	1
Erosion surface-shallow soil	0.10	1
Scarps/denutational rock slopes	0.15	1
Undulating badlands	0.20	2
Infield valleys	0.23	2
Alluvial plain and terraces	0.25	2
Erosion surface remnants with soil cover	0.25	2
Alluvial fans	0.27	2
Severe badlands	0.31	3

The following K-factor classes were defined to produce map 6:

<i>K-factor</i>	<i>Kfactor.class</i>
0.1-0.2	1 (mild erosion)
>0.2-0.30	2 (medium erosion)
>0.30	3 (severe erosion)

3.3. C-factor map

The C-factor, indicating the level of protection of a soil type under a certain land cover, was estimated using data from the literature (applied to a similar area) and information from the geomorphological map. The C-factor values given in table 2 were assigned to the different land-cover types.

Table 2. Land-cover types and corresponding C-factor values

<i>Vegetation types</i>	<i>C-factor</i>
Rock outcrops	0.00
Grassland	0.01
Woodland	0.01
Scrubland	0.02
Open woodland	0.05
Open scrubland	0.06
Crop 3 (sorghum, maize)	0.10
Crop 2 (wheat, barley)	0.15
Crop 4 (wooded cropland)	0.15
Bare soil 1	0.15
Crop 1 (tef)	0.25
Bare soil 2	1.00

The C-factor values were divided into four classes:

<i>Vegetation type</i>	<i>Cfactor.class</i>
Woodland, evergreen scrubland, grassland, rock outcrops	1 (no erosion)
Open woodland, open scrubland	2 (mild erosion)
Croplands, bare soil 1	3 (medium erosion)
Bare soil 2	4 (severe erosion)

A C-factor map corresponding to the four classes described above was produced (see map 7).

The general formula [8] to calculate the potential soil erosion (pse), for each pixel, is

$$pse = n/100 * \sum_{i=1}^n (w_i * map_i)$$

where,

map_i = the category value for the pixel in the i-th map

w_i = the specific weight assigned to the i-th map

n = the number of input maps

The formula applied to the data in the case study was:

$$pse = 3/100 * (40 * slope.class + 30 * Kfactor.class + 30 * Cfactor.class)$$

The resulting *pse* values were subdivided into seven classes as shown in table 3 and the corresponding map was produced (map 8):

Table 3. Potential soil erosion classes

Potential soil erosion (pse)	pse.classes
1.0 3.5	1
>3.5 4.5	2
>4.5 5.5	3
>5.5 6.5	4
>6.5 7.5	5
>7.5 8.5	6
>8.5 9.5	7

4. Landscape indices

The fragmentation index ppu (patch-per-unit), used as an alternative to the traditional contagion index, is given by following the formula [4]:

$$ppu = m/(n*\lambda)$$

Where m is the total number of patches, n is the total number of patch pixels in the considered *tabia*, and λ is a scaling constant equal to the area of a pixel. As the landscape becomes more fragmented, the ppu index increases.

The other index, SqP, was introduced to quantify complexity, replacing the fractal dimension. SqP considers the relationship between perimeter and area of raster data and normalizes the perimeter/area ratio to a value between 0 (for squares) and 1 (maximum perimeter, edge and deviation from that of a perfect square). SqP is given as:

$$SqP = 1 - (4*A^{1/2}/P)$$

where A is the total area and P is the total perimeter of all the patch pixels in the considered *tabia*.

The cultivated areas with the highest erosion risk were extracted from the land-cover map and potential soil erosion map. The two new landscape indices were applied the resulting map showing the areas most at risk for each *tabia*.

The results obtained from the application of these indices were compared, for each *tabia*, with the percentage of pixels with high risk of soil erosion (hse) and the density of population (dp) per hectare.

The indices were calculated in IDRISI following the steps listed below:

1. The cultivated pixels (land.classes 6, 7, 8 and 9) were selected from the land-cover map (map 2) by means of **Reclass**;
2. The cultivated pixels with the highest erosion risk (pse.classes 6 and 7) were extracted from the potential soil erosion map (map 7) using **Reclass**;
3. The two resulting maps were multiplied using **Overlay**; the final map (map 8) resulting from this operation is in Boolean format (0,1);
4. Map 8 was employed to identify contiguous groupings (patches) of pixels (including those set along diagonals), using **Group**. According to this program, all pixels belonging to the same patch are given the same identifying number, a unique integer identifier which is numbered consecutively (map 9);
5. Map 9 was used to calculate, for each *tabia*, the total number of patches, the total number of pixels grouped and the total area and perimeter of the patches, employing Area and Perimeter programs (table 4).

Table 4. Parameters, index values and statistical data for each of the tabias considered

Tabia	m	n	A*	P*	PPU	SqP	NPT*	hse	dp
1	142	3844	2402500	106500	0.0369407	0.941784	23753	16.2	5.03
2	197	1949	1218125	75850	0.1010775	0.9417963	27867	7.0	1.43
3	347	4034	2521250	149850	0.0860188	0.9576151	56474	7.1	1.9
4	54	1298	81125	35800	0.0416025	0.968176	6558	19.8	7.4
5	516	7763	4851875	266700	0.0664691	0.9669637	61170	12.7	1.05
6	149	3313	2070625	91100	0.0449743	0.9368181	17193	19.3	2.82
7	147	2441	1525625	75850	0.0602212	0.9348629	16991	14.4	3.84
8	143	3152	1970000	94050	0.045368	0.9403055	19015	16.6	2.53
9	165	1425	890625	58150	0.1157895	0.9350831	23152	6.2	2.77
10	242	3741	2338125	126100	0.0646886	0.9514959	42063	8.9	1.15
11	361	3372	2107500	135950	0.1070581	0.9572866	55568	6.1	1.15
12	382	4810	3006250	183450	0.0794179	0.9621945	57908	8.3	1.2
13	216	1972	1232500	84250	0.1095335	0.9472911	33421	5.9	1.73
14	337	2948	1842500	127300	0.1143148	0.9573484	43924	6.7	0.74
15	371	4273	2670625	158200	0.0868242	0.95868	72327	5.9	0.55
16	284	2163	1351875	98750	0.1312991	0.9529032	52881	4.1	0.56
17	231	1764	1102500	76400	0.1309524	0.9450262	44793	3.9	0.79
18	318	2275	1421875	105000	0.1397802	0.9545743	70415	3.2	0.46
19	310	2441	1525625	111550	0.1269971	0.9557091	32716	7.5	1.38
20	657	3721	2325625	187450	0.1763654	0.967458	110358	3.4	0.32
21	243	2188	1367500	91050	0.1110603	0.948626	87904	2.5	0.22

Notes: The pixel size is 25 m, the pixel area is 625 m²

m is the total number of patches

n is the total number of patch pixels

A is the total area of all the patches

P is the total perimeter of all the patches

PPU is the patch-per-unit index (fragmentation)

SqP is the square-pixel index (complexity)

hse is the percentage of pixels with high risk of soil erosion

dp is the density population (per hectare)

The identifiers in column correspond to the following *tabias*:

(1) Tsegereda/Worerba; (2) Melhay; (3) Maytium; (4) Eshir; (5) Tahetay Logomty; (6) Asay; (7) Gedeba; (8) Laelay Logomty; (9) Addis Alem; (10) Lakenay; (11) Wochi; (12) Zonghi; (13) Golgolo; (14) Zebenege; (15) Vihdet; (16) Nequa; (17) Workamba; (18) Malkua; (19) Ketema; (20) Endafelasi; (21) Golagule.

The results obtained from the application of these indices were compared, for each *tabia*, with:

- ☐ The percentage of surface area with high risk of soil erosion (hse)
- ☐ The density of population (dp)

The coefficient of correlation between the two indices (ppu, SqP) and the two parameters mentioned above (hse, dp) was calculated. The correlation matrix obtained (table 5) shows that there is a significant correlation ($P \leq 0.01$) between the hse and dp parameters and the ppu index (no significant correlation exists between the hse and dp parameters and the SqP index). The correlation values are negative, meaning that, as the percentage of the surface area at high risk of soil erosion (hse) and the density of population (dp) increase, the fragmentation index (ppu) decreases. If ppu decreases, fragmentation is low and the areas at high risk of erosion are more concentrated.

Table 5. Correlation matrix obtained from table 4 showing the significant correlation ($P \leq 0.01$)

	ppu	SqP	hse	dp
ppu	-0.876	-0.676	-0.876	-0.676
SqP				
hse				0.808
dp				

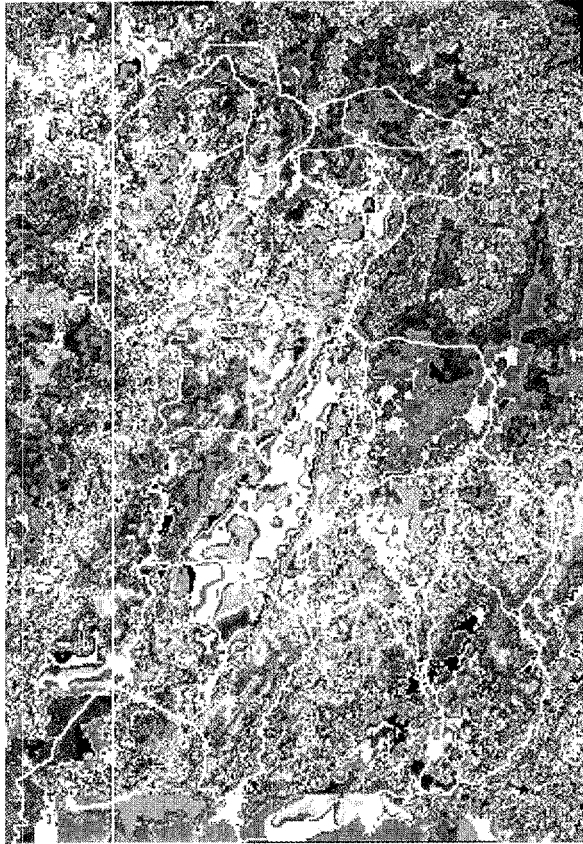
Note: ppu is the patch-per-unit index (fragmentation)

SqP is the square-pixel index (complexity)

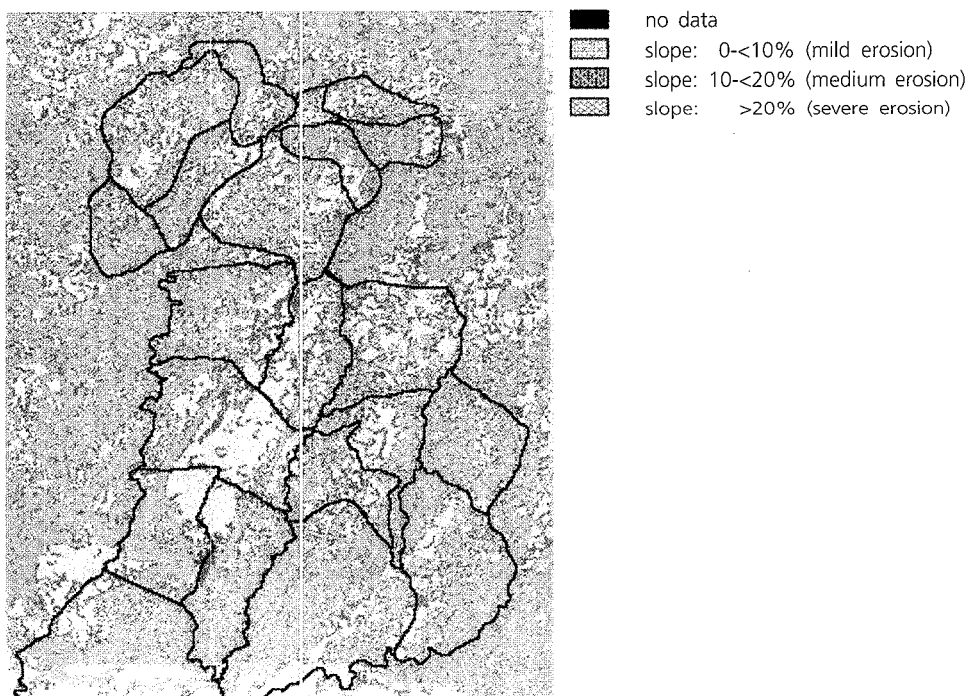
hse is the percentage of pixels with high risk of soil erosion

dp is the density of population (per hectare)

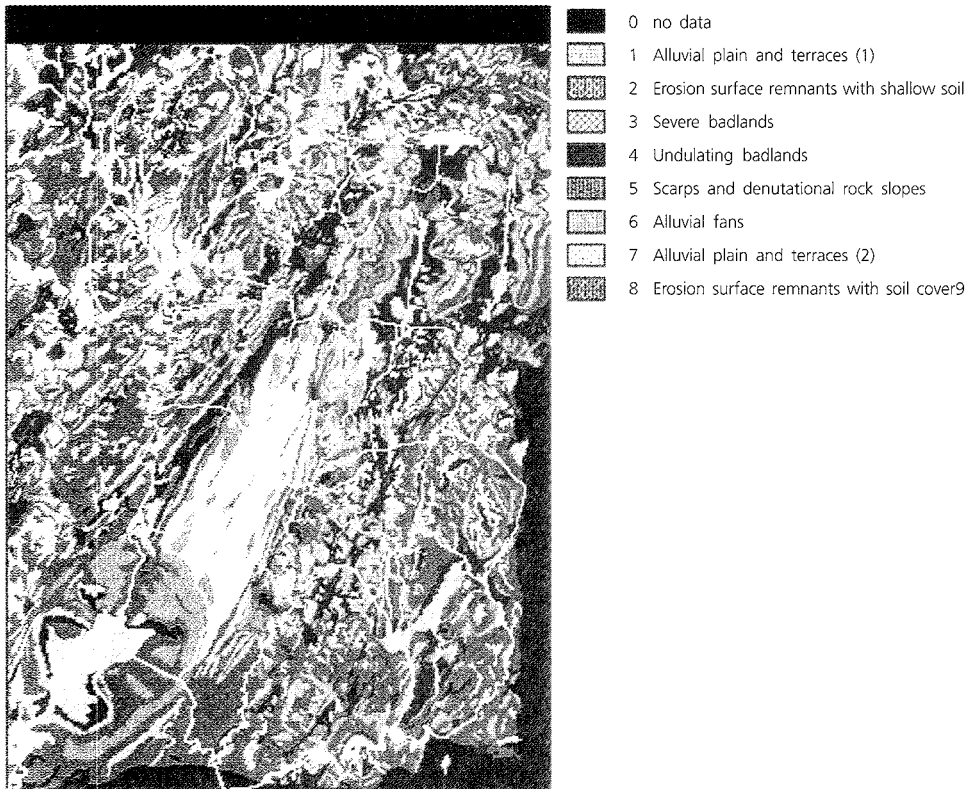
**Map 3. Digital elevation model (DEM)
derived from aerial photos 1:50,000,
with a cell size of 25 metres**



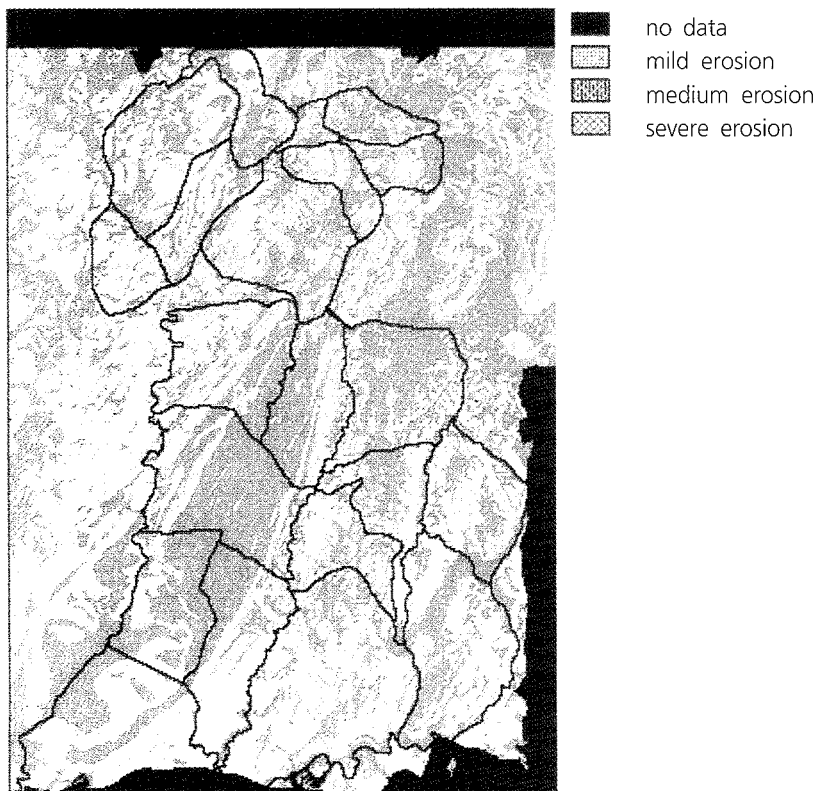
Map 4. Slope map subdivided into three percentage classes



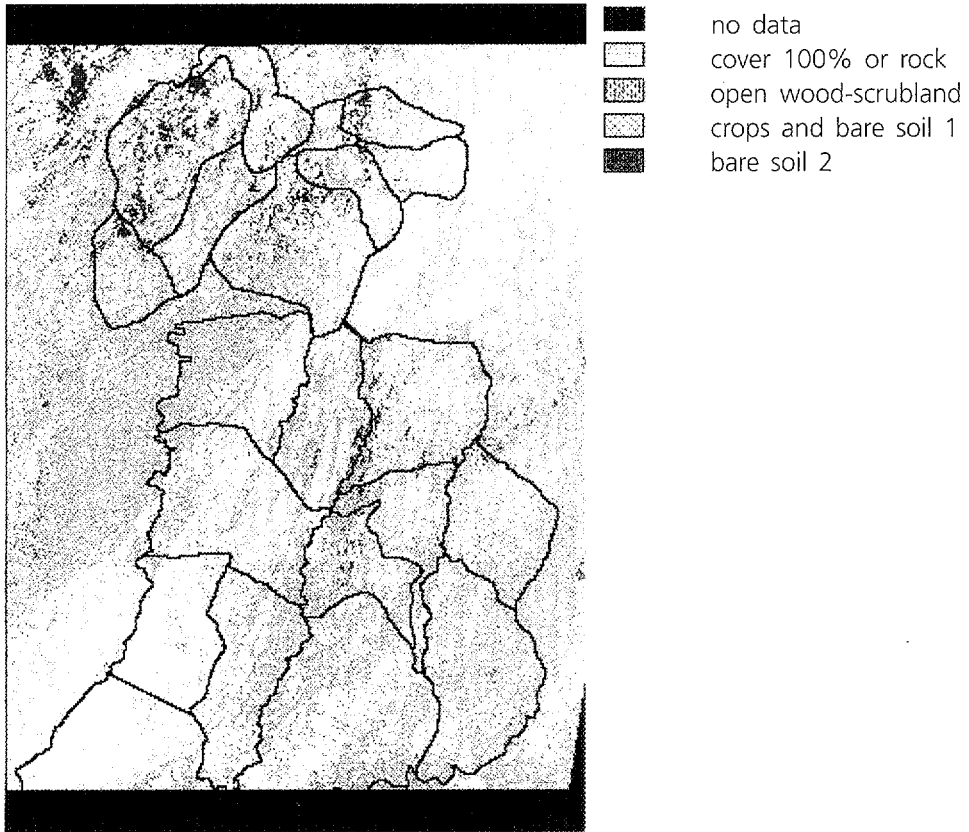
Map 5. Geomorphological map subdivided into nine classes (see table 1)



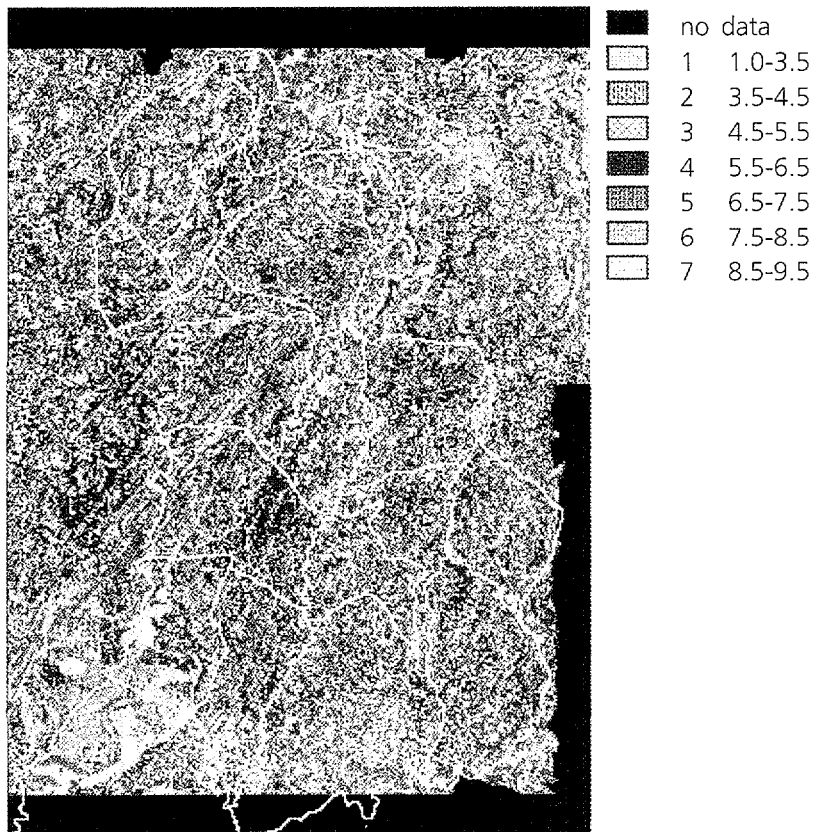
Map 6. K-factor map obtained from the geomorphological units and subdivided into three classes



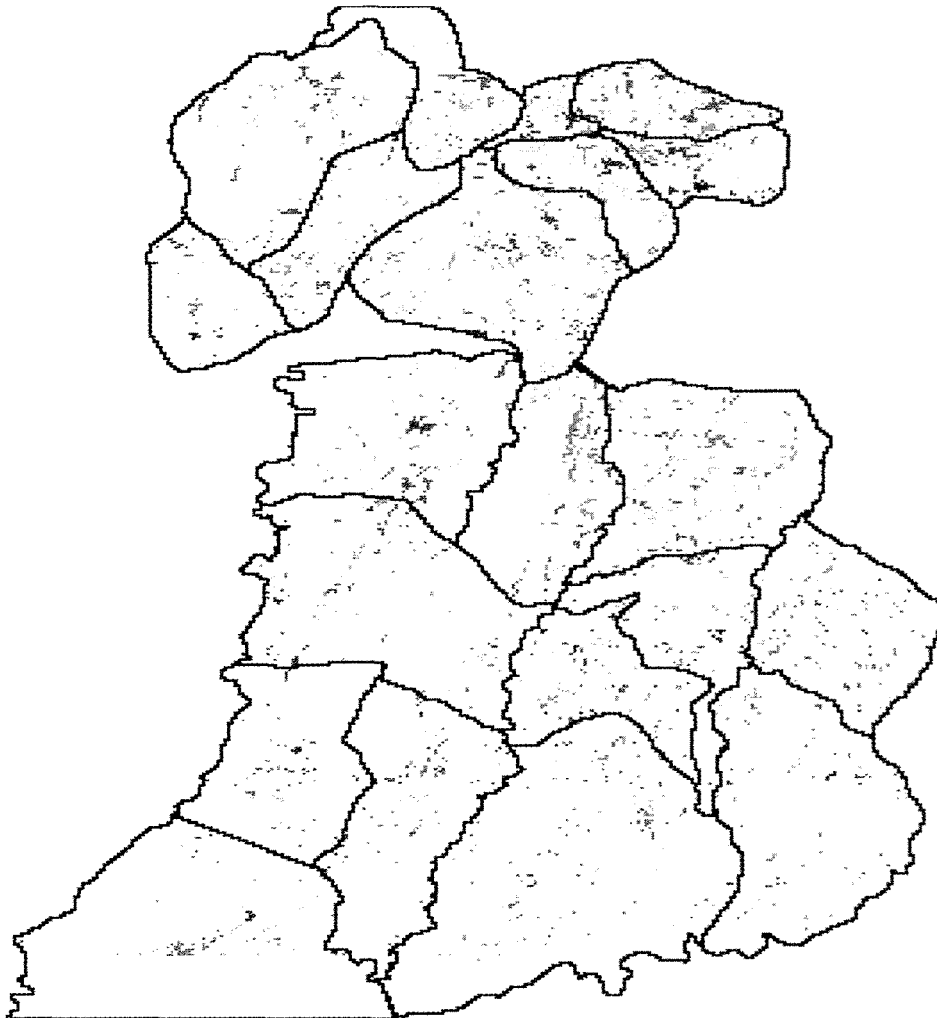
Map 7. C-factor map subdivided into four classes



Map 8. Potential soil erosion map subdivided into seven classes



Map 9. Patches map, showing the cultivated areas with the highest erosion risk, obtained using the GROUP program (each patch has a unique identifier number)

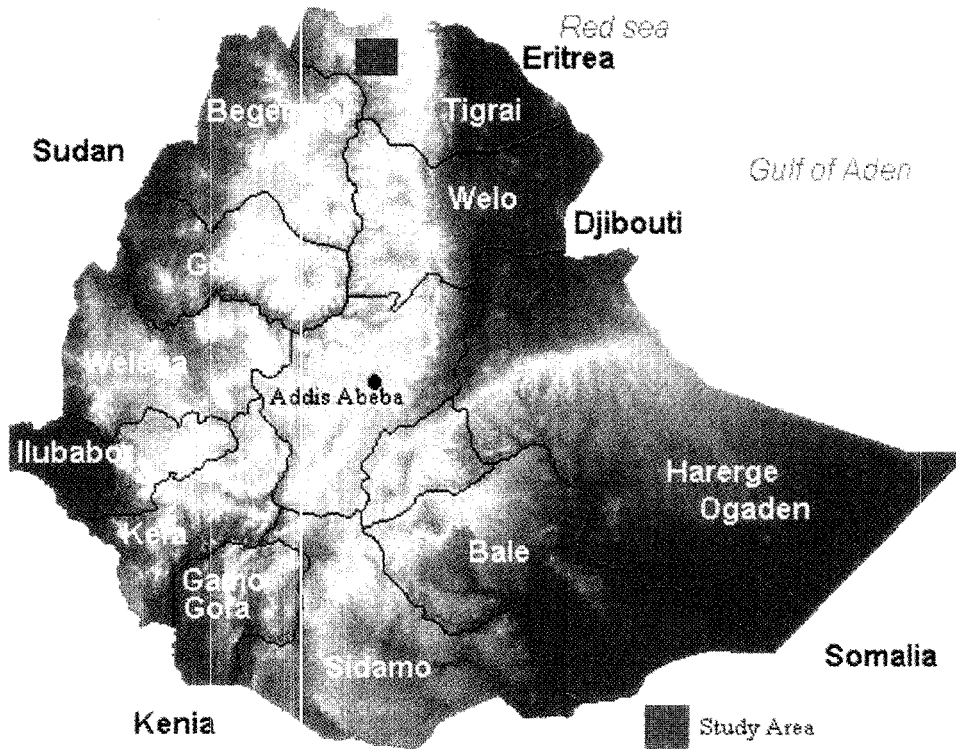


5. Simulation of application of alternative land-cover types

The simulation was carried out on an area of 841 hectares located in the Tsegereda/Warerbe *tabia* (Tigray, Ethiopia). This *tabia* is characterized by high risk of soil erosion, by high population density (5.03 inhabitant per hectare) and by a high percentage of cultivated land (60.23 %). The aim of simulation is to study the effect of the conversion of a cultivated area of 84 hectares into woodland, supposing that the people previously living from this cultivated area (about 300 individuals) would find employment in a textile factory built in the vicinity.

The various types of data were stored and processed in a geographic information system using IDRISI and PCRaster softwares. Figures 1-7 illustrate the tools used to simulate the conversion of land.

Map 10. The study area in the Tigray region of Ethiopia



Map 11. Land-cover map obtained from the Landsat-TM 5 satellite with the patches map (vector) superimposed

simulation area

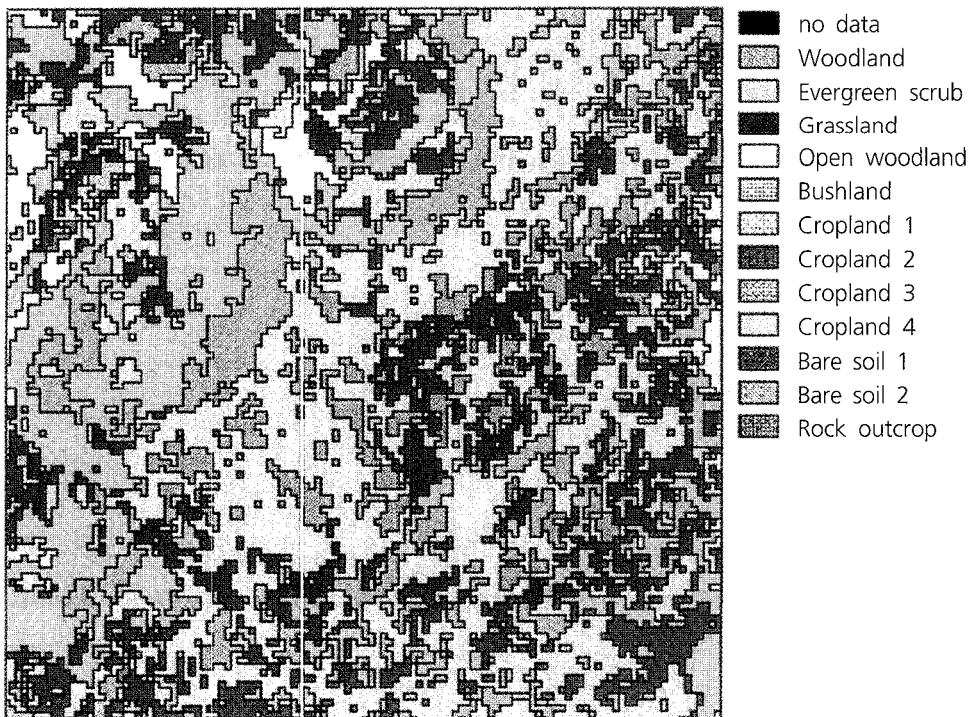


Figure 1. The GROUP program identifies all contiguous groups of cells with the same value; cells belonging to one patch are given a new unique value

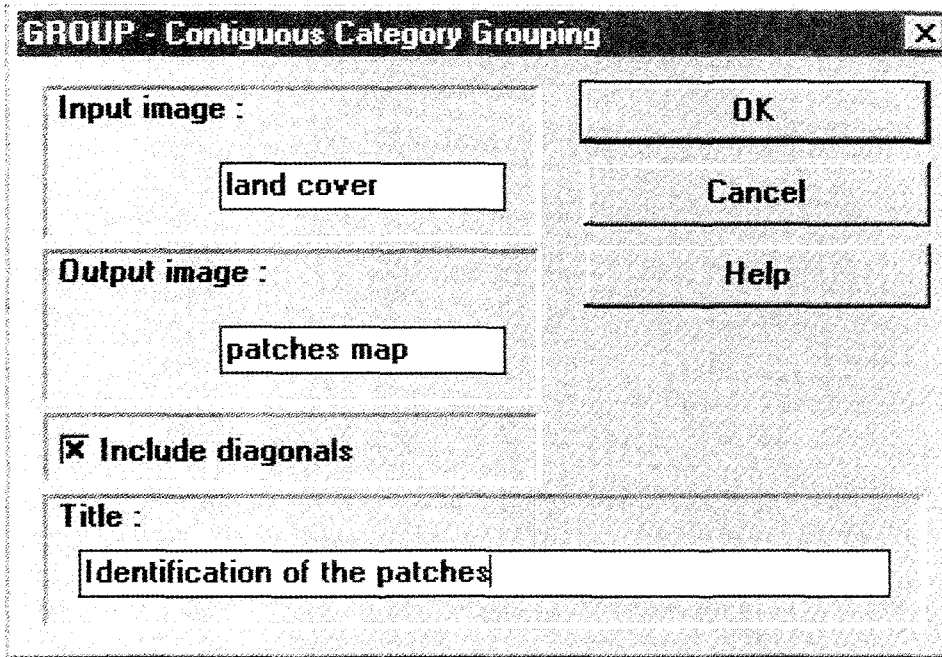


Figure 2. The EXTRACT program provides for each patch the identifying number and the corresponding land-cover category value

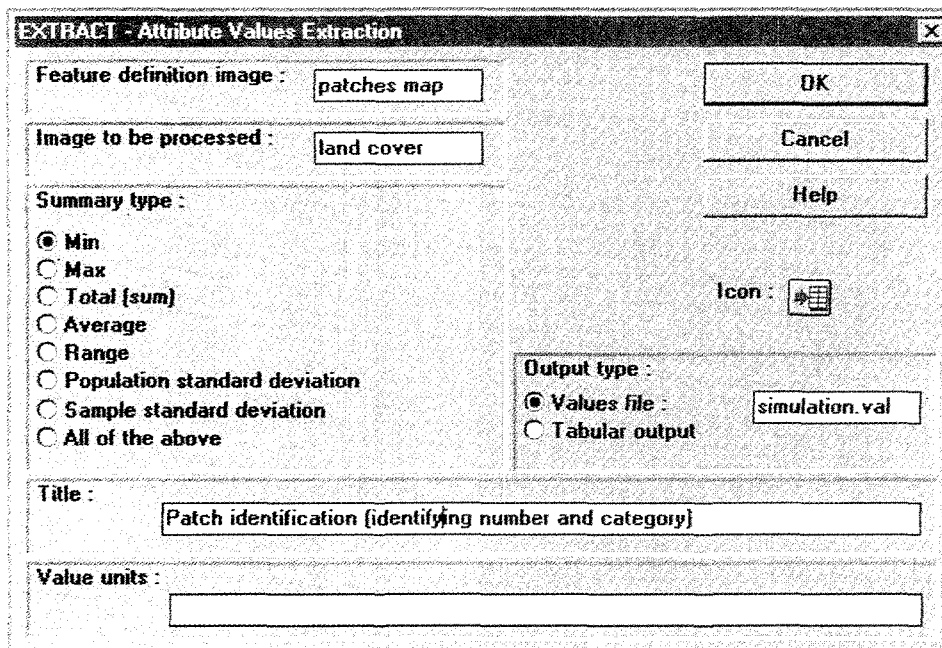


Figure 3. The output from the program is saved in an ASCII file, which can be read by the database

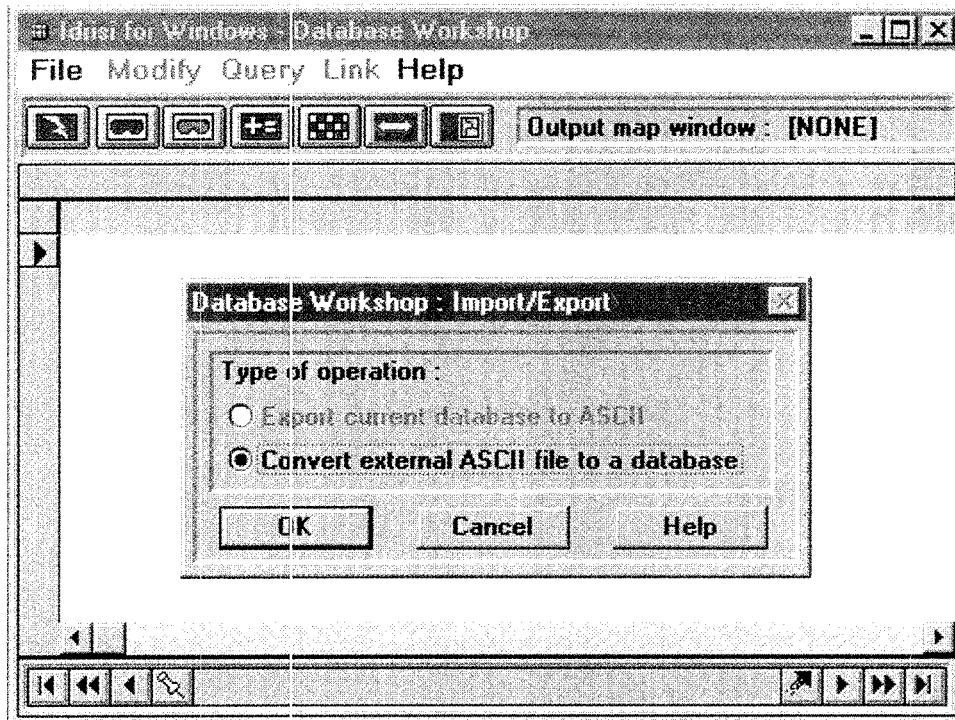


Figure 4. The ASCII file obtained from EXTRACT imported into the database structure

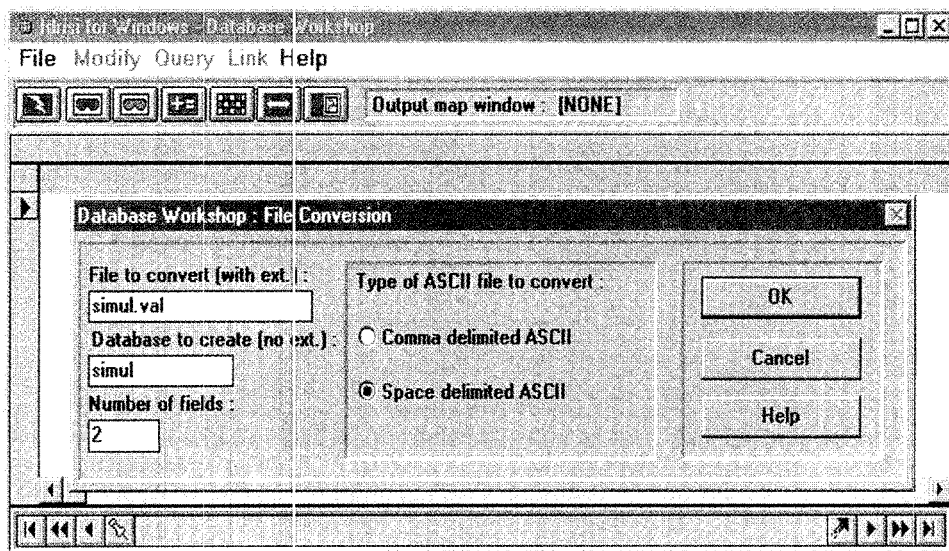


Figure 5. Patch category values

IDR_ID	field1
101	11
102	6
103	8
104	3
105	8
106	1
107	9
108	6
109	1
110	7
111	12
112	4
113	7
114	2
115	7
116	6
117	6

Figure 6. Modified patch category values

IDR_ID	field1
101	11
102	6
103	1
104	1
105	1
106	1
107	1
108	1
109	1
110	1
111	1
112	1
113	1
114	1
115	1
116	6
117	6

Figure 7. Database workshop dialogue box

Output map window : [NONE]

IDRISI TEXT LAYER DATABASE FILE

Database Workshop : Assign

Feature definition image : patches

Name of output image : new land

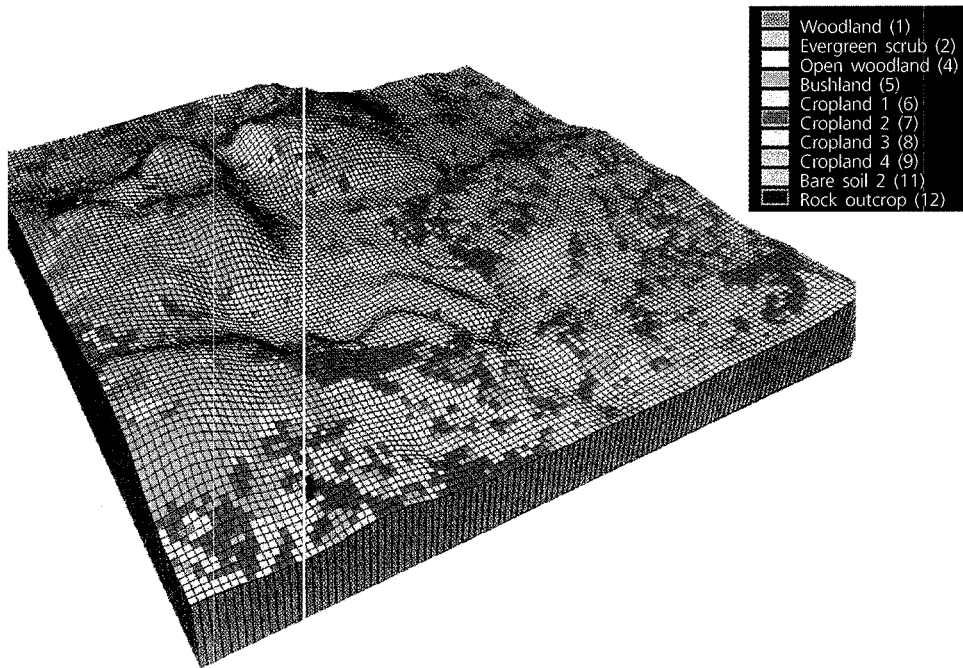
Feature definition field : IDR_ID

A data field from current database : field1

OK, Cancel, Help

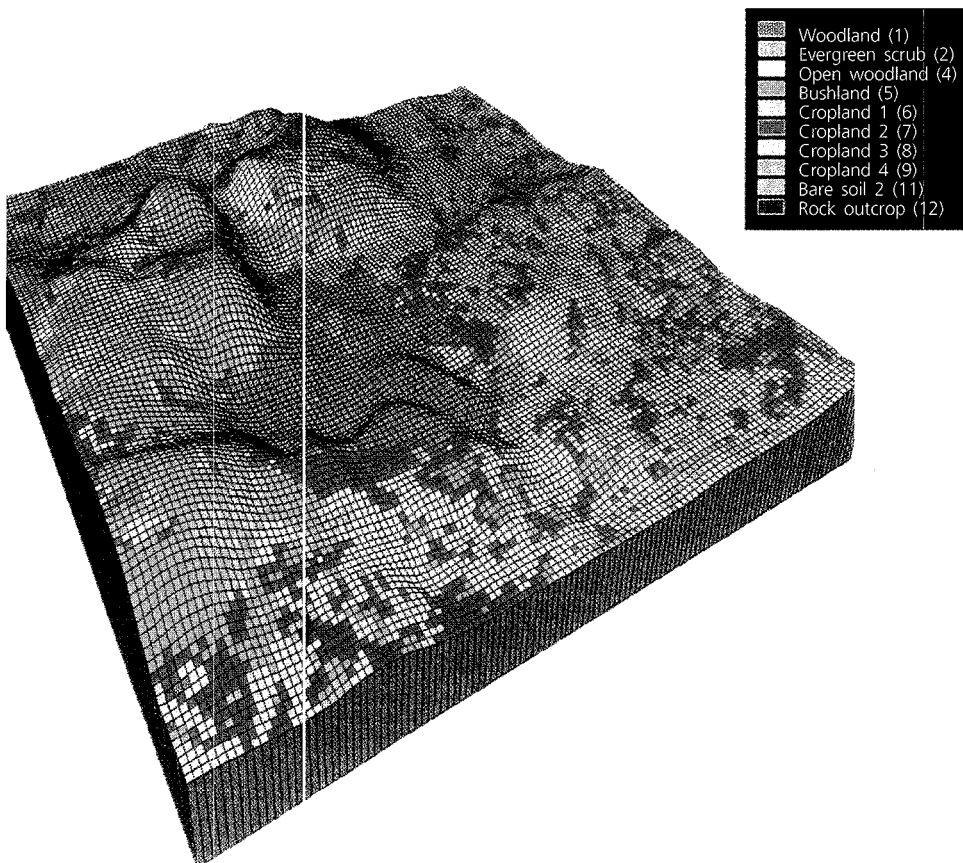
In the table created by the database (figure 5) the patch category values (field 1) are modified (figure 6). The new category values are assigned to a new map using the ASSIGN option from the Link menu (figures 7 and 8).

Map 12. Image of study area prior to simulation



The cultivated area of 84 hectares will be transformed into woodland. The display is created using PCRaster software.

Map 13. Land-cover map showing simulation of the conversion of a cultivated area of 84 hectares into woodland. The display is created using PCRaster software



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9

Appendix

9

Appendix

Multi-fold ground penetrating radar

Ground penetrating radar systems (GPR) are used to find and represent objects that are usually deep in the ground, but also objects in concrete walls. GPR can locate metal objects and, unlike many methods, can also locate non-metallic objects (such as plastic pipe, cadavers and void objects). The only requirement is that the materials have different electrical properties than the host material [1].

GPR is very similar to conventional radar in that an electromagnetic pulse is launched in a specific direction. The data consist of measurements of strength of reflections and time duration until the reflection is received. In the case of GPR, the electromagnetic pulse is launched into the ground and reflections are received from subsurface features where a change in electromagnetic properties occurs. Because of the characteristics of many soils, the frequency content of the radar pulse is usually limited to the range of 10-100 MHz. This limit in frequency content sets the signal wavelength and thus sets the resolution of the target detail. The person operating this type of instrument must be able to interpret data variations to make predictions about subsurface characteristics.

GPR is a highly effective tool for the non-intrusive and non-destructive evaluation of solid or subsurface objects. By transmitting and receiving high-frequency radar waves from hand-held antennas, operators can acquire images of the underground structure much like above-ground radar is used to acquire images of air planes in the sky.

GPR is applicable to mapping and imaging locations of the following:

- Buried utilities
- Plastic, cement, asbestos, clay or metal pipes
- Underground storage tanks and service lines
- Hazardous waste and buried drums (metal and plastic)
- Archeological sites (e.g., foundations, burial sites and chambers)
- Forensic targets (bodies, weapons and drugs)
- Topsoil characteristics and shallow geological structures
- Dinosaur fossils and animal burrows
- Unexploded ordnance, plastic land mines
- Concrete structures (bridges and dams)

Multi-fold ground penetrating radar (GPR) techniques for ultra-high resolution (UHR) investigation are applied to:

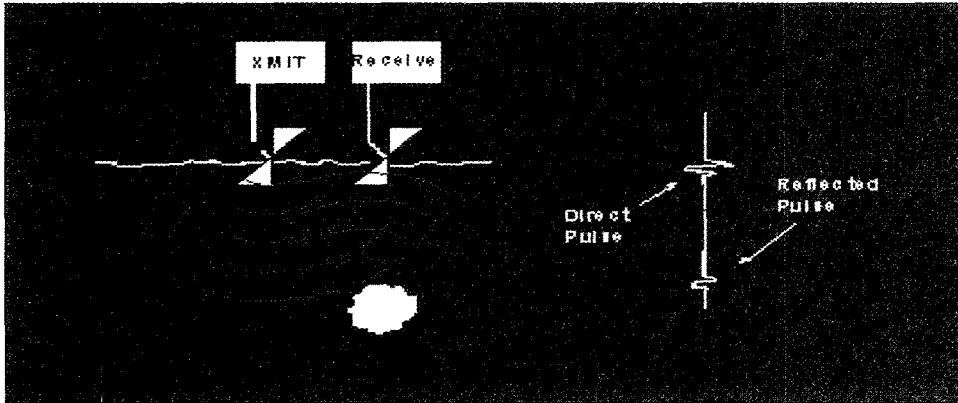
- Archeology
- Environment (site contamination studies, environmental risk assessment)
- Civil engineering

1. How GPR works: basic principles

A radar system (figure 1) includes a radio transmitter and receiver, connected to a pair of antennas coupled to the ground. The transmitted signal penetrates a short distance into the

ground, and some of it reflects off any object with different electrical properties than the host soil. For example, since plastic pipe and voids do not have the same properties as soil, they will reflect the signal. There is a delay in the radio signal that reflects from the object in the ground. Echo sounds and fish finders work in a similar fashion.

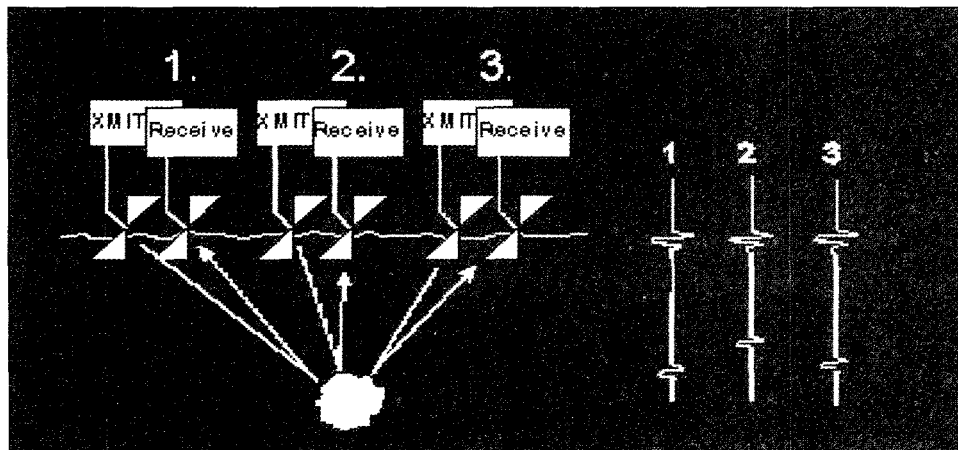
Figure 1. Radar system



1.1. Image construction

To construct an image that the operator can interpret (figure 2), the radar plots the echo from the object on some sort of display, on a screen similar to a computer monitor. The radar is moved along the ground and each new echo is plotted alongside the previous ones. When enough of these signals are plotted side-by-side, the operator can see a pattern, which can be interpreted as an object.

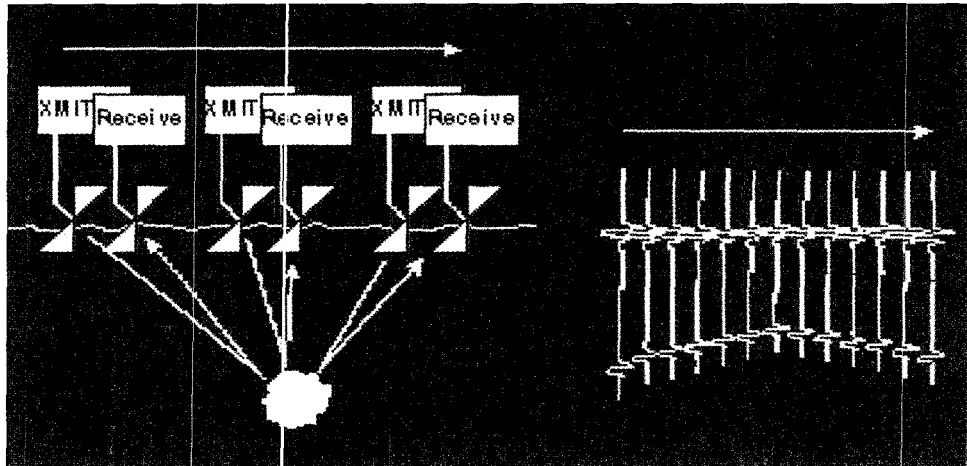
Figure 2. Image construction



1.2. Hyperbola

When the object is ahead of the radar, it takes more time for the echo to bounce back to the antenna. As the radar passes over the object, the time grows shorter and then longer again as the radar passes the object. This effect causes the image to take the shape of a hyperbola (figure 3). Experienced users recognize that a hyperbola is actually the image of a smaller object (for example, a pipe) located at the centre of the pattern. Other patterns are produced by different structures. For example, a buried tank might have a flat image with curves down from either end.

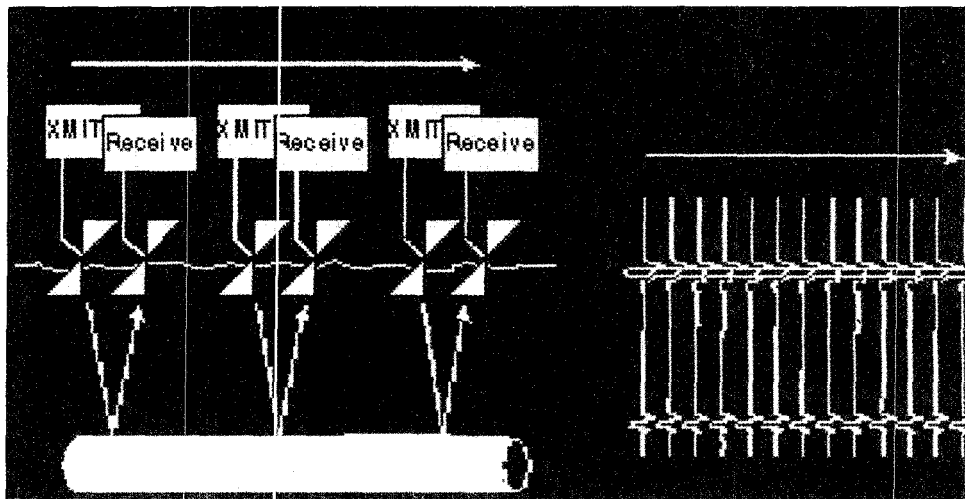
Figure 3. Samples from a hyperbola



1.3. Resulting images

The hyperbola results from crossing a pipe, but the image will be a straight line, since the distance from the pipe does not change (figure 4). The problem is that other conditions will produce the same effect, especially layers in the soil, bedrock or the water table. It is difficult to map pipes by following them as is done with other locating methods. Instead, the antenna must be moved across the pipe in a meandering or zigzag fashion.

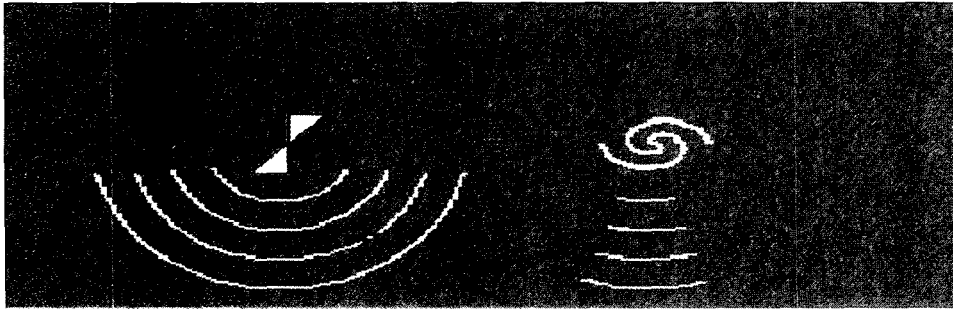
Figure 4. Ambiguity of the same images



1.4. Effects of antenna pattern

There are different types of antennas with different beam shapes. The most common antennas (dipole) have a very wide beam and horizontal polarization. Consequently, the hyperbolas are very wide. Log-spiral antennas (like those used on the GeoRadar 1000B) have a narrow beam with circular polarization and the images are smaller. The difference is like comparing a floodlight to a spotlight. (The two types are shown in figure 5.) The narrow beam on the GeoRadar system creates images that look more like the actual target, and closely spaced objects can be resolved.

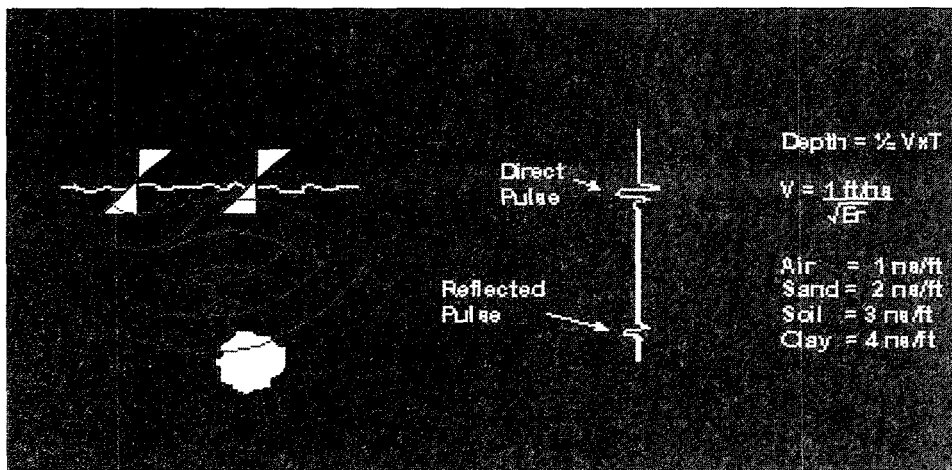
Figure 5. Dipole antenna (left) and log-spiral antenna (right)



1.5. Determining the depth of the object (figure 6)

It is not easy to determine the depth of an object without some knowledge about the dielectric constant in the local soil. The GPR can measure time very accurately, but the speed of the radar signal varies considerably with the soil type. In air, radar waves travel at 186,000 miles per second (or about 1 foot in one nanosecond). If one knows the dielectric constant (from experience) or can look at the image of an object with a known depth, the GPR can be adjusted to read depth accurately.

Figure 6. Determining the depth of the object



2. How deep can GPR see?

When radar signals penetrate the ground, they can attenuate rapidly depending on the soil type. The depth to which GPR can locate objects depends on the soil type, the size of the object, and the material contrast.

As a general rule, GPR works well in many areas and can locate objects that cannot be found otherwise. The following conditions can determine the effectiveness of GPR:

- Metal can be seen at greater depths than concrete or clay objects, which can be seen at greater depths than plastic;
- Large objects can be seen at greater depths than small objects;
- GPR is very effective in clean, non-metallic sands and non-conductive soils, but less effective in conductive soils like clay, especially wet clay;
- GPR is effective in fresh water but does not perform well in salt water.

In good conditions, radar can reach 10 or 20 feet, but in bad conditions just a few inches. The pulse-video radar systems can use large/low-frequency antennas and reach several tens of feet, but with limited resolution. Such systems are good for mapping geological structures, but not for imaging objects. In many cases, changes in the geological structure can be seen (for example, a trench or grave) while the object (e.g., a pipe in the bottom of a trench) cannot be imaged.

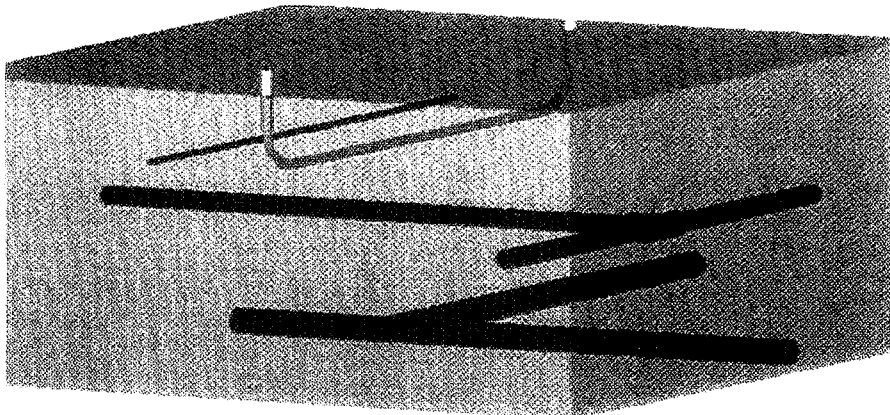
3. Three-dimensional subsurface imaging

In the future, ground-penetrating radar systems may provide three-dimensional images of objects in the subsurface. Figures 7 and 8 show three-dimensional images created by Roger Hackman with partial funding from the Electric Power Research Institute. The data were gathered with GeoRadar Inc. Model 1000B ground-penetrating radar. The raw field record as viewed on the screen of the GPR is shown in GPR images.

3.1. Test pit

Figure 7 shows the arrangement of pipes in a test pit. There are two pipes at a depth of 2 feet, a T-shaped pipe that is 4-feet deep, and pipes at depths of 6 and 8 feet. All the pipes are metal, except for the U-shaped pipe. The test pit is dug in clay soil and filled with clean sand.

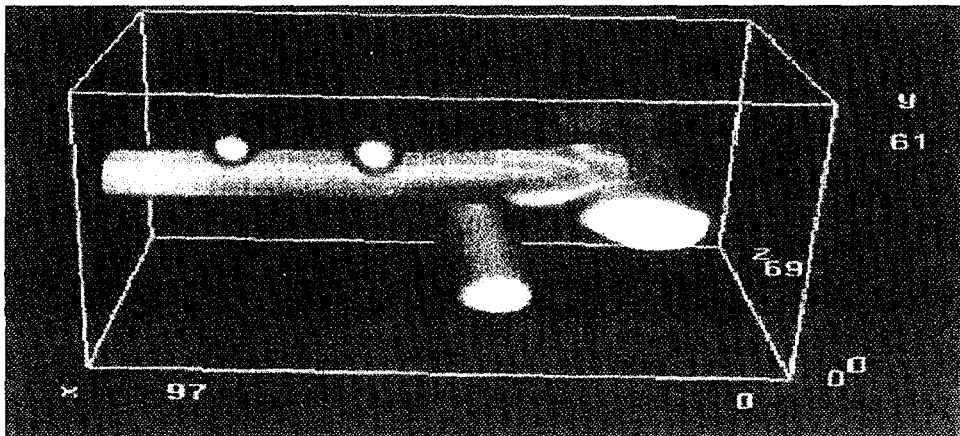
Figure 7. Arrangement of pipes



3.2. Computer processed image

The data were acquired in a 4-inch (10 cm) two-dimensional grid on the surface, then processed on a Silicon Graphics workstation using proprietary algorithms (developed by R. Hackman). The images were processed using Synthetic Aperture Processing and enhanced with a two-directional linear filter.

Figure 8. Computer processed image



4. GPR applications

4.1. Target-detection applications

GPR can be used for location and mapping of the following:

- Pre-screening of bore hole locations and excavations for the presence of subsurface utilities or other potential hazards;
- Detecting and mapping underground tanks, vaults and utility lines (electric, gas, water, sewer, TV cable etc.). GPR can locate plastic as well as metal lines;
- Detection and mapping of buried drums and other types of waste containers;
- Location and mapping of subsurface-waste disposal systems, septic systems, dry-wells, leach fields, trenches and pits;
- Detection and mapping of sinkholes and voids for construction projects.

4.2. Geologic-mapping applications

Examples of applications in which GPR supports subsurface investigations include the following:

- Mapping of geologic features of importance to hydrogeologic investigations, such as the configuration of the water table and the bedrock surface;
- Detailed stratigraphic mapping of shallow sediments and/or geologic units;
- Detection and mapping of hydrocarbon and chlorinated-solvent contaminant plumes in shallow unconsolidated media and in bedrock;
- Detection and mapping of bedrock-defect structures such as faults, fractures and joints;
- GPR mapping of stratigraphy and contaminant-related GPR-signal anomalies can be used to guide the location of monitoring and remediation wells;
- Detection and mapping of sinkholes and voids.

5. GPR usage and limitations

According to L. Dolphin [2], GPR systems usually operate in the VHF-UHF region of the electromagnetic spectrum. The frequency used is a compromise. One desires to use the lowest possible frequency because low frequencies give reasonably high penetration depths into the earth. But a sufficiently high frequency must be selected so that the radar wavelength is short, allowing detection and resolution of small objects such as pipes. For cart-mounted radar, 150 MHz is a typical centre frequency; however, 300 and 500 MHz are sometimes used for shallow, high-resolution probing, and frequencies as low as 20 MHz are used for locating deep caves or mine tunnels.

GPRs are also known as "impulse radar" because the transmitted pulse is very short and is ordinarily generated by the transient voltage pulse generated from an overloaded avalanche transistor. Resistively loaded antennas are employed because one can not tolerate antenna ringing. The distances in the ground where such radar look are measured from inches to tens of feet. This corresponds to travel times measured in nanoseconds, that is, billionths of a second. Short transmitted pulses imply wide radar bandwidths, so a GPR operating at a central frequency of 150 MHz actually radiates substantial energy from 75 to 300 MHz.

The performance capability of this type of radar is strongly dependent on the soil electrical conductivity at the site. If the soil conductivity is high, attenuation of the radar signal in the soil can severely restrict the maximum penetration depth of the radar signal. In California, United States, for example, where soils in many areas are often high in clay content, the soil absorptive losses can be quite high. Whereas maximum penetration depth achievable with this type of radar can be tens of feet in favourable environments, these numbers are reduced to a few feet or less at many sites in California.

GPR surveys should be performed in the dry season if at all possible. Soil moisture, especially in high-clay soils, only increases the radar attenuation rates, further limiting the radar performance.

Spurious radar echoes (known as "clutter") can also be expected in many test areas because of buried debris such as old rails, wire scraps, boulders and small metal objects. Usually a trained operator can interpret the desired radar signatures in the midst of a moderate amount of such clutter.

It is not possible to build GPR antennas so that the antenna beam width is narrow. The wide antenna beam width of cart-mounted ground-penetrating radar makes it difficult to resolve closely spaced objects, such as two parallel pipes in a common trench. In some cases the fill in the trench or the trench walls may be detected on the radar, but the pipes in the trench may not be radar discernible. Interpretation of GPR records is an art as well as a science, even with the best available state-of-the-art radar.

In principle, ground-penetrating radar are capable of locating plastic pipes as easily as metallic pipes since the radar signal reflection from the pipe depends on contrasting dielectric properties of the soil and pipe, not just a high electrical conductivity for the pipe. In actual practice GPR has the following limitations:

- ❑ Soil attenuation may restrict the use of GPR to shallow depths;
- ❑ The GPR antenna beam width is broad, making it difficult for radar to discriminate between closely spaced pipes;
- ❑ In disturbed ground, the radar may detect the walls of a trench, for example, but not the pipe it contains.

Nevertheless GPR can be very useful when a thorough search of the site is required. GPR normally has an accuracy of several feet or less when measuring the depth of a buried object.

Cart-mounted GPRs rely on motion of the cart to generate a continuous radar record of traverse distance versus depth in the earth. GPR data are ordinarily recorded on video-tape, with voice comments for archive purposes, and printed out on thermal printer paper on-site for immediate analysis. The successful interpretation of GPR records is an art as well as a science requiring considerable operator experience for good results.

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