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OCCASION

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**INTERNATIONAL CENTRE FOR SCIENCE
AND HIGH TECHNOLOGY**



AREA Science Park, Building L2, Padriciano 99, 34012 Trieste, Italy
Tel.: +39-040-9228108, Fax: +39-040-9228136, <http://www.ics.trieste.it>

FINAL REPORT

*Training Course on
"Image Processing and Remote Sensing for Industrial
Development in Coastal Areas"*

*Iglesias, Cagliari, Italy
4-8 June 2002*

*organized by
ICS-UNIDO*

*in collaboration with
FORGEA INTERNATIONAL
(Training and Cooperation Centre in the Field of Geo-Mining and Environment)*

*and the
Italian Ministry of Foreign Affairs*



Ministero degli Affari Esteri

BACKGROUND

Coastal zone management refers to the management of coastal resources. Resources are common to other areas (urban, industrial, agricultural, forestry, military, tourism and recreation, mining, dumping and waste disposal, etc.) but also they are specific to coastal areas (fishing, navigation, port and harbor, desalination and salt production, etc.).

The complex structure of coastal zone is distinguished by a particularly "attractive" area, with a high population density and economically dynamic, which includes large cities and big ports. In this particular area, made up of inland and marine ecosystems, also large-scale industries (agro-industry, iron and steel, metallurgy, chemical, mechanical, shipyards and tourism), are settled frequently compensating natural landscapes and resources.

To achieve balanced environmental planning and sustainable exploitation of natural resources in coastal areas, industrial development has to be supported by a knowledge-based management system. This system should integrate advanced technologies for monitoring the development in all its aspects.

In this context, ICS-UNIDO has organized in collaboration with FORGEA International, a Training Course on "Image Processing and Remote Sensing for Monitoring Industrial Development in Coastal Areas" from 4 to 8 June 2002. This Training Course was developed within the activities of the ICS Area of Earth, Environmental and Marine Sciences and Technologies, under the Coastal Zone Management (CZM) Sub-programme.

JUSTIFICATION

Integration of Remote Sensing with other related technologies/disciplines such as GIS (geographic information systems), DSS (decision-support systems) and computer science is essential to acquire complete benefits of this technique. However, in most cases the separation between those technologies is apparent because of the cost and the availability. Remote Sensing experts are not well exposed to the technology of GIS and GIS specialists do not receive enough knowledge and sufficient training on image acquisition and processing. Therefore, a complete knowledge fusion between GIS and Remote Sensing needed to be conducted and experts should be exposed to all technologies.

For example, spatial data processing and multi-criteria decision-support systems are necessary tools for industrial siting, urban planning and for establishing a system of monitoring stations, suitable for registering atmospheric and aquatic pollution. The integration of coastal environment engineering, GIS technology, GPS applications, numerical modelling with remotely sensed data management can be done through image processing and GIS technologies. This is useful for presenting a common "interface" and "approach" to tackle environmental problems and to control industrial impact.

In this context, the training course has provided participants with practical expertise used to solve problems in real case studies based on some lessons on remote

sensing and image processing relied on a mixture of theory and practical applications followed by exercises to complement theoretical lecture topics in order to create a good training environment.

The course has given to the participants the opportunity to access advanced software packages using remotely sensed data for elaborating some exercises developed on real case studies for supporting decision-making process.

OBJECTIVES

In this Training Course, ICS intended to train junior experts on image processing and remote sensing techniques, as supporting tools for the management of coastal areas, using advanced software packages.

The specific objective was the development of skills in the use of remotely sensed data for the purpose of knowledge of image acquisition methods, data merging, image rectification, image enhancement, image classification and image algebra.

STRUCTURE OF THE COURSE

The course started with some introductory lectures presenting an overview of the state of the environment linked to socio-economical development, in particular industrial development in coastal areas, followed by some lessons on the basic concepts of remote sensing, GIS, DSS, process simulation, multivariate analysis and multi-criteria evaluation. During the training course a practical session in which participants profited from a direct access to specific software was of great interest.

RESULTS

- Trained experts;
- Strengthening ICS collaboration with international institutions and organizations.

CONCLUSIONS AND RECOMMENDATIONS

Coastal zone is of extreme significance to human affairs. In this specific area, the real conflict is not between sea and shore but between man and nature. The management of coastal resources should be based on:

- An integrated approach, which requires an integration of advanced technologies including Remote Sensing, GIS and DSS for understanding, analyzing and managing physical, chemical and biological structure of coast in relation to anthropogenic exploitation. This approach involves various forms of analysis including simulation and modeling;
- A concrete collaboration between international institutions interested in developing strategies for sustainable industrial development by transferring technologies that are useful to monitor landscape changes in industrial areas

and their surrounding environment and to support decision-makers for coastal zone management plans.

IMMEDIATE FOLLOW-UP

- A final report of the training course, which can be subject to scientific editing and publication and should include all presentations, exercises and lecture notes;
- Build-up a mailing list for the participants to exchange information and knowledge;
- Preparation of a new presentation for GIS-GRASS users' conference according to some suggestions from participating experts.

LIST OF ANNEXES

PROGRAMME

See attached Annex I.

LIST OF PARTICIPANTS

See attached Annex II.

PRESENTATIONS

See attached Annex III.

STATISTICS

Se attached Annex IV.

Annex I
PROGRAMME

*Training Course on
"Image Processing and Remote Sensing for Monitoring
Industrial Development in Coastal Areas"*

*Iglesias, Cagliari, Italy
4-8 June 2002*

Programme

Tuesday, 4 June 2002

- 09:00-09:30 Registration
09:30-10:30 Welcome speech by host
Introduction to ICS, Mr. G. Longo
Overview on the objectives of the Training Course and presentation of the participants, Mr. E. Feoli
10:30-11:00 *Coffee break*
11:00-12:00 Overview of the importance of industry, trade and tourism in coastal areas: mining activity in Sardinia, in Iglesias and its territory, Mr. L. Ottelli
12:00-13:00 Definition of land use/land cover for planning industrial development, Mr. E. Feoli
13:00-14.30 *Lunch break*
14:30-15:30 Process Simulation for a sustainable industrial development, Mr. G. Longo
15:30-15.45 *Coffee break*
15:45-17:00 Technological tools for coastal zone management, Mr. G. Tore
17:00-17:15 Open discussion

Wednesday, 5 June 2002

- 09:15-11:00 GIS and Spatial Data integration, Mr. E. Feoli
11:00-11:15 *Coffee break*
11:15-13:00 Remote Sensing techniques, Mr. A. Altobelli
13:00-14:30 *Lunch break*
14:30-15:30 Practical exercises on "satellite images acquisition, data analysis, information extraction, correction techniques and image processing", Mr. A. Altobelli and Mr. M. Ghribi
15:30-15:45 *Coffee break*
15:45-16:45 GIS applications using MultiSpec for unsupervised and supervised classification of LANDSAT images, Mr. A. Altobelli
16:45-17:00 Open discussion

Thursday, 6 June 2002

- 09:00-11:00 Introduction to multivariate data analysis, Mr. E. Feoli
11:00-11:15 *Coffee break*
11:15-13:00 GIS, remote sensing and spatial decision support systems (SDSS) for coastal zone management, Mr. M. Ghribi

13:00-14:30 *Lunch break*

14:30-15:30 Practical exercises using MultiSpec and IDRISI, Mr. A. Altobelli
15:30-15:45 *Coffee break*
15:45-16:45 Practical exercises on Image Processing and Multi-Criteria Evaluation (MCE) using IDRISI software package, Mr. M. Ghribi (cont.)
16:45-17:00 Open discussion

Friday, 7 June 2002

- 09:00-11:00 Presentation of ICS case studies, Mr. M. Ghribi
11:00-11:15 *Coffee break*
11:15-13:00 Application of classification and ordination methods in landscape assessment, Mr. E. Feoli

13:00-14:30 *Lunch break*

14:30-15:30 Practical exercises on Image Processing and Multi-Criteria Evaluation (MCE) using IDRISI software package, Mr. M. Ghribi (cont.)
15:30-15:45 *Coffee break*
15:45-16:45 Practical exercises on Image Processing and Multi-Criteria Evaluation (MCE) using IDRISI software package, Mr. M. Ghribi (cont.)
16:45-17:00 Open discussion

Saturday, 8 June 2002

- 09:00-10:45 Focus on the Impacts of industrial development on marine environment and landscape, Mr. N. Candeloro
10:45-11:00 *Coffee break*
11:00-13:00 Conclusions and Closure of the Training Course

Annex II
LIST OF PARTICIPANTS

*Training Course on
"Image Processing and Remote Sensing for Monitoring Industrial
Development in Coastal Areas"
Iglesias-Cagliari, Italy
4-8 June 2002*

List of Participants

Participants:

Albania

Ms. Rajola Dervishi
INIMA - Institute of Informatics and Applied Mathematics
Rr. Lek Dukagjini, 3
Tirana, Albania
Tel.: +355-42-26234
Mobile : +355-68-2139478
Fax: +355-43-62122
E-mail: inima@inima.al
rsot@inima.al

Ms. Nevila Resulaj
INIMA - Institute of Informatics and Applied Mathematics
Rr. Lek Dukagjini, 3
Tirana, Albania
Tel.: +355-42-26234
Mobile: +355-68-2138195
Fax: +355-43-62122
E-mail: inima@inima.al
nresulaj@inima.al
nresulaj@hotmail.com

Ms. Fatlinda Struga
Institute of Urban Studies
RR Muhamed G. Jollesha
Prane ISTN
Tirana, Albania
Tel.: +355-42-23361
Fax: +355-42-23361

Bosnia and Herzegovina

Mr. Branko Vucijak
HEIS - Hydro-Engineering Institute Sarajevo
Stjepana Tomica, 1
71000 Sarajevo, Bosnia and Herzegovina
Tel.: +387-33-207949
Fax: +387-33-207949
E-mail: branko.vucijak@heis.com.ba
heis@heis.com.ba

Bulgaria

Ms. Zhenya Valcheva
Executive Environment Agency
Bld. Tzar Boris III, 136
1618 Sofia, Bulgaria
Tel.: +359-2-9406418
Fax: +359-2-9559015
E-mail: valcheva@nfp-bg.eionet.eu.int

Croatia

Mr. Boris Legović
INA - Oil Refinery Rijeka
51222 Kostrena, Croatia
Tel.: +385-51-203499
Fax: +385-51-203000
E-mail: boris.legvic@ina.hr

Hungary

Ms. Rozália Jamniczky
University of Veszprem
P.O. Box 158
H-8201 Veszprem, Hungary
Tel.: +36-88-425049
Mobile: +36-30-3613656
Fax: +36-88-425049
E-mail: jrozi@almos.vein.hu
glenbenton7@freemail.hu

Ms. Henrietta Nagy
Szent Istvan University
2103 Gödöllő, Hungary
Tel.: +36-28-522000/2065
Mobile: +36-30-2678970
Fax: +36-28-410802
E-mail: hnagy@freemail.hu

Poland

Ms. Bernadetta Zawadzka
Institute of Soil Science and Plant Cultivation
Czartoryskich, 8
24100 Pulawy, Poland
Tel.: +48-81-8863421 ext. 259
Fax: +48-81-8864547
E-mail: zawadzka@gnom.iung.pulawy.pl

Romania

Ms. Simona Catana
INMH - National Institute of Meteorology and Hydrology
Soseaua Bucuresti - Ploiesti 97, Sector 1
71552 Bucharest, Romania
Tel.: +40-1-2303240
Fax: +40-1-2303143
E-mail: simcat@meteo.inmh.ro
simcat2001@yahoo.com

Ms. Ana Nitu
INMH - National Institute of Meteorology and Hydrology
Soseaua Bucuresti - Ploiesti 97, Sector 1
71552 Bucharest, Romania
Tel.: +40-1-2303116
Fax: +40-1-2303143
E-mail: anan@meteo.inmh.ro
ananitu@yahoo.com

Turkey

Ms. Sevgim Deniz Azcanli
General Directorate of Environmental Impact
Assessment and Planning
Ministry of Environment
Eskisehir Yolu 8 km
Ankara, Turkey
Tel.: +90-312-2879963
Fax: +90-312-2852910
E-mail: sdazcanli@ucvt.gov.tr
dazcanli@yahoo.com

Mr. Sadat Kadioglu
Environment Expert
Department of Water and Solid Management
General Directorate of Prevention Pollution and Control
Ministry of Environment
Ankara, Turkey
Tel.: +90-312-9879963/5412
Fax: +90-312-2855875
E-mail: sedatkad@yahoo.com

Ms. Zeynep Fikran Yenice
The Authority for the Protection of Special Areas
Ministry of Environment
Koza Sk., No. 32
06700 Cankaya, Ankara, Turkey
Tel.: +90-312-4408551/233
Fax: +90-312-4408553
E-mail: zeysin2000@hotmail.com
zeynepyenice@yahoo.com

Lecturers:

Mr. Nicola Candeloro
Director
Eurallumina S.p.a.
Portovesme
Casella Postale n°64
09010 Portoscuso, Cagliari, Italy
Tel.: +39-0781-500302
Fax: +39-0781-500310

Mr. Luciano Ottelli
Via S. Antonio, 2
09016 Iglesias, Cagliari, Italy
Tel.: +39-0781-23852
Mob.: +39-340-3994001

Mr. Giorgio Tore
Progemisa S.p.a.
Società Sarda Valorizzazione Georisorse
Via Contivecchi, 7
09122 Cagliari, Italy
Fax: +39-070-271402
E-mail: giorgio.tore@tin.it

From ICS-UNIDO

Mr. Alfredo Altobelli
Scientific Consultant
Earth, Environmental and Marine
Sciences and Technologies
ICS-UNIDO
AREA Science Park
Padriciano 99, Bldg. L2
34012 Trieste, Italy
Tel.: +39-040-9228148
Fax: +39-040-9228136
E-mail: alfredo.altobelli@ics.trieste.it

Mr. Enrico Feoli
Senior Scientific Consultant
Earth, Environmental and Marine
Sciences and Technologies
ICS-UNIDO
AREA Science Park
Padriciano 99, Bldg. L2
34012 Trieste, Italy
Tel.: +39-040-9228109
Fax: +39-040-9228136
E-mail: enrico.feoli@ics.trieste.it

● Mr. Mounir Ghribi
Environmental Technologies Engineer
Earth, Environmental and Marine
Sciences and Technologies
ICS-UNIDO
AREA Science Park
Padriciano 99, Bldg. L2
34012 Trieste, Italy
Tel.: +39-040-9228105
Fax: +39-040-9228136
E-mail: mounir.ghribi@ics.trieste.it

● Mr. Gennaro Longo
Area Director
Earth, Environmental and Marine
Sciences and Technologies
ICS-UNIDO
AREA Science Park
Padriciano 99, Bldg. L2
34012 Trieste, Italy
Tel.: +39-040-9228104
Fax: +39-040-9228136
E-mail: gennaro.longo@ics.trieste.it

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Annex III
PRESENTATIONS

List of Presentations

- G. Longo Introduction to ICS
- L. Ottelli Overview of the Importance of Industry, Trade and Tourism in Coastal Areas: Mining Activity in Sardinia, in Iglesias and its Territory
- E. Feoli Definition of Land Use/Land Cover for Planning Industrial Development
- G. Longo Process Simulation for Sustainable Industrial Development
- G. Tore Technological Tools for Coastal Zone Management
- E. Feoli GIS and Spatial Data Integration
- A. Altobelli Remote Sensing Techniques
- A. Altobelli and M. Ghribi Practical Exercises on "Satellite Images Acquisition, Data Analysis, Information Extraction, Correction Techniques and Image Processing"
- A. Altobelli GIS applications using MultiSpec for unsupervised and supervised classification of LANDSAT images
- E. Feoli Introduction to Multivariate Data Analysis
- M. Ghribi GIS, Remote Sensing and Spatial Decision-Support Systems (SDSS) for Coastal Zone Management
- M. Ghribi Practical Exercises on Image Processing and Multi-Criteria Evaluation (MCE) using IDRISI Software Package
- M. Ghribi ICS Case Studies Presentation
- E. Feoli Application of Classification and Ordination Methods in Landscape Assessment
- N. Candeloro Focus on the Impacts of Industrial Development on Marine Environment and Landscape

Introduction to ICS
by G. Longo



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Gennaro Longo

Area Director

Earth, Environmental and Marine Sciences and Technologies
ICS-UNIDO
AREA Science Park, Padriciano 99, Building L2, 34012 Trieste, Italy
Tel: +39.040.9228104 - Fax: +39.040.9228136
E-mail: gennaro.longo@ics.trieste.it



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ICS

Autonomous Institution operating

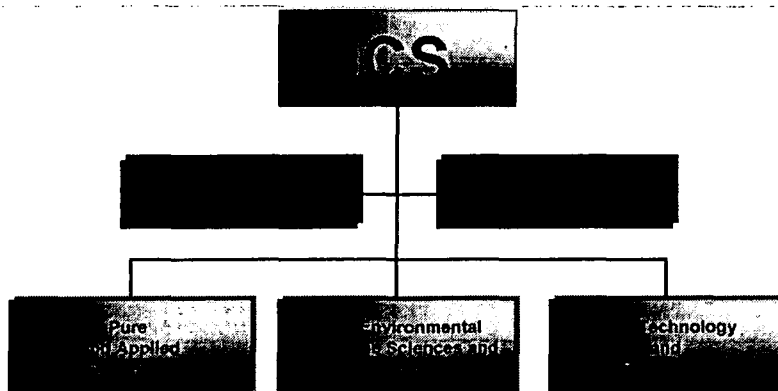
within UNIDO legal framework



- **Founded by Nobel prize-winner Prof. Abdus Salam in 1988**
- **Supported by Italian Government**
- **Headquarters: Trieste, Italy (within the AREA Science Park)**



Institutional Structure



Steering Committee

- **Representatives of Italian Government**
- **Representative of UNIDO**
- **Representative of Developing Countries**

Objectives of ICS

- **To foster and facilitate the transfer of technology in specific high-tech areas to developing countries.**
- **To provide high-tech SME's in developing and in transition-economy countries with advanced tools and services for the enhancement of their sustainability and competitiveness.**
- **To assist in the formulation of eligible projects to be financed by international donors.**



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Implementation Instruments...

Training activities

- Training courses
- Scientific workshops
- High-level seminars
- Fellowships
- Publications and training packages



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...Implementation Instruments

Project proposals

- Traditional training activities at ICS support the identification and formulation of projects, which are submitted to donors for funding.
- Project proposals are identified and implemented with the support of experts and fellows from industries or institutions.



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Networking

- Support to the establishment of networks to improve the exchange of experience.
- Identification in various regions of the world, selection and evaluation of partner institutions willing to offer:

Cooperation and support



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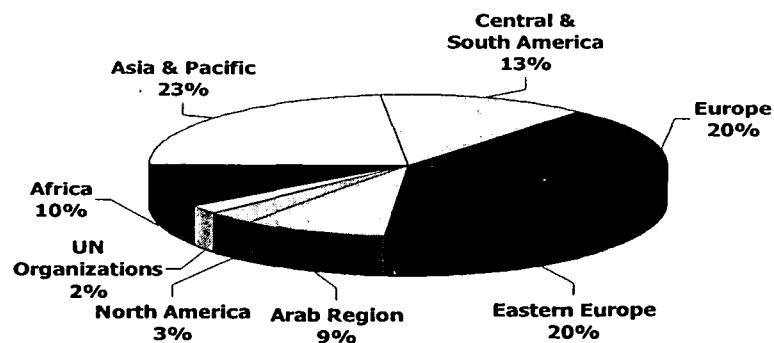
International Cooperation

- CEI (Central European Initiative)
- CP/RAC (Cleaner Production - Regional Activity Centres)
- UNEP/MAP (Mediterranean Action Plan)
- UNIDO (United Nations Industrial Development Organization)

ICS Activities (1988-2001)

- 380 Workshops, Training Courses, Expert Group Meetings
- 13165 Participants

Participants (1988-2001)





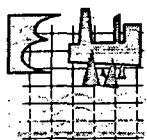
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Technical Areas



Pure and Applied Chemistry

Area Director: Mr. Stanislav Miertus



Earth, Environmental and Marine Sciences and Technologies

Area Director: Mr. Gennaro Longo



High Technology and New Materials

Area Director: Mr. Emilio Vento



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Pure and Applied Chemistry

- **Catalysis and Sustainable Chemistry**
Transformation of polluting obsolete chemical technologies into cleaner alternatives using catalysis.
- **Environmentally Degradable Plastics**
Renewable resources.
Plastic waste disposal.
- **Remediation**
Decontamination of polluted sites.
- **Combinatorial Chemistry and Technologies**
Pharmaceutical and agrochemical industry applications.
Development of new chemical compounds.



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High Technology and New Materials

➤ **High Technology**

Laser applications and optical technologies for industry and medicine.

➤ **New Materials**

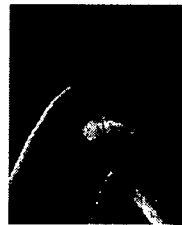
Composite materials for low-cost housing.

➤ **Photovoltaic Solar Energy**

Diffusion of pv systems and applications.

➤ **Telecommunication Technologies**

Radio communications, fixed, mobile, satellite and rural networks.



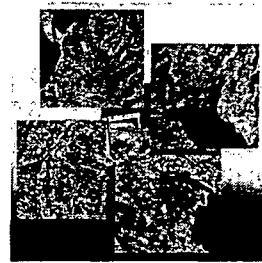
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Earth, Environmental and Marine Sciences and Technologies



Main Focus

- **Pollution prevention.**
- **Waste reduction at source.**
- **Medicinal and aromatic plants industrial exploitation.**



Objectives

- **Balanced environmental planning.**
- **Sustainable industrial exploitation of natural resources.**
- **Clean technologies.**
- **Sustainable industrial development of coastal activities.**



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Technical support

- **Process Simulation & Environment Simulation**
- **Remote Sensing**
- **Image Processing**
- **Geographic Information Systems**



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Software...

➤ **Geographic Information Systems (GIS)**

- **ARCINFO**
- **GRASS**
- **IDRISI**
- **ARCVIEW**

➤ **Image Engineering**

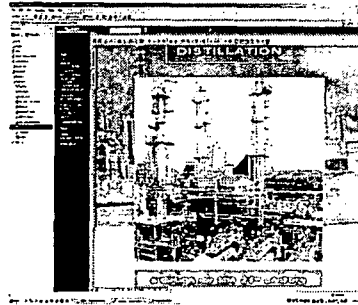
- **IMAGINE**
- **GEOMATICA**



...Software

➤ *Process Simulation*

- PRO II
- ASPEN PLUS
- Delft3D



➤ *Statistical Analysis*

- STATISTICA
- SPSS

➤ *Mathematical Modeling*

- MATLAB

Subprogrammes

- **Decision Support Systems for Sustainable Industrial Development**
- **Coastal Zone Management**
- **Industrial Utilization of Medicinal and Aromatic Plants**

DSS for Sustainable Industrial Development

➤ ***Reinforcement of decision-making process
for sustainable industrial development***

- Process Simulation
- Environment Simulation
- Remote Sensing
- Image Processing
- GIS



Coastal Zone Management

- **Sustainable development of coastal economics.**
- **Integration of scientific, economic, legislative aspects.**
- **Application of decision-support systems for:**

- industrial siting
- resource management and control
- control and monitoring of pollution



Industrial Utilization of Medicinal and Aromatic Plants

- Consolidation of existing technology for developing countries.
- Technical assistance in product R&D.
- Raising government awareness.



Publications and Products...

- Training Manual on “Introduction to GIS for Industrial Development”.
- Training Package on “Integrated Coastal Area Management”.
- Manuel de Formation “Approche stratégique d’une gestion environnementale intégrée dans les entreprises industrielles algériennes”.



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...Publications and Products...

- Elaboration of a database on Essential Oils, provided by the African Laboratory for Natural Products (ALNAP), in collaboration with the Addis Ababa University, Ethiopia.
- Updated links to Medicinal and Aromatic Plants databases.
- Technical and economical assessment of various technologies for Essential Oil Extraction.



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...Publications and Products...

- Video documentary on “Standardization Techniques for Herbal Medicinal Products”.
- “Industrial Development in Coastal Areas of South-East Asia” (Workshop Proceedings)
- “The Role of Process Simulation in Sustainable Industrial Development” (EGM Proceedings).



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...Publications and Products

- **Bioprospecting Strategies for Industrial Exploitation of Medicinal and Aromatic Plants (Workshop Proceedings).**

- **Trade and Production of Herbal Medicines and Natural Health Products.**

- **Industrial Utilization of Pyrethrum (Workshop Proceedings).**



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Activities 2002...

- **Workshops on the “Role of Process Simulation for Sustainable Industrial Development in Cleaner Production Centres”, Brazil, Ecuador and Nigeria.**

- **Training Course on “Sustainable Industrial Development: Process Simulation, Analysis, Optimization and Control”, Bangkok, Thailand.**

- **Training Course on “Quality Control and Standardization of Herbal Drugs”, Guatemala, Guatemala.**

...Activities 2002...

- Training Course on “Image Processing and Remote Sensing for Monitoring Industrial Development in Coastal Areas”, Iglesias, Italy.
- Training Course on “Integrated Coastal Area Management”, Tegucigalpa, Honduras.
- Workshop on “Industrial Case Studies by Cleaner Production Centres”, Nairobi, Kenya.

...Activities 2002

- Workshop on “Regulations for Production and Marketing of Medicinal Plant Products”, Trieste, Italy.
- Workshop on “Results of the PRTR Pilot Project”, Alexandria, Egypt.

Projects 2002...

- **Ecological Protection of the Modrac Reservoir as Basic Resource for Water Supply of Citizens and Industry of Tuzla Canton, Danube River Basin.**
- **“Pollutant Release and Transfer Register (PRTR)” Mediterranean Pilot Project, Alexandria, Egypt.**
- **Process Simulation for In-plant Cleaner Production Assessment and Process Optimization, Nairobi, Kenya.**

...Projects 2002

- **Pre-investment Study for Pollution Assessment in the Industrial Area of Zadar, Croatia.**
- **Industrial Exploitation of Tea Polyphenols, Chandigarh, India.**

Future trends...

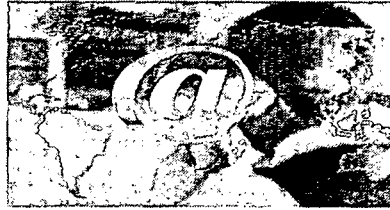
- **Commitments and priorities indicated by the Italian Government.**
- **Follow-up of ongoing activities - draft plan for next years - (events, projects, "products", in-house expertise).**
- **Complementarity and synergy between ICS specialized services and UNIDO programmes of intervention.**

...Future trends

- **Periodic survey of urgent problems and priority needs of developing and in transition countries through Expert Group Meetings, Workshops and Scientific Committee Meetings.**
- **Trends in Sustainable Industrial Development.**



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For additional information please visit our web site:

<http://www.ics.trieste.it>

*Overview of the Importance on Industry, Trade and Tourism in
Coastal Areas: Mining Activity in Sardinia,
in Iglesias and its Territory
by L. Ottelli*

Overview of the Importance of Industry, Trade and Tourism in Coastal Areas:
MINING ACTIVITY IN SARDINIA, IN IGLESIAS AND ITS
TERRITORY

When the dossier on the value of the millennial mining activity on our island was presented, the attention of 170 Unesco members was impressed. They carefully listened to the long and complex geological events that led to the exploitation of the considerable deposits of the most different minerals, that saw man struggle and suffer to mine the most secret treasures of the island subsoil.

The mining activity tells us of 8000 years of history in which our land has been object of research and mine working of various minerals, apart from being a meeting point for different cultures and populations coming from all over the Mediterranean sea.

During those 8000 years, the searched and used materials have naturally changed, going from obsidian to gold, according to the change in the interested populations and, still today, this search and exploitation of new minerals go on.

The decline of the mining activity in Sardinia, that brought to the almost complete closure of the mining plants, has not been followed by the deserved attention and sensibility. Every mine, in fact, once the useful mineral has been depleted, can be reused for all its cultural, scientific and human contents that naturally possesses but that have been incremented during its development.

It is also true, however, that the mining activity leaves on the territory, heavy marks of itself, deeply modifying the landscape with superficial minings, dumps and decantation basins. Such marks represent a kind of visual pollution but, above all, a presence of heavy metals on soils and waters.

Different projects of depollution are being fulfilled in the Iglesias area. Concerning heavy metal pollution, for instance, the main problem

is represented by the settling tank of washery muds and heaps of metallurgic waste, that have proved to be sources of environmental pollution in a few cases and are, in general, a potential risk of environmental damage, and require urgent safety engineering intervention, impact minimisation and monitoring. Finally, mining activity has affected the hydrogeological system, the landscape and land morphology, and has caused significant impoverishment of woods that have been cut and used to support underground cavities or the production of energy.

The problem of soil and water pollution caused by mining activity became apparent in the mid-nineteenth century as a result of large amounts of extracted materials and the absence of environmental protection. With the abandonment of mining activity, more or less pronounced, diffused and canalised drilling processes have caused collapses and erosion near the tailings heaps. This led to the unconditioned transport of fines and their discharge into watercourses and soils, causing both surface and deep chemical contamination, a less apparent risk though, in the long term, the most dangerous.

Surveys seem to indicate that the heaped mine tailings amount to over fifteen million cubic meters, not counting the waste that a few mines have discharged directly into the sea.

According to the Mine Office, the quantity of material discharged in rivers between 1949 and 1958 amounts to five millions cubic meters, but specific studies on heavy pollution have only been carried out in recent years.

As a result of a few geochemical and hydrogeochemical survey carried out on vast portions of land affected by mining activity, sampling of the most representative parts of the spoil banks confirmed the presence of high contents of Pb (>5000 ppm), As (>100 ppm) and Cd (>100 ppm), above legal toxicity limits provided for industrial wastes.

There are not specific studies on the effects on air contamination, though several environmental analyses have shown that a few mining

areas particularly exposed to the dominant winds present accumulations of sediments from the spoil banks and a significant amount of dust.

However, it has to be pointed out that, the mining activity through history, gives Sardinia a peculiar aspect. Its geological, mineralogical, paleontological, hydrological elements, its biologic rarities and endemics, its humid zones, its spectacular landscapes in the morphology of its coasts, internal mountains and underground cavities and all the archeological remains deeply related to the mining areas, constitute, all together, a perhaps unique heritage in the world.

Nevertheless, among these characteristics, it was the geological and mining exigencies that most intensely spelled out the social and cultural history of the island, an island with strategic natural resources, deposits whose variety and size have attracted Mediterranean and other populations from the most ancient times up to recent years.

The mineral richness of Sardinia appears through the innumerable mines scattered in its territory. All those mines have different productive, scientific and cultural values, but are all indispensable to understand the evolution of events in over 8000 years of uninterrupted exploitation. Mining history reflects the history and culture of the Mediterranean man and this is the reason why the Unesco interest has arisen together with the following recognition of the "PARCO GEOMINERARIO STORICO ED AMBIENTALE DELLA SARDEGNA" as a proposal of valorization of a cluster of cultural and environmental values that few other countries possess. And, in this context, the Iglesias territory is the one that most represents the evolution of mining through the centuries.

The mining activity has, in fact, left on the territory witnesses of Phoenician-Carthaginian, Roman and Pisan processing, the last one of which for the extraction of silver from the smelting of galena. (XIII and XIV century).

During the Pisan period, the Gherardesca family was the most distinguished and from 1256 onwards, ruled the South-Western part of the island, the so called Sulcis-Iglesiente. As already pointed out, this part

of Sardinia was particularly rich in minerals and mines and the Pisans left many first-hand accounts of their activity as well as the first mining codex of the island entitled “BREVE DI VILLA DI CHIESA DI SIGERRO”.

The Breve is a set of operational and behavioural norms and provisions that all citizens were to respect. “... The exploitation of mines in Sardinia was mainly for silver. Workings for silver-bearing ore were made through thin shafts from the surface along the metalliferous vein. At times, an incredible number of shafts were made especially in the calcareous mountains neighbouring Iglesias... sometimes the shafts or pits were dug down to depths of more than 80-100 meters and, in some places, even to 200 meters”. This fervid activity reached its apex in the second half of the XIII century with Ugolino della Gherardesca dei Conti di Donoratico and his sons Guelfo and Lotto.

Silver had at that time a higher value compared to today and the amount of material extracted in the Iglesiente area was so big to justify the building of a mint in which two kinds of coins were struck: the Aquilino d'argento and the Aquilino minuto.

The breve was unfortunately the only document escaped from the big fire of the city short after 1350.

The other witnesses of the mining activity in the area are from XIX and XX century, a period in which great engineering works were made that gathered the attention of the entire industrialized world. Some of those works are being recovered and they will soon be given back to the community for didactic, technical, scientific and turistic aims.

Different examples of the technical skills and of the sacrifices made by the workers can be found all over the territory as well as thousands of historical and technical documents testifying the different ways of working and the most futuristic techniques used. In this context, one of the most curious engineering work realized in Iglesiene is “Porto Flavia” built on the cliffs on Masua in 1924 by Eng. Cesare Vecelli who named the work after his little daughter Flavia. Porto Flavia was built in order to

load the ore directly onto the ships and thus avoid the transportation by ox-driven carts or by the workers who carried the ore in baskets on their backs. This system had a loading capacity of 400 tons/hour and in a few hours it could load ships that would have taken days to load with the old system.

The peculiar mining habitat in which such important architectures are present is being preserved and enhanced. It is an incomparable patrimony that tells us the great history of our island and the man sacrifice in this hard and dangerous activity.

Luciano Ottelli

June 2002

*Definition of Land Use/Land Cover for Planning
Industrial Development
by E. Feoli*



1.1. The CORINE programme

If our environment and natural heritage are to be properly managed, decision-makers need to be provided with both an overview of existing knowledge, and information which is as complete and up-to-date as possible on changes in certain features of the biosphere.

To this end, the three aims of the CORINE (Coordination of information on the environment) programme of the Commission European are:

- * to compile information on the state of the environment with regard to certain topics which have priority for all the Member States of the Community;
- * to coordinate the compilation of data and the organization of information within the Member States or at international level;
- * to ensure that information is consistent and that data are compatible.

On 27 June 1985 the Council, on a proposal from the Commission, adopted a decision on the CORINE programme. This Commission work programme concerns 'an experimental project for gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community' (Official Journal L 176, 6.7.1985).

In order to determine the Community's environment policy, assess the effects of this policy correctly and incorporate the environmental dimension into other policies, we must have a proper understanding of the different features of the environment:

- * the state of individual environments,
- * the geographical distribution and state of natural areas,
- * the geographical distribution and abundance of wild fauna and flora,
- * the quality and abundance of water resources,
- * land cover structure and the state of the soil,
- * the quantities of toxic substances discharged into environments,
- * lists of natural hazards, etc.

A further objective of the CORINE programme is to bring together all the many attempts which have been made over the years at various levels (international, Community, national and regional) to obtain more information on the environment and the way it is changing.

Two main types of complementary action have been taken to meet the programme's objectives:

- * devising procedures for collating, standardising and exchanging data on the environment in the EC Member States;
- * creating a geographical information system to provide the information on the environment which is essential when preparing and implementing Community policies.

Figure 1.1. Organization of the project

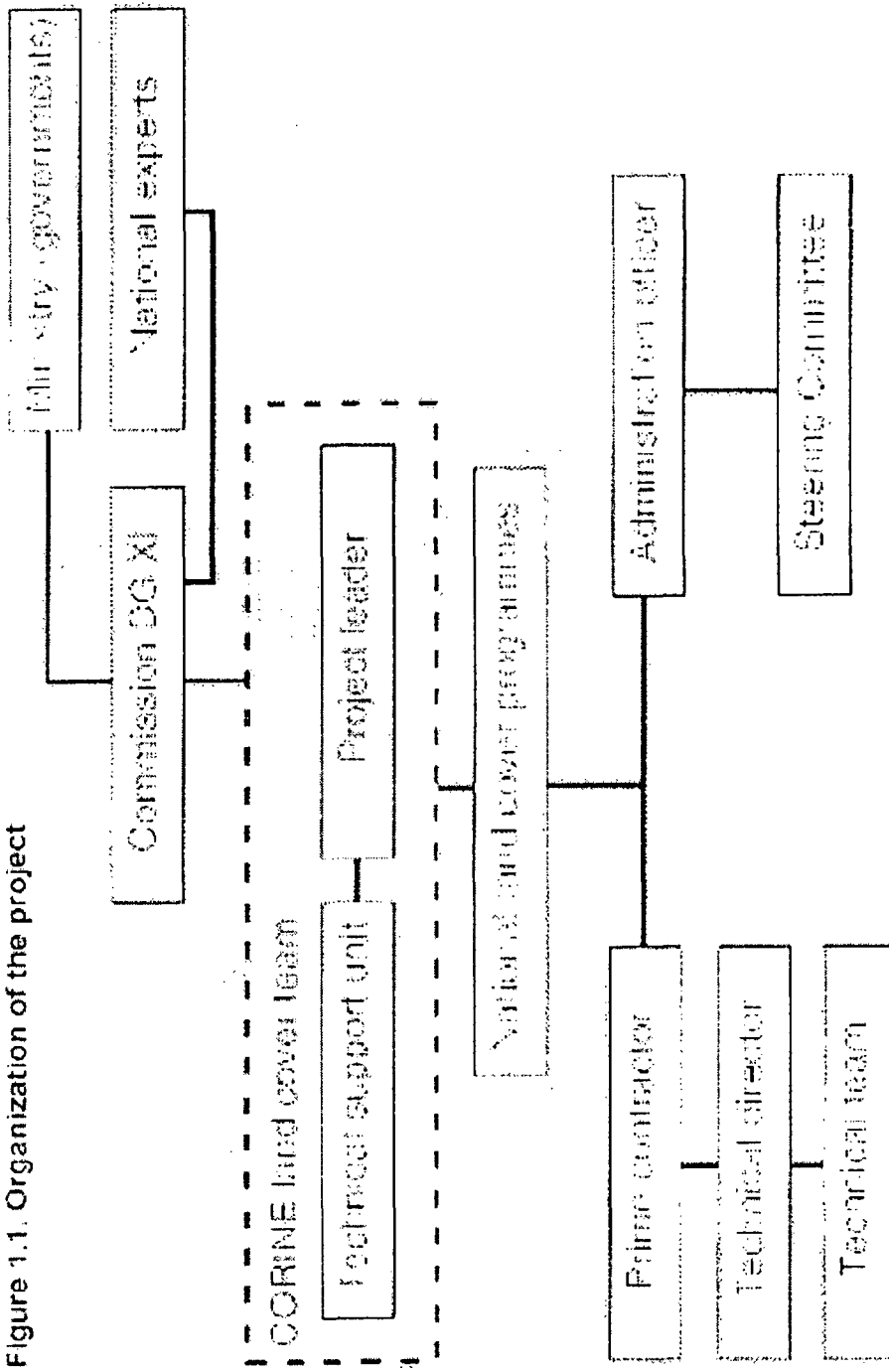


Table 1.1. The CORINE land cover project in figures

- Area covered: 2.3 millions km²
 - * 12 countries
 - * from 62° N (The Faeroes) to 28° S (Canary Islands)
 - * from 14' W (Canary Islands) to 29° E (Kastellorizon)
- Working scale: 1/100000
 - * i.e. 1 500 standard map sheets produced using 10 different projection systems
- Area of the smallest mapping unit: 25 hectares
 - * i.e. more than 700000 basic unit (polygons) or a vector data-base around of 1 gig
- Land cover nomenclature with three levels
 - * First level: five headings
 - * Second level: 15 headings

* Third level: 44 headings

- National teams

DP specialists, geographers, photointerpreters and cartographers working on the production of satellite images, computer-aided interpretation and the digitization and integration of data into the CORINE land cover database.

- A central technical unit consisting of four specialists:

Michel Bossard: Photo-interpretation

Yves Heymann: Project leader

Michel Lenco: Statistics

Chris Steenmans: Data processing

1.2. The CORINE land cover project

The land cover project is part of the CORINE programme and is intended to provide consistent localized geographical information on the land cover of the 12 Member States of the European Community.

The project is necessary for the following reasons:

- * preliminary work on the CORINE information system showed that information on land cover, together with information on relief, drainage systems etc., was essential for the management of the environment and natural resources; information on land cover therefore provides a reference source for various CORINE database projects;
- * in all the countries of the Community, the information on land cover available at national level is heterogeneous, fragmented and difficult to obtain.

At Community level, in the CORINE system, information on land cover and changing land cover is directly useful for determining and implementing environment policy and can be used with other data (on climate, inclines, soil, etc.) to make complex assessments (e.g. mapping erosion risks).

The benefits of using a single joint project to meet both Community and national (or even regional) needs considerably influenced the general features of the land cover project: scale, area of the smallest mapping unit and nomenclature.

1.2.1. Information on land cover

Until recently, it was generally assumed that in the long term human activity had little lasting effect on the land thanks to nature's ability to restore itself. This view remained prevalent for a long time despite the fact that farming practices have been causing irreversible damage in certain areas for centuries.

Over the last few decades, the effects of certain phenomena have shown that we do need to look after land cover and all its various components. These include:

- * the gradual desertification of certain regions,
- * the rapid disappearance of vast areas of forest,
- * the wholesale of poor farmland,
- * the gradual drying-up of wetlands,
- * continuous urban development along coastlines, etc.

If the aim is to do more than resort to basic emergency action in the face of disaster and instead manage vast areas of land rationally, information on land cover is essential. Yet, despite the urgency and the scale of the problem, confirmed by all the studies, progress in this area is limited and often disappointing.

Those industrialised countries which have devoted considerable resources to producing large-scale maps of national territories and keeping up-to-date inventories and maps of land ownership have never seriously considered the problem of making and updating land cover inventories. This may be because the serious nature of the effects of some of man's actions on the biosphere has only recently been fully understood, or because data compilation and management techniques did not previously lend themselves to this type of operation.

As a result, information on land cover has been available only for small areas affected by urban development, agricultural development, major infrastructure projects, etc.

Against this background, the CORINE land cover project launched by the Commission of the European Communities sets out to meet a new need and provides support for the Commission in its efforts to use and develop advanced data compilation and management techniques in carrying out its policies.

Over the last decade, awareness of serious environmental problems has lent new urgency to the question of land cover inventories.

We can no longer rely on thematic information from topographic maps which are updated every 10 or 15 years, and even less use can be made of statistical assessments which are the by-products of agricultural and forestry inventories and surveys, when attempting to cope with the following:

- * disappearance of areas of wetlands,
- * destruction of Mediterranean woodland by fire,
- * intensification of agriculture in vulnerable areas,
- * development of tourism along coastlines,
- * emergence of scrub on farmland,
- * disappearance of species deprived of their biotopes, etc.

For environmental management purposes, land cover information will have to meet special requirements: it must be cartographic as well as statistical and it must be possible to reproduce the information at different scales to be useful at various decision-making levels.

The following table gives a summary.

Table 1.2 - Map inventory: relationship between scale and needs met

Scale	Needs met	Type of decision
1:1000 000	Main long-term trends in land cover International comparison of land cover patterns	Guiding national and Community programmes and preparing major development programmes
1:1 00 000	National management of the environment: identifying and locating major problem areas	Monitoring the implementation of Community and national policies
1:25 000	National land use policy: deciding which areas to protect Monitoring regional land use Managing sensitive areas	Local management

The nomenclature used at the various scales must enable decision-makers to identify, analyse and monitor land use in the areas under their responsibility.

It must be possible for decision-making bodies to update the information on their areas easily and quickly.

1.2.2. Origins of the project

Previous projects in certain countries have shown how difficult it is to delineate, categorise and map types of land cover even in small areas. This is particularly evident when attempting to compare the land cover statistics of several countries or to collect all the information available on land cover in one single country.

However, over the last 15 years or so, the launching of Earth observation satellites seems to have improved the chances of success in compiling land cover inventories of vast areas. The marketing of geographical information software has also made it easier to use the information from these inventories and to update them more rapidly. In fact the Council's recommendation to use satellite data is well justified in the particular case of the CORINE land cover project.

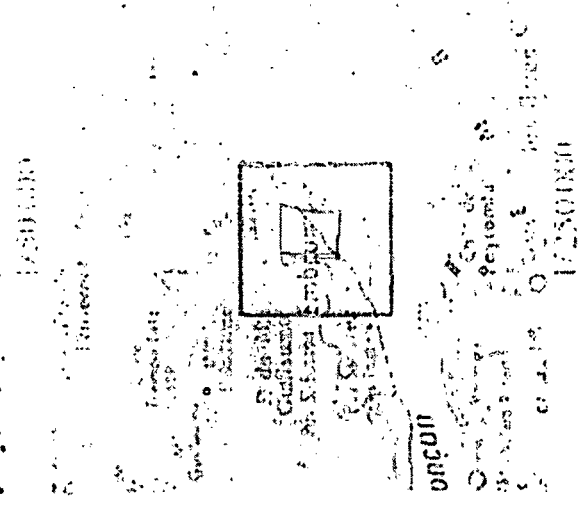
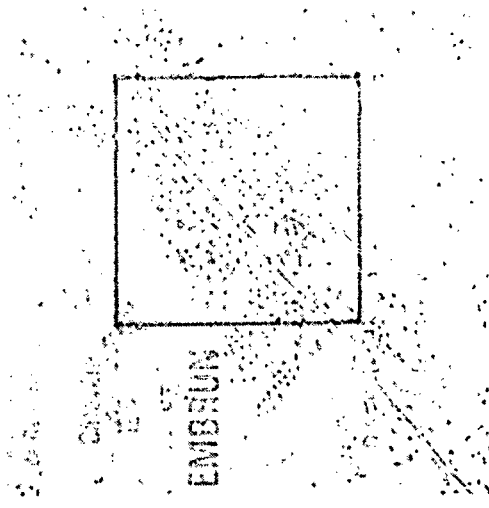
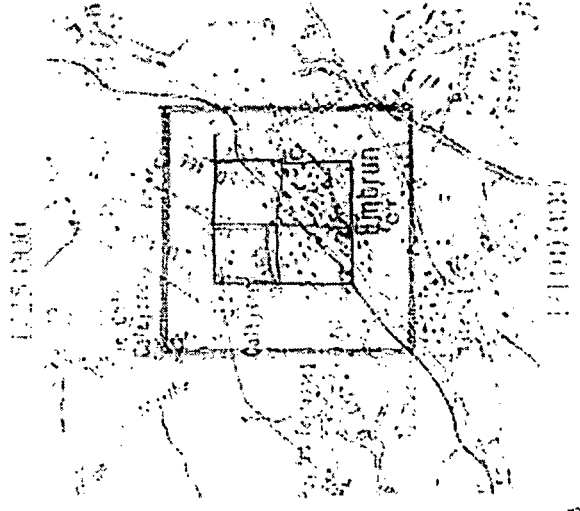
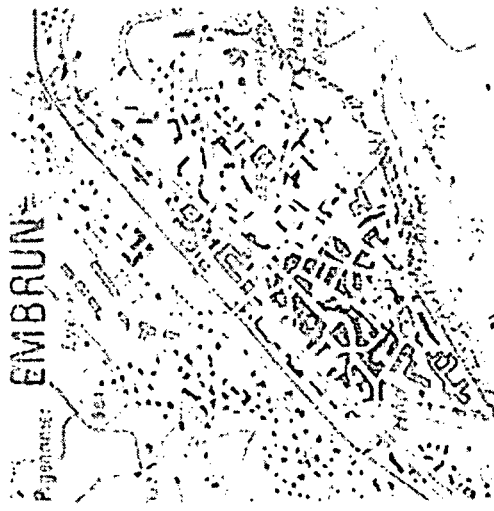
Earth observation satellite data have the following characteristics:

- they are available on a regular basis for all points on the globe (subject to there being no cloud cover); data may be acquired every 16 days in the case of Landsat and every 26 days in the case of SPOT; with the satellites currently in service, and taking account of cloud patterns over certain countries, it is estimated that all the countries of the can be covered twice a year.
- they are inexpensive.

2.1. The mapping scale

The scale chosen for the project is 1:100 000.

Figure 2.1. Cartographic scales



There are several reasons for this choice:

- * Land cover data provided on smaller scales (1:250 000, 1:500 000) are not detailed enough to be useful to the Commission. At such scales, the size of the smallest unit mapped is very large and the corresponding nomenclature includes relatively few headings (e.g. level-2 nomenclature, with about 15 headings).
- * It is well suited to serve as a basis for specific studies at larger scale within a country, such as preliminary investigations for civil development projects or environmental protection.
- * It (e.g. coastal erosion), but it is also compatible with projects which use a smaller scale (e.g. 1:1 000 000), since space-borne remote sensing allows generalisation at that basic cartographic scale.
- * It is consistent with budgetary constraints and time limits for carrying out such a programme in the 12 Community countries.
- * The maps can be fairly easily updated on a regular basis.
- * This is a common mapping scale for most Community countries, albeit with a wide range of projection systems (see Table 2.1).



Country	Scale	Projection	Number of sheets = 42	
Belgium	(B) 1:100 000 1:50 000	Lambert Lambert	24 74	
Denmark	(DK) 1:100 000	UTM	34	
Germany -former Federal Republic of Germany -former German Democratic Republic	(D) 1:100 000	Gauss Kruger	151 115	
Greece	(GR) 1:200 000 1:100 000	UTM UTM	54 134	
Spain	(E) 1:50 000	Azimuthal equidistance	333	
France	(F) 1:100 000	UTM	297	
Ireland	(F) 1:100 000	Lambert	293	
Italy	(IRL) 1:126 720	Transverse Mercator	20	
Luxembourg	(I) 1:100 000	Gauss Bonaga	278	
Netherlands	(L) 1:100 000	Gauss	1	
Portugal	(NL) 1:100 000	Stereographic	8	
United Kingdom	(P) 1:100 000	Bonne	53	
Northern Ireland	(UK) 1:50 000 1:250 000	Transverse Mercator Transverse Mercator	204 17	
		1:126 720	Transverse Mercator	5
Total number of sheets (1:100000 and 1:126 720)			1413	

2.2. Definition of the unit area and size of the smallest unit mapped

Thematic mapping of the biophysical cover of the Earth's surface may be approached from two different angles:

- * Land cover essentially concerns the nature of features (forests, crops, water bodies, bare rock, etc.)
- * Land use is concerned with the socio-economic function (agriculture, habitat, environmental protection) of basic surfaces.

Since the aim of the CORINE programme is to provide users with information on the state of the environment, a cartographic inventory of land cover is required; this is the CORINE land cover project.

The feasibility study showed the land cover project's technical unit that the use of satellite data for the land cover mapping of extensive surfaces would not only raise a nomenclature problem, but would also necessitate detailed consideration of the unit area to be mapped.

Remarks on land cover mapping

In many cases thematic mapping is carried out for economic management purposes and is therefore concerned with land use.

Land cover maps often implicitly adopt the cadastral land unit as the unit area. However, the cadastre, a unit area recognized in law, is essentially limited to large-scale land use maps. The cadastral unit is very often heterogeneous in its composition and its area can vary from a few square metres to several thousand hectares.

With vegetation maps, which are a form of land cover map, the problem of the unit area (to be) mapped has not arisen

The results of certain statistical surveys (areolar surveys of land use/cover) might suggest that the problem of the unit area is not really problematic. However, it must be remembered that these surveys sample points, not surfaces. Nonetheless, in the field it is still possible to classify a point as an item in a land cover nomenclature.

2.2.1. The unit size area

To assist the understanding and use of this unit, we have decided to define it by listing its main characteristics.

- it corresponds either to an area whose cover may be considered homogeneous (grass, water, forest, etc.) or to a combination of elementary areas (homogeneous as defined above) which, in its variations, represents characteristic land cover structures (covering large surfaces which can be considered to constitute a single type of land cover in the Member States of the Community);
- given the scale, the unit must represent a significant area of land;
- it is clearly distinguishable from surrounding units;
- its structure in terms of land cover is stable enough to serve as a unit for the collection of more precise information.

Figure 2.2 - Unit area example: 1.1.2 discontinuous urban fabric, Landsat TM image



In the CORINE land cover project the unit area to be mapped has two functions:

- conceptual tool for land cover analysis;
- a tool for reading and organizing spaceborne remote-sensing data which constitutes a format - a particular representation of the heterogeneity and diversity of the objects covering the Earth's surface.

When defining this unit, it must always be borne in mind that, in reality (in the field) land cover always occurs as a combination of surfaces which are to a greater or lesser degree homogeneous/heterogeneous, whatever the scale used.

Furthermore, irrespective of how they have been processed, data acquired by spaceborne remote-sensing systems do not provide a representation of the actual land cover situation; nor can land cover be mapped in all its complexity/diversity.

Given these circumstances a spatial/statistical unit must be conceived, for all land cover mapping activities, that meets the following two requirements: (a) its content must provide the thematic data required by the users, and (b) it must provide an acceptable representation of reality.

2.2.2. Size of the smallest unit mapped

The surface area of the smallest unit mapped in the project is 25 hectares.

Establishment of the minimum surface area to be mapped must comply with three basic requirements:

- legibility of the printed map, or in the case of the land cover project, easy digitization from the interpretation manuscripts;
- it must provide a representation of the essential features of the terrain in terms that serve the thematic objectives of the project;
- it must represent a trade-off between project operating costs and provision of land cover information requirements within overall project budgetary constraints.

Taking these requirements into consideration, project managers set the minimum unit mapping size at 25 hectares.

On a scale of 1: 100 000, 25 hectares is represented by a 5 x 5 mm square or a circle with a 2.8 mm radius.

2.3. The nomenclature

In any land cover cartographic inventory four elements are inextricably linked:

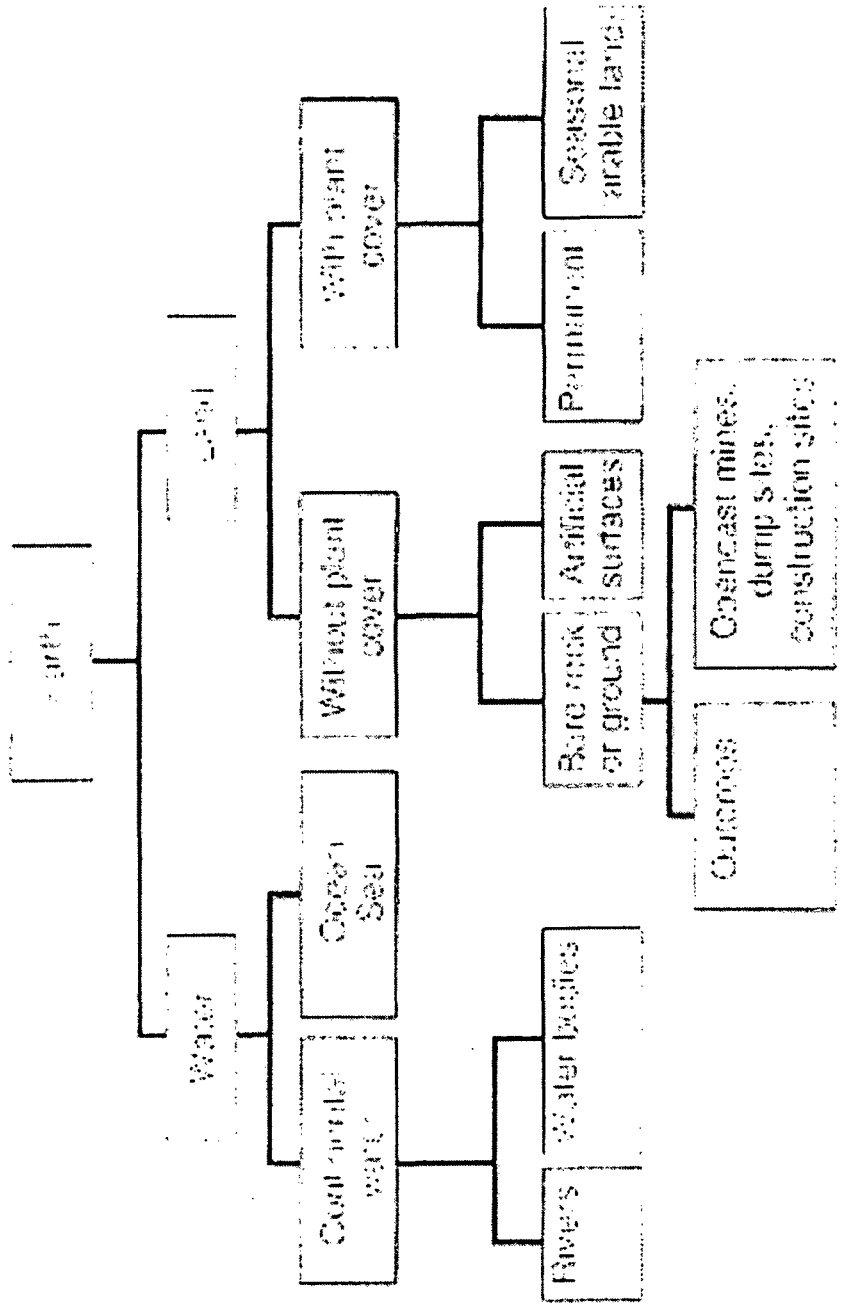
- * the scale,
- * the surface area of the smallest unit to be mapped,
- * the nature of the basic information used, in this case, Earth observation satellite data,
- * the structure of the nomenclature and the number of items it contains.

On the basis of the first three elements listed above and the provisional nomenclature used for the feasibility study, the land cover team has formulated the definitive nomenclature for the project.

This nomenclature and accompanying definitions have been the object of numerous discussions both with the final users of the CORINE database and with various experts in the Member States.

The following diagram (Figure 2.3) sets out the 'logical framework' which was used as a basis for establishing the nomenclature.

Figure 2.3 - Theoretical schematic construction of a land cover nomenclature



Based on this logical framework, the selected nomenclature must meet a certain number of requirements:

- it must be possible to map all Community territory; in other words there can be no heading for 'unclassified land';
 - the headings must correspond to the needs of future users of the geographic database, i.e. for the CORINE base, the state of the environment;
 - heading terminology must be unambiguous and avoid the vague terms often resorted to by many photointerpreters when encountering uncertain areas.
- Moreover, it must be remembered that the nomenclature applies to relatively large units, i.e. 25 hectares or more, and the total number of headings in a nomenclature is always a compromise between the user's needs and the financial constraints affecting the project.

Explanatory notes

(i) Terminology

Most nomenclatures used for mapping or statistics relating to space are land use nomenclatures produced for the purpose of compiling an inventory of human activities.

The terminology available (to designate the items in a land cover nomenclature) therefore relates to land use, so specific terminology for land cover inventories has yet to be developed.

It is fairly difficult, in one project, to establish a nomenclature which encompasses every single aspect of the area unit to be mapped.

(ii) Level of geographical application

The CORINE land cover nomenclature, as set out below, comprises three levels:

- the first level (five items) indicates the major categories (abstract to a greater or lesser degree) of land cover on the planet;
- the second level (15 items) is for use on scales of 1:500 000 and 1: 1 000 000;
- the third level (44 items) will be used for the project on a scale of 1: 100 000.

(iii) National and/or regional nomenclature

The CORINE land cover nomenclature is organized on three levels; a fourth level could be added for some or all of the items, subject to the following requirements:

- additional items must include all the land covered by the corresponding level-3 item (four-figure codes are used for these items only);
- newly created items must not relate to more than one three-figure item;
- the CORINE land cover mapping (three-figure nomenclature) must be completed prior to initiation of level-4

mapping.

Finally, care must always be taken to see that newly created items are compatible with the scale, the size of the smallest area to be mapped and the basic information, i.e. satellite data.

Table 2.2. CORINE land cover nomenclature

Level 1	Level 2	Level 3	
1 Artificial surfaces	1.1 Urban fabric	1.1.1. Continuous urban fabric	
		1.1.2. Discontinuous urban fabric	
	1.2 Industrial, commercial and transport units	1.2.1. Industrial or commercial units	
		1.2.2. Road and rail networks and associated land	
		1.2.3. Port areas	
		1.2.4. Airports	
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites	
		1.3.2. Dump sites	
		1.3.3. Construction sites	
	1.4. Artificial non-agricultural vegetated areas	1.4.1. Green urban areas	
		1.4.2. Sport and leisure facilities	
	2 Agricultural areas	2.1. Arable land	2.1.1. Non-irrigated arable land
			2.1.2. Permanently irrigated land
			2.1.3. Rice fields
2.2. Permanent crops		2.2.1. Vineyards	
		2.2.2. Fruit trees and berry plantations	
		2.2.3. Olive groves	
2.3. Pastures		2.3.1. Pastures	

- 2.3. Pastures
 - 2.3.1. Pastures
- 2.4. Heterogeneous agricultural areas
 - 2.4.1. Annual crops associated with permanent crops
 - 2.4.2. Complex cultivation patterns
 - 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation
 - 2.4.4. Agro-forestry areas
- 3. Forests and semi-natural areas
 - 3.1. Forests
 - 3.1.1. Broad-leaved forest
 - 3.1.2. Coniferous forest
 - 3.1.3. Mixed forest
 - 3.2. Shrub and/or herbaceous vegetation association
 - 3.2.1. Natural grassland
 - 3.2.2. Moors and heathland
 - 3.2.3. Sclerophyllous vegetation
 - 3.2.4. Transitional woodland shrub
 - 3.3. Open spaces with little or no vegetation
 - 3.3.1. Beaches, dunes, and sand plains
 - 3.3.2. Bare rock
 - 3.3.3. Sparsely vegetated areas
 - 3.3.4. Burnt areas

3.3.5. Glaciers and perpetual snow

4. Wetlands

4.1. Inland wetlands

4.1.1. Inland marshes

4.1.2. Peatbogs

4.2. Coastal wetlands

4.2.1. Salt marshes

4.2.2. Scaires

4.2.3. Intertidal flats

5. Water bodies

5.1. Inland waters

5.1.1. Water courses

5.1.2. Water bodies

5.2. Marine waters

5.2.1. Coastal lagoons

5.2.2. Estuaries

5.2.3. Sea and ocean

Process Simulation for Sustainable Industrial Development
by G. Longo

Process Simulation in Cleaner Production and Sustainable Industrial Development

Gennaro Longo

Earth, Environmental and Marine Sciences and Technologies Area

ICS-UNIDO

AREA Science Park, Padriciano 99, Building L2, 34012 Trieste, Italy

Tel: +39-040-9228104, Fax: +39-040-9228136, E-mail: gennaro.longo@ics.trieste.it

Overview...

- Sustainable Industrial Development (Why, What, How)
- Sustainable Chemical Technologies
- The Global Vision
- Process Simulation definition
- Process Simulation applicability
- Basic engineering design
- Programme structure

...Overview

- Main logic procedure of utilization
- Environmental policy
- Pollution prevention
- Process Simulation benefits
- Process Simulation results
- Example of plant modeling
- Conclusions

Sustainable industrial development

Why

- Pollution has become a daily issue also for human health (not only for the environment) in many countries
- Energy and materials are being consumed at a rate which could not be applicable to the total world population
- We will come to fight about the same (limited) resources
- The present situation cannot stay any longer:

It is not sustainable

Sustainable industrial development

What...

“Sustainable development is the means of improving the quality of human life with the carrying capacity of the supporting ecosystems” (*UNEP*)

“Humanity has the ability to make development sustainable, to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs” (*The Bruntland Report, 1987*)

Sustainable industrial development

...What

“Sustainability in Chemical Engineering means a continuous effort to protect and improve ecosystems, social balance and economic prosperity by a systematic and integral improvement of

- **Environmental protection**
- **Raw material exploitation**
- **Energy efficiency**
- **Safety and health protection**

in all kinds of material conversion processes and material production” (*EFCE definition*)

Sustainable industrial development

How

- Achieving Safety in production activities
- Ensuring human Health
- Protecting the Environment
- Running the world ecosystem in acceptable **steady-state conditions** with respect to materials, energy and population

This is the goal of sustainability

Sustainable chemical technologies

Environmentally sound processes

- *Under safe conditions (neither risks nor toxic compounds)*
- *With less resource consumption*
- *With less amount of residues (in air, water and soil)*
- *With higher selectivity and yields (less by-products)*
- *More based on renewable raw materials*
- *More economical (including environmental economics)*

Sustainable chemical technologies

Environmentally sound products (*Industrial Ecology*)

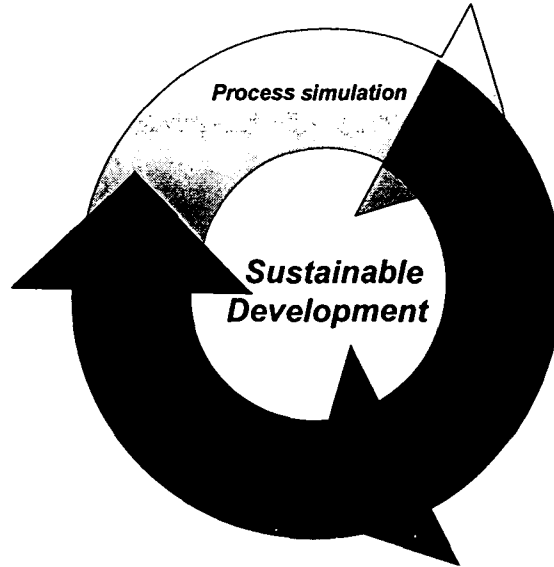
- *Minimum resource and energy use*
- *Minimum emissions*
- *Useable residuals (recycled) instead of wastes*

Sustainable chemical technologies

Role and commitment of Chemical Engineering

- *Knowledge about concepts easily extended to sustainability:*
 - *Mass and energy balances*
 - *Interactions between chemicals and environment*
 - *Safety (safe design and loss prevention)*
 - *Effects on health*
- *Availability of tools to make calculations and predictions: **Process Simulators and Environmental Simulators***
- *Design and apply of feed-back and feed-forward control procedures*

The Global vision

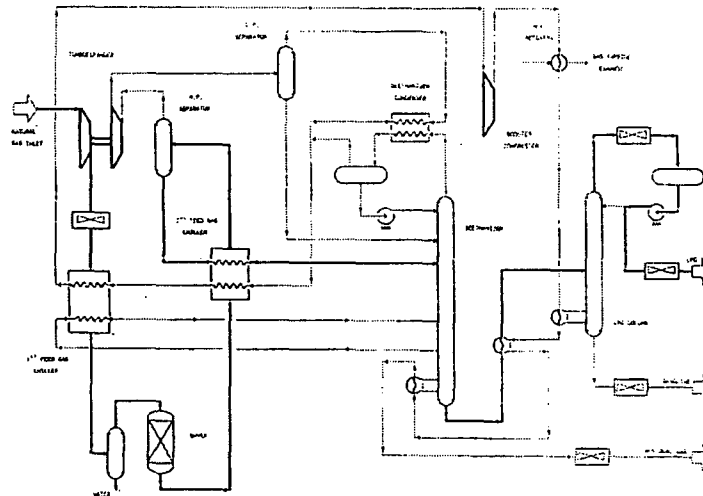


Process Simulation

Definition

- **Process:** a group of chemical-physical operations that transform input streams into product streams
- **Simulation:** the mathematical representation of the reality by using a computer
- **Process Simulation:** A tool for chemical engineers that enables the prediction of the behavior of a chemical process, by using basic engineering relationship, such as:
 - Mass balance
 - Energy balance
 - Phase equilibrium

LPG Plant modeling



LPG RECOVERY BY TURBOEXPANDER

Process Simulator...

Definition

- *A flow-sheeting computer program*
- *The simplest example: a spreadsheet for solving steady-state material balance equations*
- *In general: a robust computer code able to solve material and energy balances, related to all unit operations used in chemical process*

...Process Simulator

Main features

- *Thermophysical properties: the crucial point*
- *Data banks: the basic value*
- *Unit operations: mathematical modeling*
- *Other modules such as optimization, sensitivity analysis, numerical procedures....*
- *Cost estimation methods*
- *Utilities for equipment design*

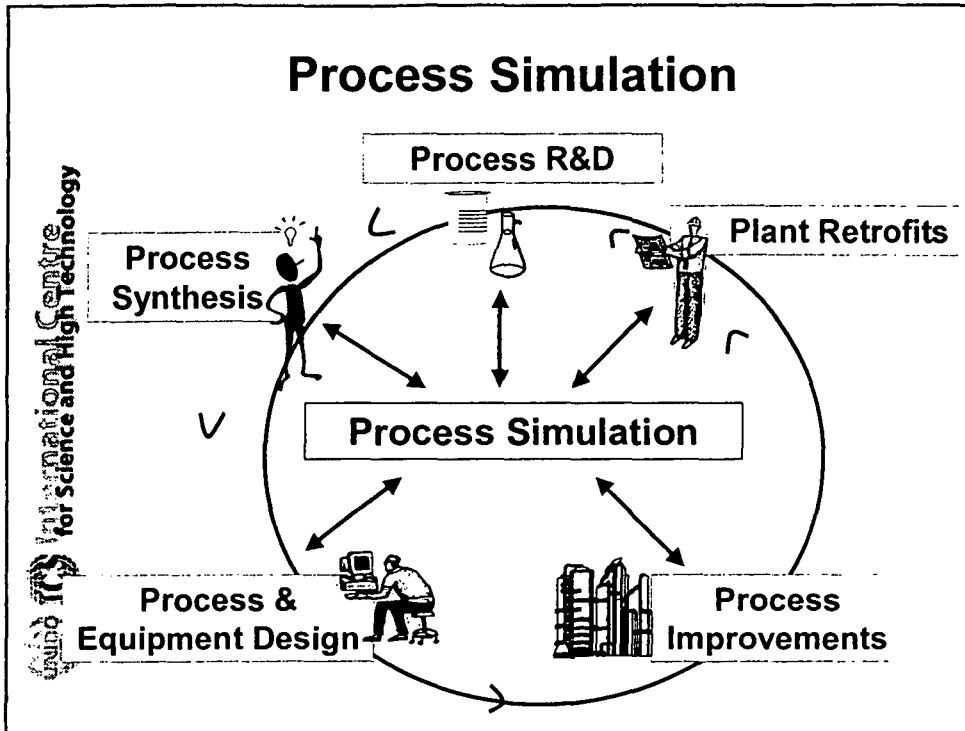
Environmental Simulator

• Definition

A program able to calculate the dispersion of pollutants in the atmosphere, in water reservoirs and in the soil, in terms of concentration profiles as a function of time and space

• Main features

- *Link to meteorologic data*
- *Link to bathymetric data*
- *Link to soil characteristics*
- *Link to process simulators to evaluate emissions from chemical plants*



Process Simulation

Applicability...

- Research and Development
 - *Process scale-up and feasibility studies*
 - *Pilot plant data analysis*

UNIDO International Centre for Science and High Technology

Process Simulation

...Applicability...

- Process Design
 - *Comparing alternative process designs*
 - *Developing heat and material balances*
 - *Designing process equipment*
 - *Evaluating process performance at different conditions*
 - *Cost analysis*

Process Simulation

...Applicability...

- Production...
 - *Predicting how to change operating conditions to accommodate changes in feedstock and/or product specifications*
 - *Evaluating process modifications, such as plant expansions, debottlenecking and revamping, incorporating technology advances such as an improved catalyst, a new solvent or a new process unit*

Process Simulation

...Applicability

- ... Production
 - *Rating the performance of an equipment or of the overall plant*
 - *Training of the plant operators*

From a traditional way of using process simulation ...

- Flow -sheet design
- Equipment Critical parameters definition (such as distillation column stages, column diameter,...)

... to the comprehensive use of Process simulation in the entire 'life' of the plant

- Control strategies design
- Process parameters optimization (==> 'better' processes)
- Time evolution of the process (start up and shut down) (==> risk analysis)
- Operator training
- Definition of procedure to reduce the unsteady state operations
- Process design

Process Simulation

Basic engineering design

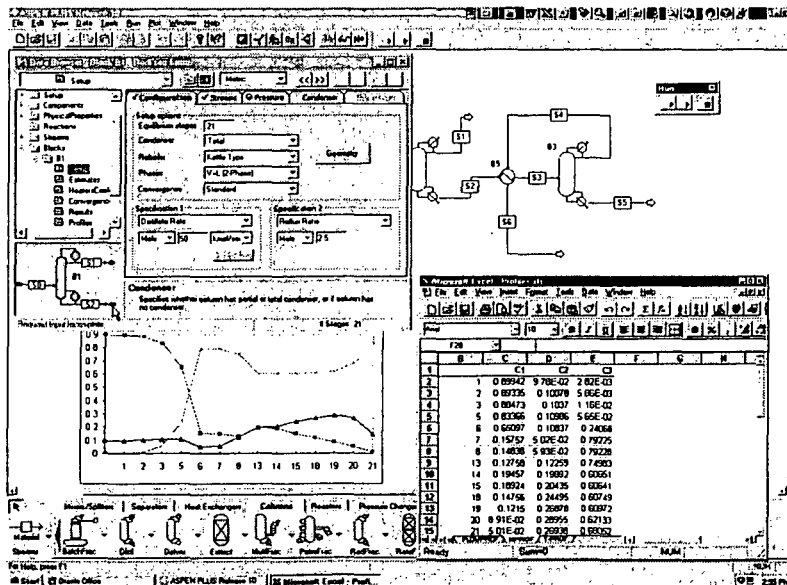
- Physical properties and phase equilibria validation
- Process Development
- Process Optimization
 - Energy recovery optimization
 - Utilities consumption minimization
 - Product yield maximization
- Process design for construction (machine design, catalyst,...)

Process Simulation

Programme structure...

- GUI
- Equations
- Interfaces to specific third-party engineering applications, user data banks and user specific applications

User Interface



Process Simulation

...Programme structure

- Modules
 - Flash
 - Pump
 - Valve
 - Mixer
 - Splitter
 - Compressor
 - Expander
 - Pipe
 - Distillation column
 - Heat exchanger
 - Reactor
- Feed- back controller and process optimizer

Process Simulation

Main logic procedure of utilization

- Flow-sheet drawing
- Components definition
- Thermodynamic calculation method selection
- Feed conditions definition
- Definition of the conditions for the unit operations
- Control parameters definition
- Simulation run and output analysis

The general context and motivations

- Pollution Prevention in the Chemical Industry
 - *Increasing cost of waste disposal*
 - *Growing number of environmental regulations*
- Environmental policy as an integral component of the corporate strategy

Environmental concern and wastes

- Waste minimization at their source leads to
 - *Cost savings*
 - *Improved product yield and quality*
 - *Reduced pollution*
 - *Safer workplace conditions*
 - *Fewer waste management needs*
 - *Conservation of natural resources*
- Waste treatment is often needed
- End-of-pipe approaches are more expensive but still necessary

Features of an environmental policy

- Leadership
 - *Combination of plant manager and health officer*
 - *Responsibility for setting goals for reduction in generation of specific chemical wastes*
- Material Balance: it aims at accounting for every quantity of a chemical that is:
 - *Shipped to the process*
 - *Created or destroyed in the process*
 - *Delivered as a product from the process*
 - *Released as gaseous, liquid, or solid waste*

Features of an environmental policy

- Cost accounting: it assigns the pollution cost to individual process, such as:
 - *Pollution control*
 - *Waste disposal*
 - *Regulatory compliance*
 - *Lost materials*
 - *Insurance*
 - *Future liabilities*
 - *Public and customer relations dealing with waste issues*
- Employee involvement at all levels
 - *From top manager to production and maintenance workers*
 - *Workers need training*

Pollution prevention techniques

- Process changes
- Operation changes
- Equipment changes
- Chemical substitution
- Product substitution

Pollution prevention: Operation changes...

- To improve plant operations
 - *Material handling and equipment maintenance*
 - *Better control of material use*
 - *Employee practices*
- To minimize
 - *Spills*
 - *Process upsets*
 - *Excessive use of chemicals*
 - *Other problems that can generate wastes*

...Pollution prevention: Operation changes



- In every stage of the process
 - *Storing*
 - *Moving*
 - *Mixing*
 - *Reacting chemicals*

Pollution prevention: other techniques



- Equipment changes
- Chemical substitutions
 - *Use of raw materials that create fewer toxic and hazardous wastes during production process without necessarily changing the process itself*
 - *Substitution of hazardous and toxic materials*
- Product changes
 - *Manufacture of the final product with the aim of reducing the creation of toxic and hazardous wastes*
 - *Final product without changing the fundamental manufacturing process*

Benefits of process simulation...

- Reduction of time to market for the development of new processes
 - *New processes*
 - *Modification of existing processes*
 - *Production of new materials*
- Fast screening of process alternatives to select the best solution
 - *Economic aspects*
 - *Environmental aspects*
 - *Energy consumption aspects*
 - *Flexibility of the proposed process*

...Benefits of Process Simulation

- Partial or total replacement of Pilot Plant operations
 - *Reduction of the number of runs*
 - *Run planning*
- Modeling of a chemical process enables to efficiently analyze the process in terms of environmental impact
- Modeling plays an integral role in company's environmental policy

Results in terms of environmental impact

- Compute the operating conditions to meet the discharge requirement
- Compute the performance, capital and operating costs for each equipment item
- Compute the properties of materials in a waste treatment process
- Prepare an integrated flow-sheet that considers design constraints
- Automatically maximize performances, within process constraints
- Fit the parameters of the waste treatment models to experimental data
- Perform sensitivity calculations

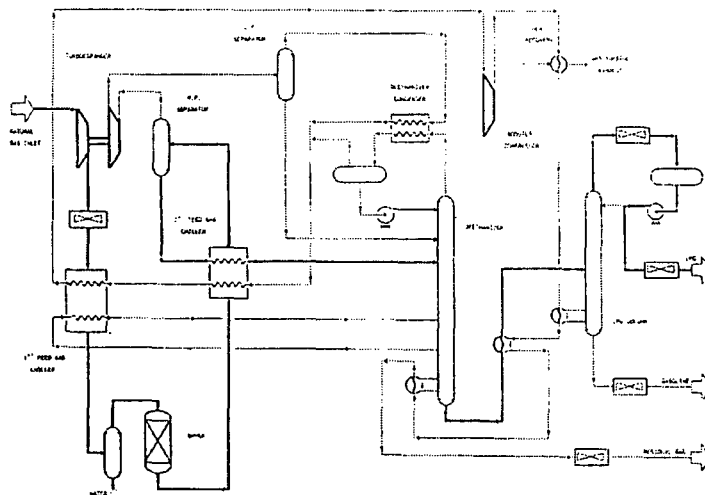
Results in terms of modeling as integral role...

- Complete material balance
- Identification of the costs and potential savings
- Pollution prevention options
- Effective vehicle of communication among managers, engineers, and production workers to describe the impact of making processes, operations or equipment changes.

...Results in terms of modeling as integral role

- What if scenarios can be evaluated
- Model allows accurate support of pilot plant tests
- Process simulation aids the engineer in understanding the process design and in evaluating process alternatives
- The waste treatment process can be optimized to identify the operating conditions which achieve the most effective and economic treatment within regulatory constraints

LPG Plant modeling



LPG RECOVERY BY TURBOEXPANDER

Process Simulation

Conclusions

Process simulation is a simple and helpful tool...

to be used by chemical engineers that fully

understand the process

Technological Tools for Coastal Zone Management
by G. Tore

Piano di Disinquinamento per il Risanamento del Territorio del Sulcis-Iglesiente

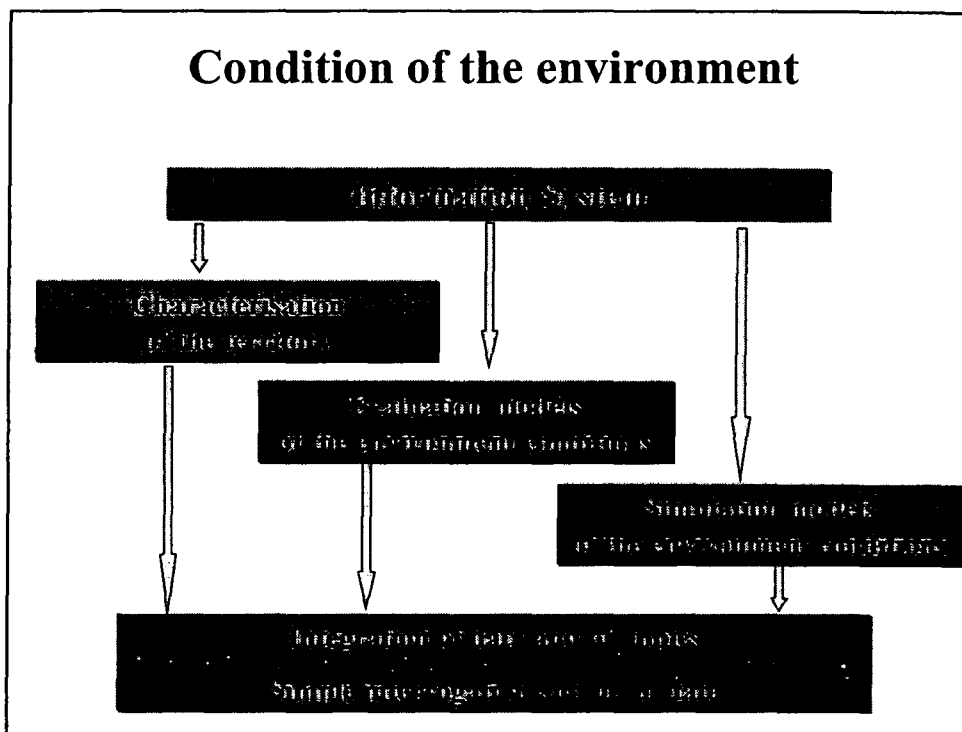
**Sistema Informativo SINA-ARIS
(scheda Q1-2 del Piano)**



Rehabilitation Plan for the Sanitation and Development of Sulcis-Iglesiente Territory

**SINA-ARIS Information System
(Task Q1-2 of the Plan)**





Main goal of the information system

To be a supporting instrument to:

- 1 - management of data and information on the territory conditions and on the environment and on its evolution;
- 2 - forecast the evolution of the conditions of the territory and the environment;
- 3 - objective and comparative evaluation of the territory and environment conditions;
- 4 - supervision of the Plan activities;
- 5 - dissemination of the information.

Informative system main software requirements

1 modular structure

2 different entry levels

3 standard technologies :

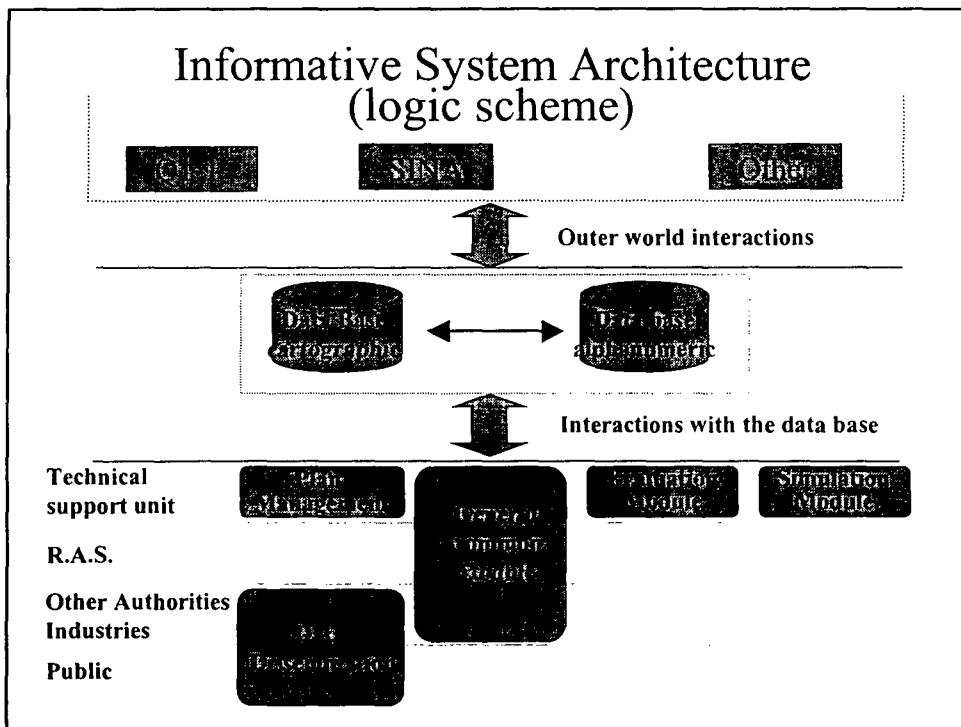
alphanumeric data: Oracle relational dbms

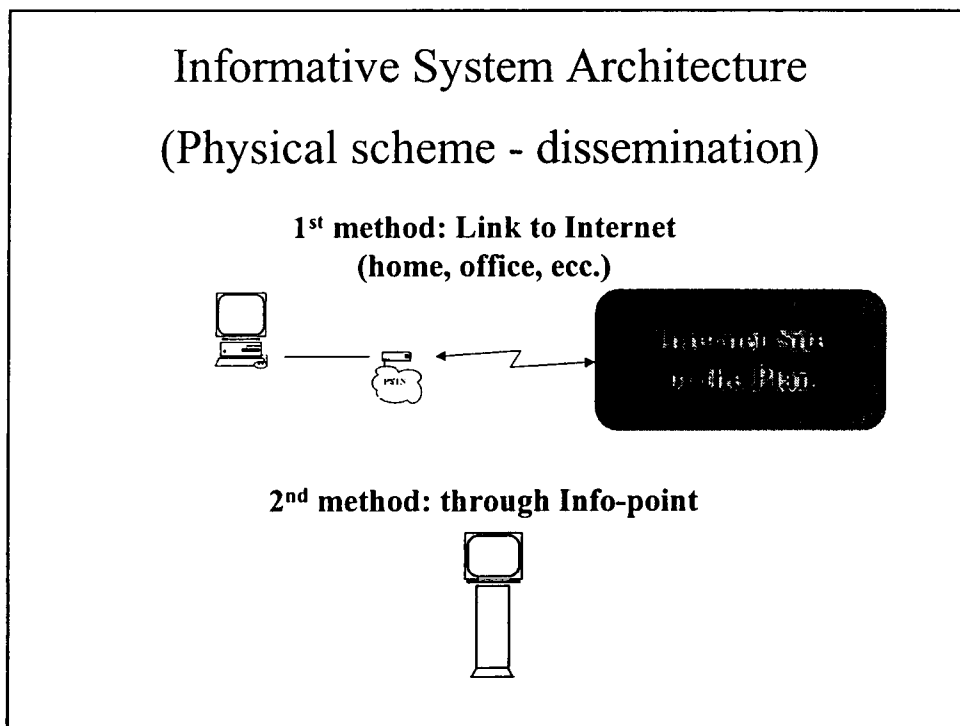
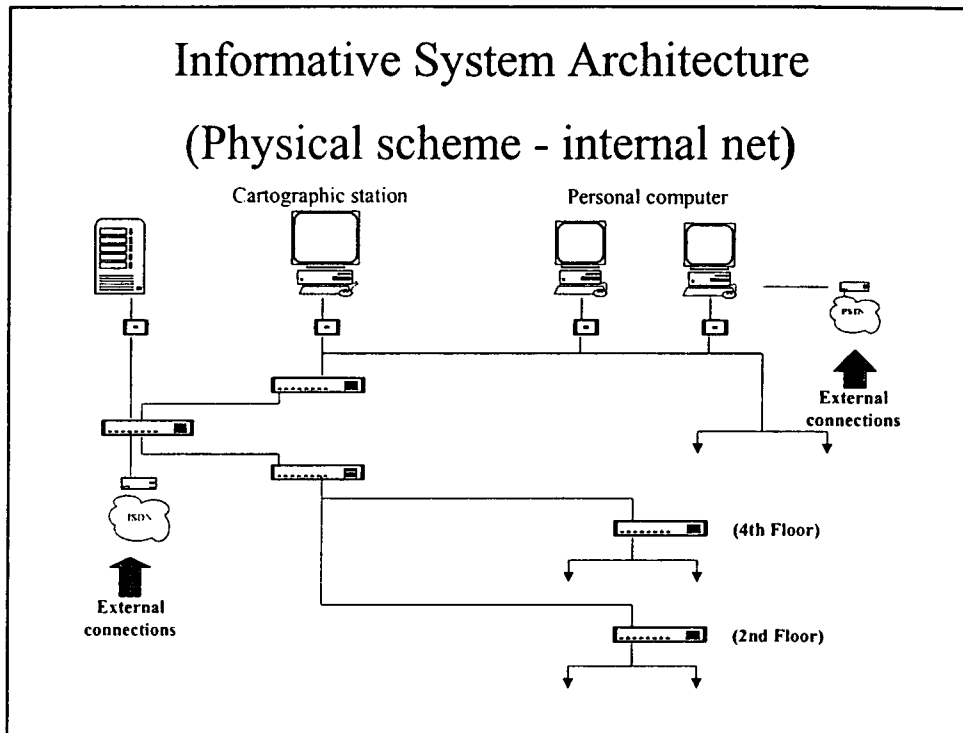
cartographic data : ArcInfo

architecture: client-server

Internet
etc.

4 user friendly






Informative System modular structure

The Informative System has been divided in five logical different modules:

- 1 General
- 2 Environmental evaluation
- 3 Environmental simulation
- 4 Dissemination
- 5 Paperwork Management

General Module

Task of the module  **Management of the alphanumeric and cartographic data of a general nature**

Main features :

- **Sub-division into sub-modules**
- **Differentiated entry levels to the sub-modules**
- **User-friendly, simple user interface**

Environmental Evaluation Module

Task \longrightarrow **Answer to the question: "Which is the quality of the environment, in a defined area, during a defined period, regarding to a definite environmental segment (water, air, etc.)?"**

Procedure of evaluation of the interactions between the environmental constituent and the endangerment centres.

Environmental constituents contemplated:

- Atmosphere
- Water
- Soil
- Flora
- Fauna

Environmental Simulation Module

Task \longrightarrow **Answer to the question: "what will happen if ... ?"**
(within the quality of the environment of the studied area)

For instance:

- * what will happen if, in a definite point of the territory, a new well is drilled from which 100 l/s of water are pumped?
- * what will happen if the highness is changed of an emission point of a defined industrial plant?

Well known mathematics models are used of high reliability, they have been made by U.S.G.S. and E.P.A. of U.S.A..

Also the package "WinDIMULA", made by the Italian E.N.E.A., has been used to implement a simulation of gas emission in the air.

Preliminary steps to the use of the models:

- calibration
- simple interface

Dissemination Module

Task \longrightarrow **Dissemination to the public of information relevant to the territory conditions and to the environment of the area at high risk.**

- Simple information easily grasped.
- The information are available; interrogation can be made by the public but the alteration and modification are not possible.

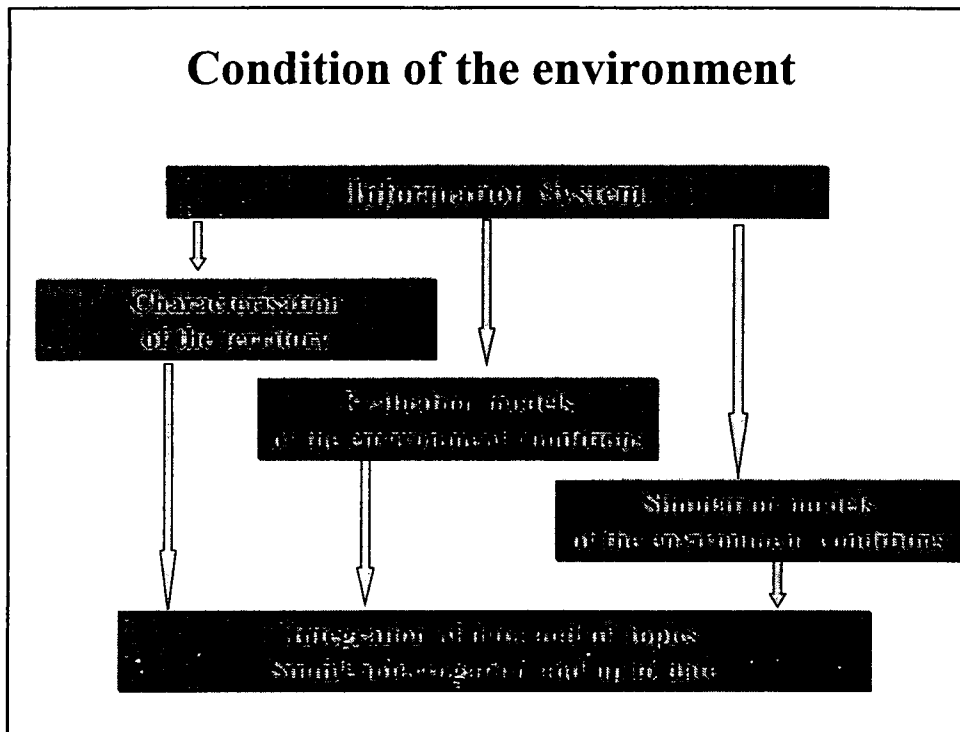
Two technologies of dissemination:

- **Info-Points - Automatic Teller Machines (PC stand-alone into a specific armoured container) to be settled in strategic areas;**
- **Internet**

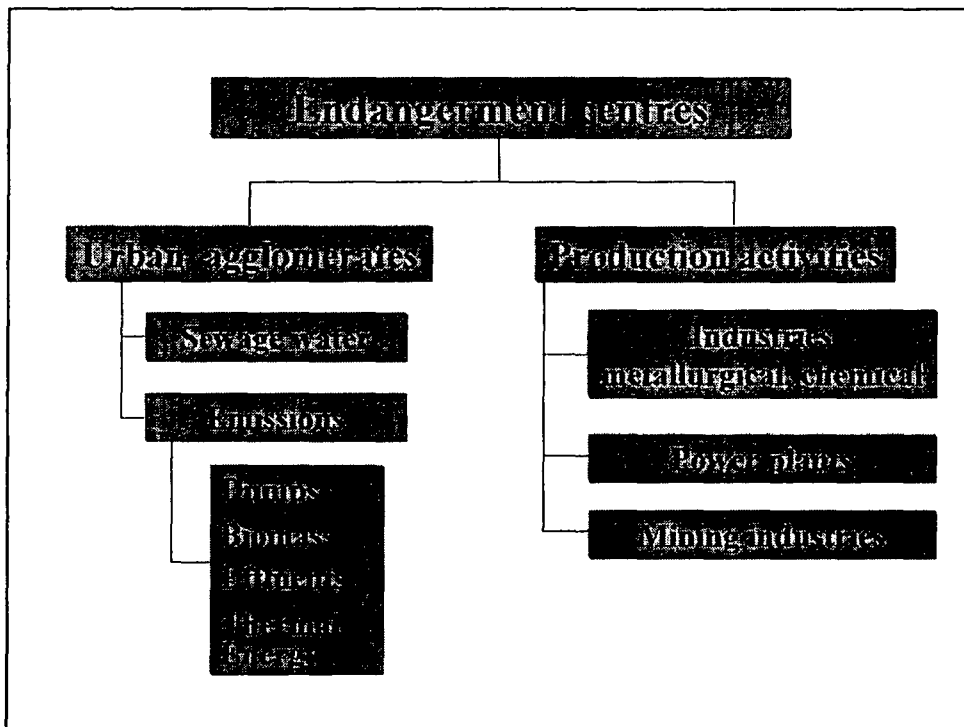
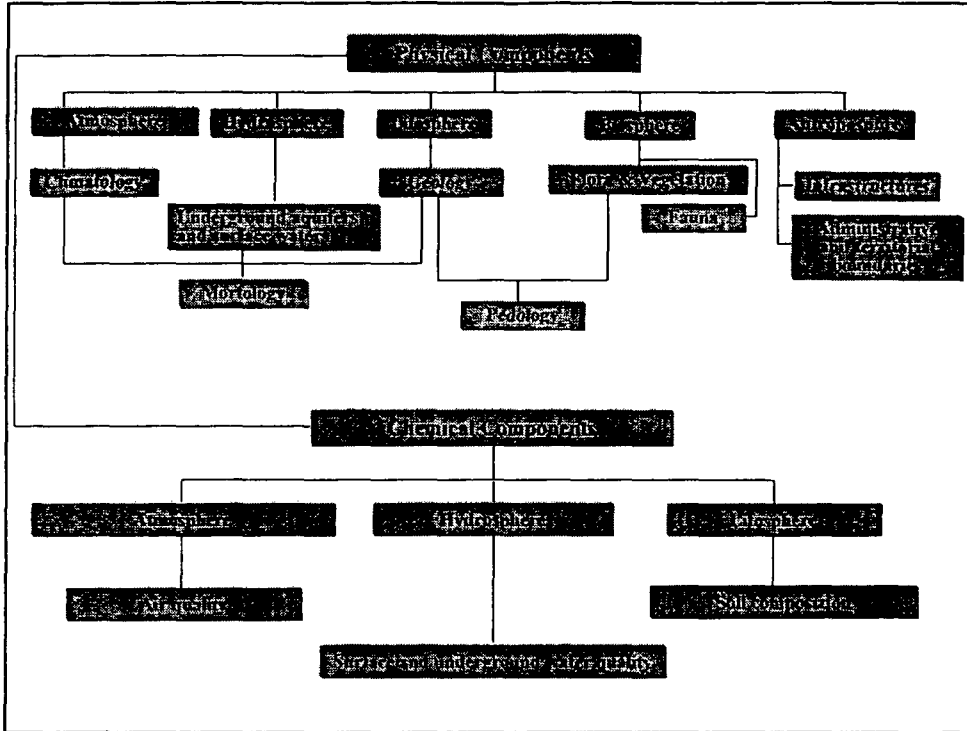
Paperwork Management Module

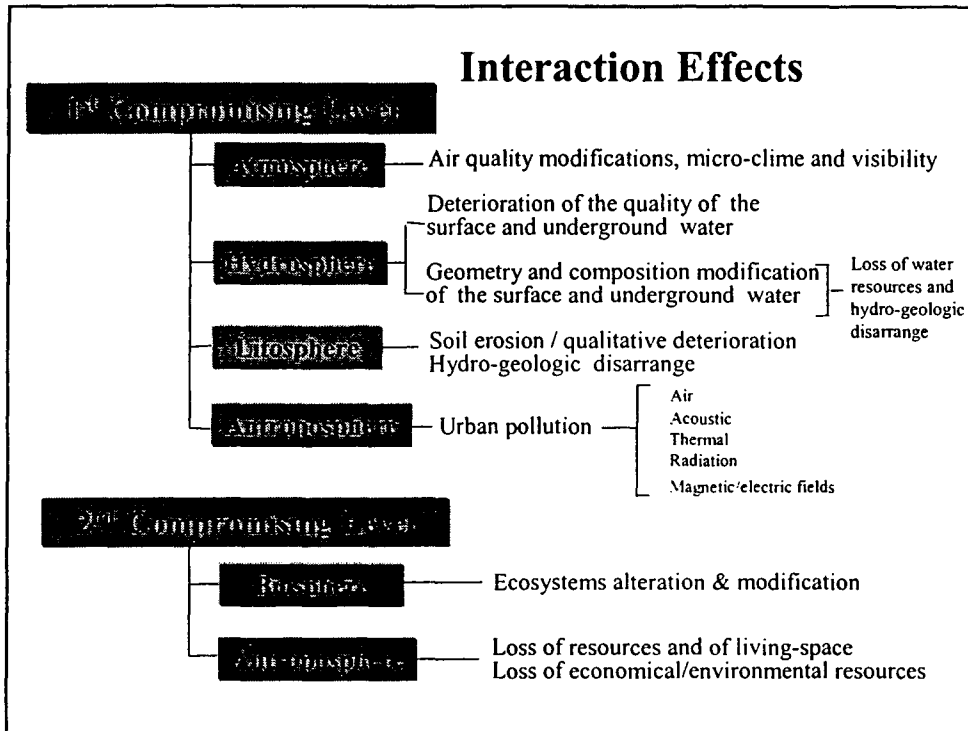
Task \longrightarrow **Management of all the paperwork, files and records of the Technical Support Unit, relevant to the various actions of the Plan.**

- **The module made it possible to follow all the phases of every action, from the design and the bid to the final acceptance test.**
- **It allows the definition of different kind of jobs, to be able to fix itself for the various needs.**
- **The module is exclusively used by the Technical Support Unit; the system administrator can allow the use (totally or in part) by other specified users.**



- ### Characterisation of the territory
- The characterisation is relevant to the following data:**
- | | |
|---|--|
| <ul style="list-style-type: none">* Cartographic:<ul style="list-style-type: none">- Topographic base:<ul style="list-style-type: none">. Toponomastic. Inhabited Centres. Roads. Infrastructures. Hydrography. Orography. Etc.- Thematic Maps :<ul style="list-style-type: none">. Geology. Hydrogeology. Pedology. Land use. Acclivity. Exposition. Etc. | <ul style="list-style-type: none">* Alphanumeric:<ul style="list-style-type: none">- Data set of cartography- Industries and economic activities :<ul style="list-style-type: none">. Company data. Products. Raw materials. Etc.- Chemical, physical, bacter. assays:<ul style="list-style-type: none">. Emissions, wastes, tails:<ul style="list-style-type: none">Into the atmosphereInto aquifers and rivers. Sample assays:<ul style="list-style-type: none">Air qualityWater qualitySoil quality- Etc. |
|---|--|





- ### Thematic cartography
- Territorial setting
 - Geologic map
 - Hydro-geologic map
 - Geomorphologic map
 - Soil map
 - Land use map
 - Road map
 - Urban planning instruments map
 - PTP map (territorial plans map)
 - Waste water discharge map
 - Portovesme map
 - Dumps location map
 - Quarries map
 - Mining areas map
 - Topography example to the 10.000

AIR QUALITY (TABLE 1)

SO₂ CONVEYED EMISSIONS [t/a]

	1991	1994	1997	1998
ALCOA	3,000	2,800	3,000	3,000
ENEL **	50,000	21,000	19,410	15,800
ENIRISORSE	2,100	2,800	2,800	2,800
EURALLUMINA	13,500	13,800	14,000	14,000
IGCC	-	-	-	-
ILA	200	160	120	120
SEAMAG	1,000	1,000	700	-
TOTAL	69,800	41,260	40,030	35,720

AIR QUALITY (TABLE 2)

CONVEYED EMISSIONS OF NO_x [t/a]

	1991	1994	1997	1998
ALCOA	-	-	-	-
ENEL **	-	-	8,450	11,300
ENIRISORSE	-	-	-	-
EURALLUMINA	-	-	1,700	1,700
IGCC	-	-	-	-
ILA	-	-	-	-
SEAMAG	-	-	-	-
TOTALE	0	0	10,150	13,000

AIR QUALITY (TABLE 3)

CONVEYED DUST EMISSIONS [t/a]

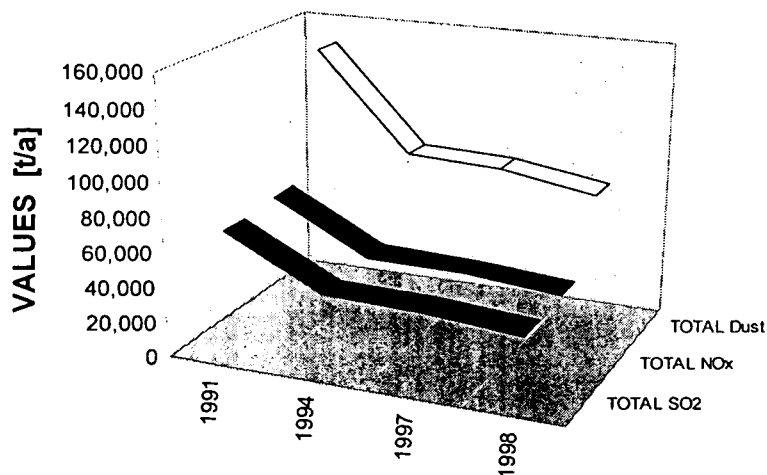
	1991	1994	1997	1998
ALCOA	600	450	660	660
ENEL **	2,500	1,400	1,400	1,650
ENRISORSE	80	70	70	70
EURALLUMINA	1,100	1,100	400	400
I.G.C.	-	-	-	-
I.L.A.	20	20	10	10
SEAMAG	150	150	70	-
TOTAL	4,450	3,190	2,570	2,790

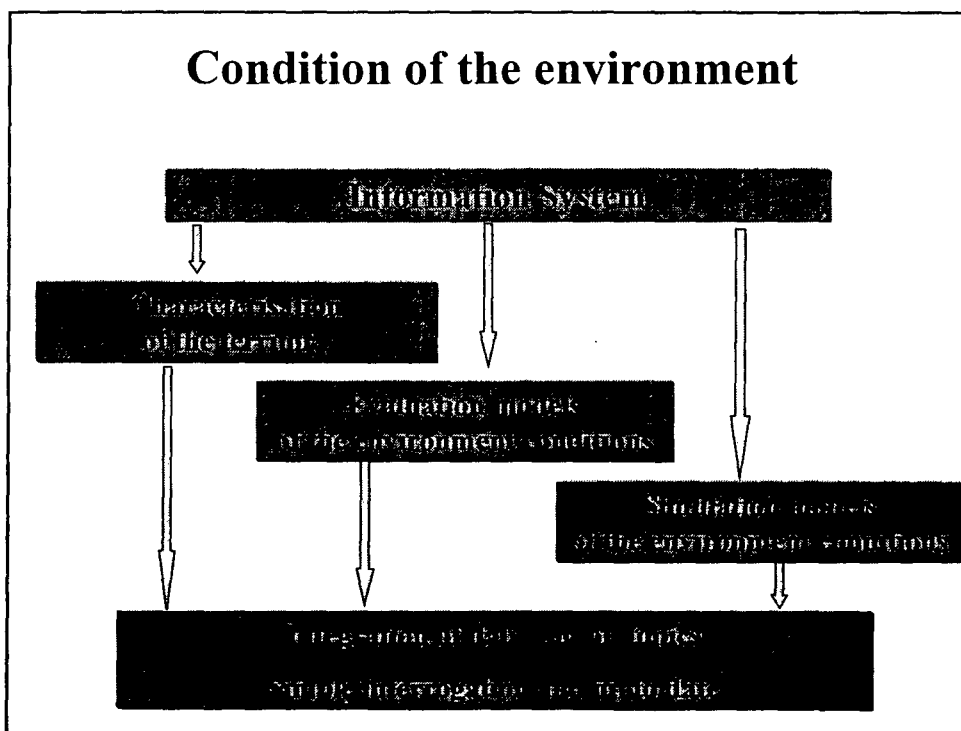
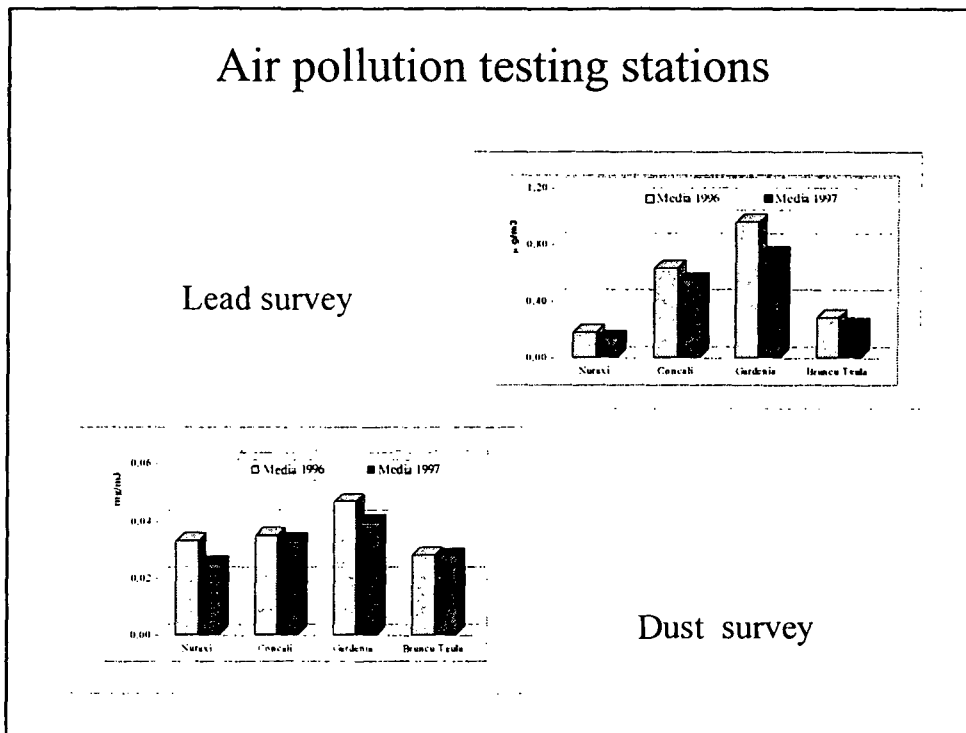
** It is assumed that all ENEL plants are feed with coal (Sulcis or imported)

ATMOSPHERIC EMISSIONS



■ TOTAL SO2 ■ TOTAL NOx □ TOTAL Dust





Environmental Evaluation Models

The quality of the environment is calculated by quality indexes. They can be built by the user in accordance with the following procedure:

- 1) definition of environmental indicators
- 2) definition of partly indexes on the environmental indicators, so that elementary indexes are implemented
- 3) definition of aggregate indexes, using one or more elementary indexes
- 4) definition of comprehensive indexes, using one or more aggregate indexes

System	Quality indicator
Atmosphere	Polluting concentration at the soil level (SO ₂ , NO ₂ , PTS)
Water - surface & underground	Chemical, physical, biological parameters
Soil & underground	Vulnerability: chemical-physical soil charact. Underground waters characteristics
Flora & Fauna	Biological indicators

Atmosphere

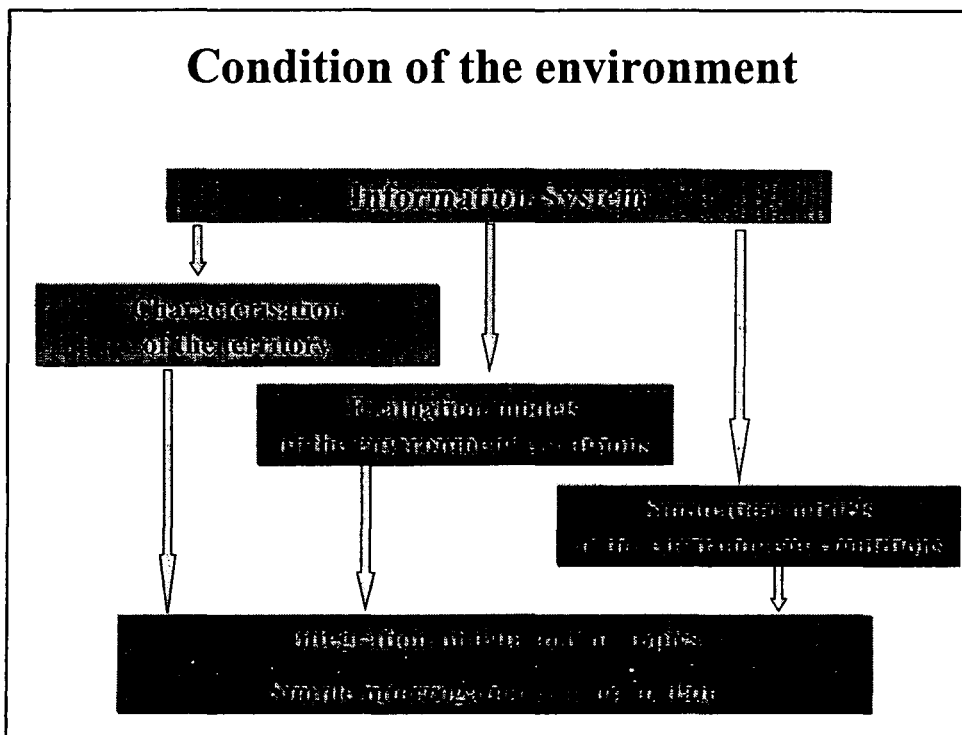
Polluting component	Parameter	Limit value
Sulphur dioxide as SO ₂	Mean of the 24 hours average concentrations measured during 1 year	80 µg/m ³
Nitrogen Oxide NO ₂	98° percentile of the 1 h average of concentrations measured during 1 year	200 µg/m ³
Fluor Compound as F-	Mean of the 24 hours average concentrations measured during 1 month	10 µg/m ³
Ozone O ₃	Mean concentration of 1 hour not to be reached more than once per month	200 µg/m ³
Carbon dioxide	Mean concentration of 8 hours Mean concentration of 1 hour	10 mg/m ³ 40 mg/m ³
Lead	Mean of the 24 hours average concentrations measured during 1 year	10 µg/m ³
Suspended inert dust	Mean of the 24 hours average concentrations measured during 1 year	150 µg/m ³

Surface Shallow and Deep Waters

Indicators	Partly indexes				
	5	4	3	2	1
pH	6.5-8.5	5.5 - 6.5 8.5 - 9.5	4.5 - 5.5 9.5 - 10.5	2 - 4.5 10.5 - 12	0 - 2 12 - 14
Conductivity mS	< 400	400 - 750	750 - 1000	1000-2000	> 2000
COD mg/l	< 10	10-15	15-20	20-30	> 30
Chloride mg/l	< 25	25 - 200	200 - 350	350 - 1200	> 1200
Sulfate mg/l	< 25	25 - 150	150 - 250	250 - 1000	> 1000
Sodium mg/l	< 20	20 - 150	150 - 210	210 - 500	> 500
Nitrate (NO ₃) mg/l	< 5	5 - 30	30 - 50	50 - 90	> 90
Magnesium mg/l	12	12+24	24+36	36+53	>53
Manganese mg/l	< 20	20 - 50	50 - 200	200 - 1000	> 1000
Aluminium µg/l	< 50	50 - 200	200 - 1000	1000-5000	> 5000
Iron µg/l	< 50	50 - 200	200 - 1000	1000-2000	> 2000
Copper µg/l	< 20	20 - 200	200 - 1000	1000-2000	> 2000
Zinc µg/l	< 100	100 - 400	400 - 1000	1000-2000	> 2000
Cromium (total Cr) µg/l	-	5-10	10-20	20-50	>50
Cadmium µg/l	-	1 - 3	3 - 5	5 - 20	> 20
Arsenic µg/l	-	20 - 50	50 - 100	100 - 500	> 500
Mercury µg/l	-	0.5 - 1	1 - 4	4 - 5	> 5
Lead µg/l	-	10 - 50	50 - 200	200 - 1000	> 1000
PCB e PCT µg/l	<0.01	0.01-0.03	0.03-0.05	0.05-0.1	>0.1
Bacterial Load tot (36°C) N/100ml	< 5	5 - 20	20 - 100	100 - 500	> 500

Soil

SOIL CHARACTERISTICS	VULNERABILITY	
Texture	S-SF-FS-A-AL	HIGH
	F-FA-FSA	LOW
	FLA-AS	MIDDLE
Internal vertical drainage	Quick, very slow	HIGH
	Obstructed	HIGH
	Normal	LOW
	Slow	MIDDLE
Soil thickness (cm)	Very shallow <50	HIGH
	Middle depth 50 -100	MIDDLE
	Deep 100-150	MIDDLE
	Very deep. >150	LOW
Depth of the underlying rock and of the pedogenetic substrate (m)	<1	HIGH
	1 - 3	MIDDLE
	>3	LOW
Depth of the water proof horizon (cm)	<50	HIGH
	50 - 70	MIDDLE
	>70 or absent	LOW
Porosity	Polyhedral coarse	HIGH
	Massive	HIGH
	Prismatic	HIGH
	Polyhedral fine or e middle	MIDDLE
	Polyhedral very fine	LOW
	Incoherent	LOW
	Little < 0,5 %	HIGH
Common 0,5% - 5%	MIDDLE	
Abundant > 5%	LOW	

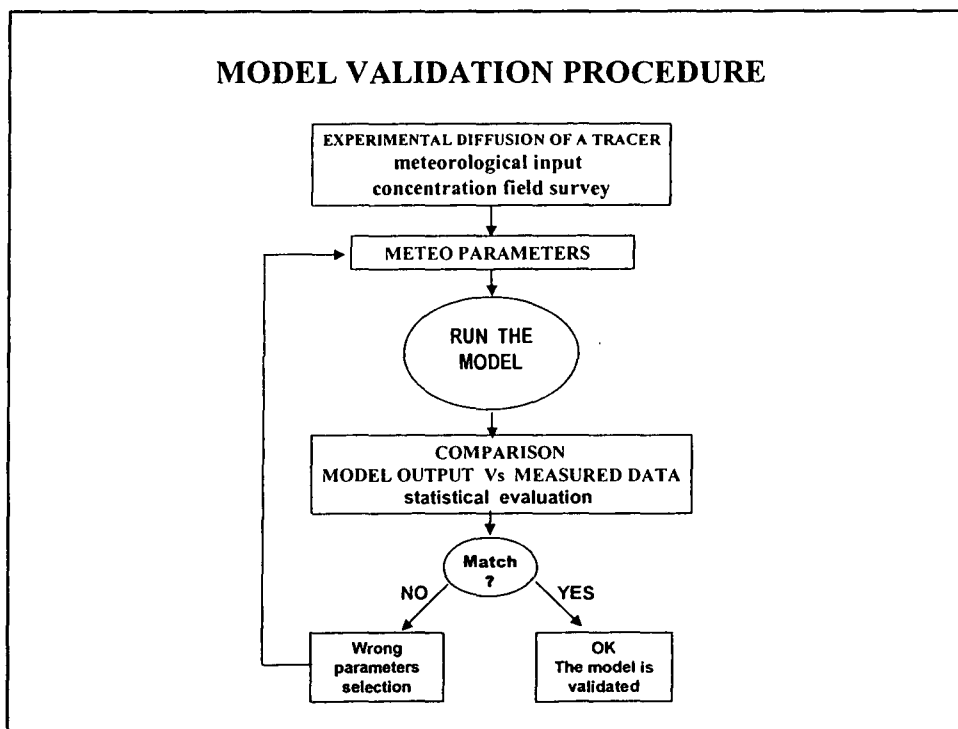
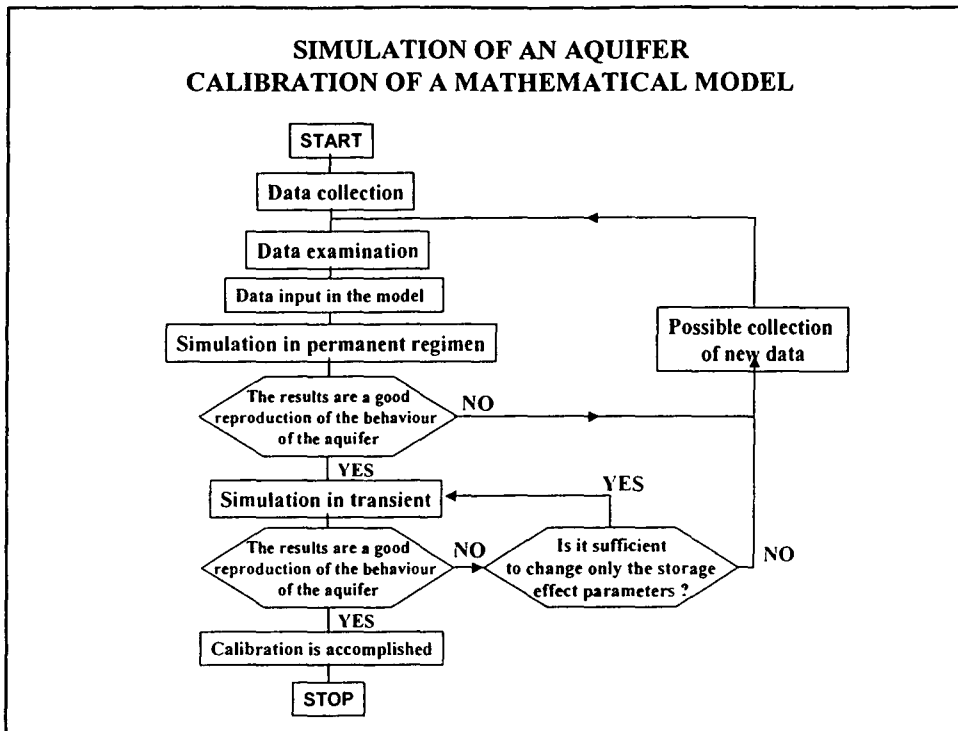


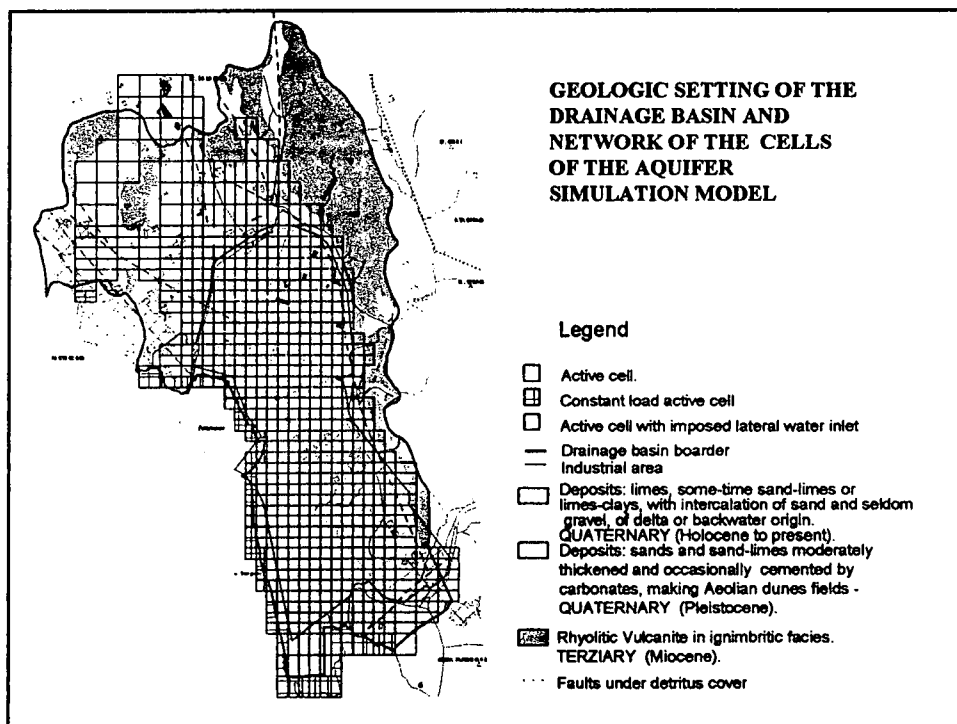
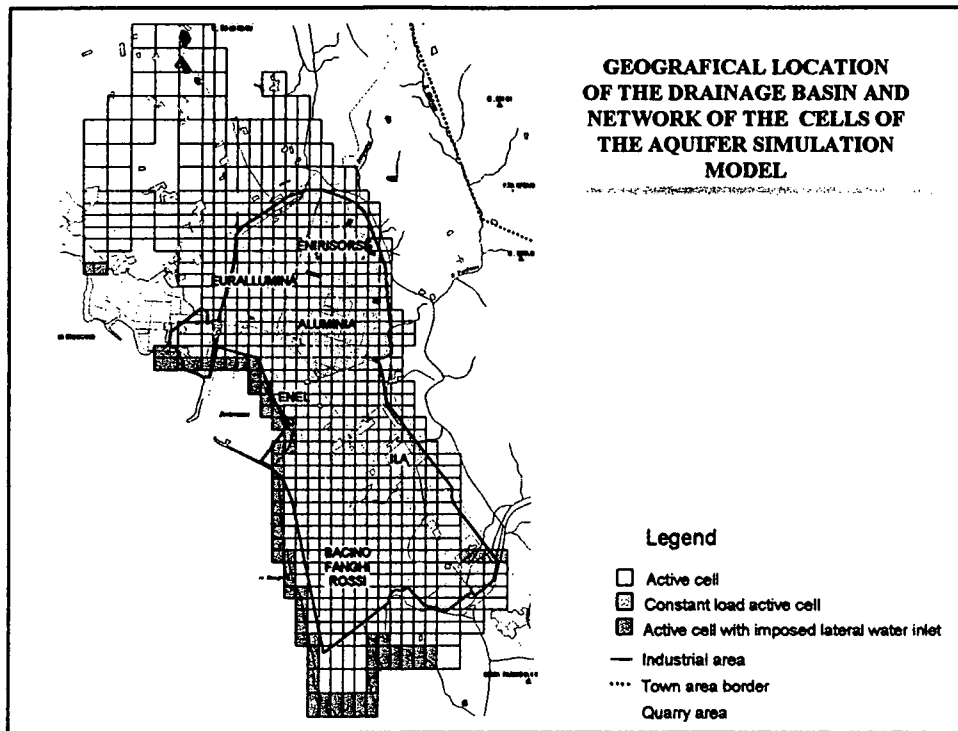
Simulation Models

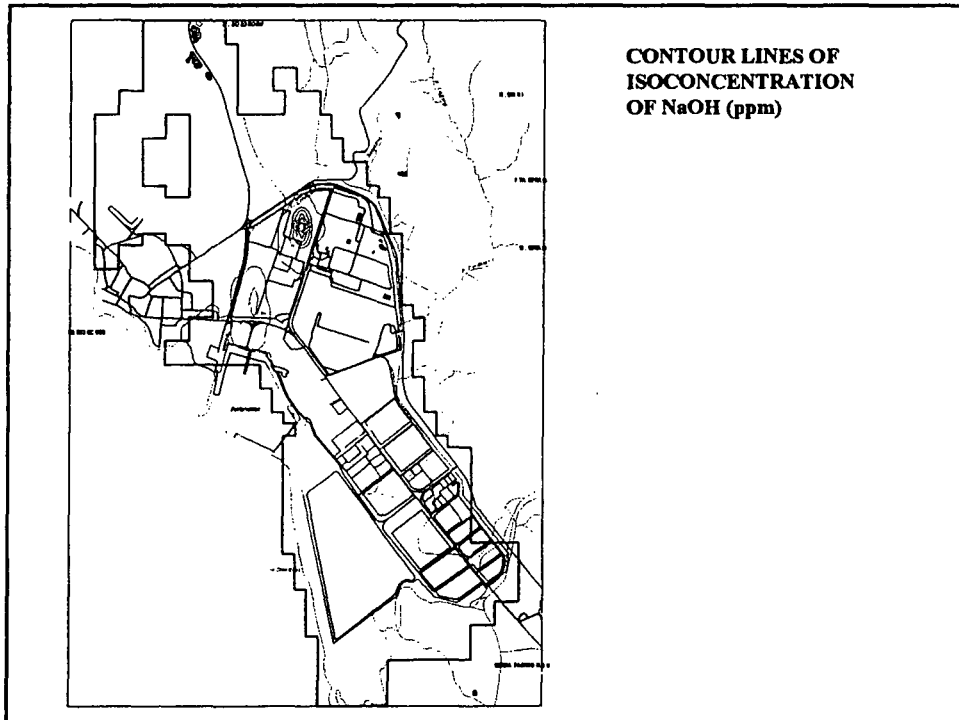
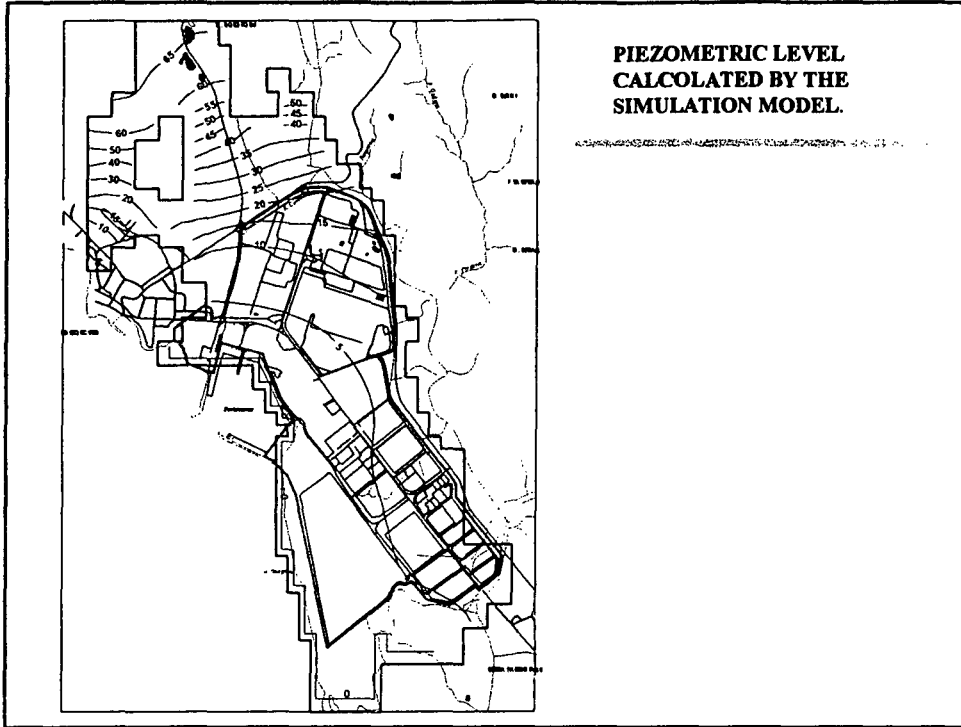
Mathematical algorithm are used to represent the conditions and the evolution of the environmental segments

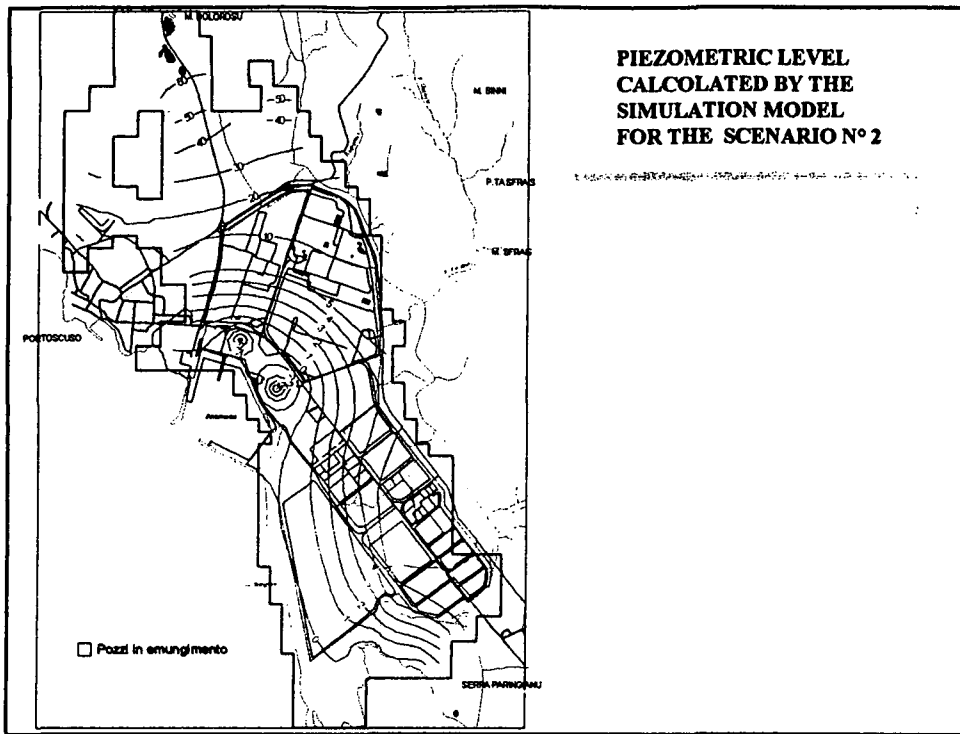
Applications:

- **Underground waters**
- **Air**









EMISSIONI CONVOGLIATE DI SO₂

	1991	1994	1997	1998
ALCOA	3,000	2,800	3,000	3,000
ENEL **	50,000	21,000	19,410	15,800
ENIRISORSE	2,100	2,800	2,800	2,800
EURALLUMINA	13,500	13,500	14,000	14,000
IGCC	-	-	-	-
ILA	200	160	120	120
SEAMAG	1,000	1,000	700	-

BENEFICI PER L'AMBIENTE (TABELLA 2)

STIMA DELLE EMISSIONI CONVOGLIATE di NOx

	1991	1994	1997	1998	2000	2003	2004
ALCOA	-	-	-	-	-	-	-
ENEL **	-	-	8,450	11,300	4,000	4,000	4,000
ENIRISORSE	-	-	-	-	-	-	-
EURALLUMINA	-	-	1,700	1,700	1,700	1,700	1,700
IGCC	-	-	-	-	-	-	2,150
ILA	-	-	-	-	-	-	-
SEAMAG	-	-	-	-	-	-	-
TOTALE	0	0	10,150	13,000	5,700	5,700	6,150

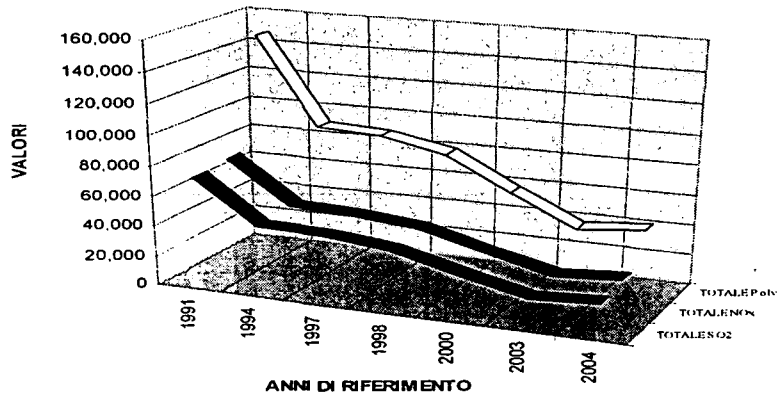
BENEFICI PER L'AMBIENTE (TABELLA 3)

	1991	1994	1997	1998	2000	2003	2004
ALCOA	600	450	660	660	660	660	660
ENEL **	2,500	1,400	1,400	1,650	1,650	800	800
ENIRISORSE	80	70	70	70	70	70	70
EURALLUMINA	1,100	1,100	400	400	180	180	180
IGCC	-	-	-	-	-	-	110
ILA	20	20	10	10	10	10	10
SEAMAG	150	150	70	-	-	-	-
TOTALE	4,450	3,190	2,610	2,750	2,570	1,720	1,860

BENEFICI PER L'AMBIENTE (GRAFICO)



TOTALE SO₂ TOTALE NO_x ■ TOTALE PoV.



GIS and Spatial Data Integration
by E. Feoli

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Enrico Feoli and Munir Ghribi

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1. Introduction

The coastal zone management requires the integration of often very large volumes of disparate information from numerous sources. The coupling of large information with efficient tools for assessment and evaluation allows broad interactive participation in the planning, assessment, and decision making process; and effective methods of communicating results and findings to a broad audience.

The ultimate objective of a computer based spatial decision support system for coastal zone resources management is, or should be, to improve planning and decision making processes by providing useful and scientifically sound information to the actors involved in these processes, including public officials, planners and scientists, and the general public.

2. The components of SDSS

- *Geographic Information System (GIS)*

A Geographic Information System (GIS) is designed as a computer tool to efficiently capture, store, update, manipulate, analyse, and display all forms of geographically referenced information (e.g., ESRI 1994). A GIS typically links data from different sets, using geo-referencing, i.e., spatial co-ordinates, as a common key between the data set. The power of a GIS stems from 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 GIS on the market, commercial and public domain GIS and they are all different each other. They may answer more or less easily and completely to the following typical questions depending on how they have been designed:

- *Spatial identification*: find locations where certain conditions are satisfied, including thelogical (Boolean) or arithmetic combination of multiple layers (overlay analysis);
- *Trends*: find the differences within an area over time or along spatial dimensions;
- *Patterns*: find correspondences between distribution of different attributes; calculate similarity between patches, fractal index, indices of fragmentation, and so on;
- *Modelling*: answer "What if" questions.

However, to answer more complex questions one needs to combine (static) geographic data layers with dynamic and spatially distributed models. A progress toward this integration may be achieved by the object-oriented approach (Malczewski, 1999). This can be considered as an alternative or a complement of the layer data base approach common in most of the GIS.

- Data Analysis and Image Processing

The maps obtained by GIS may be seen not only as cartographic representations of a classification of the landscape at the end of an analytical process, but mainly as data sources for the landscape spatial pattern analysis through the many different indices of the landscape structure such as shape, fragmentation, fractal, diversity, etc. (Ebdon, 1977; Turner, 1989; Milne, 1991; Gardner and O'Neill, 1991; Fabbri, 1991; Baker and Yunming, 1992; Cullinam and Thomas, 1992; Gustafson and Parker, 1992; Olsen, Ramsey, and Winn, 1993). Many GIS have internal data analysis and image processing systems that can calculate different pattern indices. Some GIS such as IDRISI, ILWIS, GRASS (see Malczewski, 1999, for a comparison between different GIS) have the possibility to treat remote sensing data (Image processing) coming from LANDSAT, SPOT, NOAA, etc. however there aren't GIS including data analytical and statistical techniques that are able to classify specific Operational Geographic Units (OGU) according Crovello (1981). The classification may be obtained by applying the clustering algorithms (Orlóci, 1978; Legendre and Legendre, 1983; Goodall and Feoli, 1991) or other multivariate techniques. Feoli and Zuccarello (1996) treat this aspect. GIS can manage different OGUs to obtain maps. In GISs, raster or vector (advantages and disadvantages of using raster or vector-based GISs are described in Burrough (1986), Aronoff (1989), Fabbri (1991) and Johnston (1992)), the OGUs are stored in data bases generally structured according to the relational model (Wildi, 1991). In the databases different characters may describe the OGUs. The probabilistic similarity functions proposed by Goodall (1964, 1966, 1968) that have been suggested and that have been included in the information system developed in ICS/UNIDO (Feoli 1993) would improve the interpretation by introducing the probabilistic aspect in the prediction. They are included in a package described by Goodall, Ganis and Feoli (1991). The functions can deal with 6 categories of characters: 1) binary; 2) qualitative with more than two alternative values; 3) ordinal; 4) only small integer values; 5) quantitative grouped into classes; 6) quantitative not grouped into classes.

- Modelling and Expert Systems

In GIS, the basic concept is one of location, of spatial distribution and relationship; basic elements are spatial objects. In environmental modelling, by contrast, the basic concept is one of state, expressed in terms of numbers, mass, or energy, of interaction and dynamics; the basic elements are "species", which may be biological, chemical, and environmental media such as air, water or sediment.

The overlap and relationship is apparent, and thus the integration of these two fields of research, technologies, or sets of methods, that is, their paradigms, is an obvious and promising idea (Fedra 1994,1995).

Simulation and optimization modelling is a powerful tool of analysis, and forecasting. Another example of possible integration is provided by quantitative numerical models and rule-based, qualitative expert systems. *Expert systems* can be used just as any other model to assign a value to an output variable given a set of input variables; they do this, however, by using rules and logical inference rather than numerical algorithms.

In the context of models, expert systems are often used to help configure models (implementing an experienced modellers know-how to support the less experienced user) and estimate parameters. A number of these "intelligent front end systems" or model advisors have been developed in the environmental domain (Fedra, 1993b, 1992).

A rule-based approach can also be a substitute for a numerical model, in particular, if the processes described are not only in the physical and chemical, but also in the biological

and socio-economic domain. An example could be environmental impact assessment based on a checklist of problems, which can be understood as a diagnostic or classification task. A qualitative label is assigned to potential problems, based on the available data on environment and planned action, and a set of generic rules assessing and grading the likely consequences. An example of such a rule-based system for impact assessment is described in Fedra et al., 1991.

And finally, a model can be integrated into the inference chain of an expert system (Fedra, 1992). Recent examples of environmental expert systems are given in Hushon (1990) and Wright et al. (1993).

The flexibility to use, alternatively or conjunctively, both symbolic and numerical methods in one and the same application allows the system to be responsive to the information at hand, and the user's requirements and constraints. This combination and possible substitution of methods of analysis, and the integration of data bases, geographical information systems, and hypertext, allows to efficiently exploit whatever information, data and expertise is available in a given problem situation.

The approach is based on a model of human problem solving that recursively refines and redefines a problem as more information becomes available or certain alternatives are excluded at a screening level. Learning, i.e., adaptive response to the problem situation and the information available, and the ability to modify function and behaviour, as more information becomes available, is a characteristic of intelligent systems.

- Simulation and Optimization

Another example of the integration of different methods is the coupling of simulation and optimization: optimization usually requires a (often-gross) simplification of the problem representation to become tractable. Simulation models, on the other hand, while capable of representing almost arbitrary levels of detail and complexity, are rarely capable of solving inverse problems, i.e., determining the necessary set of inputs or controls to reach a desired outcome.

One can, however, combine the approaches in that a simplified model (e.g., steady state and spatially aggregated) is used as the basis for optimization; the result of the optimization is then used as the basis for a more detailed, e.g., dynamic and spatially distributed simulation model, that also keeps track of the criteria, objectives and constraints used for the optimization, but with a higher degree of spatial and temporal resolution, and possibly a more refined process description. If, in the simulation run, constraints are violated or objectives not met, the corresponding values can be tightened or relaxed in the optimization to obtain a new solution which again is subjected to more detailed examination with the simulation model.

Modelling of marine systems has a considerable tradition in both physical and biological oceanography. For summary treatments, more recent model comparisons, and some classics in the field see, for example, Riley et al., 1949; Nihoul, 1975; Goldberg et al., 1977; Kremer and Nixon, 1978; Falconer et al., 1989; Fransz et al., 1991.

However, most of these approaches are designed to improve scientific understanding of physical and biological processes, with the notable exception of some of the fisheries models that have obvious management implications (e.g., Andersen and Ursin, 1977). Other management oriented and model based studies of marine systems include the RAND Corporation classic on the Oosterschelde (Bigelow et al., 1977) or the recent study of the North Sea MANS, Management Analysis North Sea (Rijkswaterstaat, 1988, 1989; and Klomp, 1990). Other important recent models for coastal zone management are ECOPATH, ECOSIM and ECOSPACE (Pauly et al., 2000) that are offering a set of tools for evaluating ecosystem impact of fisheries based on modelling the mass balance fluxes in the fish food-webs both in homogeneous and heterogeneous space conditions.

- Multi-criteria Decision Analysis

Criterion is some basis for a decision that can be measured and evaluated. It is the evidence upon which a decision is based. Criteria can be of two kinds: factors and constraints.

Factor is a criterion that enhances or detracts from the suitability of a specific alternative for the activity under consideration. It is therefore measured on a continuous scale.

Constraint serves to limit the alternatives under consideration. In many cases constraints will be expressed in the form of a Boolean (logical) map: areas excluded from consideration being coded with a 0 and those open for consideration being coded with a 1.

Decision Rule is the procedure by which criteria are combined to arrive to a particular evaluation and by which evaluations are compared and acted upon.

A criterion is therefore a measure on a continuous scale of the effect on the activity on a given indicator commonly named impact (Patrono, 1997).

A decision rule is the procedure by which criteria are combined to arrive at particular evaluation and by which evaluations are compared and acted upon. Decision rules are structured in the context of a specific objective for example to determine area suitable for a given activity. To meet a specific objective it is frequently the case that several criteria will need to be evaluated (Multi-Criteria Evaluation). It also happens that decisions, which satisfy several objectives, are required (Multi-Decision Evaluation).

- Multi-Criteria Evaluation

To meet a specific objective, it is frequently the case that several criteria will need to be evaluated. Such procedures are called Multi-Criteria Evaluations (MCE) (Eastman ET al., 1995). Two of the most common procedures for multi-criteria evaluation are weighted linear combination and concordance-discordance analysis (Carver, 1991). Weighted linear combination is very straightforward in a raster GIS. Indeed, it is the derivation of the weights, within the context of the decision objective that provides the major challenge. The weights are developed by providing a series of PAIRWISE comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated (Eastman, 1997).

In a Multi-Criteria Evaluation, an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective (Eastman et al., 1995). During the last two decades, further support has emerged for the view that a decision is a multidimensional concept (Nijkamp et al., 1990; Paruccini, 1994). Decisions about the allocation of land typically involve the evaluation of multiple criteria according to several, often conflicting-objectives (Eastman et al., 1995). Making-decisions about the allocation of land is one of the most fundamental activities of resource development (FAO, 1976). With the development of GIS, we now have the opportunity, for a more explicitly reasoned process of land-use evaluation. However, despite the wide range of analytical tools these systems provide, they are typically weak in the provision of decision support procedures (Honea et al, 1991).

The advantage of MCE is that it provides a flexible way of dealing with qualitative multi-dimensional environmental effects of decisions (Munda, 1995). Even in the absence of monetary information, the point of departure of any multi-criteria analysis is the generation of a discrete set of alternatives, the formulation of a set of criteria, and the evaluation of an impact of each criterion for every alternative. Janssen (1992) and Munda (1995) provide a comprehensive review of multi-criteria decision support for environmental management.

Although a variety of techniques exist for the development of weights, one of the most

promising would appear to be that of PAIRWISE comparisons developed by Saaty (1977) in the context of a decision making process known as the Analytical Hierarchy Process (AHP). In the PAIRWISE comparison method the decision-maker is asked to select the most important of each possible pair effects (Janssen & Van Herwijen, 1992). Subsequently comparison must be established in qualitative terms to what extent one effect is more important than the other one (Saaty, 1980) to express the differences of importance.

- *Multi-Objective Evaluation*

While many decisions we make are prompted by a single objective, it also happens that we need to make decisions that satisfy several objectives. A Multi-Objective problem is encountered whenever we have two candidate sets (i.e., sets of entries) that share members. These objectives may be complementary or conflicting in nature (Carver, 1991:332).

a) *Complementary Objectives*

With complementary or non-conflicting objectives, land areas may satisfy more than one objective, i.e., an individual can belong to more than one decision set. Desirable areas will thus be those, which serve these objectives together in some specified manner. For example, we might wish to allocate a certain amount of land for combined recreation and wildlife preservation uses. Optimal areas would thus be those that satisfy both of these objectives to the maximum degree possible.

b) *Conflicting Objectives*

With conflicting objectives, objectives compete for the available land since it can be used for one or the other, but not both. For example, we may need to resolve the problem of allocating land for timber harvesting and wildlife preservation. Clearly the two cannot coexist. Exactly how they compete, and on what basis one will win out over the other will depend upon the nature of the decision rule that is developed.

In case of complementary objectives, multi-objective decisions can often be solved through a hierarchical extension of the multi-criteria evaluation process. For example, we might assign a weight to each of the objectives and use these along with the suitability maps developed for each to combine them into a single suitability map indicating the degree to which areas meet all of the objectives considered (see Voogd, 1983). However, with conflicting objectives the procedure is more involved.

With conflicting objectives, it is sometimes possible to rank order to objectives and reach a *prioritised* solution (Rosenthal, 1985). In these cases, the needs of higher ranked objectives are satisfied before those of lower ranked objectives are dealt with. However, this is often not possible, and the most common solution to conflicting objectives is the development of a *compromise* solution. Undoubtedly the most commonly employed techniques for resolving conflicting objectives are those involving optimization of a choice function such as mathematical programming (Fiering, 1986) or goal programming (Ignizio, 1985). In both, the concern is to develop an allocation of the land that maximises or minimises an objective function subject to a series of constraints.

- *The User Interface*

Analysis in GIS is based on the map paradigm; maps in inherently static objects, and the basic level of analysis is (Boolean) map overlays. Complex relationships, and dynamic

processes, may require another layer of tools, namely simulation models, to be integrated with a GIS.

The integration of GIS and environmental models can come in many forms. In the simplest case, two separate systems, the GIS and the model, just exchange files: The model obtains some of its input data from the GIS, and produces some of its output in a format that allows import and further processing and display with the GIS. This seems to be a rather common approach, since it requires little if any software modifications. Only the file formats and the corresponding input and output routines, usually of the model, have to be adapted. Depending on the implementation however, a solution based on files shared between two separate applications, usually with a different user interface, is cumbersome and possibly error prone if it involves a significant amount of manual tasks. Deeper integration provides a common interface and transparent file or information sharing and transfer between the respective components. One possible way is the use of higher-level application language or application generators increasingly common as built-in features of commercial GIS packages as the basis of numerous integrated applications. Application generators and modelling capabilities with commercial GIS also offer the possibility of tight integration within the limits of the respective package options.

An alternative is to use an open GIS tool kit that uses a standardised interface, such as GRASS (< biblio >). Modules of the overall GIS system (which really is a set of tools with a standardised pipeline-type flexible coupling) can be included in modelling applications. The X Windows system and a number of interface building toolkits make this a rather efficient integration strategy. Any integration at this level, however, requires a sufficiently open GIS architecture, that provides the interface and linkages necessary for tight coupling.

Using such predefined tools and components, while efficient for fast prototyping, can also be restrictive: investments in toolkits always carry the temptation to reformulate problems in terms of the available tools rather than the other way round.

Another alternative is the use of do-it-yourself tool kits that provide both customised GIS functionality as well as interface components for simulation models. A relatively recent example of integration that draws together GIS, models, spreadsheet, and expert systems in a programmable system is RAISON (Lam and Swayne, 1991).

For having an efficient user interface we need:

An interactive, menu-driven user interface that guides the user with prompt and explain messages through the application. No command language or special format of interaction is necessary, the computer assists the user in its proper use; help and explain functions can be based on hypertext and possibly include multi-media methods to add video and audio technology to provide tutorial and background information; in other words, they must be easy to use even for the non-specialist.

Dynamic colour graphics for the model output and a symbolic representation of major problem components that allow easy and immediate understanding of basic patterns and relationships. Rather than emphasising the numerical results, symbolic representations and the visualisation of complex patterns support an intuitive understanding of complex systems behaviour; the goal is to translate a model's state variables and outputs into the information requirements of the decision making process; the coupling to one or several data bases, including geographical information systems, and distributed or remote sources of information in local or wide area networks, that provide necessary input information to the models and the user. The user's choice or definition of a specific scenario can be expressed in an aggregated and symbolic, problem-oriented manner without concern for the technical details of the computer implementation; data on

chemical properties of the substances of concern, used in pollution fate and transport models, are one obvious example;

Embedded Artificial Intelligence (AI) components such as specific knowledge bases allow user specifications in allowable ranges to be checked and constrained, and ensure the consistency of an interactively defined scenario; as a special case this could also include QSAR methods that can be implemented in a combination of rule-based methods and algorithmic methods;

Interaction is a central feature of any effective man--machine system: a real-time dialogue, including explanation, allows the user to define and explore a problem incrementally in response to immediate answers from the system. Fast and powerful systems with modern processor technology can offer the possibility to simulate dynamic processes with animated output, and they can provide a high degree of responsiveness that is essential to maintain a successful dialogue and direct control over the software.

Visualisation provides the band-width necessary to communicate and understand large amounts of highly structured information, and permits the development of an intuitive understanding of processes and interdependencies, of spatial and temporal patterns, and complex systems in general. Also, many of the problem components in a real-world planning or management situation, such as risk or reliability, are rather abstract: a graphical representation of such concepts makes them tangible objects that can literally be manipulated and understood intuitively.

Intelligence requires software to be knowledgeable not only about its own possibilities and constraints, but also about the application domain and about the user, i.e., the context of its use. Defaults and predefined options in a menu system, sensitivity to context and history of use, built-in estimation methods, learning, or alternative ways of problem specification depending on the user can all be achieved by the integration of expert systems technology in the user interface and in the system itself.

Customisation is based on the direct involvement of the end-user, and the consideration of institutional context and the specifics of the problem domain in systems design and development. It is the users view of the problem and their experience in many aspects of the management and decision making process that the system is designed to support. This then must be central to a system's implementation to provide the basis for user acceptance and efficient use.

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Extended References

- Abdel-Aal, F.H. (1992) Shoreline changes modelling, In: Computer Modelling of Seas and Coastal Regions, Computational Mechanics Publications, Elsevier Applied Science.
- Ajjour, M. and Drabih, S. (1997) Strategy for Coastal Zone Planning and Management in Gaza-Palestine. In: Özhan, E. [ed.] Proceedings of the Third International Conference on the Mediterranean Coastal Environment MEDCOAST 97, November 11-14 1997; Qawra, Malta.
- Andersen, K.P. and Ursin, E. (1977) A Multispecies Extension to the Beverton and Holt Theory of Fishing, with Accounts of Phosphorus Circulation and Primary Production. Medd. Fra Danm.Fisk.-og Havunders., N.S. 7, 319-435.
- Anderson, V. and Skrizhevskaya, E.V. (1997) Integrated Coastal Zone Management with GIS: the case of Ukrainian Black Sea Region. 738-747, In: Geographical Information '97. Proceedings of the Third Joint European Conference and Exhibition on Geographical Information, Austria Center, Vienna, April 16-18 1997. 402-411. IOS Press, Amsterdam.
- ASCE (1996) State-of-the-art of Modelling Transport and Fate of Oil Spills. Journal of Hydraulic Engineering, Vol. 122, 11. 594-609.
- Barale, V. and Zin, I. (1997) Impact of Continental Margins in the Mediterranean Sea: Hints from Surface Colour and Temperature Historical Record. 753-766, In: Özhan, E. [ed.] Proceedings of the Third International Conference on the Mediterranean Coastal Environment MEDCOAST 97, November 11-14 1997; Qawra, Malta.
- Barnes, K.B. (1988) Cartographic Modelling of Nonpoint Pollutant Surfaces for a Coastal Drainage Area, in K.B. Barnes, W.L. Lyke and T.J. Hoban [eds.], Proceedings of the Symposium on Coastal Water Resources. American Water Resources Association, pp. 133-146.
- Bigelow, J.H., De Haven, J.C., Dzitser, C., Eilers, P. and Peeters, J.C.H. (1977) protecting an Estuary from Floods - a Policy Analysis of the Oosterschelde. Vol III. Assessment of Long-run Ecological Balances. R-2121/4-NETH. Rand Corporation. Santa Monica. 215p.
- Biswas, A.K. and S.B.C. Agarwala, editors (1992). Environmental Impact Assessment for Developing Countries. Butterworth, Oxford.
- Bonissone, P.P., and Decker, K., (1986). "Selecting uncertainty calculi and granularity: an experiment in trading-off precision and complexity". In: Kanal, L.N., and Lemmer, J.F., (eds.) Uncertainty in Artificial Intelligence. North-Holland; Elsevier Science.
- Carvalho, T.M.M. and Coelho, C.O.A. (1997). Coastal Risk Perception: A case study in Aveiro District, Portugal. 235-239, In: Ale, B.J.M., Janssen, M.P.M., and Pruppers, M.J.M. [eds.], Mapping Environmental Risks and Risk Comparison, RISK '97, International Conference, 21-24 October 1997, Amsterdam.
- Carver, S. J. (1991). Integrating Multi-Criteria Evaluation with Geographical Information Systems, International Journal of Geographical Information Systems, 5(3): 321-339.
- Carver, S.J., (1991). Integrating Multi-Criteria Evaluation with Geographical Information Systems. *International Journal of Geographical Information Systems* 5, 3, 321-339.

- Clark, J. (1977) Coastal Ecosystem Management. A Technical Manual for the Conservation of Coastal Zone Resources. 928 pp., John Wiley, New York
- Collins, M.B., et al., (1980) Industrial Embayments and their Environmental Problems. A Case Study of Swansea Bay. Pergamon Press.
- Colombo, A.G., editor, (1992). Environmental Impact Assessment. Euro Courses Volume 1. Kluwer, Dordrecht.
- Connolly, J.P. (1991). Application of a Food Chain Model to Polychlorinated Biphenyl Contamination of the Lobster and Winter Flounder Food Chains in New Bedford Harbor. Environ. Sci. Technol. 25, 760-770. American Chemical Society.
- Craig, W.J. and David M.D. (1991) Progress on the Research Agenda: URISA '90. URISA Journal, Volume 3, Number 1, spring 1991, pp.90-96.
- Curr, R.H.F., Edwards, E., Koh, A., Williams, A.T. and Davies, P. (1997) Analysis of Mediterranean Sand Dunes Using Digital Imaging. 812-820, In: Özhan, E. [ed.] Proceedings of the Third International Conference on the Mediterranean Coastal Environment MEDCOAST 97, November 11-14 1997; Qawra, Malta.
- De Wispelaere, D., Schiermeier, F.A. and Gillani, N.V. [eds.] (1986) Air Pollution Modelling and Its Application V. NATO - Challenges of Modern Society. Volume 10. Plenum Press. 773p.
- Densham, P.J. (1991) Spatial Decision Support Systems. In: Maguire, D.J., M.F. Goodchild, and D.W. Rhind, eds. Geographical Information Systems: Principles and Applications, vol.1, London: Langman, 403-412.
- Durand, N, Fiandrino, A., Ouillon, S, Fraunie, P. and Forget, P. (1997) 3D Numerical Study of the Ebro Delta Zone Hydrodynamics. 1112-1121, In: Özhan, E. [ed.] Proceedings of the Third International Conference on the Mediterranean Coastal Environment MEDCOAST 97, November 11-14 1997; Qawra, Malta.
- Eastman, J. R. (1997) IDRISI for windows, version 2.0, tutorial exercises, 4.1. Worcester, MA: Graduate school of Geography, Clark University.
- Eastman, J.R., Jin, W., Kyem, P. A. K. and Toledano, J. (1995) Raster Procedures for Multi-Criteria/ Multi-Objective Decisions. Photogrammetric Engineering & Remote Sensing, Vol. 61, No. 5, May 1995, pp. 539-547.
- ESRI (1992) Understanding GIS. The Arc/Info Method. Environmental Systems Research Institute, Inc., Redlands, CA.
- Falconer, R.A., Goodwin, P. and Matthew, R.G.S. [eds] (1989) Hydraulic and Environmental Modelling of Coastal, Estuarine and River Waters. Proceedings of the International Conference held at the University of Bradford, 19-21 September 1989. Gower Technical, Aldershot, UK. 694p.
- FAO (1976) A Framework for Land Evaluation, Soils Bulletin 32, Food and Agricultural Organisation of the United Nations, Rome.
- Fedra, K. (1991). Smart Software for Water Resources Planning and Management. In: Decision Support Systems. NATO ASI Series, Vol. G26. Proceedings of NATO Advanced Research Workshop on Computer Support Systems for Water Resources Planning and Management. September 24-28, 1990. Eiriceiria, Portugal. Springer. pp.145-172.
- Fedra, K. (1994). GIS and Environmental Modelling. In: Goodchild M.F., Parks B.O. and Steyaert L.T., [eds.] *Environmental Modelling with GIS*, 35-50, Oxford University Press, New York.
- Fedra, K. (1994) Marine Systems Analysis and Modelling. Proceedings of the Symposium: *The Challenge to Marine Biology in a Changing World*. September 13-18, 1992, Heloland. Helgoländer wiss. Meeresunters. 49, 617-632.
- Fedra, K. (1995). Distributed Models and Embedded GIS: Strategies and Case Studies of

- Integration. In: Goodchild, M.F., Steyart, L.Y., Parks, B.O., Johnston, C., Maidment, D., Crane, M. and Glendinning, S. [Eds.], *GIS and Environmental Modelling: Progress and Research Issues*, pp. 413-417. GIS World Books, Fort Collins, CO. 1996.
- Fedra, K. (1997). Integrated Risk Assessment and Management: Overview and State-of-the-Art. 3-18, , In: Ale, B.J.M., Janssen, M.P.M., and Pruppers, M.J.M. [eds.], *Mapping Environmental Risks and Risk Comparison*, RISK '97, International Conference , 21-24 October 1997, Amsterdam.
- ¹Fedra, K. and Kubat, M. (1993) Hybrid GIS and Remote Sensing in Environmental Applications. RR-93-20. International Institute for Applied Systems Analysis. A-2361 Laxenburg, Austria. *Hybrid Geographical Information Systems* reprinted from *EARSel Advances in Remote Sensing* (1992) 1(3):89-100. *A Global Change Impact Assessment System: GIS, Models and Expert Systems* reprinted from *Proceedings of the 25th International Symposium on Remote Sensing and Global Environmental Change* (1993) ISSN:1068-9281, pps. I-657-I-668.
- Fedra, K. and Loucks, D.P. (1985) Interactive Computer Technology for Planning and Policy Modelling. *Water Resources Research*, 21/2, 114-122.
- Fedra, K. and Reitsma, R.F. (1990) Decision Support and Geographical Information Systems. In: H.J. Scholten and J.C. H. Stillwell [eds.] *Geographical Information Systems for Urban and Regional Planning*. Kluwer Academic Publishers, Dordrecht. pp.177-186.
- Fedra, K., L. Winkelbauer, and V.R. Pantulu (1991). Expert Systems for Environmental Screening. An Application in the Lower Mekong Basin. RR-91-19. International Institute for Applied Systems Analysis. A-2361 Laxenburg, Austria.
- Feoli, E. (1995) Data Analysis and Data Integrartion in Coastal Zone Management: the ICS experience. *Public Enterprise* 15:65-73.
- Feoli E. and Zuccarello V. (1996) Spatial pattern of ecological processes: the role of similarity in GIS applications for landscape analysis. In M. Fisher, H.J.Scholten and D. Unwin (eds.) "Spatial Analytical Perspectives on GIS". pp. 175-185. Taylor& Francis, London.
- Feiring, R.B. (1986) Linear Programming, An introduction to Quantitative Applications in the Social Sciences 60.
- Fiering, B.R., (1986) Linear Programming: An Introduction. *Quantitative Applications in the Social Sciences*, Vol. 60. (London: Sage Publications).
- Fransz, H.G., Mommaerts, J.P. and Radach, G. (1991) Ecological Modelling of the North Sea. *Netherlands Journal of Sea Research*. 28(1/2), 67-140.
- Gardels, K. (1988) GRASS in the X-Windows Environment. Distributing GIS data and technology. In: *GIS/LIS '88, Accessing the World*. Proceedings, Third annual international conference, San Antonio. Vol 2, 751-758.
- Garofalo, G., Fortunati, L, Cannizzaro, L. and Scalisi, M. (1997) Mapping of Marine Resources by Means of Geostatistical Analysis and GIS Technology.832-837, In: Özhan, E. [ed.] *Proceedings of the Third International Conference on the Mediterranean Coastal Environment MEDCOAST 97*, November 11-14 1997; Qawra, Malta.
- Geoffrion, A.M. (1983) Can OR/MS Evolve Fast Enough? *Interfaces* 13: 10-25.
- Goldberg, E.D., McCave, I.N., O'Brien, J.J. and Steele, J.H. [eds] (1977). *The Sea. Ideas and Observations on Progress in the Study of the Seas*. Volume 6. John Wiley and Sons. 1048p.
- Goodall, D.W. (1964) A probabilistic similarity index. *Nature* 203: 1098.
- Goodchild, M.F. and Densham, P.J. (1990) Spatial Decision Support Systems: Scientific Report for the Specialist Meeting, technical Report 90-5, National Center for Geographic

Information and Analysis.

- Gorry, A. and Scott Morton, M. S. (1971) A frame works for information systems, *Solan Management Review* 13: 55-77.
- Holcomb Research Institute (1976). *Environmental Modelling and Decision Making. The United States Experience.* A report by the Holcomb Research Institute Butler University for the Scientific Committee on Problems of the Environment. Praeger Publishers. 152p.
- Honea, R.B., Hake, K.A. and Durfee, R.C. (1991) Incorporating GISs into Decision Support Systems: GIS Applications in Natural Resources, (M. Heit and A. Shortreid, editors), GIS World, Inc., Fort Collins, Colorado. In: (Eastman, et al., 1995). *Raster Procedures for Multi-Criteria/ Multi-Objective Decisions*, *Photogrammetric Engineering & Remote Sensing*, Vol. 61, No. 5, May 1995, pp. 539-547.
- Hultkrantz, L. (1991). The Cost of Edible Fish - effects on the Swedish and Finnish forest industries from the imposition of effluent charges on chlorine residuals in Sweden. *Journal of Environmental Management*, 32, 145-164. Academic Press Limited.
- Hushon, J.M, editor. (1990) *Expert Systems for Environmental Applications.* ACS Symposium Series 431. American Chemical Society, Washington DC.
- Ignizio, J.P., (1985) Introduction to Linear Goal Programming. *Quantitative Applications in the Social Sciences*, 56, (London: Sage Publications).
- Janssen R. and van Herwijnen, M. (1992) Decision Support Applied to Decisions Changing the Use of Agricultural Land, In *Multiple Criteria Decision Support. Proceeding of the International Workshop held in Helsinki, Finland, 7-11 August 1989*, edited by P. Korhonen, A. Lewandowski and J. Wallenius (Berling, Springer Verlag), p. 293-302.
- Janssen, R. (1992) *Multi-objective Decision Support for Environmental Management*, Kluwer Academic Pbl., Dordrecht.
- Klomp, R. (1990) Modelling the Transport and Fate of Toxics in the Southern North Sea. *The Science of the Total Environment*. 97/98, 103-114. Elsevier Science Publishers B.V., Amsterdam. The Netherlands.
- Kremer, J.N. and Nixon, S.W. (1978) *A Coastal Marine Ecosystem - Simulation and Analysis.* Springer-Verlag. Berlin-Heidelberg. 217p.
- Krohn, J., Müller, A. and Puls, W. (1991). Pollutant Transport Monitoring and Prediction by Mathematical Modelling: North Sea and adjacent estuaries. *Marine Pollution Bulletin*. 23, 699-702.
- Labadie, J.W., Brazil, L.E., Corbu, I. and Johnson, L.E. (1989) Computerized Decision Support Systems for Water Managers. *Proceedings of the 3rd Water Resources Operations Workshop*, Colorado State University, Fort Collins, CO, June 27-30, 1988. 978p., ASCE, New York.
- Lam, D.C.L. and Swayne, D.A. (1991) Integrating Database, Spreadsheet, Graphics, GIS, Statistics, Simulation Models and Expert Systems: Experiences with the Raison System on Microcomputers. *NATO ASI Series*, Vol.G26. 429-459. Springer, Heidelberg.
- Lean, G. and Hinrichsen, D. (1992). *Atlas of the Environment.* 192 pp., Helicon, Oxford.
- Lewis, R.E. and Riddle, A.M. (1989). *Sea Disposal: modelling studies of waste field dilution.* *Marine Pollution Bulletin*. 20(3), 124-129. Pergamon Press.
- Loucks, D.P. and Fedra, K. (1987). Impact of Changing Computer Technology on Hydrologic and Water Resource Modelling. In: *Review of Geophysics*, Vol.25, No.2, March.
- Loucks, D.P., Kindler, J. and Fedra, K. (1985) Interactive Water Resources Modelling and Model Use: An Overview. *Water Resources Research*, 21/2, 95-102.
- Malczewski J. (1999) *GIS and Multicriteria Decision Analysis.* J. Wiley & Sons, New York,

pp. 392.

- Mates, A. and Scheinberg, Y. (1991). A Model for Approving and Controlling Sea Water Pollution for Recreational Activity. *Toxicological and Environmental Chemistry*. 31-32, 479-487. Gordon and Breach Science Publishers, S.A.
- Meaden, G. and Do Chi, T. (1996) *Geographical Information Systems - Applications to marine fisheries*. FAO Fisheries Technical Paper No. 356. FAO, Rome, Italy.
- Moon, G. (1992) Capabilities Needed in Spatial Decision Support Systems. *GIS/LIS '92*, vol.2: 594-600.
- Munda, G. (1995) *Multicriteria Evaluation in a Fuzzy Environment*, Physica-Verlag, Heidelberg, pp. 255.
- NCGIA (1992) *A Research Agenda of The National Center for Geographic Information and Analysis*. Technical Report: 92-7.
- Nihoul, J.C.J. [Editor] (1975). *Modelling of Marine Systems*. Elsevier Scientific Publishing Company. Amsterdam. 272p.
- Nijkamp, P., Rietveld P. and Voogt H. (1990). *Multi-criteria Evaluation in Physical Planning*, North-Holland, Amsterdam.
- Pauly, D. Christensen, V. and Walters, C. (2000) ECOPATH, ECOSIM, and ECOSPACE as tools for evaluating ecosystem impact of fisheries. *IICES Journal of Marine Science* 57: 000-000. (in press).
- Papazoglou, I.A., Nivolianitou, Z.S., and Bonanos, G.S. (1997) Land Use Planning Policies Stemming from the Implementation of the Seveso Directive in the EU. 323-329, In: Ale, B.J.M., Janssen, M.P.M., and Pruppers, M.J.M. [eds.], *Mapping Environmental Risks and Risk Comparison*, RISK '97, International Conference, 21-24 October 1997, Amsterdam.
- Paruccini, M. (1994) *Applying Multi-criteria Aid for Decision to Environmental Management*, Kluwer, Dordrecht.
- Pasqualini, V., Clabaut P., Benyousse, L., Pergent-Martini, C., and Pergent, G. (1997) Impact of Human Activities on Littoral Ecosystems: Contribution of Sonar Image Analysis. 784-795, In: Özhan, E. [ed.] *Proceedings of the Third International Conference on the Mediterranean Coastal Environment MEDCOAST 97*, November 11-14 1997; Qawra, Malta.
- Patrono, A. (1997). *Introduction to Decision Support Systems*, ICS training course on GIS and water management for industrial activity, Hanoi, Vietnam, 9-18 June, 1997.
- Reed, M., French, D., Grigalunas, T. and Opaluch, J. (1989). Overview of a Natural Resource Damage Assessment Model System for Coastal and Marine Environments. *Oil & Chemical Pollution*. 5, 85-97. Elsevier Science Publishers Ltd. England.
- Rijkswaterstaat, North Sea Directorate (1988) *MANS - Management Analysis North Sea*. Summary Report 1987. The Hague, The Netherlands.
- Riley, G.A., Stommel, H., and Bumpus, D.F. (1949) Quantitative Ecology of the Plankton of the Western North Atlantic. *Bull. Bingham Oceanogr. Coll.* 12:1-169.
- Romão, T., Sousa, I., Molendijk, M. and Scholten, H. (1997) Mutidimensional Visualisation Tools in Coastal Zone Management. In: *Geographical Information '97*. Proceedings of the Third Joint European Conference and Exhibition on Geographical Information, Austria Center, Vienna, April 16-18 1997. 402-411. IOS Press, Amsterdam.
- Rosenthal, R.E. (1985) Concepts, theory and techniques: Principles of multi-objective optimisation, *Decision Sciences* 16 (2): 133-152.
- Rosenthal, R.E., (1985) Concepts, Theory and Techniques: Principals of Multiobjective optimisation. *Decision Sciences*, 16, 2, 133-152.
- Saaty, T. L. (1977) A Scaling Method for Priorities in Hierarchical Structures, *J. Math.*

- Psychology, 15:234-281.
- Saaty, T. L. (1980) *The Analytical Hierarchy Process*. McGraw Hill, New York .
- Schmucker, K.J., 1982. *Fuzzy Sets, Natural Language Computations and Risk Analysis*. Computer Science Press.
- Sol, H. G. (1983) Processes and tools for decision support: Inferences for future developments. In *Processes and Tools for Decision Support*, (ed. Sol, H. G.), North Holland, Amsterdam, the Netherlands, pp 1-6.
- Sprague, R.H. and Watson, H.J (1986) *Decision Support Systems: Putting Theory into Practice*. Prentice Hall, New Jersey.
- Stanners, D. and Bourdeaux, P.[eds.] (1994) *Europe's Environment. The Dobri Assessment*. 676 pp., Office for Official Publications of the European Communities, Luxembourg.
- Terfai, L. and Schimpf, W. (1997). *The Use of Geographic Information Systems and Remote Sensing Imagery Data for Development of Decision Support Systems for Environmental Management, Case Study: Coastal Zone Management*, Joint Research Centre of the European Commission, Space Application Institute, Italy.
- Tsanis, I.K., and Boyle, S.J. (1997). A Closely Coupled Hydrodynamic/Pollutant Transport GIS Model. 1124-1134, In: Özhan, E. [ed.] *Proceedings of the Third International Conference on the Mediterranean Coastal Environment MEDCOAST 97*, November 11-14 1997; Qawra, Malta.
- UNEP (1995). *Guidelines for Integrated Planning and Management of Coastal and Marine Areas in the Caribbean*. RCU/CEP/UNEP, Kingston, Jamaica.
- Vallega, A. (1993) *Mastering Resource Uses and Enhancing the Mediterranean Environment. Methodological Tools*. In: *Management the Mediterranean. Information for Decision Making*. p 40-45, *Proceedings of the Workshop*, 18-20 November 1993, ISDGM, Venice, Italy.
- Van Voris, P., Millard, W.D., Thomas, J. and Urban, D. (1993). *Terra-vision: The integration of scientific analysis into decision making process*, *International journal of Geographic Information Systems* 7(2); 143-164.
- Voogd, H. (1983) *Multi-Criteria Evaluation for urban and regional planning*, PION, London.
- Voogd, H., (1983) *Multicriteria Evaluation for Urban and Regional Planning* (London: Pion, Ltd.).
- Wright, J.R., L.L. Wiggins, R.K. Jain, and T.J. Kim, editors. 1993. *Expert Systems in Environmental Planning*. Springer, Berlin.
- Yager, R., 1988. "On Ordered Weighted Averaging aggregation operators in multicriteria decision making", *IEEE Transaction on Systems, Man and Cybernetics*. Vol. 8, No. 1, pp. 183-190.
- Zadeh, L.A., 1965. *Fuzzy Sets*. *Information and Control*, Vol. 8, pp. 338 - 353.

Remote Sensing Techniques
by A. Altobelli

Basics of Remote Sensing from Satellite

by A. Altobelli

What is remote sensing?

“ Remote Sensing” refers to the science of measuring properties of the Earth’ s surface (land and sea), and atmosphere from a distance, using sensors onboard airplanes or satellites. The information needs a physical carrier to travel from the object/phenomena to the sensor through a medium. Electromagnetic radiation is normally used as an information carrier in remote sensing.

The electromagnetic spectrum

The entire array of electromagnetic waves comprises the electromagnetic (EM) spectrum. The EM spectrum has been arbitrarily divided into regions or intervals to which descriptive names have been applied. At the very energetic (high frequency; short wavelength) end are gamma rays and x-rays. Radiation in the ultraviolet region extends from about 1 nanometer (nm) to about 0.40 micrometers. The visible region occupies the range between 0.4 and 0.7 μm , or its equivalents of 400 to 700 nm. The infrared (IR) region, spans between 0.7 and 100 μm , more than 100 times as wide as the visible portion!

The infrared region can be divided into two categories based on their radiation properties the reflected IR, and the emitted or thermal IR.

Radiation in the reflected IR region is used for remote sensing purposes in ways very similar to radiation in the visible portion. The reflected IR covers wavelengths from approximately 0.7 μm to 3.0 μm . There are two different categories of IR waves: near-IR (from 0.7 to 1.3 μm) and mid-IR (from 1.3 to 3 μm). The thermal IR region is quite different than the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat. The thermal IR covers wavelengths beyond 3.0.

Longer wavelength intervals are measured in units ranging from millimetres (mm) through meters (m). The microwave region spreads across 1 mm to 1 m; this includes all of the intervals used by man-made radar systems.

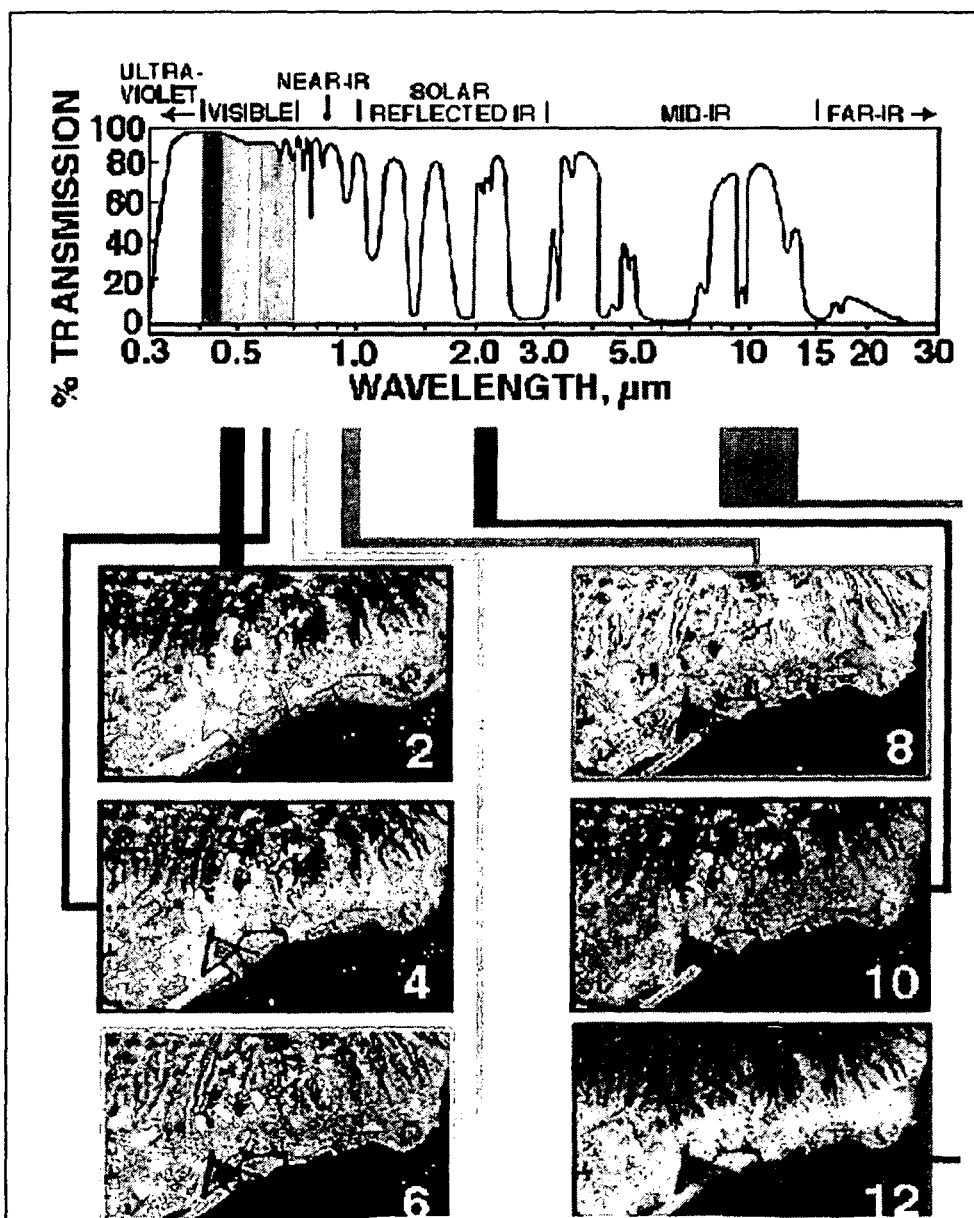
The lowest frequency (longest wavelength) region beyond 1 m is associated with radio waves.

Effects of Atmosphere

Atmospheric constituents absorption and scattering of radiation. These effects degrade the quality of images. Some of the atmospheric effects can be corrected before the images are subjected to further analysis and interpretation.

A consequence of atmospheric absorption is that certain wavelength bands in the electromagnetic spectrum are strongly absorbed and effectively blocked by the atmosphere. The wavelength regions in the electromagnetic spectrum usable for remote sensing are determined by their ability to penetrate atmosphere.

These regions are known as the atmospheric transmission windows. Remote sensing systems are often designed to operate within one or more of the atmospheric windows. These windows exist in the microwave region, some wavelength bands in the infrared, the entire visible region and part of the near ultraviolet regions.



These images are registered by an electronic camera at the same time in different parts of the spectrum.

Notice that the vertical axis (called % transmission) shows where our atmosphere allows a large quantity of the Sun's rays to reach the ground. It is easy to see why our eyes work in the visible part of the spectrum, because it is here that almost 100% of the Sun's energy reaches the surface. In contrast, due to water vapour in the atmosphere, almost no energy (%0 transmission) reaches the ground at 1.4 and 1.9 microns

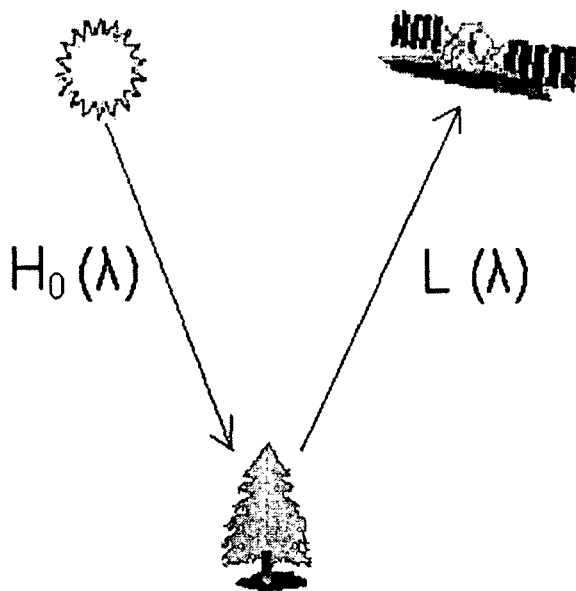
The images are all obtained in between 0.4 and 12.0 microns as a set of 12 individual black and white images. All 12 images are obtained at exactly the same time, and each is a computer image where we can assign an 8-bit binary number between 0 (black) and 255 (white). In this diagram, we show six of these images (or "bands"), along with the wavelength of the band. We show bands 2, 4, 6, 8, 10, and 12 just to cover the whole range, and to show that not all bands have the same wavelength range (the width of the colour bar beneath the spectrum). See how Band 12 is very wide (about 4 microns) while band 4 is very narrow (about 0.05 microns).

The various dimensions of remote sensing

Three typical measurement techniques:

Reflected (Passive) in visible and near IR

$$R(\lambda) = L(\lambda) / H_0(\lambda) \quad (\text{reflected}) / (\text{sun irradiation})$$

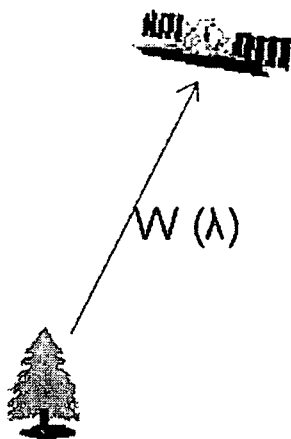


Emission (Passive) in thermal IR

Measured as a function of blackbody temperature (T)

$$W = \epsilon \sigma T^4$$

Where W is the exitance from the surface of a material, ϵ is the emissivity factor, σ is the Stefan-Boltzmann constant and T the absolute temperature (K) of the emitting material.

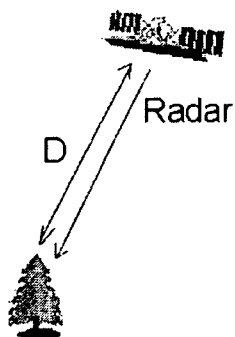


Scattering/dielectric (active) in microwaves

Measured returned signal (W_R) is attenuated by distance (D) and σ_0 (roughness, dielectric)

$$W_R = A \times (\sigma_0 / D^4) \times W_E$$

Where W_E is the emitted signal.



Optical - infrared remote sensing

In optical remote sensing, optical sensors detect solar radiation in the visible and infrared wavelength region.

When electromagnetic energy from the sun hits the earth's surface three fundamental energy interactions are possible. Various fractions of energy are:

Reflected

Absorbed

Transmitted

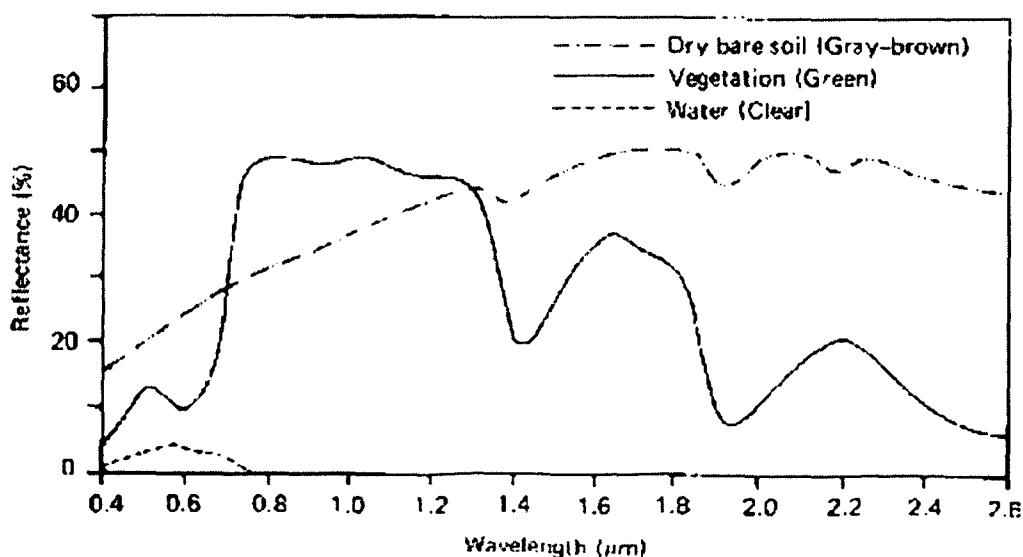
The proportions of energy reflected, absorbed, and transmitted will vary for different earth features. These differences permit us to distinguish different features of an image.

The interpretation of optical images requires the knowledge of the spectral curve (spectral signature) of the various materials (natural or man-made) covering the surface of the earth.

Spectral reflectance curves

The figure below shows typical spectral reflectance curves for three basic types of earth features: healthy green vegetation, dry bare soil, and clear lake water. These curves indicate how much incident energy would be reflected from the surface, and subsequently recorded by a remote sensing instrument. At a given wavelength, the higher the reflectance, the brighter the object appears in an image.

Note that vegetation reflects much more energy in the near-infrared (0.8 to 1.4 microns) than it does in visible light (0.4 to 0.7 microns). The amount of energy that vegetation reflects is related to the internal structure of the plant, and the amount of moisture in the plant. Another feature to notice is that clear water reflects visible light only, so it will appear dark in infrared images.

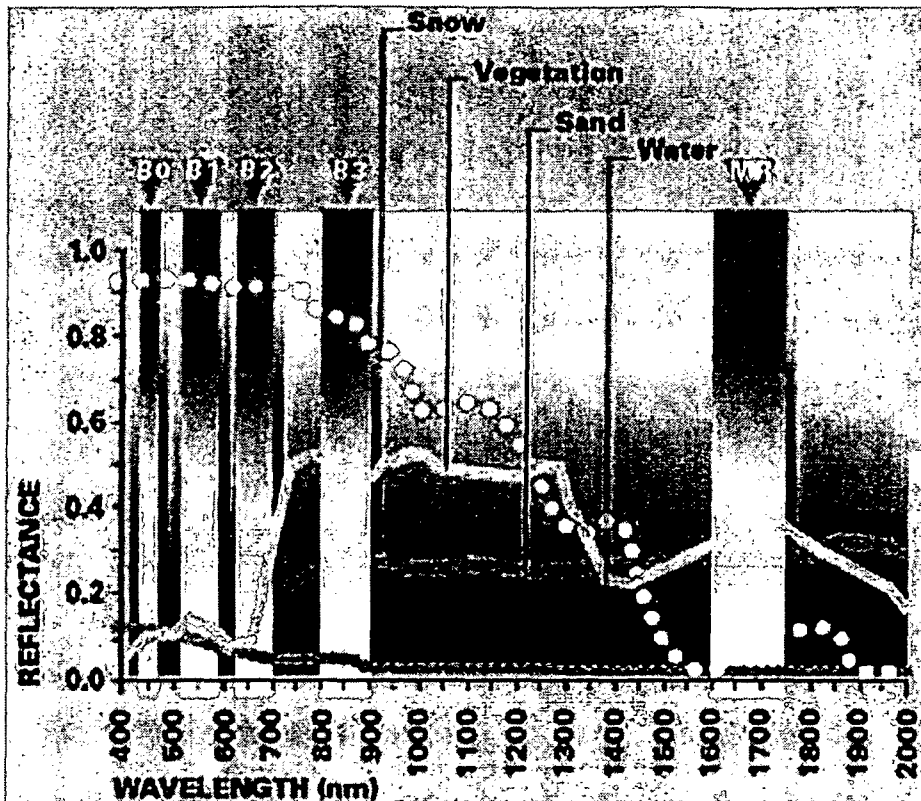


The red edge is the reflectance inflection point observed in the spectrum of green plants at the transition between the visible and near-infrared wavelengths. It is the long-wavelength edge of the chlorophyll absorption feature and has been used to describe the variation in leaf and canopy chlorophyll concentration. This boundary point in reflectance typically occurs between 690 and 740 nm in fresh leaves and is determined by the interaction between chlorophyll absorption of red light and the internal scattering process in the leaf. Increased chlorophyll concentration causes a deepening and broadening of the chlorophyll absorption feature, while stressed causing chlorosis usually increase reflectance and narrow the absorption feature, making the inflection point appear to move to longer or shorter wavelength, respectively. The relationship has been utilized to detect symptoms of mineral deficiency and air pollution damage.

Satellites characteristics

	Spectral bands	Nadir IFOV	Swath Width	Revisit at equator	Bits per pixels
NOAA/AVHRR	Red-IR-TIR	1 Km	2700 Km	2 passes/day	16 MS, 8 NDVI
Landsat TM	VIS-IR-TIR	30m MS 120m TIR	185 Km	16 days	8
Landsat ETM+	VIS-IR-TIR PAN	30m MS 120m TIR 15m PAN	185 Km	16 days	8
SPOT	VIS-IR-PAN	20m MS 10m PAN	60 Km	26 days	8
ERS1/2	C-band	30 m	100 Km	35 days	
Ikonos	VIS-IR-PAN	4m MS 1m PAN	11 Km		11
QuickBird	VIS-IR-PAN	2,44 m MS 0,61 m PAN	16.5 Km		11

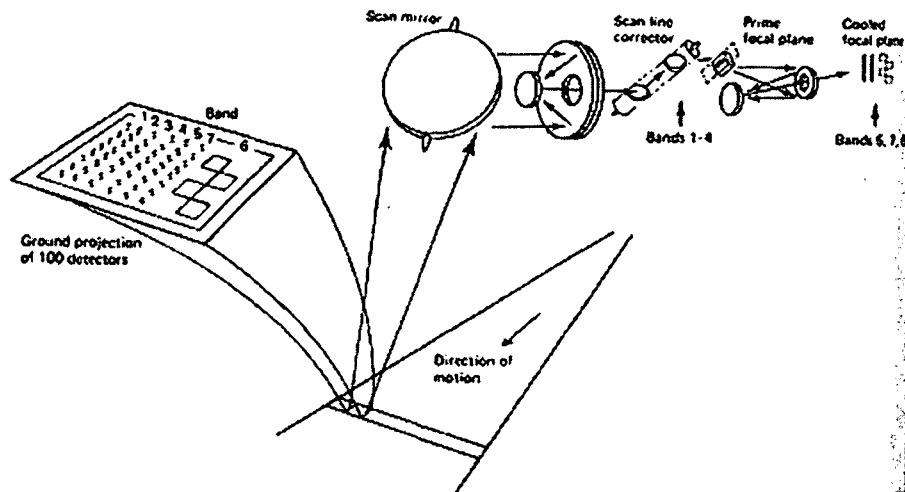
IFOV Instantaneous Field of View, Ms multispectral, VIS Visible, IR reflected infrared, TIR thermal infrared, PAN panchromatic.



"Xi" multispectral mode (Spot 4). The bands used are band B1 covering 0.50 to 0.59 μm (green), band B2 covering 0.61 to 0.68 μm (red), band B3 covering 0.79 to 0.89 μm (near infrared). plus a Short Wave Infrared band B4, covering 1.58 to 1.75 μm .

The Landsat program

The Landsat program consists of a series of optical-infrared remote sensing satellites for land observation. The program was first started by The National Aeronautics and Space Administration (NASA), in 1972. The first satellite in the series, Landsat-1 (initially named as the Earth Resource Technology Satellite ERTS-1) was launched on 23 July 1972. Landsat-2 was launched on 22 January 1975 and three additional Landsat satellites were launched in 1978, 1982, and 1984 (Landsat-3, 4, and 5 respectively). Landsat-6 was launched on October 1993 but the satellite failed to obtain orbit. A new satellite LANDSAT-7 was launched on 15 April 1999. Currently, only Landsat-5 and 7 are operational.



The Landsat satellites operate in near-polar, sun synchronous orbits. The altitude of the orbit of Landsat 5 (with Thematic Mapper) is 705 Km, Each orbit takes approximately 99 minutes, with just over 14.5 orbits being completed in one day. The orbit being sun synchronous implies that the satellite when travelling from north to South, passes the equator always at the same local time, 9:45 am for Landsat 5.

Between two successive orbits the earth rotates approximately $1/14.5 \times 360^\circ = 24.8^\circ$, which corresponds to 2754 Km at the equator. With a trace width of only 185 Km each day only a small portion of the earth surface can be scanned. The orbit is chosen in such a way that every 16 days the whole earth surface is covered.

To keep an orbit sun synchronous it has to be near polar instead of exactly polar.

The oscillation mirror acquires data of 16 scan lines (474 m) within each sweep in both directions, since there are 16 detectors for each of the six bands (4 for the thermal band). At receiving stations, TM imagery is resample to 30 x 30 m ground resolution (120 for the thermal band).

Thematic Mapper Spectral Bands

Band	Wavelength (μm)	Spectral name	Principal Applications
1	0.45 – 0.52	Blue	Designed for water body penetration, Making it useful for coastal water mapping. Also useful for soil/vegetation discrimination and forest type mapping.
2	0.52 – 0.60	Green	Designed to measure green reflectance peak of vegetation for vegetation discrimination and vigour assessment.
3	0.63 – 0.69	Red	Designed to sense in a chlorophyll absorption region aiding in plant species differentiation.
4	0.76 – 0.90	Near infrared	Useful for determining vegetation types, vigour and biomass content, for delineating water bodies and for soil moisture discrimination.
5	1.55 – 1.75	Mid infrared	Indicative of vegetation moisture content and soil moisture. Also useful to differentiate snow from clouds.
6	10.5 – 12.5	Thermal Infrared	Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications.
7	2.08 – 2.35	Mid Infrared	Useful for discrimination of mineral and rock types. Also sensitive to vegetation moisture content.

Panchromatic and multispectral images

A panchromatic image consists of only one band. It is usually displayed as a grey scale image, i.e. the displayed brightness of a particular pixel is proportional to the pixel digital number which is related to the intensity of solar radiation reflected by the targets in the pixel and detected by the detector. Thus, a panchromatic image may be similarly interpreted as a black-and-white aerial photograph of the area, though at a lower resolution.

A multispectral image consists of several bands of data. For visual display, each band of the image may be displayed one band at a time as a grey scale image, or in combination of three bands at a time as a colour composite image.

In displaying a colour composite image, three primary colours (red, green and blue) are used. When these three colours are combined in various proportions, they produce different colours in the visible spectrum. Associating each spectral band (not necessarily a visible band) to a separate primary colour results in a colour composite image. When displaying a natural colour composite image, the spectral bands (some of which may not be in the visible region) are combined in such a way that the appearance of the displayed image resembles a visible colour photograph, i.e. vegetation in green, water in blue, soil in brown or grey, etc. Many people refer to this composite as a "true colour" composite. However, this term may be misleading since in many instances the colours are only simulated to look similar to the "true" colours of the targets. For example, the bands 3 (red band), 2 (green band) and 1 (blue band) of a Landsat TM image can be assigned respectively to the R, G, and B colours for display. In this way, the colours of the resulting colour composite image resembles closely what would be observed by the human eye.

The display colour assignment for any band of a multispectral image can be done in an entirely arbitrary manner. In this case, the colour of a target in the displayed image does not have any resemblance to its actual colour. The resulting product is known as a false colour composite image. There are many possible schemes of producing false colour composite images. However, some scheme may be more suitable for detecting certain objects in the image. R = (NIR band), G = (red band), B = (green band).

This false colour composite scheme allows vegetation to be detected readily in the image. In this type of false colour composite images, vegetation appears in different shades of red depending on the types and conditions of the vegetation, since it has a high reflectance in the NIR band.

Clear water appears dark-bluish (higher green band reflectance), while turbid water appears cyan (higher red reflectance due to sediments) compared to clear water. Bare soil, roads and buildings may appear in various shades of blue, yellow or grey, depending on their composition.

In the RGB colours combination 7 (mid IR band), 5 (mid IR band) and 2 (green band) of a Landsat TM the inclusion of the mid-infrared bands provide additional information on rock morphology.

Vegetation indices

Different bands of a multispectral image may be combined to accentuate the vegetated areas. One such combination is the ratio of the near-infrared band to the red band. This ratio is known as the Ratio Vegetation Index (RVI)

$$RVI = NIR/Red$$

Since vegetation has high NIR reflectance but low red reflectance, vegetated areas will have higher RVI values compared to non-vegetated areas. Another commonly used vegetation index is the Normalised Difference Vegetation Index (NDVI) computed by

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

In the NDVI map shown above, the bright areas are vegetated while the nonvegetated areas (buildings, clearings, river, sea) are generally dark. Note that the trees lining the roads are clearly visible as grey linear features against the dark background. The NDVI band may also be combined with other bands of the multispectral image to form a colour composite image which helps to discriminate different types of vegetation, for example:

$$R = (NIR \text{ band}), G = (NDVI \text{ band}), B \text{ (green band)}$$

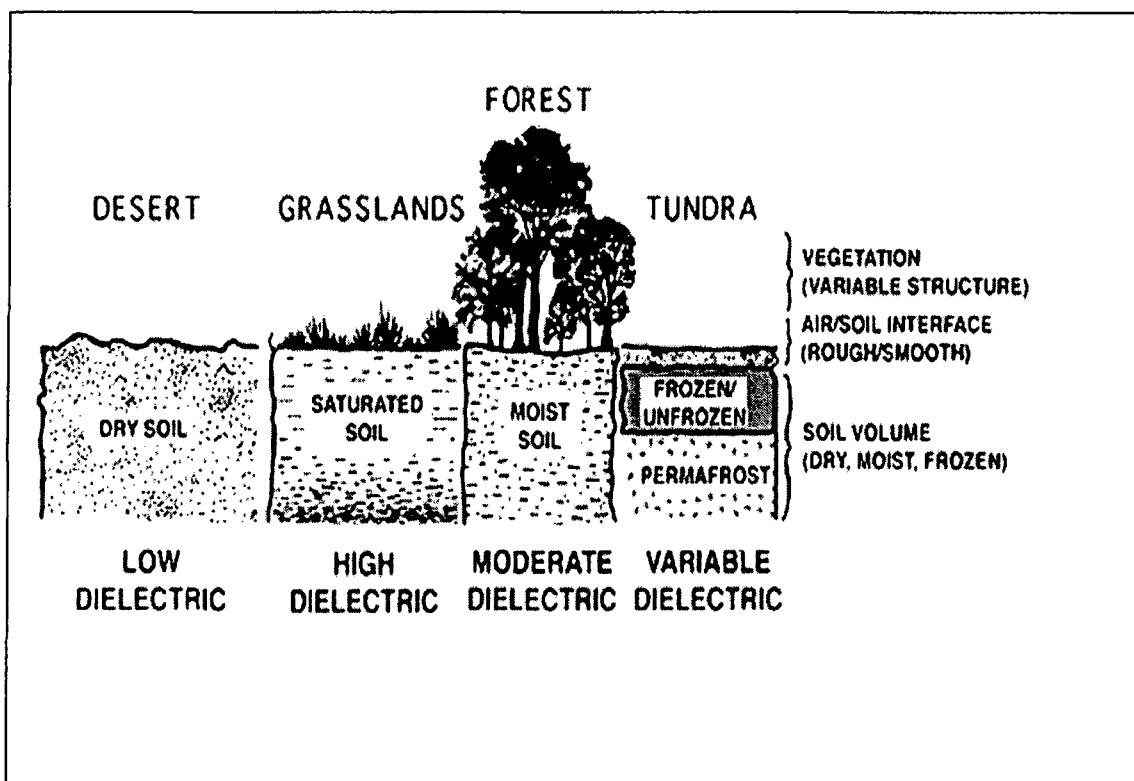
Microwave Remote Sensing

The active sensor emits pulses of microwave radiation to illuminate their targets. Images of the earth surface are formatted by measuring the microwave energy scattered by the ground or sea back to the sensors. The images can thus be acquired day and night.

Microwaves have an additional advantage as they can penetrate clouds. Images can be acquired even when there are clouds covering the earth surface.

Real researchers who use radar data have to worry about many different aspects of the surface. Different vegetation types (e.g., desert, grasslands, forests or frozen tundra) will all have different backscatter properties. In addition, the basic reflectivity of the soil, called the "dielectric constant" will change depending on the amount of water that the soil contains. Dry soil has a low dielectric constant, so that little radar energy will be reflected. Saturated soil will have the opposite effect, and will be a strong reflector. Moist and partially frozen soils will have intermediate values.

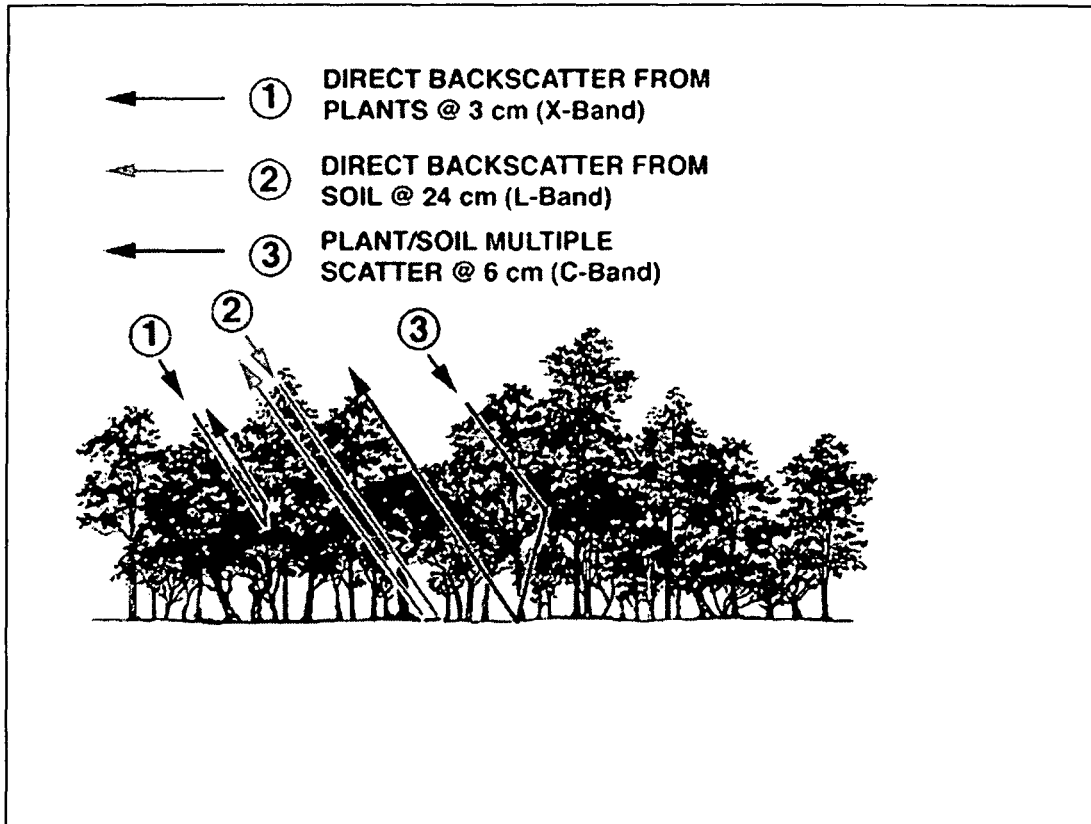
Thus, if we keep the radar incidence angle constant, we can use radar to study large differences in moisture content of the soil. This is often done in deserts (looking for subsurface water) or in tropical rain forests (looking for flooded rivers beneath the tree canopies).



Radar signals can be generated at several different wavelengths, which is useful because energy has an ability to travel through vegetation or soil to different amounts that are controlled by the dielectric constant of the material. As this diagram shows, short wavelength radar (3 cm) will be reflected from the tops of trees. Long wavelength radar (24

cm) data will normally go right down to the ground and be reflected off of the surface. Intermediate wavelength radars (say, 6 cm) will sometimes experience multiple scattering events within the canopy.

If we had a set of different wavelength radar images over a forest, it should be possible to use this changing penetration capability to study the structure of the trees and the total amount of material ("biomass") in the forest



Projection and datum

Maps are flat, but the surfaces they represent are curved. Transforming the three-dimensional space onto a two-dimensional map is called "projection". There are many examples that can be used to describe the projection process. One of the most common describes the result of trying to flatten an orange peel. Take an orange and remove the peel, as much as possible, in one piece. When you try to flatten the peel, the edges crack, pieces break off, and parts of the peel remain raised and distorted. Projections make it possible to create maps of areas of the earth with as little distortion as possible. The projection process affects four properties: area, shape, distance, and direction. There is no projection that maintains the integrity of all four properties at the same time. A particular

projection should be chosen based on the importance to your project of one of the affected properties. For example, if you want to analyse land use with respect to the percentage of area used for different purposes (i.e. agricultural versus residential) the reliability of your results rest with an accurate estimate of area. Therefore, you would choose an "equal area" projection such as Lambert Azimuthal Equal Area. An "equal area" projection is one that reports accurate area measurements while incurring some distortion of the remaining three properties-shape, distance, and direction.

If you want to optimise for shape, you would choose a "conformal projection" such as Lambert Conformal Conic. A conformal projection maintains shapes such as rectangles (buildings) at the expense of area, distance, and direction. The Universal Transverse Mercator (UTM) projection tries to maintain a happy medium among all four properties. A Geodetic datum is a reference point that describes the position, orientation and scale relationships of a reference ellipsoid to the Earth. The North American Datum of 1927 (NAD 27) uses Clarke spheroid of 1866 to represent the shape of the earth.

Lambert Azimuthal Equal-Area Projection

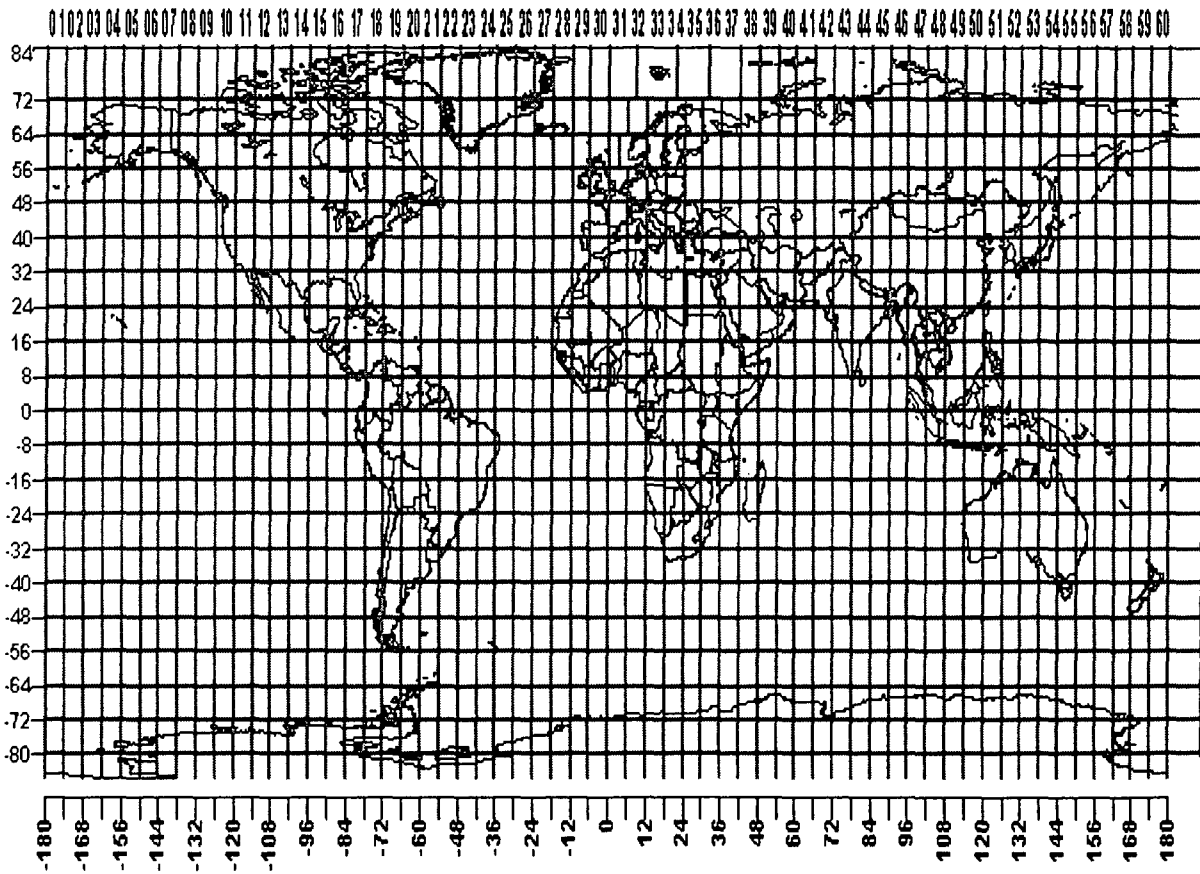


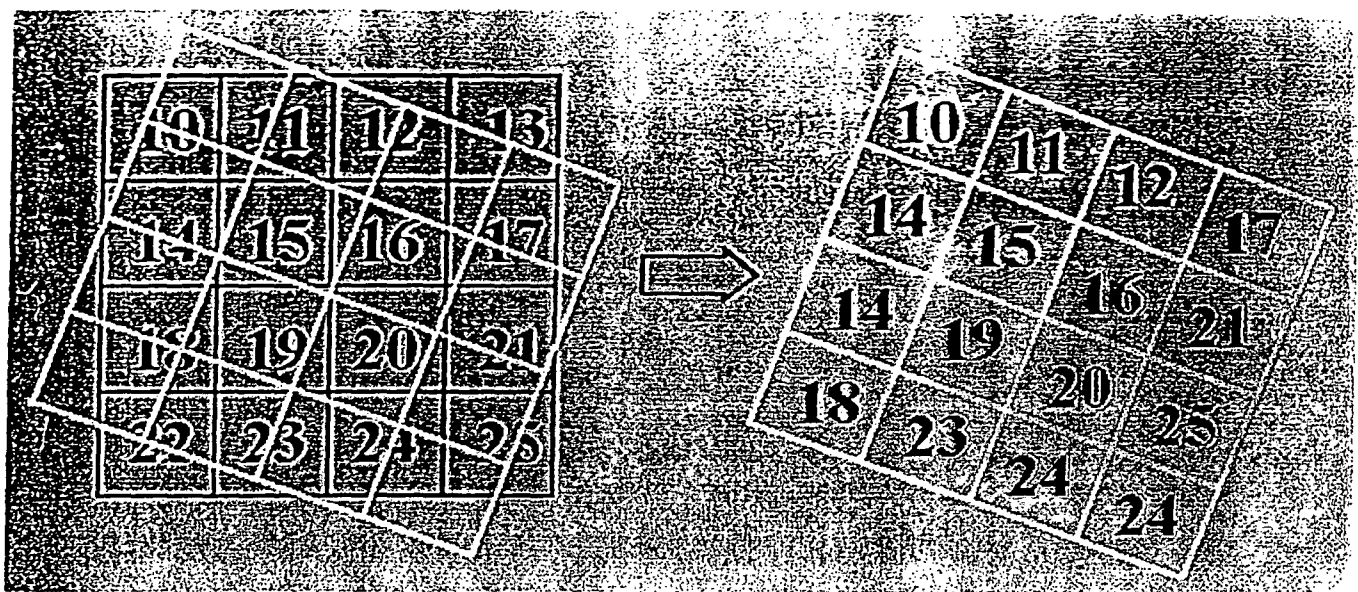
Geographic Coordinate System



Universal Transverse Mercator (UTM) System

UTM Zone Numbers





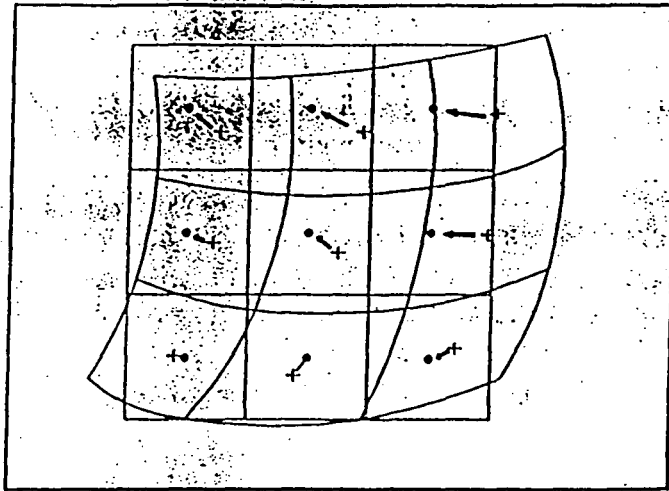


Figure 3.19 Nearest neighbour resampling

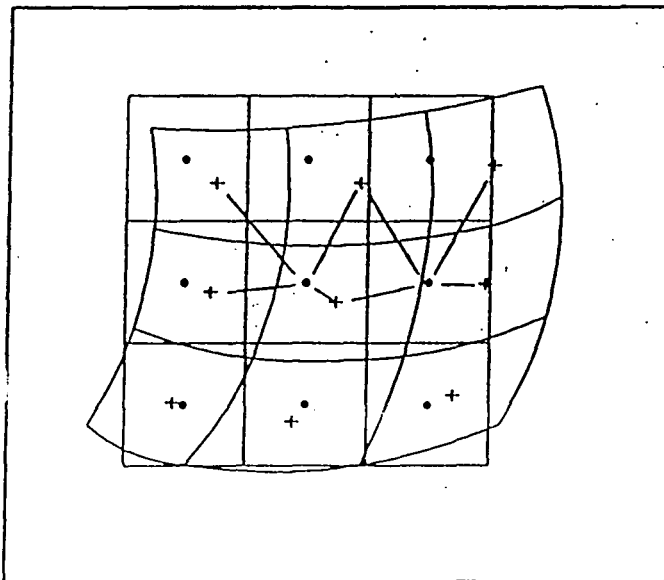
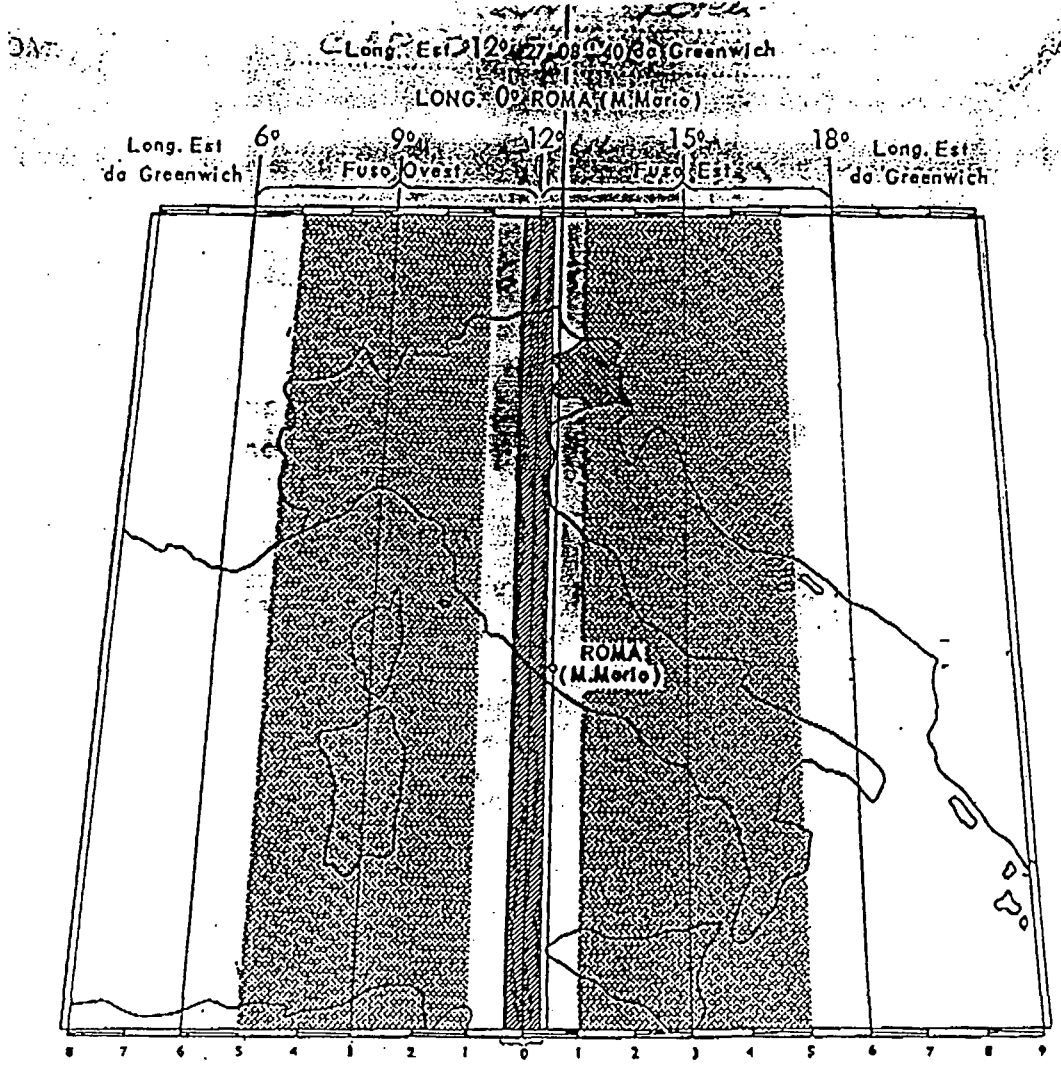


Figure 3.20 Bi-linear resampling



Zona di sovrapposizione

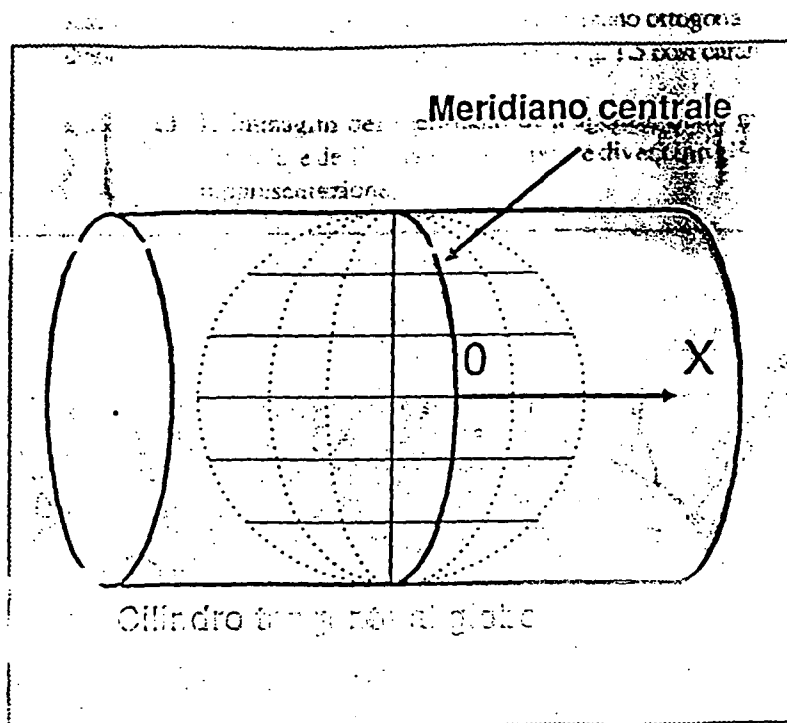


Figura 1.4 - Proiezione trasversa di Mercatore: il cilindro è tangente al globo lungo un meridiano detto meridiano centrale.

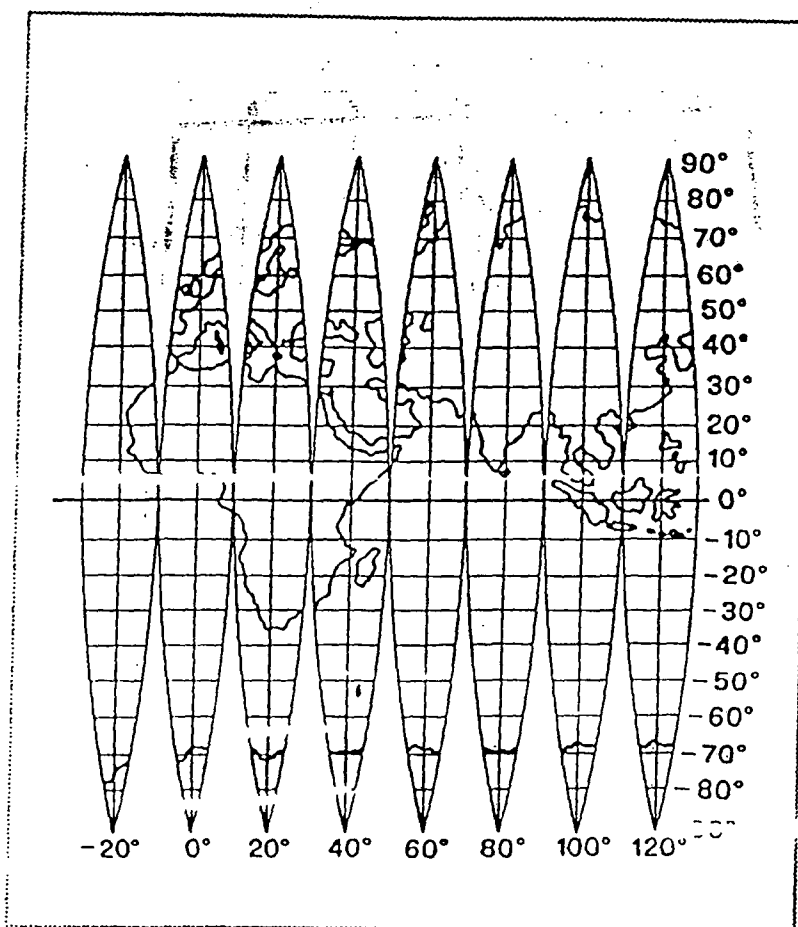
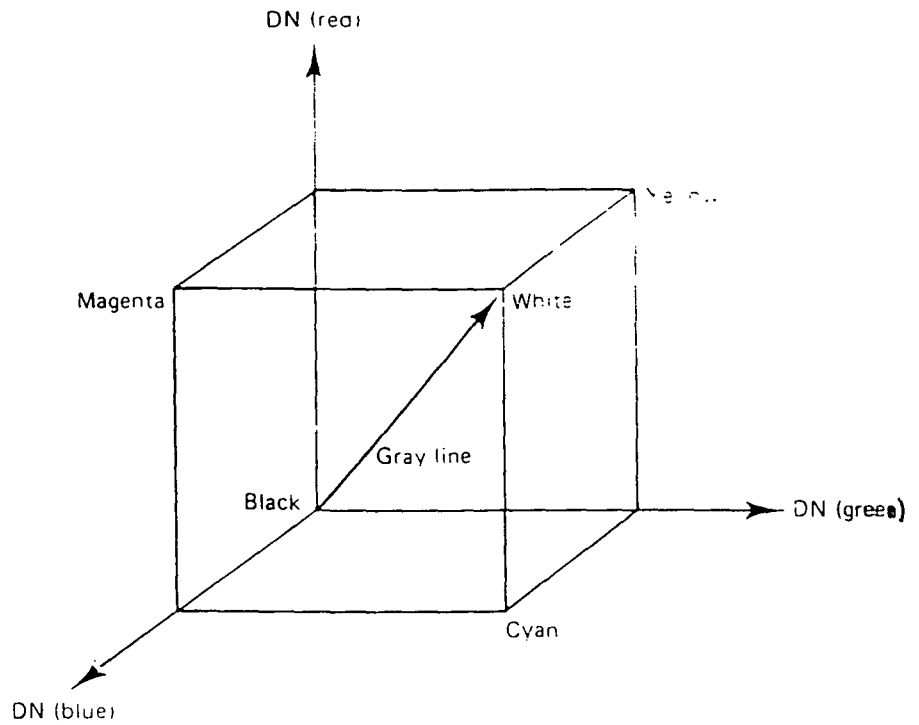


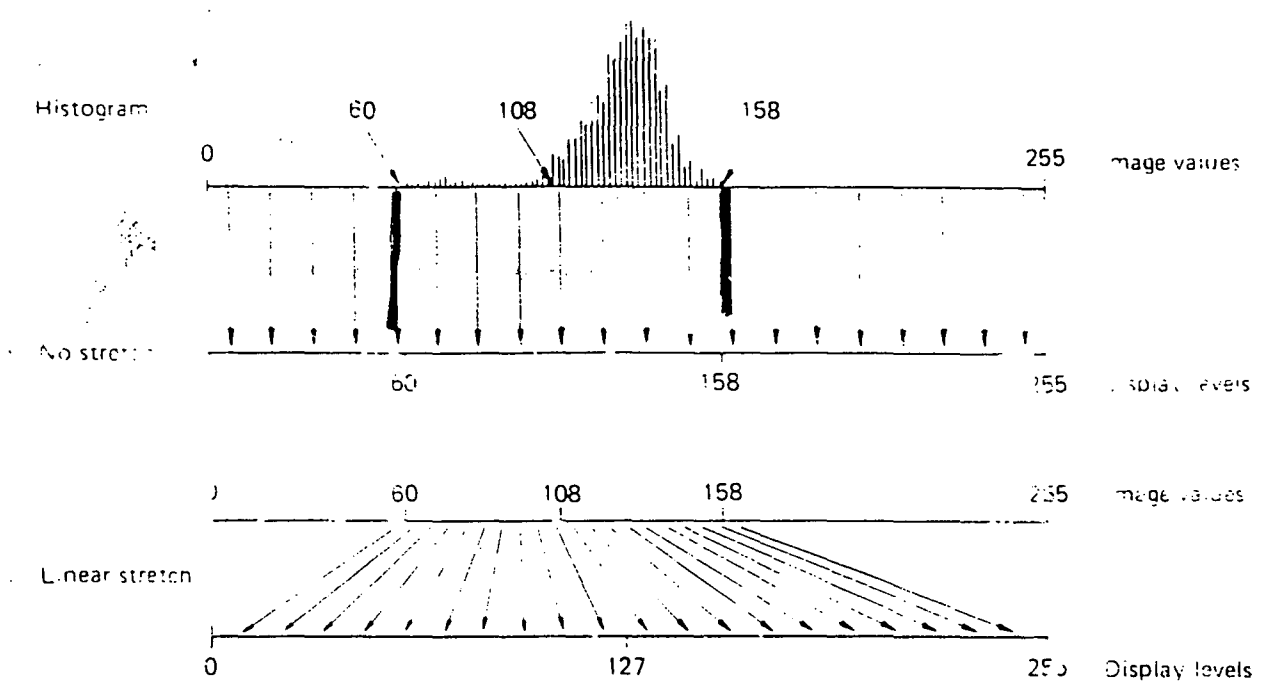
Figura 1.1.6 - Fusi nella carta di Gauss: i fusi rappresentati hanno ampiezza di 20 (da G. Bezoari e altri, op. cit.).



	R	G	B
TM	3	2	1
TM	4	3	2
TM	5	4	3

FOTO AEREA
 FOTO ALL'INFRAROSSO
 CONIFERE/LATI FOGLIA

CONTRAST STRETCHING



$$N' = \left(\frac{DN - MIN}{MAX - MIN} \right) \times 255$$

- LINEAR STRETCH
- HISTOGRAM EQUALIZATION

ORIGINAL BANDS



FEATURES SELECTION (FEATURE SPACE)

↳ CLASSIFICATION { (1) UNSUPERVISED
(2) SUPERVISED

(1) CLUSTERING ALGORITHMS { SINGLE PASS ALGORITHM
ITERATIVE TYPE - ISODATA

(2) MAXIMUM LIKELIHOOD } MultiSpec
ECHO SPECTRAL-SPATIAL }
.....
NEURAL NETWORK

MultiSpec: free Mac and PC image processing software

PURDUE University, IN

<http://dynamics3.econ.purdue.edu/~rbiehl/MultiSpec/index.html>

Idris 3.2 Release 2: Geographic Analysis and Image Processing Software

CLARK Lab. - Clark University, MA

Academic single user license	\$ 600
Non-profit single user license	\$ 800
Unlimited student lab. kit	\$ 4000

<http://www.clarklabs.org/>

GRASS (Geographic Resources Analysis Support System)

Open source, free GIS (Linux)

<http://grass-its.it>

Data Processing and Analysis

Kauth-Thomas transformations were applied to strengthen the correlation between spectral response and biophysical reality. These transformations resulted in six new features, three of which were considered directly relevant to this research: brightness, greenness, and wetness, related to soil brightness, green biomass reflectance, and moisture condition, respectively. The model coefficients for brightness, greenness, and wetness were obtained from Crist and Cicone (1984) and $B_1, B_2, B_3, B_4, B_5,$ and B_7 are the reflectance values of TM bands 1, 2, 3, 4, 5, and 7, respectively.

$$\begin{aligned} \text{Brightness} = & 0.33183 \times B_1 + 0.33121 \times B_2 + 0.55177 \times B_3 \\ & + 0.42514 \times B_4 + 0.48087 \times B_5 + 0.25252 \times B_7 \end{aligned} \quad (3)$$

$$\begin{aligned} \text{Greenness} = & -0.24717 \times B_1 - 0.162663 \times B_2 - 0.40639 \times B_3 \\ & + 0.85468 \times B_4 + 0.05493 \times B_5 - 0.11749 \times B_7 \end{aligned} \quad (4)$$

$$\begin{aligned} \text{Wetness} = & 0.13929 \times B_1 + 0.22490 \times B_2 + 0.40359 \times B_3 \\ & + 0.25178 \times B_4 - 0.70133 \times B_5 - 0.45732 \times B_7 \end{aligned} \quad (5)$$

of the TM6 must be converted into thermal radiance L_{TM6} (expressed in $\text{mW cm}^{-2}\text{sr}^{-1}\mu\text{m}^{-1}$) by means of the pre-launch calibration coefficients (Markham and Barker, 1986):

$$L_{TM6} = 0.0056322 \times DN6 + 0.1238 \quad (113)$$

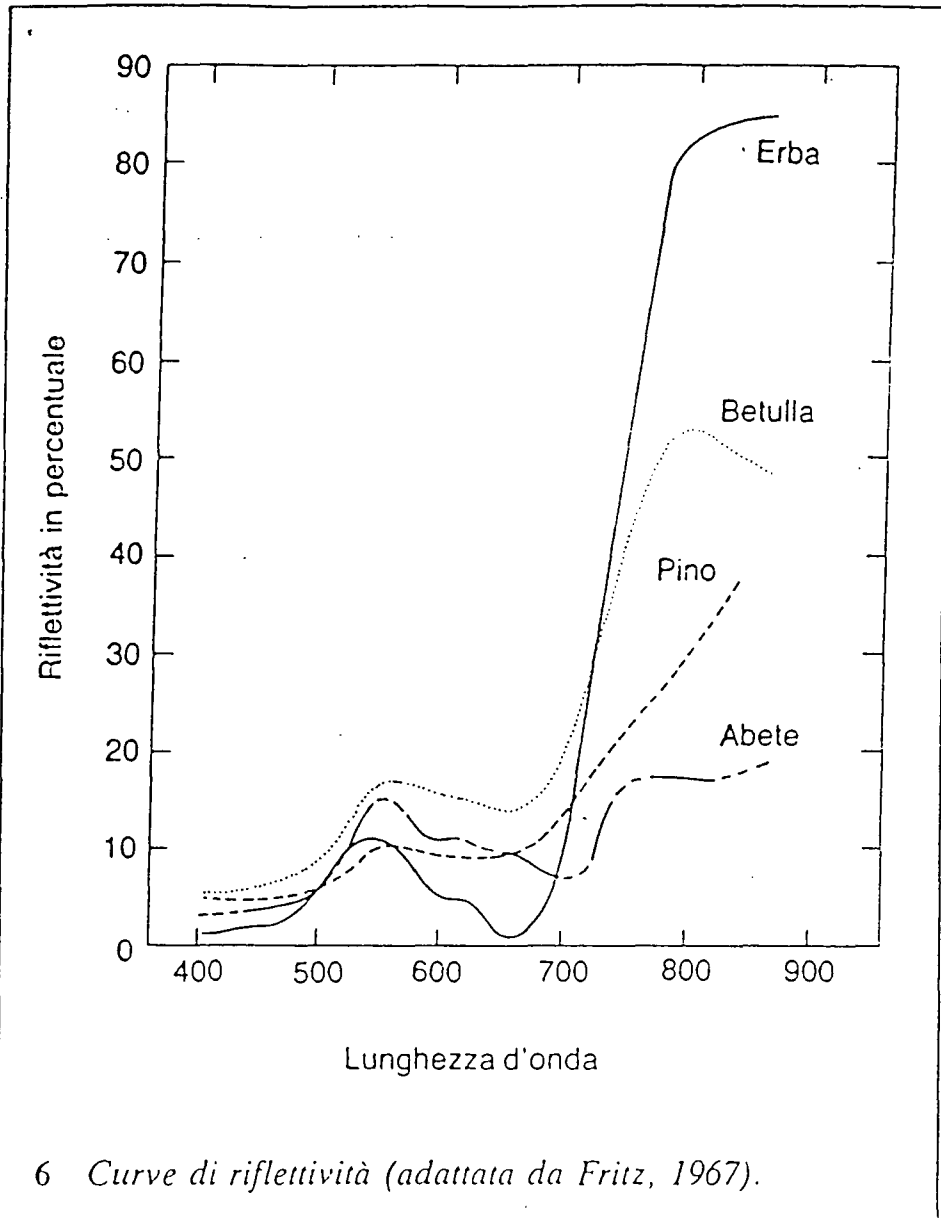
Using the inverse Planck's law, the thermal radiances are converted to radiant temperature:

$$T = \frac{k_2}{\ln\left(\frac{k_1}{L_{TM6}} + 1\right)} \quad (\text{K}) \quad (114)$$

where: k_1 and k_2 are the Landsat TM thermal band calibration constants, respectively for Landsat-4: 67.162 and 1284.3; for Landsat-5: 60.776 and 1260.56.

Table 1.1: Thematic Mapper Spectral Bands (from Lillesand and Kiefer [244])

Band	Wavelength (μm)	Spectral Name	Principal Applications
1	0.45 - 0.52	Blue	Designed for <u>water body penetration</u> , making it useful for <u>coastal water mapping</u> . Also useful for <u>soil/vegetation discrimination and forest type mapping</u> .
2	0.52 - 0.60	Green	Designed to measure green reflectance peak of vegetation for <u>vegetation discrimination and vigor assessment</u> .
3	0.63 - 0.69	Red	Designed to sense in a chlorophyll absorption region aiding in <u>plant species differentiation</u> .
4	0.76 - 0.90	Near infrared	Useful for determining <u>vegetation types, vigor, and biomass content</u> , for <u>delineating water bodies</u> , and <u>for soil moisture discrimination</u> .
5	1.55 - 1.75	Mid-infrared	Indicative of <u>vegetation moisture content and soil moisture</u> . Also useful to <u>differentiate snow from clouds</u> .
6	10.4 - 12.5	Thermal Infrared	Useful in <u>vegetation stress analysis</u> , <u>soil moisture discrimination</u> , and <u>thermal mapping applications</u> .
7	2.08 - 2.35	Mid-infrared	Useful for discrimination of <u>mineral and rock-types</u> . Also sensitive to <u>vegetation moisture content</u> .

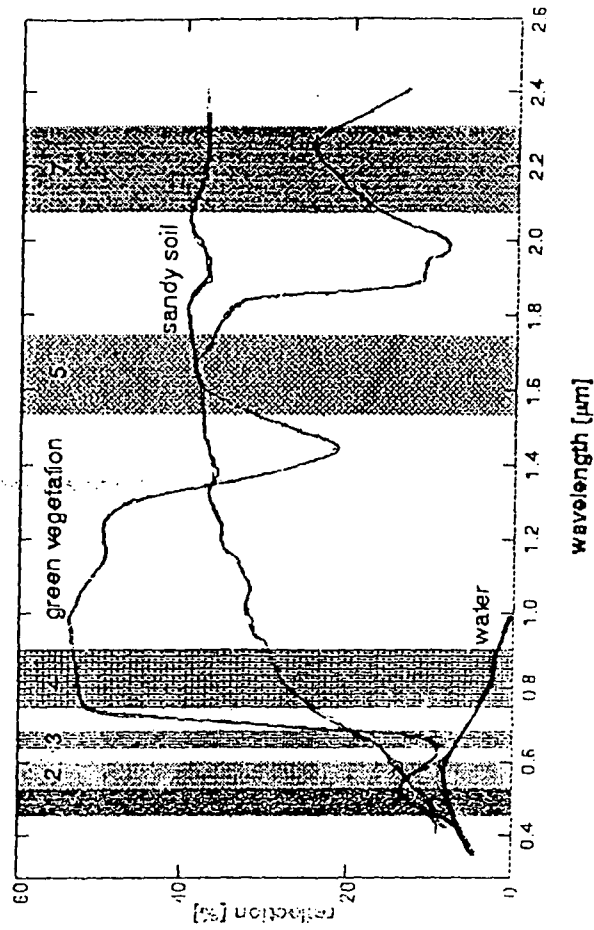


PART 2: Spectral Mixture Analysis

Table 1.1: Thematic Mapper Spectral Bands (from Lillesand and Kiefer [244])

Band	Wavelength (μm)	Spectral Name	Principal Applications
1	0.45 - 0.52	Blue	Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation discrimination and forest type mapping.
2	0.52 - 0.60	Green	Designed to measure green reflectance peak of vegetation for vegetation discrimination and vigor assessment.
3	0.63 - 0.69	Red	Designed to sense in a chlorophyll absorption region aiding in plant species differentiation.
4	0.76 - 0.90	Near infrared	Useful for determining vegetation types, vigor, and biomass content, for delineating water bodies, and for soil moisture discrimination.
5	1.55 - 1.75	Mid-infrared	Indicative of vegetation moisture content and soil moisture. Also useful to differentiate snow from clouds.
6	10.4 - 12.5	Thermal Infrared	Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications.
7	2.08 - 2.35	Mid-infrared	Useful for discrimination of mineral and rock types. Also sensitive to vegetation moisture content.

Introduction: Spectral responses of different objects (with related LANDSAT TM5 bands)



RESOLUTION

- SPATIAL RESOLUTION

- SPECTRAL RESOLUTION

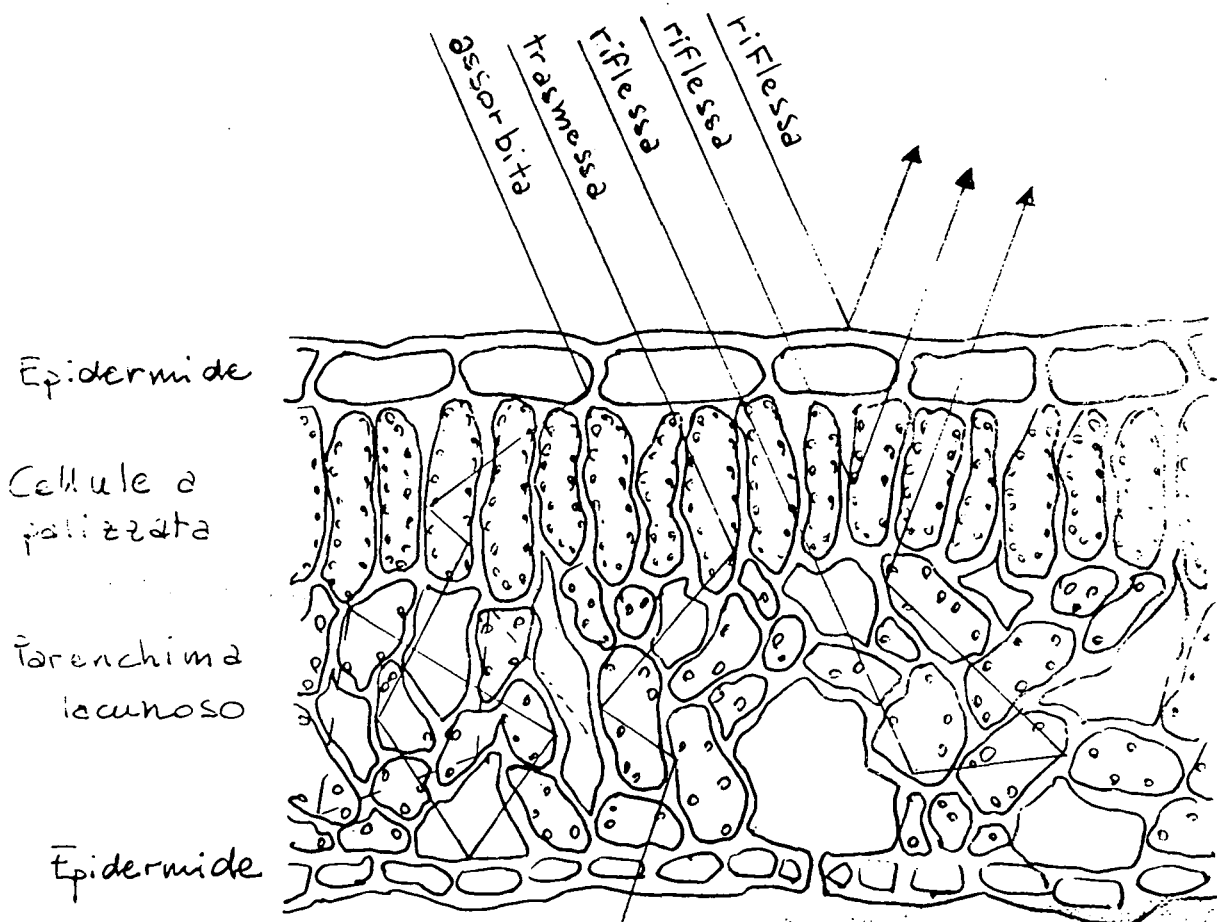
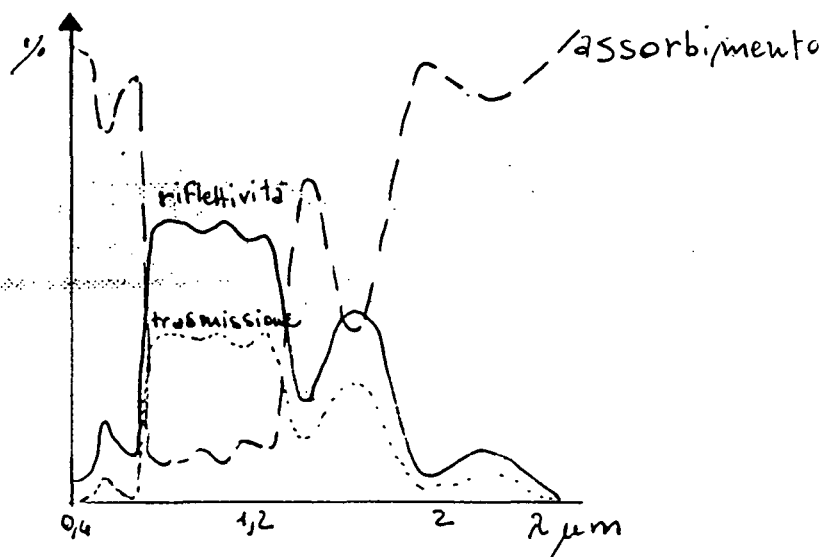
- TEMPORAL RESOLUTION

- RADIOMETRIC RESOLUTION

SATELLITE	SPECTRAL BANDS	NADIR IFOV	SWATH WIDTH	REVISIT AT EQUATOR	BITS PER PIXEL
NOAA AVHRR	RED IR-TIR	1 Km	2700 Km	2 PASSES/DAY	16 MS 8 NDVI
LANDSAT TM	VIS IR-TIR	30m MS 120m TIR	185 Km	16 DAYS	8
LANDSAT ETM+	VIS-IR-TIR PAN	30m MS 60m TIR 15m PAN	185 Km	16 DAYS	8
SPOT	VIS-IR PAN	20m MS 10m PAN	60 Km	26 DAYS	8
ERS-1 ERS-2	C-BAND	30 m	100 Km	35 DAYS	
IKONOS	VIS-IR PAN	4m MS 1m PAN	11 Km		11
QUICKBIRD	VIS-IR PAN	2.44m MS 0.61m PAN	165 Km		11

Spettro di riflettività, trasmissione e assorbimento

della parte superiore di una foglia



Percorso ipotetico della radiazione solare attraverso una Foglia

FIRME SPECTRUM (SILICATE SALT)



RESPONSE PATTERNS

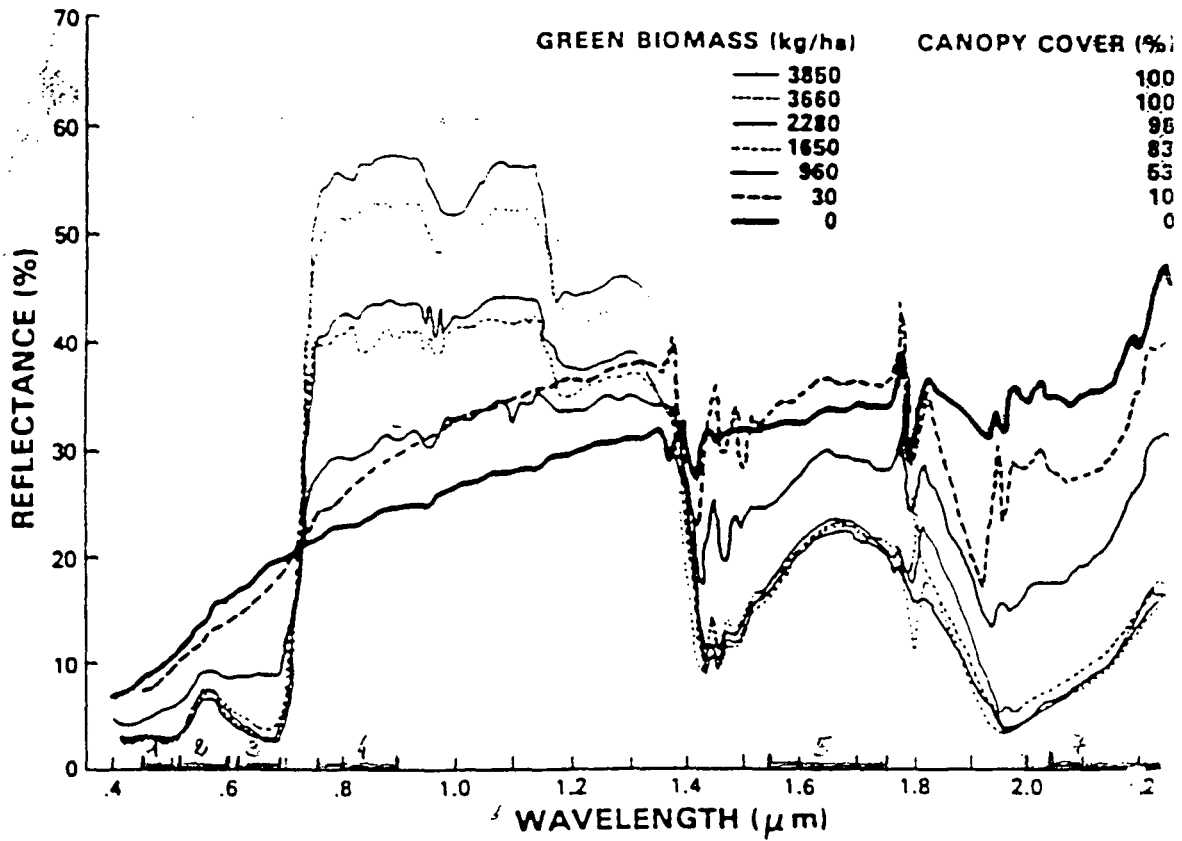


FIGURE 3.2: CROP CANOPY SPECTRAL SIGNATURE (From Deering, 1984).

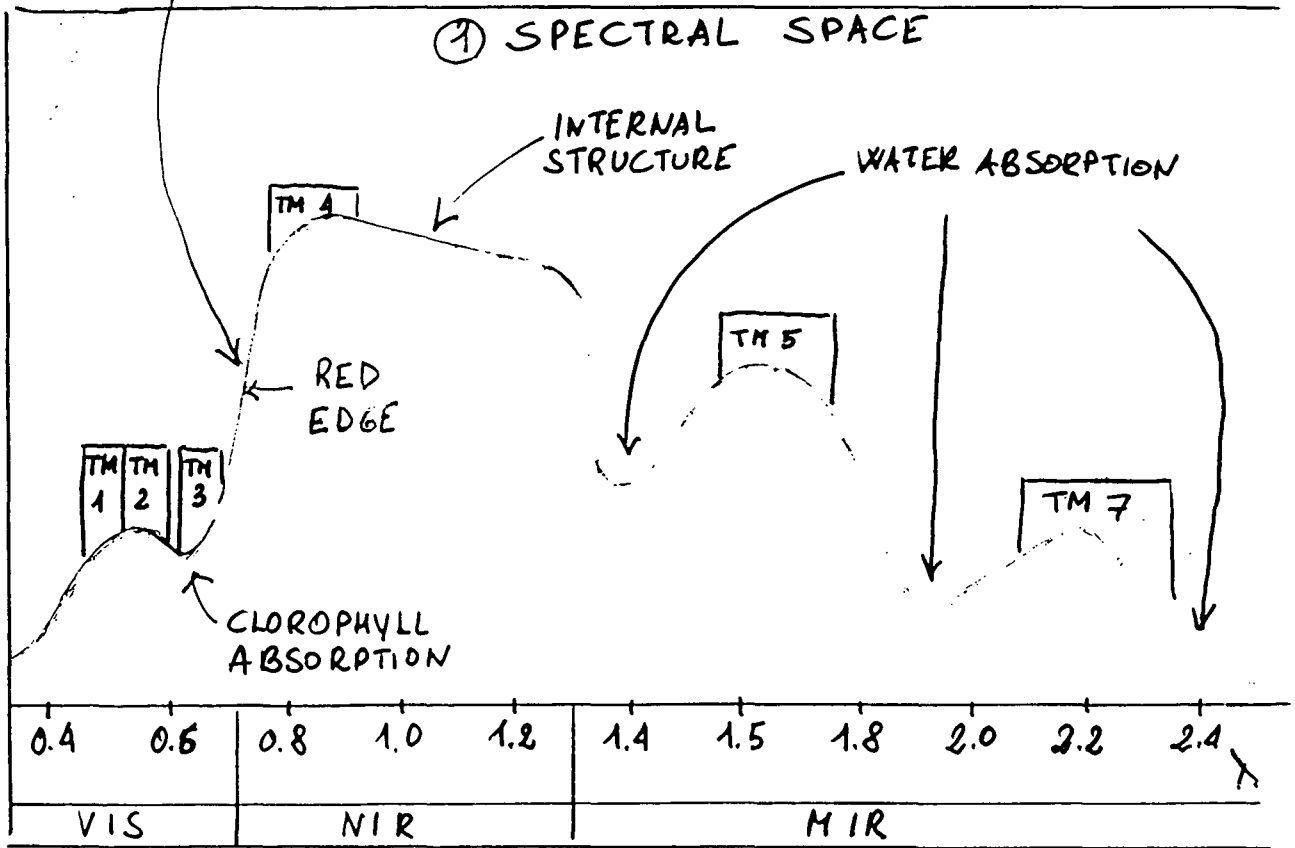
16

THE FORMS FOR REPRESENTING MULTISPECTRAL DATA

VEGETATION INDEX

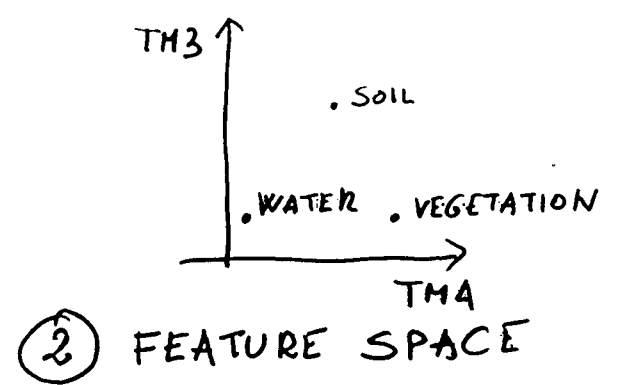
$$RVI = \frac{TM4}{TM3}$$

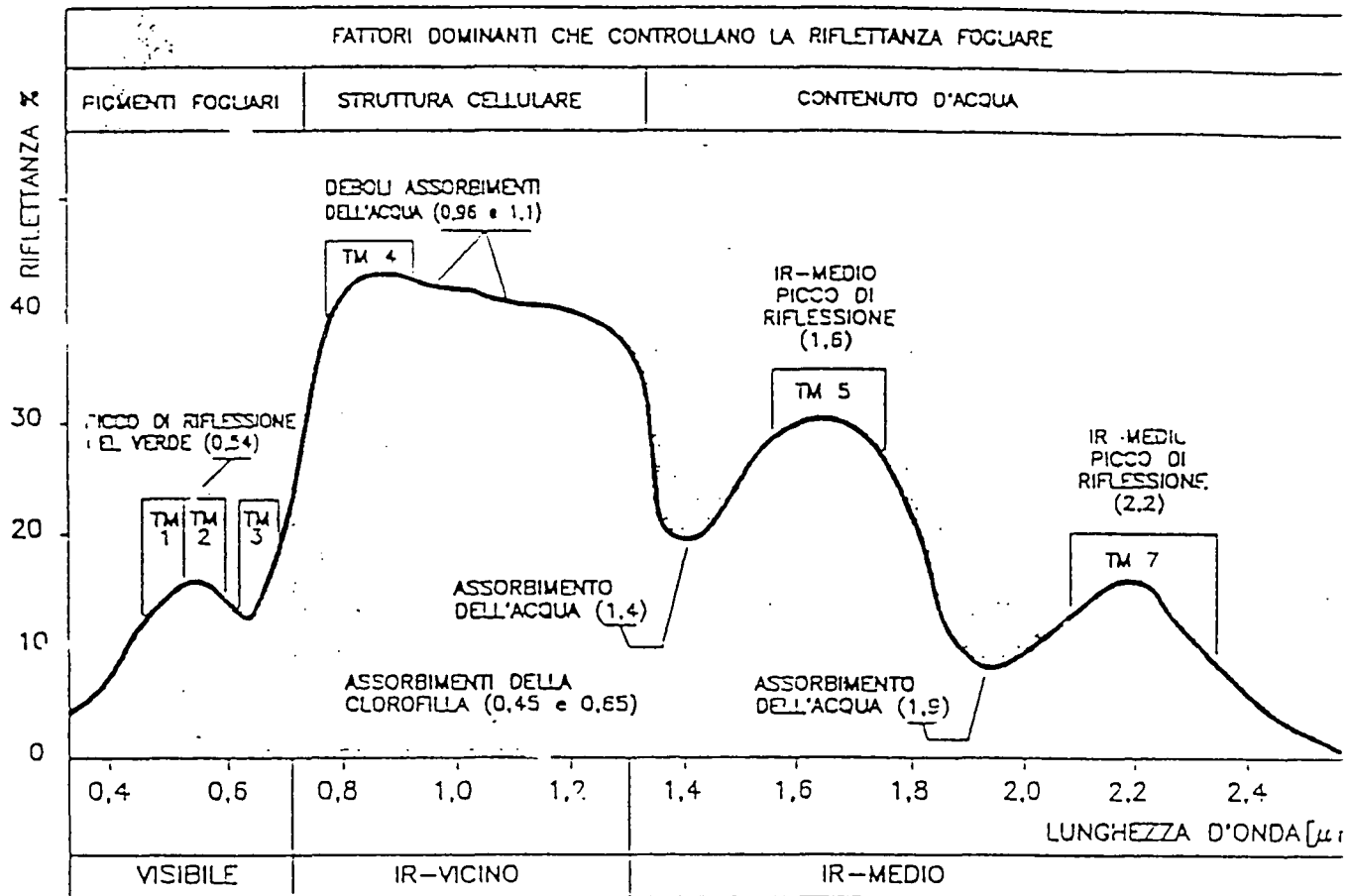
$$NDVI = \frac{TM4 - TM3}{TM4 + TM3}$$

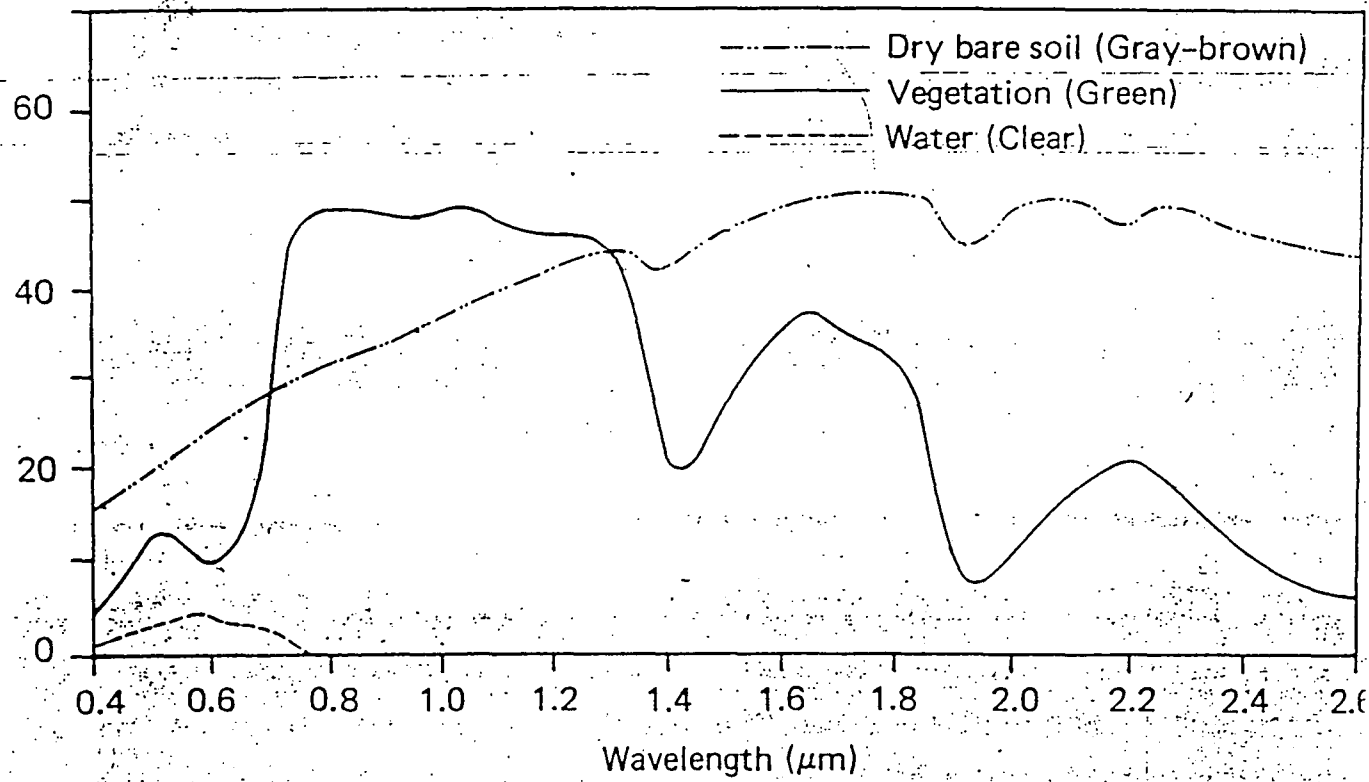


300	120	80	20	10

IMAGE ③ SPACE (SPATIAL)

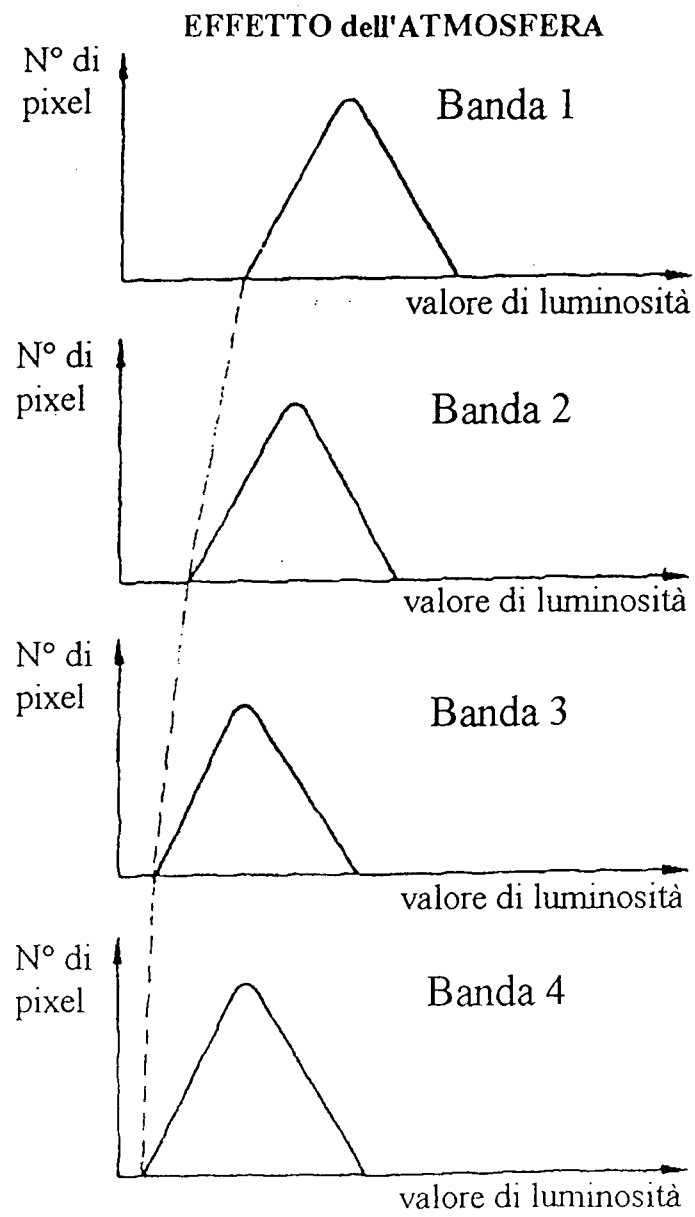






14 ~~18~~ 0v

Fig. 3.6. Effetti dell'atmosfera sugli istogrammi delle immagini satellitari



Fonte: Richards

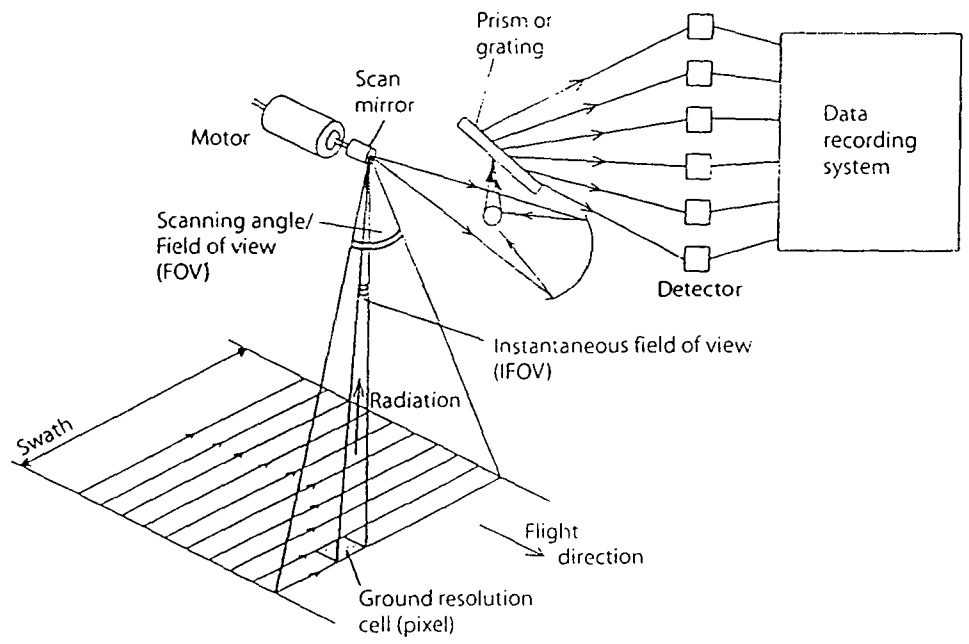
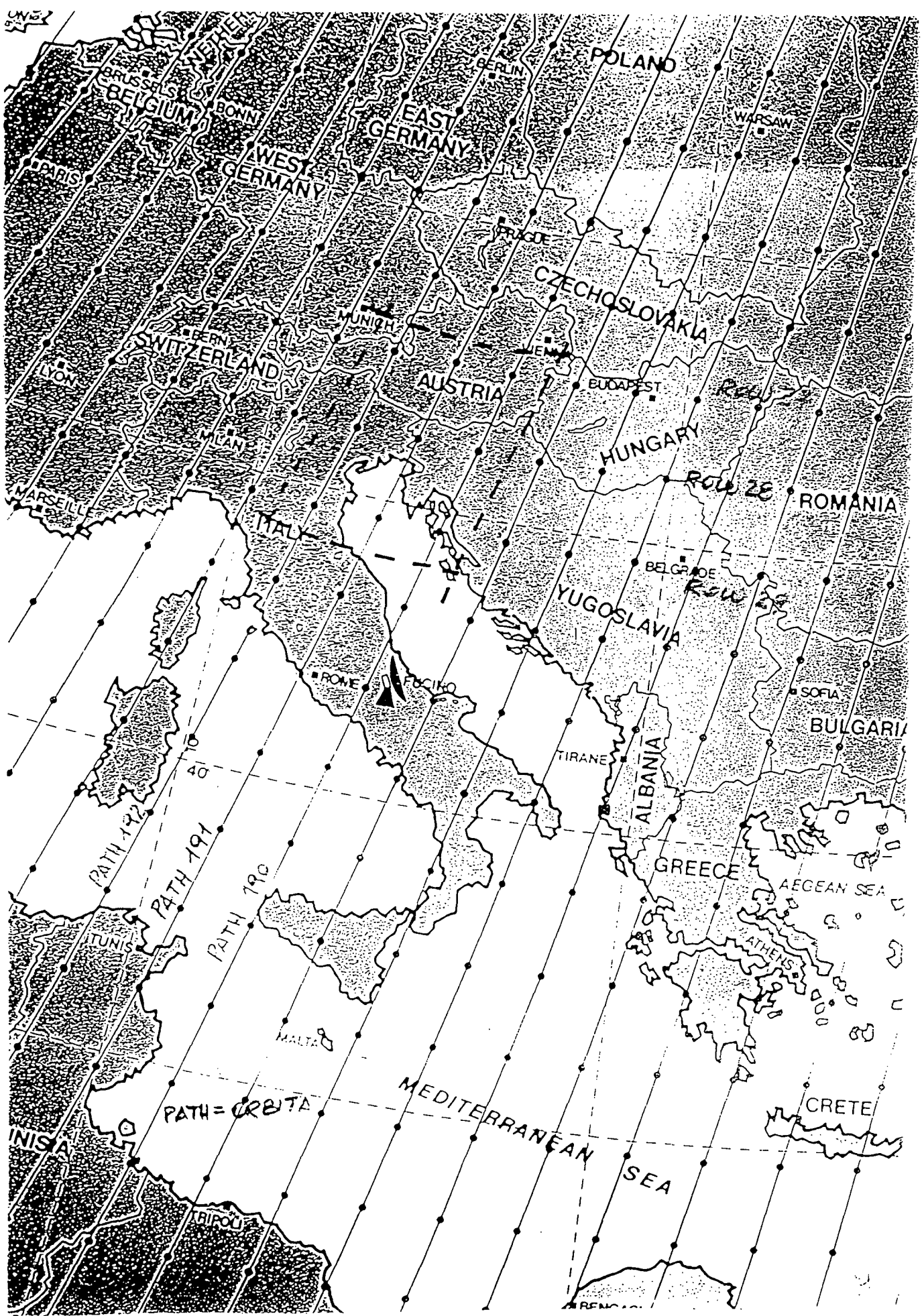
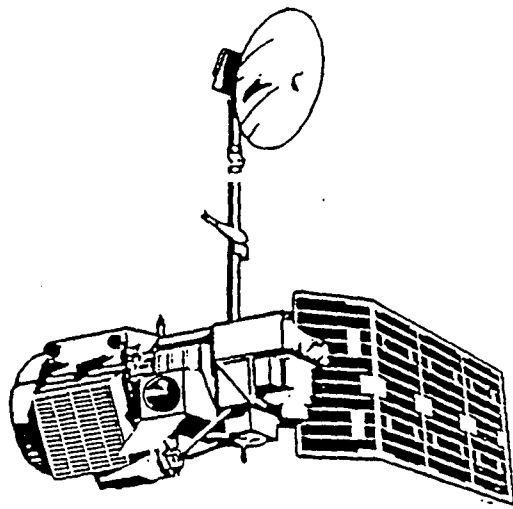
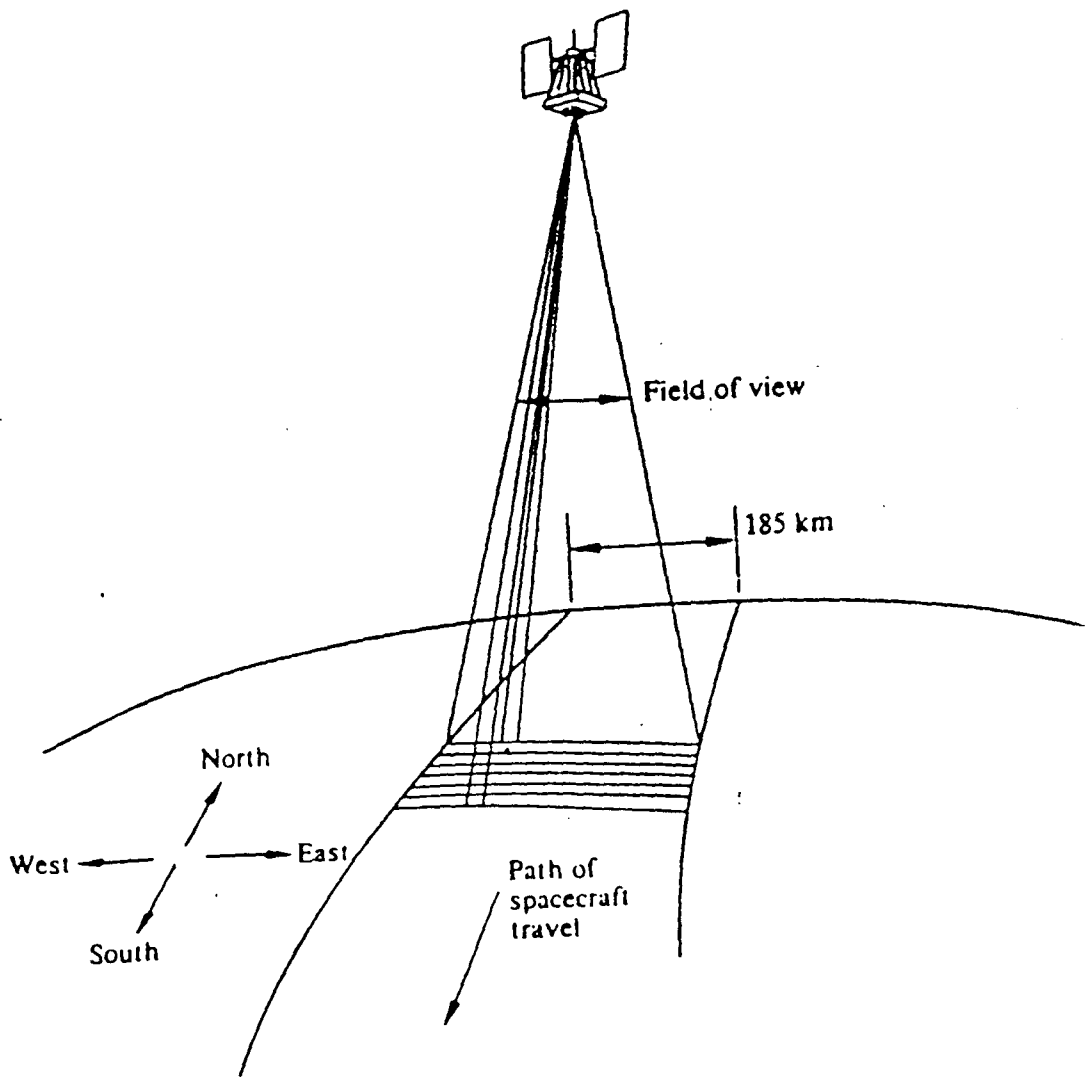


Fig. 3.8. The principle of optical-mechanical line scanners (modified after Gupta 1991)



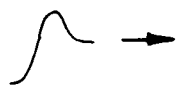
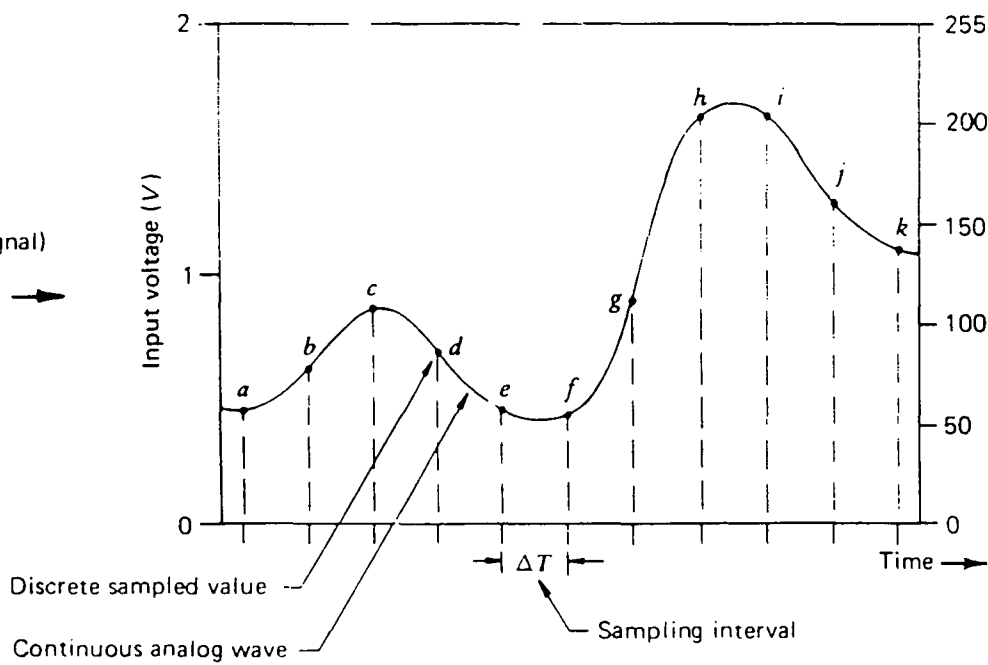


LANDSAT 5



CONVERSIONE ANALOGICO-DIGITALE DEL SEGNALE

INPUT
continuous signal)

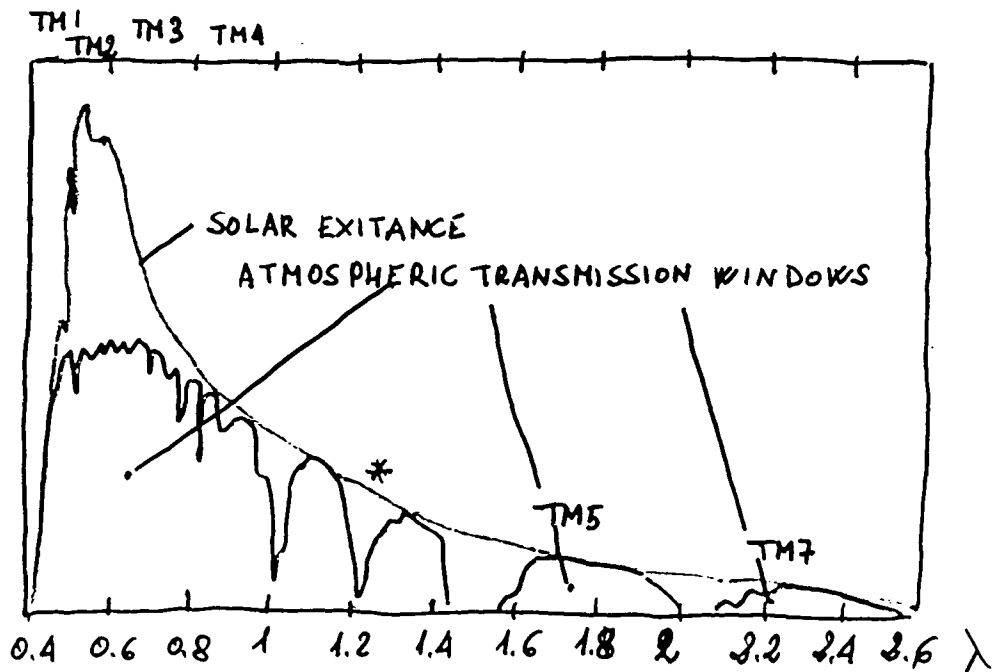
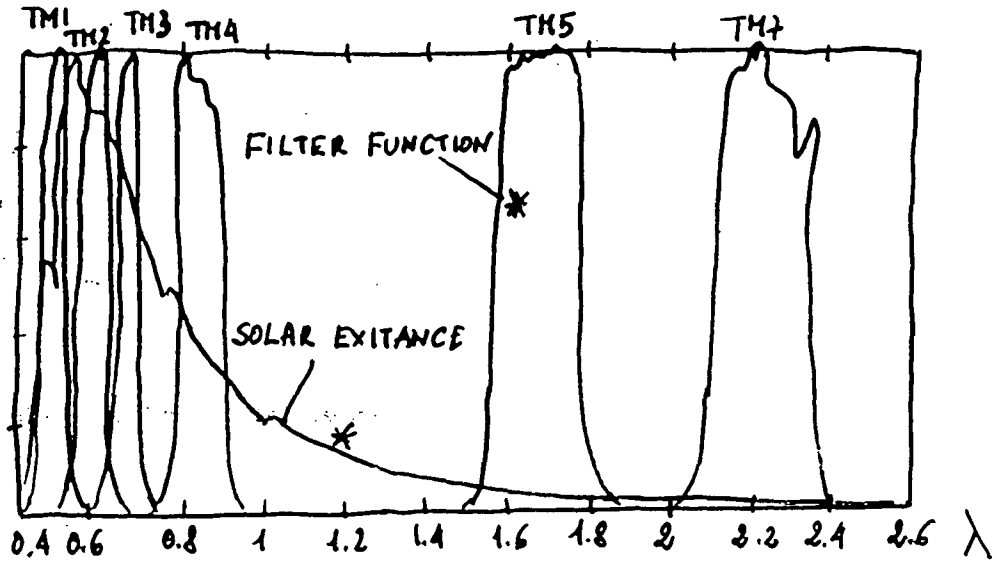



OUTPUT
(Series of number:

a	59
b	81
c	108
d	87
e	58
f	56
g	117
h	203
i	205
j	162
k	138



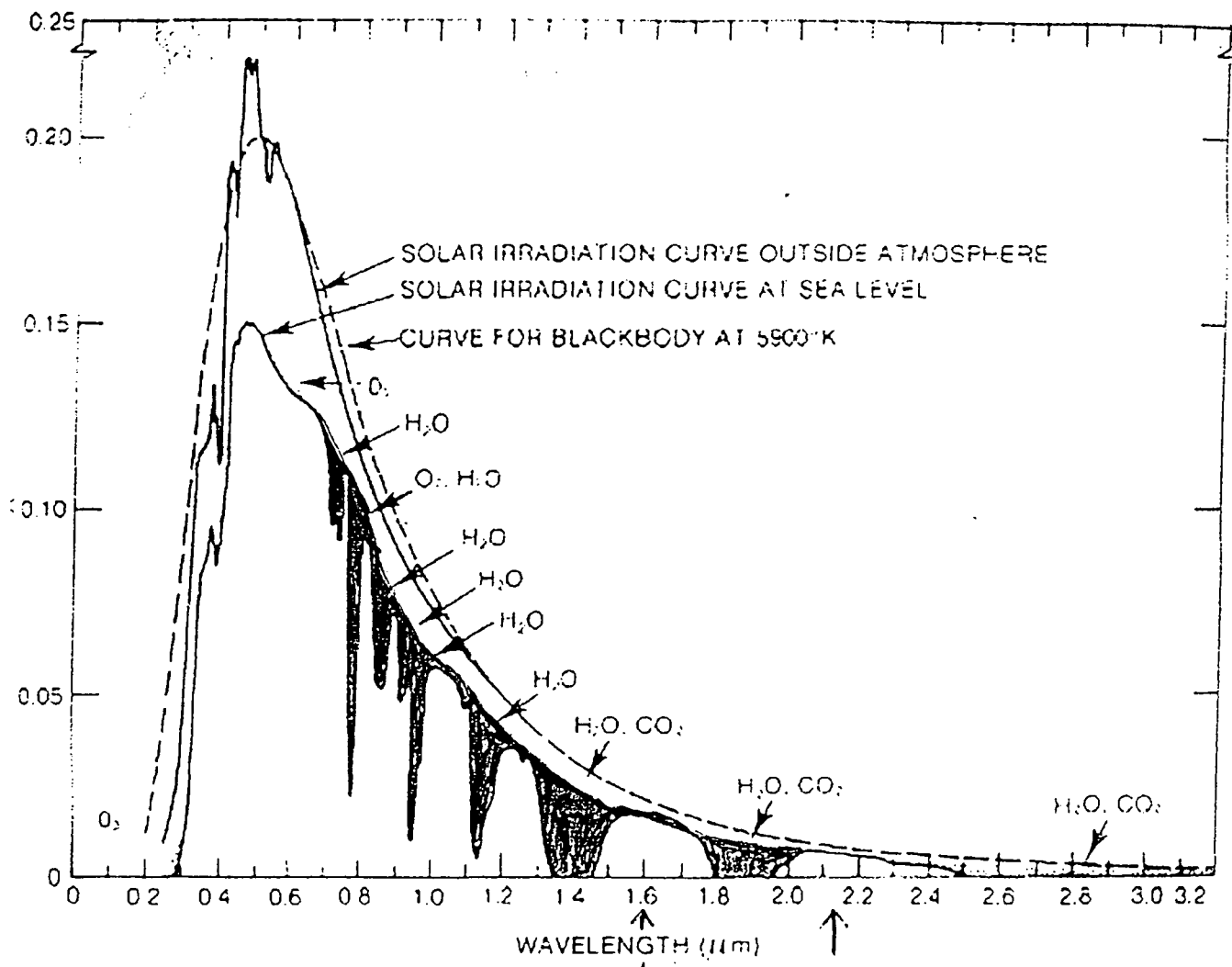
EFFECTS OF ATMOSPHERE, EXOATMOSPHERIC SOLAR SPECTRUM AND FILTER FUNCTION OF THE SPECTRAL CHANNELS OF LANDSAT TM



BAND	WAVELENGTH (LANDSAT TM)	
VIS	1	0.45-0.52
	2	0.52-0.60
	3	0.63-0.69
NIR	4	0.76-0.90
MIR	5	1.55-1.75
	7	2.08-2.35
TIR	6	10.4-12.5

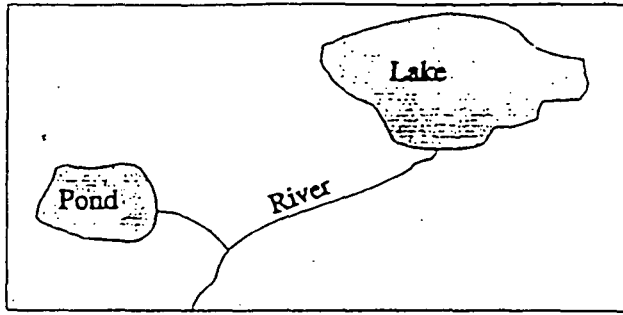
* EXOATMOSPHERIC SOLAR SPECTRUM

* SPECTRAL RESPONSE CURVES OF THE SEVEN LANDSAT-TM SENSORS

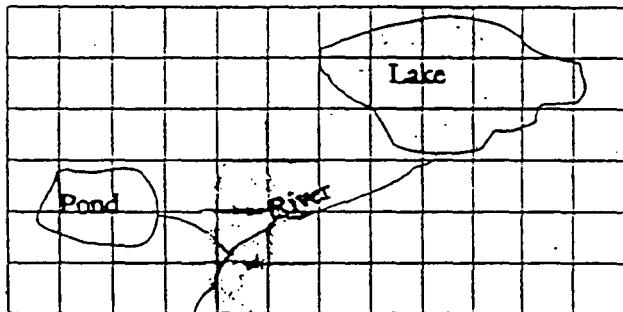


↑
14.5

↑
14.7



Reality - Hydrography

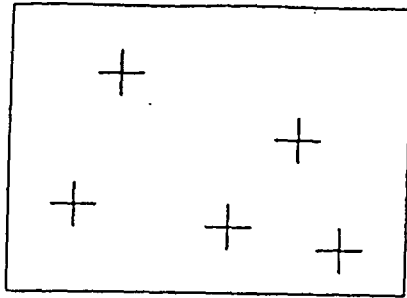


Reality overlaid with a grid

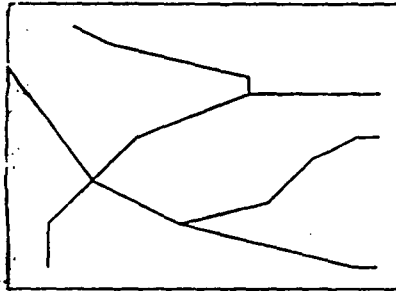
0	0	0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	0	1	1	1	1	1	0
0	0	0	0	0	0	0	1	1	1	0	0
0	1	1	0	0	0	2	2	0	0	0	0
0	1	1	2	2	2	0	0	0	0	0	0
0	0	0	2	0	0	0	0	0	0	0	0

0 = No Water Feature
 1 = Water Body
 2 = River

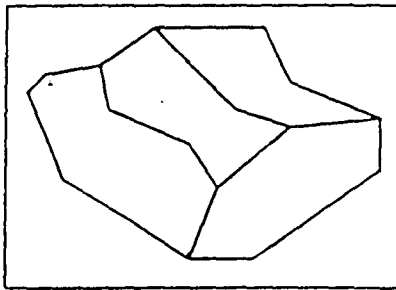
Resulting raster



Points
(Symbols)



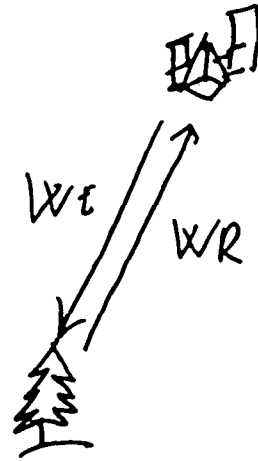
Lines
(Vectors or Open Polygons)



Polygons
(Closed Polygons)

3) SCATTERING, DIELECTRIC (ACTIVE) IN MICROWAVES

$$W_R = A \cdot \left(\frac{\sigma_0}{D^4} \right) \cdot W_E$$



W_R = RETURNED SIGNAL

W_E = EMITTED SIGNAL

D = DISTANCE

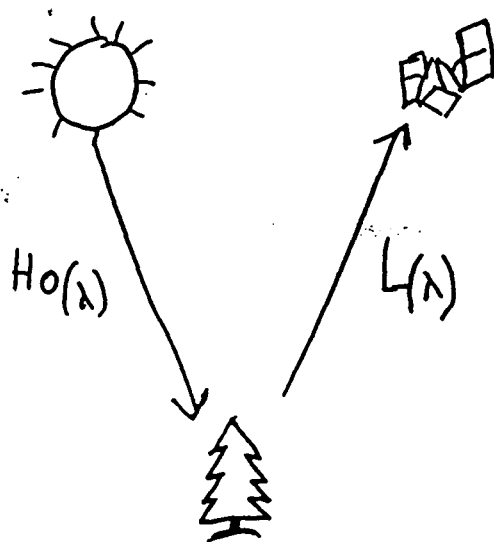
σ_0 = ROUGHNESS / DIELECTRIC

A = SYSTEM CONSTANT

THE VARIOUS DIMENSIONS OF REMOTE SENSING

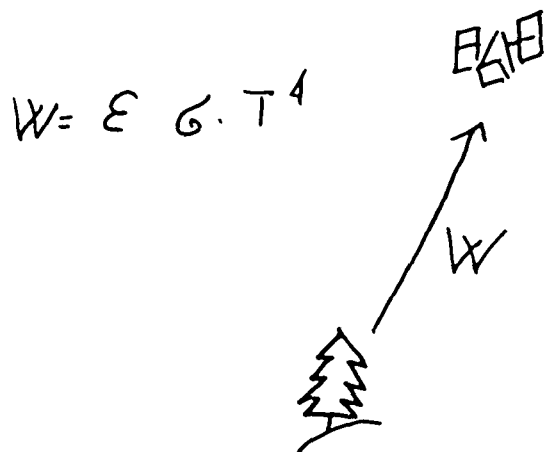
THREE TYPICAL MEASUREMENT TECHNIQUES

1) REFLECTED (PASSIVE) IN VISIBLE AND NEAR IR



$$\text{SPECTRAL REFLECTANCE} = \frac{\text{ENERGY OF WAVELENGTH } \lambda \text{ REFLECTED FROM THE OBJECT}}{\text{ENERGY OF WAVELENGTH } \lambda \text{ INCIDENT UPON THE OBJECT}} \times 100$$

2) EMISSION (PASSIVE) IN THERMAL IR



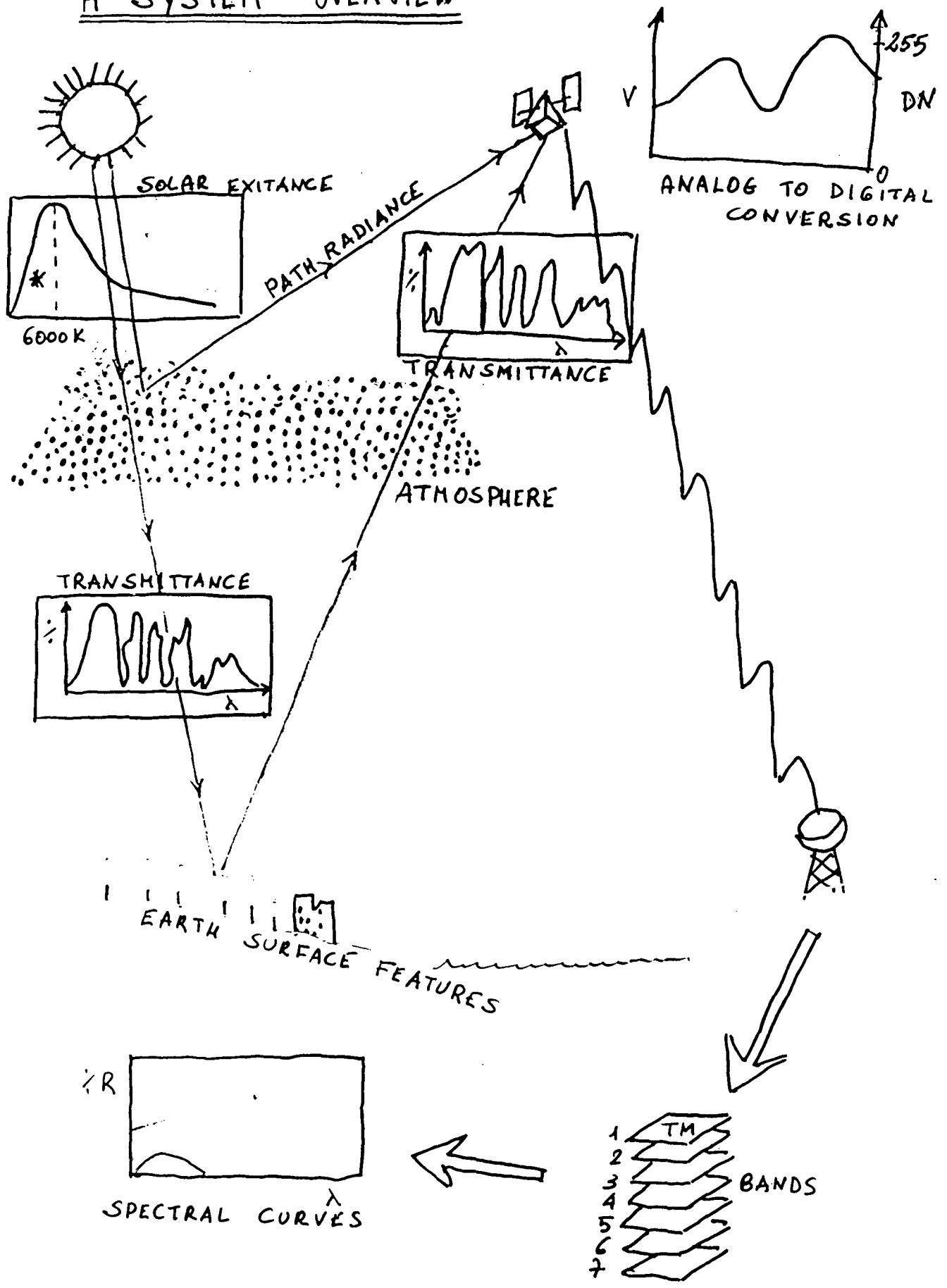
$$W = \epsilon \sigma \cdot T^4$$

W = EXITANCE FROM THE SURFACE OF A MATERIAL

ϵ = EMISSIVITY FACTOR

σ = STEFAN-BOLTZMANN CONSTANT

M SYSTEM OVERVIEW



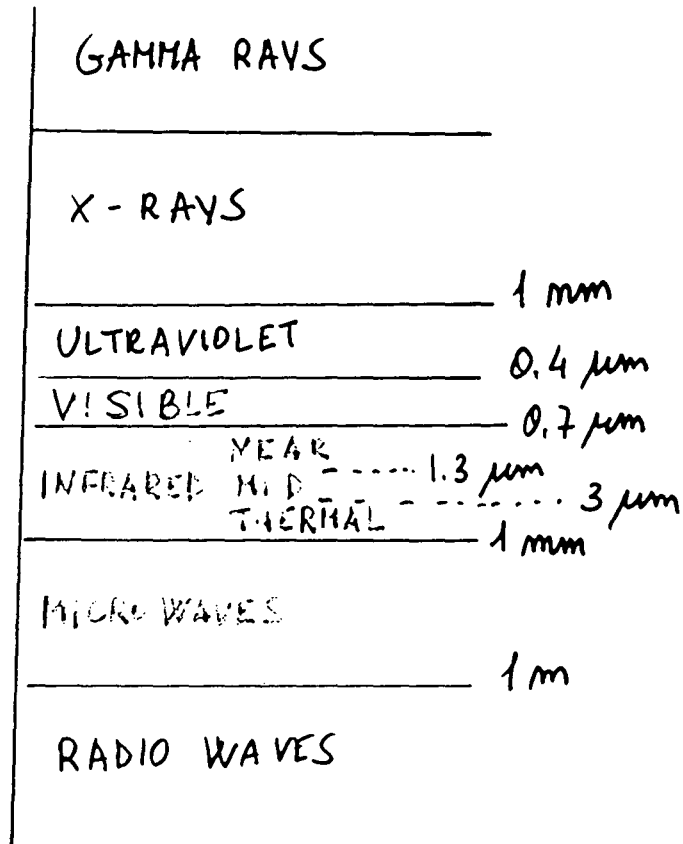
* EXOATMOSPHERIC SOLAR SPECTRUM

REMOTE SENSING → THE SENSOR IS REMOTE
 → THE INFORMATION CARRIER IS ELECTROMAGNETIC RADIATION

BASIC PRINCIPLE OF MULTISPECTRAL REMOTE SENSING:

OBJECT ↔ SHAPE OF REFLECTANCE CURVE

THE ELECTROMAGNETIC SPECTRUM

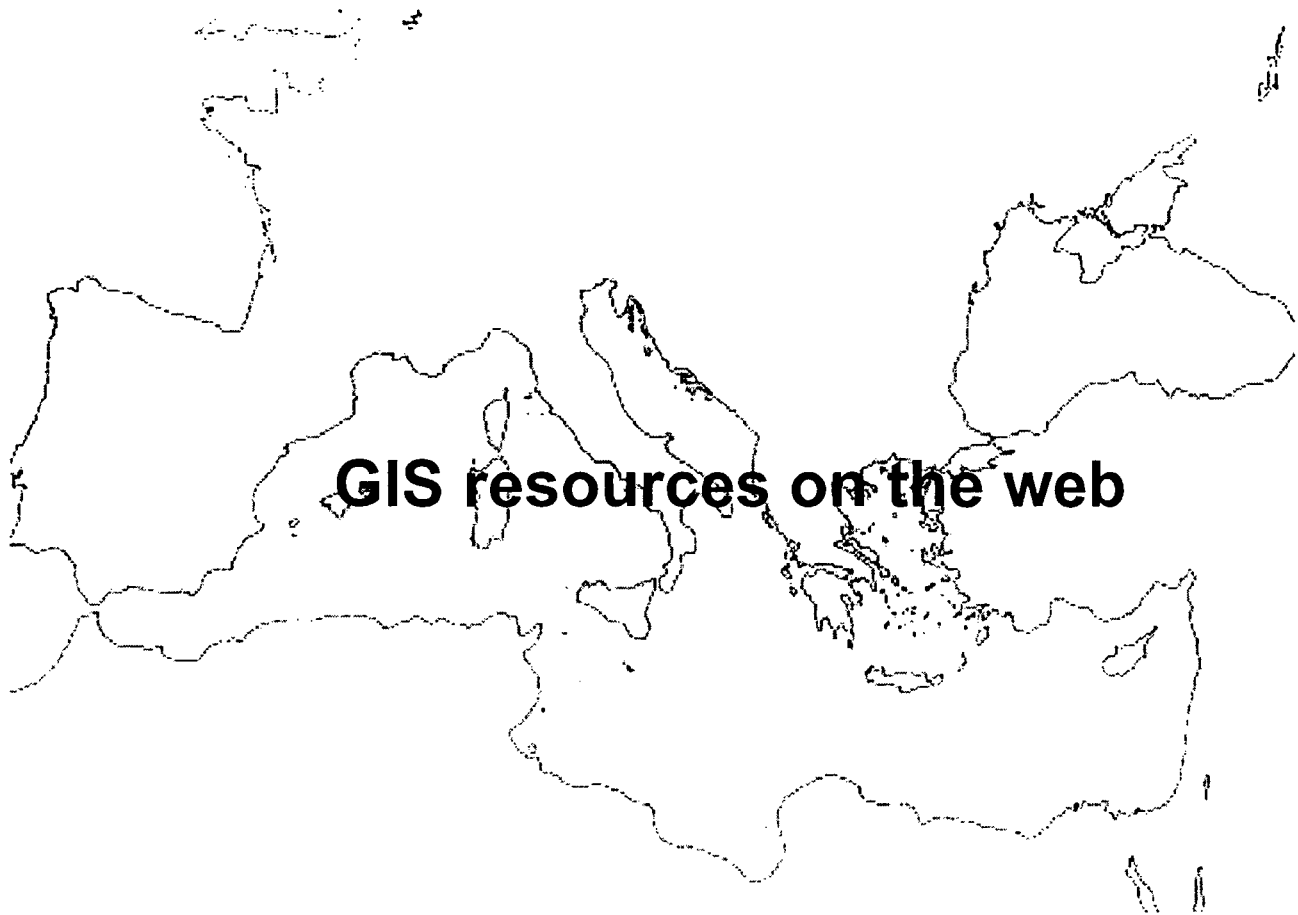


*Practical Exercises on "Satellite Images Acquisition, Data
Analysis, Information Extraction, Correction Techniques
and Image Processing
by A. Altobelli and M. Ghribi*



International Centre for Science and High Technology

AN AUTONOMOUS BODY OF THE UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION



Mounir Ghribi
Environmental Technologies Engineer
Earth, Environmental & Marine Sciences and Technologies
ICS-UNIDO
AREA Science Park, Building L2
Padriciano 99, 34012 Trieste, Italy
Tel. +39-040-9228105, Fax. +39-040-9228136
E-mail: mounir.ghribi@ics.trieste.it

Exercises

Geographic Information Systems (GIS) MAPPING APPLICATIONS ON THE WEB

The URLs below provide information about Geographic Information Systems (GIS) and a variety of examples of how GIS has been applied to communicate information and ideas.

<http://www.nativemaps.org/>

The Aboriginal Mapping Network Web site is a collection of resource pages to help share information throughout the aboriginal mapping community. It is a source for both basic information on cartography, to technical information on GIS mapping.

<http://www.epa.gov/enviro/html/mod/index.html>

U.S. Environmental Protection Agency Maps on Demand-Interactive mapping applications and a storehouse of Environmental data.

<http://www.esri.com/>

Home Page for ESRI, the world's leading provider of GIS software, according to computer industry analysts.

<http://www.esri.com/industries/k-12/k-12form.html>

ArcVoyager Special Edition, available on the CD in the 1998 Geography Awareness Week package, or on the ESRI K12 CD#4. If you don't have ArcView or the other items, you can request the ESRI K12 CD#4 (containing lots of good introductory and instructional tools)

<http://www.esri.com/data/online/esri/wobmselect.html>

ArcVoyager Special Edition includes a basic set of country data. There is a lot of detailed data available for free and easy download.

<http://www.maproom.psu.edu/dcw/>

Pick and choose your area, and you can request to download data, which will arrive as a compressed set of ".e00" files. These require use of ESRI's Import utility (converts .e00 files into ARC/INFO coverage), freely available from

<http://www.esri.com/company/free.html>

<http://www.esri.com/data/online/tiger/index.html>

The full 1995 TIGER data from the U.S. Census Bureau, including streets blocks, streams, and so forth, is waiting to be downloaded, already in a shapefile format. After registering, choose the county, choose the desired layers, and download a ZIP file containing ZIP files you've selected plus readme and license in HTML format. <http://www.esri.com/data/online/tiger/index.html>

<http://www.epa.gov/ostwater/BASINS/>

US Watershed Data. The US Environmental Protection Agency has created a site containing vast quantities of downloadable data, for the conterminous 48 states. Click "Downloads", then, after registering, go to "BASINS GIS Data". Choose the state, pick the watershed, and, for starters, just download the elevation (DEM) and stream (RF3) data, already in compressed shapefiles. <http://www.esri.com/data/online/tiger/index.html>

<http://andes.esri.com/events/seminarlist.cfm>

A listing of seminars and training sessions provided by ESRI, a producer and distributor of GIS software.

<http://alexandria.sdc.ucsb.edu>

The Alexandria Digital Library - Links to significant collections of geospatially referenced information.

<http://mapfinder.nos.noaa.gov>

National Ocean Service Map Finder Home Page - A one-stop World Wide Web service that provides direct Internet access to primary NOS imagery and data holdings.

<http://gis.mit.edu/projects>

Computer resource lab at MIT - Links to Internet GIS research projects in progress.

<http://www.weather.com/weather/maps/index.html>

The Weather Channel - Interactive Weather-mapping site.

<http://plue.sedac.ciesin.org/plue/ddviewer>

Demographic data viewer home page Java-Based interactive census data viewer.

<http://www.fmri.usf.edu/surf>

Florida Marine Research Institute-Interactive mapping application for browsing the conditions and vulnerability of any of the 2,111 watersheds within the continental United States.

<http://www.ramaker.com/gis/pds/pdsmapfrm.htm>

Village of Prairie Due Sac, Wisconsin - Interactive GIS Web site where citizens can access local GIS data online.

<http://crusty.er.usgs.gov:80/mapit>

U.S. Geological Survey Map-It-Form-based map generator uses latitude/longitude coordinates to create local maps.

<http://thoth.sbs.ohio-state.edu/osumap/>

The OSU MAP-for-the-PC is primarily intended for instructional use in colleges and universities, although its enhanced capabilities may also make it useful in other situations (e.g., small planning agencies or in the third world) where professional staff need some introduction to GIS prior to the acquisition and utilization of a larger, commercial GIS.

<http://www.hdm.com/gis3.htm>

Great GIS net sites

<http://www.mrsc.org/planning/gis/gis.htm>

This information on geographic information systems (GIS) was compiled by Carol Shenk, a graduate student in library and information science at the University of Washington and a former MRSC employee.

<http://www.mapsonus.com>

Maps on Us - A map, route and yellow pages service

<http://www.gis.umn.edu/snf/info/brochures/maps.html>

Superior National Forest Map - Interactive Map Server

<http://www.gisca.adelaide.edu.au/cgi-bin/eco/ecogis>

Eco-tourism Interactive GIS- An interactive map design.

<http://www.visa.com>

Visa-ATM Locator-Interactive bank and ATM locator

<http://www.realtor.com>

Realtor.com - Search over one million new and resale homes.

<http://www.co.cabarrus.nc.us>

Cabarrus County - A county government public-access property ownership and tax records database.

<http://www.inforain.org>

Interrain Pacific INFORAIN Web Site-Bioregional Geographic Information Server for the North American coastal rain forest.

http://www.gulasidorna.se/e_gula.html

GulaSidorna/2 English- Sweden's largest online business directory.

<http://icg.fas.harvard.edu/~maps>

Harvard University Map collection - Links to the Massachusetts Electronic Atlas and other Internet GIS resources.

<http://gis.ci.ontario.ca.us/gis>

City of Ontario, California Geographic Information Server - A parcel search and site locator.

<http://www.macavsat.org>

Metropolitan Airports Commission Department of Environment Web site - Web-based airport noise and operations monitoring system at the Minneapolis Metropolitan Airports Commission.

<http://godiva.geoserve.com/forms/godiva.htm>

Godiva Chocolate - Godiva Chocolatier U.S. store locator

<http://www.nursinghomeinfo.com>

Nursing Home INFO-Nationwide Nursing Home Directory. Click on "Find a Nursing Home."

<http://openspace.ci.boulder.co.us/gis/osmap.html>

City of Boulder Open Space Interactive Map - Public Access GIS site established to promote discussion Of open space issues in Boulder, Colorado.

<http://poca.osmre.gov>

West Virginia Division of Environmental Protection-Create customized maps of environmental issues affecting the state of West Virginia.

<http://www.stickmap.com>

Seismic Geophysical Exploration Data from @stickmap.com-Commercial data vendor site.

<http://www.gis.umn.edu/snf/info/brochures/maps.html>

Superior National Forest Map - Interactive Map Server

<http://www.maxwell.com/caltrans>

Southern California Traffic Report - Real-time traffic conditions for Southern California.

<http://www.kennebunk.maine.org/mapserver/home.html>

Town of Kennebunk - Mapserver Index - Links to several interactive street, parcel and other maps.

<http://www.cast.uark.edu/products/MAPPER>

University of Arkansas - Arkansas Interactive Mapper.

<http://www.unh-eos-explorer.sr.unh.edu>

UNH EOS Explorer - Prototype Java application features data from Brazil's Legal Amazon region and contains a total of thirty-seven themes.

<http://www.geoinformatics.com/>

GeoInformatics expresses the vision of a continuing integration of the separate disciplines dealing with spatial information. Therefore, the editorial content of the magazine addresses all links in the spatial data production chain. From acquisition (geodesy, surveying, photogrammetry, remote sensing), to processing (mapping, GIS, database management), presentation and distribution (cartography, reporting, networking).

<http://www.gisdatadepot.com/catalog/>

This is the place to access FREE data from online inventory of more than 2 terabytes of geospatial data.

<http://www.geog.uni-hannover.de/grass/index2.html>

GRASS GIS (Geographic Resources Analysis Support System) home page.

<http://edcdaac.usgs.gov/1KM/comp10d.html>

FTP access to Global AVHRR 10-day composite data.

<http://www.pes.com/pes/demprog.html>

1-Degree DEM File Finder.

<http://www.gis.umn.edu/rsgisinfo/rsgis.html>

All sorts of information regarding remote sensing and geographic information systems (GIS) are provided here as a reference for RSL students and staff.

<http://www.lib.utexas.edu/maps/europe.html>

The screenshot shows a web browser window with the address bar displaying <http://www.lib.utexas.edu/maps/europe.html>. The page header includes the UT Library Online logo and navigation links such as "ABOUT THE LIBRARY", "LIBRARY SERVICES", "FINDING INFORMATION", and "DIGITAL LIBRARY SERVICES". A search bar is present with a "GO" button. The main content area is titled "Perry-Castañeda Library Map Collection" and "Europe Maps". A disclaimer states: "The following maps were produced by the U.S. Central Intelligence Agency, unless otherwise indicated." Below this, a list of map titles and file sizes is provided, including "Europe (Reference Map) 2001 (249K)", "Europe (Reference Map) 2001 (1MB) [pdf format]", and "Europe Historical Maps". A navigation menu on the left lists various geographical regions like Africa, Asia, and Europe. The browser's status bar at the bottom indicates "Internet".

<http://edcdaac.usgs.gov/1KM/comp10d.html>

Land Processes Distributed Active Archive Center

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Your browser
is not
JavaScript-
enabled,
These buttons
will not work.

FTP access to Global AVHRR 10-day composite data



New Notice to Global 1-km AVHRR Data Users

Production of the Global AVHRR composites has been temporarily suspended while funding and new processing techniques are under consideration.

Questions? Please be sure to check the detailed information available from the Global Land 1-KM AVHRR Project web site by clicking [here](#).

Past Notices

In order to better serve our users, the most recent three global 10-day composites will also be made available via FTP at <ftp://edcdaacftp.cr.usgs.gov/pub/avhrr/global>. See the README file in that directory for more information.

Prior to April 15, 1995 the data *provided via this interface* did not conform to IGBP processing standards. The primary difference is in the scaling method applied to byte and integer data.

● 10-day composite period:

May 1-10, 1992	▲
May 11-20, 1992	▾
May 21-30, 1992	
June 1-10, 1992	▼

- The original data resolution is 1-km. Subsampled data is also available. Select the desired resolution, in kilometers.

Resolution:

- You can select the complete global image (default) or a geographic subset. Enter the coordinates of the desired subset. Coordinates can be in either decimal degrees or degrees and minutes (see [examples](#)). The actual area retrieved will be slightly larger.

Select the complete global image or a geographic subset Northernmost Latitude:

Westernmost Longitude:	<input type="text"/>
Southernmost Latitude:	<input type="text"/>
Easternmost Longitude:	<input type="text"/>

- Each band must be retrieved separately. Select the desired band.

Band:

For band 10 the date index files are available.

- The data can be compressed with the standard Unix compress program or the [GNU gzip](#)

Compress

- Byte Order

●

1-KM Homepage

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[Disclaimers, Statements and Accessibility](#)

URL: <http://edcdaac.usgs.gov/1KM/comp10d.html>

Technical Contact: edc@eos.nasa.gov

Last Update: Wednesday, 29-May-2002 10:36:12 CDT

[Download Adobe Acrobat Reader](#)



Convert Pathfinder Global Goode's Homolosine image to Lat/Long.

File Display GIS Analysis Modeling Image Processing Reformat Data Entry Window List Help

Data Paths

Idrisi File Explorer
Metadata
Collection Editor

Run Macro

Shortcut On

User Preferences

Import

Export

Idrisi File Conversion (16/32)

Exit

General Conversion Tools

Government / Data Provider Formats

Desktop Publishing Formats

Software-Specific Formats

Landsat ETM (NLAPS/FAST/GeoTIFF/MDF)

SPOT (GeoTIFF/SPOT Scene/GeoSPOT-SPOTView)

GeoTIFF

RADARSAT

GOODE2LL (Goode to Lat/Long)

SDTS

DLG (USGS)

CTG (USGS)

DEMIDRIS (USGS)

GOODE2LL - Goode to lat/long

Input file:

Output file:

Resolution:

Northern latitude:

Western longitude:

Southern latitude:


Eastern longitude:

OK Cancel Help

*GIS Applications Using MultiSpec for Unsupervised and
Supervised Classification of LANDSAT Images
by A. Altobelli*

MultiSpec©

MultiSpec is being developed at Purdue University, West Lafayette, IN, by David Landgrebe and Larry Biehl from the School of Electrical and Computer Engineering and LARS. It results from an on-going multiyear research effort which is intended to define robust and fundamentally based technology for analyzing multispectral and hyperspectral image data, and to transfer this technology to the user community in as rapid a manner as possible. The results of the research are implemented into MultiSpec and made available to the user community via the download pages. MultiSpec© with its documentation© is distributed without charge.

<u>Description</u>	Latest Releases	<u>Other Information</u>
<u>What's New to 5.20.02</u>	Macintosh: 5-20-2002 Windows: 5-20 -2002 Note: <u>Documentation Revised</u> on 5-01 	Download <u>Macintosh</u> <u>Windows</u>
<u>Other Sites</u>	<u>Documentation</u>	<u>LARS</u>

These pages look best when viewed using Netscape 1.1 or later. Mosaic 2.0 or later and Internet Explorer can also be used.

Updated: May 20, 2002. Please send questions or comments to Larry Biehl, webwriter.

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MultiSpec©

A Multispectral Image Data Analysis System

MultiSpec (©Purdue Research Foundation) is a processing system for interactively analyzing Earth observational multispectral image data such as that produced by the Landsat series of Earth satellites and hyperspectral image data from current and future airborne and spaceborne systems such as AVIRIS. The primary objective of MultiSpec is as an aid to export the results of our research into devising good methods for analyzing such hyperspectral image data. It has also found significant use in other applications such as multiband medical imagery and in K-12 and university level educational activities. There are currently in excess of several thousand known, registered users.

MultiSpec satisfies the following design goals:

- The implementation should be on a readily available computer platform which has adequate processing power, but is financially within the reach of any Earth science researcher (i.e., computer platforms < \$2000).
- The system should be easy to learn and easy to use, even for the infrequent user, using the most modern of software environments.
- The system should provide for easy import of data in a variety of formats, and easy export of results, both in thematic map and in tabular form.

The work of building the current capability began by implementing an upgraded version of the LARSYS multispectral image data analysis system. LARSYS is one of the first remote sensing multispectral data processing systems, originally created during the 1960's. A number of systems in government laboratories, university research labs, and several commercially offered products are descendants of LARSYS. The current system, called MultiSpec, has been implemented for the Apple Macintosh and PC-Windows personal workstations. A reasonably current generation, middle range machine and color display, would have a street price of less than \$2000 at the present time. Such a system is capable of classifying in excess of 6 million pixel-classes per minute using 12 bands and a Gaussian maximum likelihood scheme. Given the current cost/performance trends, even more cost-effective systems are likely to be available in the future.

New capabilities are continually added to MultiSpec as they emerge from our research on hyperspectral processing. Capabilities of the current version of MultiSpec include the following.

- **Import data** in either Binary or ASCII format with or without a header, and in Band Interleaved by Line (BIL), Band Sequential (BSQ), or Band Interleaved by Sample (BIS) formats. The data may have either one or two bytes per data value, and may have 4, to 16 bits per data value. In the case of two bytes per sample, the two bytes may be in either order.
- **Display multispectral images** in a variety of B/W or color formats using linear or equal area gray scales; display (internally generated) thematic images also in B/W or color, with an ability to control the color used for each theme. ArcView Shape Files may be overlain on the images.
- **Histogram** data for use in determining the gray scale regime for a display or for listing and graphing.
- **Reformat** the data file in a number of ways, e.g., by adding a standard header, changing from any one of the three interleave formats to either of the other two, editing out channels, combining files, adding or modifying channel descriptions, mosaicing data sets, changing the geometry of a data set, and a number of other changes.

- **Create new channels** of data from existing channels. The new channels may be the result of a principal components or feature extraction transformation of the existing ones, or they may result from the ratio of a linear combination of existing bands divided by a different linear combination of bands.
- **Cluster data** using either a single pass or an iterative (isodata) clustering algorithm. Save the results for display as a thematic map. Cluster statistics can also be saved as class statistics. Use of clustering followed by ECHO spectral/spatial classification provides an effective multivariate scene segmentation scheme.
- **Define classes** via designating rectangular or polygonal training fields or mask image files, compute field and class statistics, and define test fields for use in evaluating classification results quantitatively. A feature called "Enhance Statistics" also allows one to improve the extent to which the defined class statistics fit the composite of all data in the data set. A covariance estimation scheme (LOOC) can optimize that estimate for small training sets.
- **Determine the best spectral features** to use for a given classification using (a) searching for the best subset of features using any of five statistical distance measures, (b) a method based directly upon decision boundaries defined by training samples, or (c) a second method based directly upon the discriminant functions. Also included are methods especially designed to search for narrow spectral features such as spectroscopic characteristics, and for use of projection pursuit as a means of further improving the features extracted.
- **Classify** a designated area in the data file. Six different classification algorithms are available: use of minimum distance to means, correlation classifier (SAM), matched filter (CEM), Fisher linear discriminant, the Gaussian maximum likelihood pixel scheme, or the ECHO spectral/spatial classifier. Save the results for display as a thematic map, with or without training and test fields being shown. Apply a threshold to a classification, and generate a probability/threshold map showing the degree of membership of each pixel to the class to which it was assigned.
- **List classification results** of training or test areas in tabular form on a per field, per class, or groups of classes basis.
- Show a graph of the spectral values of a currently selected pixel or the mean \pm s for a selected area. Show scatter diagrams of data from pairs of bands and ellipses of concentration for training sets and selected areas. Show a graph of the histograms of the class or field data values used for training. Show the coordinates of a currently selected area.
- Show a **color presentation** of the **correlation matrix** for a field or class as a visualization tool especially for hyperspectral data.
- Several additional **utility functions** including listing out a subset of the data e.g., for use externally, conducting principal component analysis, etc.
- **Transfer** intermediate or final **results**, be they text, B/W image or color image, to other application programs such as word processors, spreadsheet, or graphics program by copying and pasting or by saving and then opening the saved file within another application.

The MultiSpec implementation is carried out in such a way that the primary limit on the number of lines or columns of the data, the number of spectral bands, etc., are those determined by the available disk and memory space. Taken together, these capabilities provide a state-of-the-art capability to analyze moderate and high dimensional multispectral data sets of practical size. All versions, along with a 170+ page document listing its capabilities in more detail and providing tutorial exercises in its use, is available, along with substantial additional documentation, via the World Wide Web.

| [MultiSpec](#) | [Description](#) | [Other Information](#) | [What's New](#) | [Download Mac, Win](#) | [Documentation](#) |

Introduction to Multivariate Data Analysis
by E. Feoli

Introduction to Multivariate Data Analysis

by
Enrico Feoli

Draft for ICS-UNIDO Training Course on "Image Processing and Remote Sensing for Monitoring Industrial Development in Coastal Areas"

Iglesias-Cagliari, Italy, 4-8 June 2002

Multivariate data analysis deals with matrices of data of different nature. The matrices contain descriptions of objects, at the same time or in different times, by variables that can be measured in different scales. Data matrices generate multidimensional spaces in which the row and column vectors find their mutual position. In order to represent the multidimensional space it is useful to standardize and/or normalise the variables and the objects.

Some basic formulas:

$$\text{Translation} \quad x_i = x - x_{\min} \quad (0.1)$$

$$\text{Centering} \quad x_i = x - \bar{x} \quad (0.2)$$

$$\text{Relative centering} \quad x_i = \frac{x - \bar{x}}{\sqrt{n-1}} \quad (0.3)$$

$$\text{Standardisation} \quad z = x_i = \frac{x - \bar{x}}{\sqrt{\frac{\sum (x - \bar{x})^2}{n}}} \quad (0.4)$$

$$\text{Standardisation with max} \quad x_i = \frac{x}{x_{\max}} \quad (0.5)$$

$$\text{Standardization and translation} \quad x_i = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \quad (0.6)$$

$$\text{Normalization} \quad x_i = \frac{x}{\sqrt{\sum x_i^2}} \quad (0.7)$$

$$\text{Normalization of centred variables} \quad x_i = \frac{x - \bar{x}}{\sqrt{\sum (x - \bar{x})^2}} \quad (0.8)$$

$$\text{Standardization by total} \quad x_i = \frac{x}{\sum x} \quad (0.9)$$

Double centering $x_i = x - \bar{x}_r - \bar{x}_c + \bar{x}$ (0.10)

Deviation from expectation $x_i = x - \frac{\sum x_r \sum x_c}{\sum \sum x}$ (0.11)

norma_y $= \sqrt{x_{1j}^2 + x_{2j}^2 + \dots + x_{kj}^2} = \sqrt{\sum_{i=1}^k x_{ij}^2}$ (0.12)

An example of a data matrix

	1	2	3	4
<i>ph</i>	6.8	5.9	7.5	7.1
<i>A (m)</i>	1200	1000	950	1150
<i>T (C°)</i>	18	21	22	19

Transformation parameters

	<i>x</i> _{min}	<i>x</i> _{max}	\bar{x}	<i>s</i>
<i>ph</i>	5.9	7.5	6.83	.68
<i>A (m)</i>	950	1200	1075	119
<i>T (C°)</i>	18	22	20	11.83

Transformation by Eq. (0.5)

	1	2	3	4
<i>ph</i>	.907	.787	1.00	.947
<i>A (m)</i>	1.00	.833	.792	.958
<i>T (C°)</i>	.818	.955	1.00	.864

Transformation by Eq. (0.6)

	1	2	3	4
<i>ph</i>	.563	.000	1.00	.750
<i>A (m)</i>	1.00	.200	.000	.800
<i>T (C°)</i>	.000	.750	1.00	.750

Transformation by Eq. (0.4)

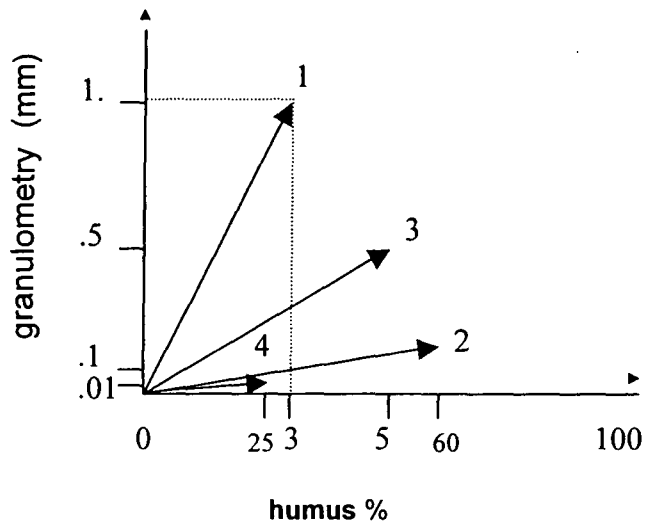
	1	2	3	4
<i>ph</i>	-.037	-1.36	.993	.404
<i>A (m)</i>	1.05	-.630	-1.05	.630
<i>T (C°)</i>	-1.10	.548	1.10	-.548

Transformation by Eq. (0.8)

	1	2	3	4
<i>ph</i>	.496	.431	.547	.518
<i>A (m)</i>	.556	.463	.440	.532
<i>T (C°)</i>	.449	.523	.548	.474

An example of another data matrix

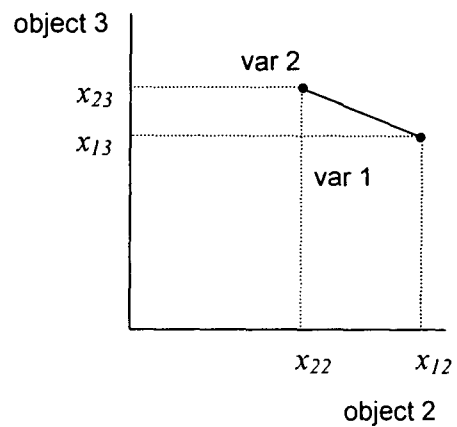
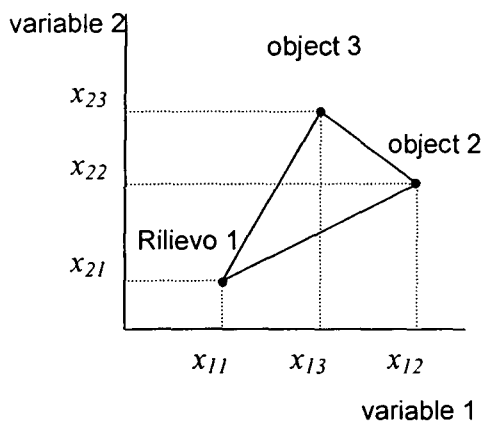
	1	2	3	4
<i>Humus (peso %)</i>	30	60	50	25
<i>Granulometry (mm)</i>	1	0.1	0.5	0.01
<i>ph</i>	6.5	7.7	8.1	7.3
<i>Potassium (p.m.)</i>	52	102	78	120



DUALITY OF THE MULTIDIMENSIONAL SPACE:

Modality Q

Modality R



The mutual position of the vectors in the multidimensional space can be defined by the resemblance functions. They are scalars that are functions of the values of the variables in the objects.

The application of resemblance functions to the data matrices gives origin to RESEMBLANCE Matrices:

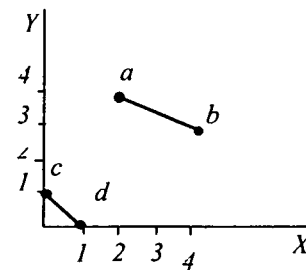
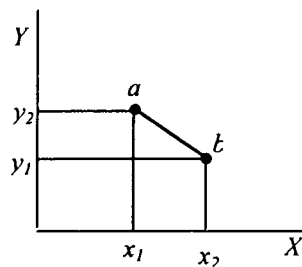
A symmetric matrix

	1	2	3	...	n
1	s_{11}	s_{12}	s_{13}	...	s_{1n}
2	s_{21}	s_{22}	s_{23}	s_{ji}	s_{2n}
3	s_{31}	s_{32}	s_{33}	...	s_{3n}
...	...	s_{ij}
n	s_{n1}	s_{n2}	s_{n3}	...	s_{nn}

DISTANCES :

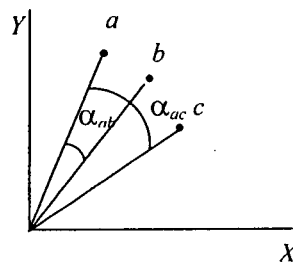
$$D_{euclidea(a,b)} = \sqrt{\sum_{i=1}^m (x_{ia} - x_{ib})^2} \quad (0.13)$$

$$D_{corda(a,b)} = \sqrt{2 \left(1 - \frac{\sum_{i=1}^m x_{ia} x_{ib}}{\sqrt{\sum_{i=1}^m x_{ia}^2} \sqrt{\sum_{i=1}^m x_{ib}^2}} \right)} \quad (0.14)$$

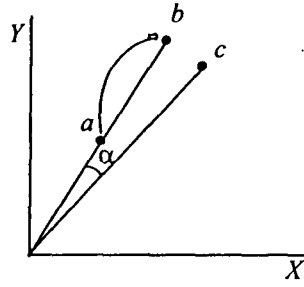


Scalar products:

$$S_{PS(a,b)} = \sqrt{\sum_{i=1}^m x_{ia}^2} \sqrt{\sum_{i=1}^m x_{ib}^2} \cos \alpha \quad (0.15)$$



$$\cos \alpha = \frac{\sum_{i=1}^m x_{ia} x_{ib}}{\sqrt{\sum_{i=1}^m x_{ia}^2} \sqrt{\sum_{i=1}^m x_{ib}^2}}$$



$$S_{PS(a,b)} = \frac{\sum_{i=1}^m x_{ia} x_{ib}}{\max(\sum_{i=1}^m x_{ia}^2, \sum_{i=1}^m x_{ib}^2)} \quad (0.16)$$

$$S_{SR(a,b)} = \frac{\sum_{i=1}^m x_{ia} x_{ib}}{\sum_{i=1}^m x_{ia}^2 + \sum_{i=1}^m x_{ib}^2 - \sum_{i=1}^m x_{ia} x_{ib}} \quad (0.17)$$

$$r_{i,h} = \frac{\sum_{j=1}^n (x_{ij} - \bar{x}_i)(x_{hj} - \bar{x}_h)}{\sqrt{\sum_{j=1}^n (x_{ij} - \bar{x}_i)^2} \sqrt{\sum_{j=1}^n (x_{hj} - \bar{x}_h)^2}} \quad (0.18)$$

$$r_{i,h} = \frac{n \sum_{j=1}^n x_{ij} x_{hj} - \sum_{j=1}^n x_{ij} \sum_{j=1}^n x_{hj}}{\sqrt{n \sum_{j=1}^n x_{ij}^2 - (\sum_{j=1}^n x_{ij})^2} \sqrt{n \sum_{j=1}^n x_{hj}^2 - (\sum_{j=1}^n x_{hj})^2}} \quad (0.19)$$

$$S_{i,h} = \frac{\sum_{j=1}^n (x_{ij} - \bar{x}_i)(x_{hj} - \bar{x}_h)}{n-1} \quad (0.20)$$

RELATIONSHIP BETWEEN DISTANCE AND SCALAR PRODUCT:

$$D^2_{(a,b)} = \sum x_{ia}^2 + \sum x_{ib}^2 - 2 \sum x_{ia} x_{ib} \quad (0.21)$$

BINARY VARIABLES:

		2		
		+	-	
1	+	a	b	a+b
	-	c	d	c+d
		a+c	b+d	n

$$S_{Jaccard} = \frac{a}{a+b+c} \quad (0.22)$$

$$S_{Sorensen} = \frac{2a}{2a+b+c} \quad (0.23)$$

$$S_{Ochiai} = \frac{a}{\sqrt{(a+b)(a+c)}} \quad (0.24)$$

Euclidean distance for binary data:

$$D_{euclidean} = \sqrt{b+c} \quad (0.25)$$

Cord distance for binary data (0.24):

$$D_{corda} = \sqrt{2 \left(1 - \frac{a}{\sqrt{(a+b)(a+c)}} \right)} \quad (0.26)$$

Correlation coefficient:

$$r = phi = \frac{ad - bc}{\sqrt{(a+b)(a+c)(b+d)(c+d)}} \quad (0.27)$$

r is related to χ^2 :

$$r = \sqrt{\frac{\chi^2}{n}} \quad (0.28)$$

Simple matching" (Sokal & Michener),

$$S_{SM} = \frac{a+d}{n} \quad (0.29)$$

Yule's index:

$$S_{Yule} = \frac{ad - bc}{ad + bc} \quad (0.30)$$

Gower' index for mixed data::

$$S_{Gower(a,b)} = \frac{\sum_{i=1}^m w_{iab} S_{iab}}{\sum_{i=1}^m w_{iab}} \quad (0.31)$$

$S_{i(a,b)}$ has values between 0 and 1. For nominal data $S_{i(a,b)}=1$ if the objects agree for character i , $S_{i(a,b)}=0$ if they disagree, for continuous data:

$$S_{i(a,b)} = 1 - \frac{|x_{ia} - x_{ib}|}{R} \quad (0.32)$$

R is $x_{max} - x_{min}$.

Transformation of similarity to dist:

$$D = 1 - S \quad (0.33)$$

$$D = - \log S \quad (0.34)$$

$$D = 1 / (1 + S) \quad (0.35)$$

Examples of calculus:

a data table

	1	2	3	4	media
<i>Specie A</i>	10	5	15	20	12.5
<i>Specie B</i>	12	20	0	0	8
<i>Specie C</i>	0	10	7	15	8

Euclidean distance [eq. (0.13)]:

$$D_{euclidean(1,2)} = \sqrt{(10-5)^2 + (12-20)^2 + (0-10)^2} = 13.75$$

Cord distance [eq. (0.14)]:

$$D_{\text{corda}(1,2)} = \sqrt{2 \left(1 - \frac{10 \times 5 + 12 \times 20 + 0 \times 10}{\sqrt{(10^2 + 12^2 + 0^2) \times (5^2 + 20^2 + 10^2)}} \right)} =$$

$$= \sqrt{2 \left(1 - \frac{50 + 240}{\sqrt{(100 + 144) \times (25 + 400 + 100)}} \right)} = \sqrt{2 \left(1 - \frac{290}{\sqrt{128100}} \right)} = \sqrt{2(1 - 0.81)} = 0.616$$

Scalar product:

$$S_{\text{PS}(1,2)} = 10 \times 5 + 12 \times 20 + 0 \times 10 = 290$$

$$\cos \alpha_{1,2} = \frac{10 \times 5 + 12 \times 20 + 0 \times 10}{\sqrt{(10^2 + 12^2 + 0^2)} \sqrt{(5^2 + 20^2 + 10^2)}} = \frac{290}{\sqrt{244} \sqrt{525}} = \frac{290}{357.91} = 0.810$$

$$S_{\text{PS}(1,2)} = \frac{10 \times 5 + 12 \times 20 + 0 \times 10}{\max[(10^2 + 12^2 + 0^2), (5^2 + 20^2 + 10^2)]} = \frac{290}{\max(244, 525)} = \frac{290}{525} = 0.552$$

Similarity ratio [eq. (0.17)]:

$$S_{\text{SR}(1,2)} = \frac{10 \times 5 + 12 \times 20 + 0 \times 10}{(10^2 + 12^2 + 0^2) + (5^2 + 20^2 + 10^2) - (10 \times 5 + 12 \times 20 + 0 \times 10)} = \frac{290}{244 + 525 - 290} = 0.605$$

Coefficiente di correlazione [eq. (0.18)]:

$$r_{A,B} = \frac{(10 - 12.5)(12 - 8) + \dots + (20 - 12.5)(0 - 8)}{\sqrt{(10 - 12.5)^2 + \dots + (20 - 12.5)^2} \sqrt{(12 - 8)^2 + \dots + (0 - 8)^2}} =$$

$$= \frac{(-2.5)4 + (-7.5)12 + 2.5(-8) + 7.5(-8)}{\sqrt{6.25 + .56.25 + 6.25 + 56.25} \sqrt{16 + 144 + 64 + 64}} = \frac{-10 - 90 - 20 - 60}{\sqrt{125} \sqrt{288}} = \frac{-180}{189.74} = -0.949$$

Binary data

An example of binary data

	1	2	3	4	5	6
<i>Specie A</i>	1	1	0	0	0	1
<i>Specie B</i>	1	0	1	0	1	1
<i>Specie C</i>	1	1	1	1	0	0
<i>Specie D</i>	1	0	1	1	1	1
<i>Specie E</i>	0	1	0	1	0	1

Contingency table between objects

		Object 5		
		presente	assente	
Object 3	presente	a=2	b=1	a+b=3
	assente	c=0	d=2	c+d=2
		a+c=2	b+d=3	n=5

Contingency table between variables

		Species D		
		presente	assente	
Species B	presente	a=4	b=0	a+b=4
	assente	c=1	d=1	c+d=2
		a+c=5	b+d=1	n=6

Index of Jaccard [eq. (0.21)]:

$$S_{\text{Jaccard}(3,5)} = \frac{2}{2+1+0} = 0.667$$

Index of Sorensen [eq. (0.22)]:

$$S_{\text{Sorensen}(3,5)} = \frac{2 \times 2}{2 \times 2 + 1 + 0} = 0.8$$

Index of Ochiai [eq. (0.23)]:

$$S_{\text{Ochiai}(3,5)} = \frac{2}{\sqrt{3 \times 2}} = 0.816$$

Euclidean distance [eq. (0.24)]:

$$D_{\text{euclidean}(3,5)} = \sqrt{1+0} = 1$$

Cord distance [eq. (0.25)]:

$$D_{\text{corda}(3,5)} = \sqrt{2 \left(1 - \frac{2}{\sqrt{(3 \times 2)}} \right)} = \sqrt{2(1 - 0.816)} = 0.606$$

Variables association:

Correlation coefficient [eq. (0.26)]:

$$r_{B,D} = \frac{4 \times 1 - 0 \times 1}{\sqrt{4 \times 5 \times 1 \times 2}} = 0.632$$

"Simple matching" [eq. (0.28)]:

$$S_{\text{SM}(B,D)} = \frac{4+1}{6} = 0.833$$

Index of Yule [eq. (0.29)]:

$$S_{\text{Yule}(B,D)} = \frac{4 \times 1 - 0 \times 1}{4 \times 1 + 0 \times 1} = 1$$

Mixed data:

Example of a mixed data matrix

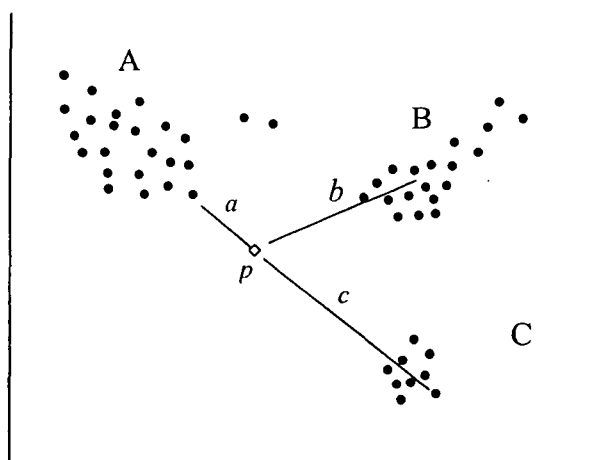
	1	2	3	4
A	+	+	-	-
B	L	V	/	L
C	r	r	W	W
D (cm)	5	7	3	4
E	10	7	5	7

$$S_{\text{Gower}(1,2)} = \frac{1+0+1+[1-(7-5)/(7-3)]+[1-(10-7)/(10-5)]}{1+1+1+1+1} = 0.58$$

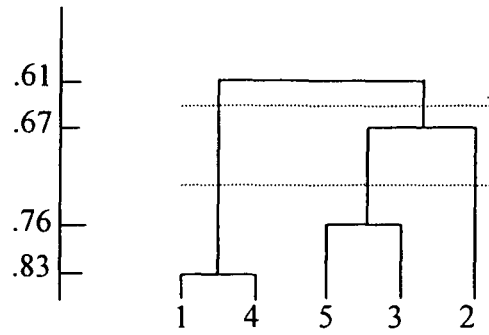
$$S_{\text{Gower}(3,4)} = \frac{1+0+1+[1-(4-3)/(7-3)]+[1-(7-5)/(10-5)]}{1+0+1+1+1} = 0.8375$$

$$S_{\text{Gower}(2,3)} = \frac{0+0+0+[1-(7-3)/(7-3)]+[1-(7-5)/(10-5)]}{1+0+1+1+1} = 0.15$$

Classification algorithms:



a = single linkage, b = average linkage, c = complete linkage



Example of dendrogram

Cross validation

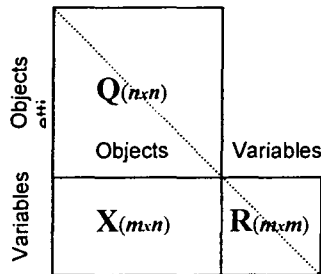
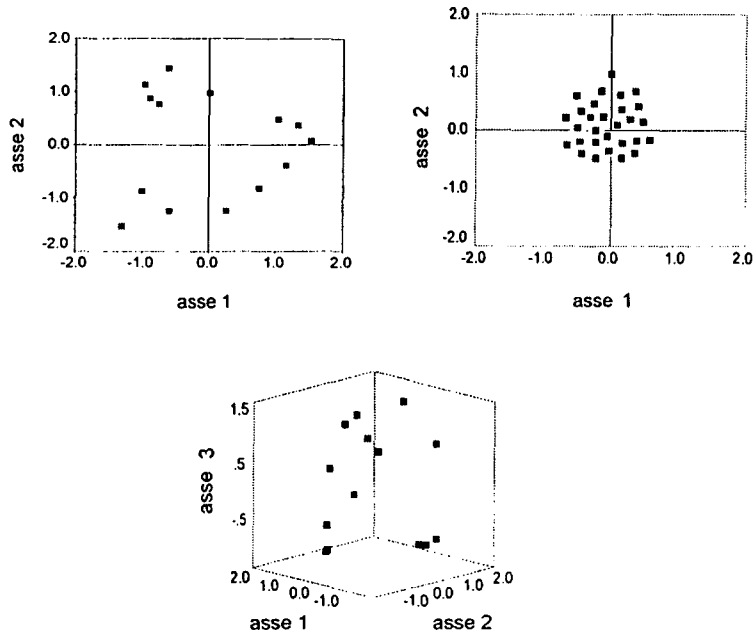
Objects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
I classif.	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3
II classif.	1	1	1	1	1	3	3	3	3	3	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2

Cross table of the two classificatios. Index of Cramer=0.59.

		II			
		1	2	3	
I	1	5	0	5	10
	2	3	10	0	13
	3	0	2	0	2
		8	12	5	25

ORDINATION

Objects and variables are disposed according to axes:



Given a matrix X two symmetric matrices may be obtained

$$(SB_i - \lambda_i B_i) = 0 \quad (0.1)$$

$$(S - \lambda_i I_p) B_i = 0 \quad (0.2)$$

The scalars λ_i are eigenvalues of S , while the vector B_i associated to λ_i is called eigenvector.

$$(S - \lambda_i I_p) B_i = 0$$

$$\begin{pmatrix} s_{11} - \lambda & s_{12} & \dots & s_{1p} \\ s_{21} & s_{22} - \lambda & \dots & s_{2p} \\ \dots & \dots & \dots & \dots \\ s_{p1} & s_{p2} & \dots & s_{pp} - \lambda \end{pmatrix} \begin{pmatrix} b_1 \\ b_2 \\ \dots \\ b_p \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ \dots \\ 0 \end{pmatrix}$$

or:

$$\left\{ \begin{array}{l} (s_{11}-\lambda)b_1 + s_{12}b_2 + \dots + s_{1p}b_p = 0 \\ s_{21}b_1 + (s_{22}-\lambda)b_2 + \dots + s_{2p}b_p = 0 \\ \dots + \dots + \dots + \dots = 0 \\ s_{p1}b_1 + s_{p2}b_2 + \dots + (s_{pp}-\lambda)b_p = 0 \end{array} \right. \quad (0.3)$$

$$|S - \lambda_i I| = 0 \quad (0.4)$$

$$\begin{vmatrix} s_{11} - \lambda & s_{12} & \dots & s_{1p} \\ s_{21} & s_{22} - \lambda & \dots & s_{2p} \\ \dots & \dots & \dots & \dots \\ s_{p1} & s_{p2} & \dots & s_{pp} - \lambda \end{vmatrix} = 0 \quad (0.5)$$

The solution of the polynomial of p degree gives the λ_i . The efficiency of the solution is:

$$\lambda_i^{\%} = \frac{\lambda_i}{\sum \lambda_i} 100 \quad (0.6)$$

Example

Given the matrix

		Objects					Aver:
		1	2	3	4	5	
Vari.	1	1	2	5	0	5	2.6
	2	3	4	5	2	3	3.4

Let's compute the covariance between variables 1 and 2 and the respective variances:

$$s_{1,2} = \frac{(1-2.6)(3-3.4) + \dots + (5-2.6)(3-3.4)}{4} = 1.7$$

:

$$S_{mxm} = \begin{pmatrix} 5.3 & 1.7 \\ 1.7 & 1.3 \end{pmatrix}$$

Let's compute now the eigenvalues:

$$|S - \lambda_i I_2| = \begin{vmatrix} 5.3 - \lambda & 1.7 \\ 1.7 & 1.3 - \lambda \end{vmatrix} = 0$$

$$(5.3 - \lambda) \times (1.3 - \lambda) - 1.7 \times 1.7 = 0$$

$$\lambda^2 - 6.6\lambda + 4 = 0$$

$$\lambda_1 = 3.3 + \frac{\sqrt{3.3^2 - 4}}{1} = 5.925$$

$$\lambda_2 = 3.3 - \frac{\sqrt{3.3^2 - 4}}{1} = 0.675$$

$$\sum \lambda_i = \lambda_1 + \lambda_2 = 5.925 + 0.675 = 6.6$$

$$\sum s_{ii} = s_{11} + s_{22} = 5.3 + 1.3 = 6.6$$

$$\lambda_1^{\%} = (5.925 / 6.6) \times 100 = 89.77$$

$$\lambda_2^{\%} = (0.675 / 6.6) \times 100 = 10.23$$

Now let's calculate the eigenvectors

$$\begin{cases} (5.3 - 5.925)b_1 + 1.7b_2 = 0 \\ 1.7b_1 + (1.3 - 5.925)b_2 = 0 \end{cases}$$

$$\begin{cases} 0.625b_1 + 1.7b_2 = 0 \\ -1.7b_1 + 4.625b_2 = 0 \end{cases}$$

let $b_1=1$, then:

$$\begin{cases} 1.7b_2 = 0.625 \\ 4.625b_2 = 1.7 \end{cases}$$

b_2 is 0.3676.

By assigning arbitrary values the elements of eigenvectors remain always proportional, in fact if we put $b_1=3$, $b_2=3 \times (0.3676)=1.1028$, and if $b_2=1$, $b_1=1.7/0.625=2.72$; in all the cases the $b_1/b_2 = 2.72$ and $b_2/b_1 = 0.3676$. To avoid arbitrary values the eigenvectors are normalised:

$$b_1 = \frac{1}{\sqrt{1^2 + 0.3676^2}} = 0.9386$$

$$b_2 = \frac{0.3676}{\sqrt{1^2 + 0.3676^2}} = 0.345$$

Summarising:

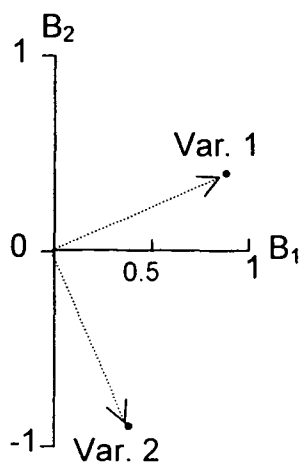
$$B_1 = \begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} 1 \\ 0.3676 \end{pmatrix} \text{ normalising} = \begin{pmatrix} 0.939 \\ 0.345 \end{pmatrix}$$

With the similar procedure we find the second eigenvector B_2 corresponding to the second eigenvalue λ_2 :

$$B_2 = \begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} 1 \\ -2.722 \end{pmatrix} \text{ normalising} = \begin{pmatrix} 0.345 \\ -0.939 \end{pmatrix}$$

Table of eigenvalues and eigenvectors of the example.

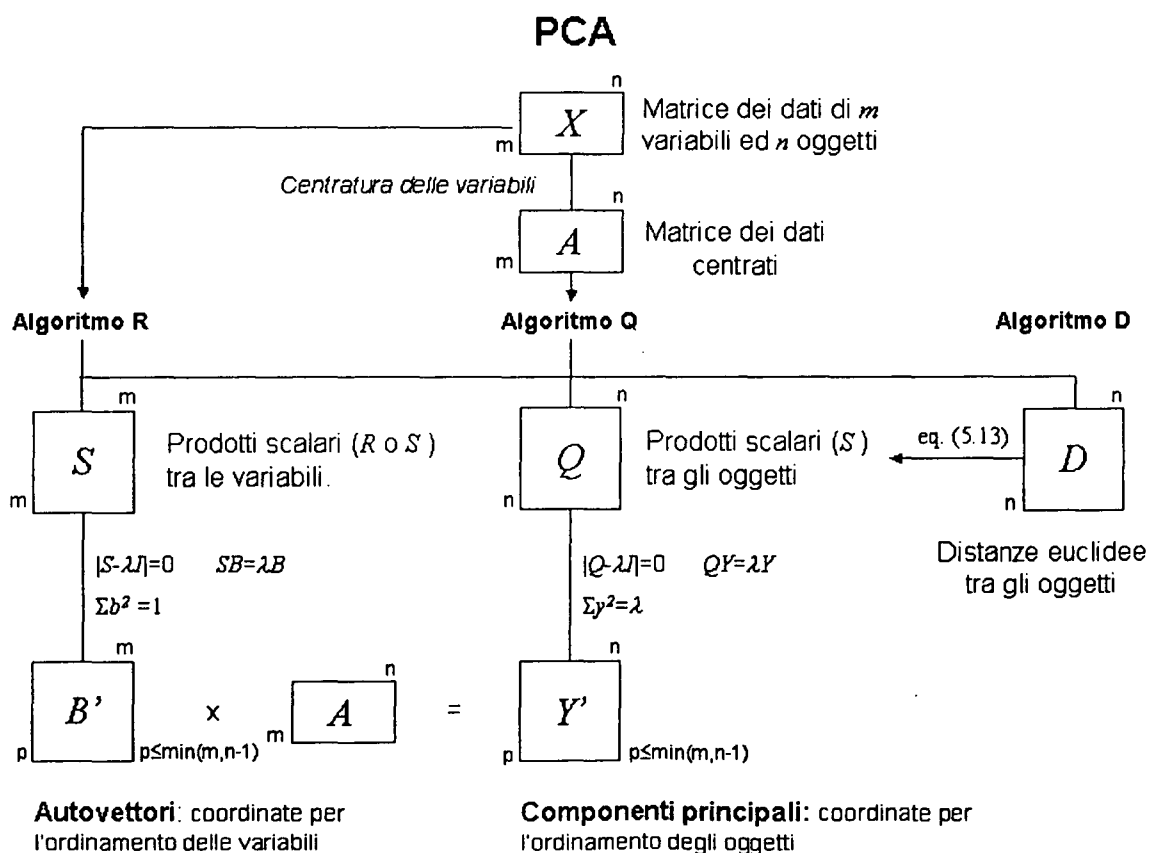
	Eigenval.	Variance %	Eigenvector	1	2
λ_1	5.925	89.77	B_1	0.939	0.345
λ_2	0.675	10.23	B_2	0.345	-0.939

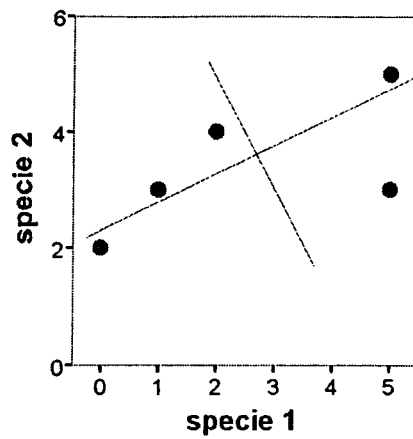


Scattergram of the two variables

Principal Component Analysis

(PCA) R , Q and D described by Ortoci (1978).





Scattergram of the 5 points and PCA

$$Y_i = B_i' X \quad \text{for } i=1, m \quad (0.7)$$

$$y_{ij} = \sum_{h=1}^m b_{hi} x_{hj} = b_{1i} x_{1j} + b_{2i} x_{2j} + \dots + b_{mi} x_{mj} \quad (0.8)$$

Algorithm R

$$(S - \lambda_i I_p) B_i = 0 \quad (0.9)$$

$$B_i' B_i = \sum_{j=1}^m b_{ij}^2 = b_{i1}^2 + b_{i2}^2 + \dots + b_{im}^2 = 1 \quad (0.10)$$

The components are $(Y_i = B_i' A)$,

The elements in A are:

$$(0.11)$$

F_j is the standardisation factor.

Table of F that allows different solutions of PCA automatically normalised to the square root of eigenvalues.

F_i	Eq.	Indice di S	Eq.
1		Centred scalar product	
$\sqrt{n-1}$	(0.12)	Covariance	(0.20)
$\sqrt{\sum(x_{ij} - \bar{x})^2}$	(0.13)	Correlation coefficient	(0.18)

Anyway it is always possible to standardize the components by:

$$y_j = \frac{y_j}{\sqrt{\sum y_i^2}} \sqrt{\lambda_i} \quad (0.14)$$

The correlation coefficient r_{hi} between the original h -th variable and the i -th component is:

$$r_{hi} = \frac{\sqrt{\lambda_i} b_{hi}}{\sqrt{s_{hh}}} \quad (0.15)$$

where b_{hi} is the coefficient of the i -th component of the variable h -th, λ_i is the i -th eigenvalue and s_{hh} is the diagonal value of S of variable h -th. If S is a correlation matrix (R), s_{hh} is 1 and:

$$r_{hi} = \sqrt{\lambda_i} b_{hi} \quad (0.16)$$

D and Q algorithms

d_{ij} of matrix D is transformed Q by:

$$q_{ij} = -0.5d_{ij}^2 + 0.5(D_i + D_j - D_i) \quad (0.17)$$

where:

$$D_i = \frac{\sum_{i=1}^n d_i^2}{n} \quad D_j = \frac{\sum_{j=1}^n d_j^2}{n} \quad D_i = \frac{\sum_{i=1}^n \sum_{j=1}^n d_{ij}^2}{n^2}$$

R-Components

Data matrix

		objects											
		1	2	3	4	5	1	2	3	4	5	$\sum y_{ij}^2$	
Variabl.	1	-0.8	-0.3	1.2	-1.3	1.2	Y_1	-0.82	-0.18	1.4	-1.46	1.06	5.925
	2	-0.2	0.3	0.8	0.7	-0.2	Y_2	-0.09	-0.38	-0.34	0.21	.6	0.675

$$Y = B'A = \begin{pmatrix} 0.939 & 0.345 \\ 0.345 & -0.939 \end{pmatrix} \times \begin{pmatrix} -0.8 & -0.3 & 1.2 & -1.3 & 1.2 \\ -0.2 & 0.3 & 0.8 & 0.7 & -0.2 \end{pmatrix} = \begin{pmatrix} -0.82 & -0.18 & 1.4 & -1.46 & 1.06 \\ -0.09 & -0.38 & -0.34 & 0.21 & 0.6 \end{pmatrix}$$

The detailed calculations:

$$y_{11} = (0.939)(-0.8) + (0.345)(-0.2) = -0.819$$

$$y_{12} = (0.939)(-0.3) + (0.345)(0.3) = -0.178$$

.....

$$y_{21} = (0.345)(-0.8) + (-0.939)(-0.2) = -0.088$$

$$y_{22} = (0.345)(-0.3) + (-0.939)(0.3) = -0.385$$

To normalize the components of eigenvectors to $\sqrt{\lambda}$ (0.14):

$$b_{11} = \frac{0.939 \times \sqrt{5.925}}{1} = 2.2857$$

$$b_{21} = \frac{0.345 \times \sqrt{0.675}}{1} = 0.2834$$

$$b_{12} = \frac{0.345 \times \sqrt{5.925}}{1} = 0.8398$$

$$b_{22} = \frac{-0.939 \times \sqrt{0.675}}{1} = -0.7715$$

Correlations with components are:

$$r_{11} = \frac{0.939 \times \sqrt{5.925}}{\sqrt{5.3}} = 0.991$$

$$r_{12} = \frac{0.345 \times \sqrt{0.675}}{\sqrt{5.3}} = 0.123$$

$$r_{21} = \frac{0.345 \times \sqrt{5.925}}{\sqrt{1.3}} = 0.737$$

$$r_{22} = \frac{-0.937 \times \sqrt{0.675}}{\sqrt{1.3}} = -0.675$$

Q matrix of scalar product of objects in the data matrix

	1	2	3	4	5
1	.68	.18	-1.12	1.18	-.92
2	.18	.18	-.12	.18	-.42
3	-1.12	-.12	2.08	-2.12	1.28
4	1.18	.18	-2.12	2.18	-1.42
5	-.92	-.42	1.28	-1.42	1.48

D matrix

	1	2	3	4	5
1	0	.707	2.24	.707	2
2	.707	0	1.58	1.41	1.58
3	2.24	1.58	0	2.92	1
4	.707	1.41	2.92	0	2.55
5	2	1.58	1	2.55	0

$$D_1 = \frac{(0^2 + 0.707^2 + 2.236^2 + 0.707^2 + 2^2)}{5} = 2$$

$$D_2 = \frac{(0.707^2 + 0^2 + 1.58^2 + 1.41^2 + 1.58^2)}{5} = 1.5$$

$$D_i = \frac{(0^2 + 0.707^2 + 2.236^2 + \dots + 2.539^2 + 0^2)}{5^2} = 2.64$$

to obtain q values by (0.17) :

$$q_{11} = -0.5 \times 0^2 + 0.5(2 + 2 - 2.64) = 0.68$$

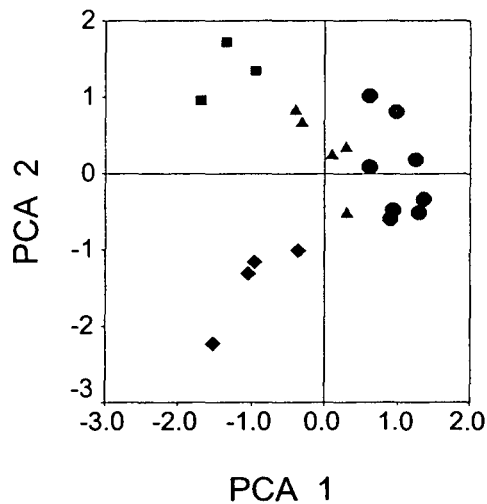
$$q_{12} = -0.5 \times 0.707^2 + 0.5(2 + 1.5 - 2.64) = 0.18$$

$$q_{22} = -0.5 \times 0^2 + 0.5(1.5 + 1.5 - 2.64) = 0.18$$

RESULTS of Q and D PCA:

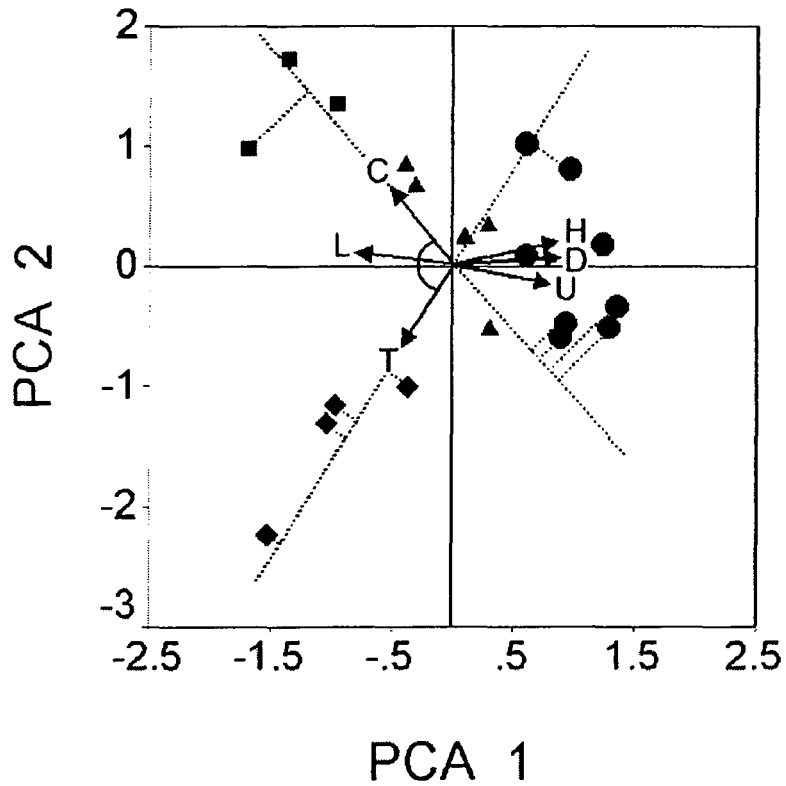
Eigenvalues		Eigenvectors					
		1	2	3	4	5	
1	5.9249	B_1	-0.337	-0.073	.576	-.601	.434
2	0.6751	B_2	-.107	-.469	-.410	.254	.732
PCA							
		1	2	3	4	5	
	Y_1	-0.820	-0.178	1.402	-1.462	1.057	
	Y_2	-0.088	-0.385	-0.337	0.209	.602	

BIPLOT:



Euclidean biplot eigenvector normalized to 1 and components to the square root of the corresponding eigenvalue.

Covariance biplot eivenvecotors normalized to the square root of eigenvalues and components normalized to 1.



Correlation between variables and components

	PCA I	PCA II
U	.979	.139
H	.977	.070
G	.934	-.173
L	-.948	.107
T	-.522	-.787
C	-.409	.860

*GIS, Remote Sensing and Spatial Decision-Support Systems
(SDSS) for Coastal Zone Management
by M. Ghribi*

Spatial Decision-Support Systems for Integrated Coastal Area Management

Enrico Feoli¹ and Mounir Ghribi²
Area of Earth, Environmental and Marine Sciences and Technologies
International Centre for Science and High Technology
United Nations Industrial Development Organization, ICS-UNIDO
AREA Science Park, Padriciano 99, Trieste, Italy

¹Tel.: +39-040-9228109 Fax: 0039-040-9228136
E-mail: enrico.feoli@ics.trieste.it

²Tel.: +39-040-9228105 Fax: +39-040-9228136
E-mail: mounir.ghribi@ics.trieste.it

Abstract

This paper presents an overview of methods and tools of spatial data analysis useful for establishing computer based decision-support systems (DSS) for an integrated coastal area management (ICAM). The spatial DSS refer to those systems based on the use of GIS (Geographic Information Systems) technology. The integration of those information technologies provides an important source of methods that are usefully incorporated in a decision-support system and make use of geographically referenced information.

After a brief introduction on the peculiarities and unique management problems of coastal areas, the paper first describes the meaning and role of Decision Analysis (DA) and then the major tools and components for constructing a Spatial Decision-support Systems (SDSS) for Coastal Zone Management (CZM).

Key words: Methods, tools, spatial data analysis, DSS, GIS, integration information technologies, SDSS, CZM

1. Introduction

This paper is based on ICS-UNIDO experience in developing advanced information technologies for integrated coastal area management.

According to Fedra and Feoli (1998), the definition of coastal zone for the purpose of this paper is "the area, on both sides of the actual land-water interface, where the influences of land and water on each other are still a determining factor - climatically, physiographically, ecologically, or economically".

The characteristics of the coastal zone are therefore related both to the landside and the waterside.

In the first case the coastal zone shows a high population density with a large number of urban conglomerations, and as consequence, in most countries, a fast population growth.

In the water side there are fisheries and aquaculture, exploiting a generally highly productive ecosystem, that is not only productive in its own right, but plays an important role in the aquatic ecology as a breeding and nursing ground for many commercially important fish species. Very specific, valuable and vulnerable typical coastal ecosystem includes estuaries, salt marshes, mangroves, sea grass meadows and coral reefs.

The environmental problems of coastal zones are both anthropological and natural. Concerning the anthropological problems, Vallega (1993) offers a systematic classification of coastal zone uses. They include: seaports, shipping (carriers, routes, navigational aides), sea pipeline, cables, air transportation, biological resources, hydrocarbons, metallurgic resources, renewable energy, defence, recreation, waste disposal, research, archaeology, environmental preservation and protection. These are further subdivided into a total of 250 kinds of uses, all focussing more or less on the aquatic part of the coastal zone. A similar classification can be found for land-based activities, with urban development, industry (ranging from mining to manufacturing) and commerce, agriculture and recreation as the main elements in Ajjour and Drabih (1997). All these uses are causes of pollution and environmental changes.

The set of natural problems is related to the exposure of the terrestrial zone to marine impacts, and on other terrestrial impacts on the coastal waters. These include such phenomena as storms, tides, and surges, the occasional tsunami, and the prospect of sea level rise, coastal erosion, salt water intrusion in rivers and aquifers caused by (often man made) low-flow and excessive withdrawal.

Since all of the activities in coastal zone compete, for space, for resources, and for the waste absorption capacity of the coastal ecosystems, it follows that there is an obvious and often dominating spatial aspect, which makes coastal zone management a spatial problem.

2. Spatial Decision-Support Systems and Coastal Zone Management

2.1 Definitions

Definitions of decision-support systems range from: "Interactive computer based systems that decision-makers utilize data and models to solve unstructured problems" (Gorry and Morton, 1971) to "Any system that makes some contribution to decision-making" (Sprague and Watson, 1986).

A *decision* is a choice between alternatives. The *alternatives* may represent different courses of action or different hypotheses. Rational human behaviour involves

the evaluation of choice alternatives based on some criteria. A *criterion* is some basis for a decision that can be measured and evaluated. It is the evidence upon which a decision is based. Criteria can be of two kinds: 1) constraints, which serve to limit the alternatives under consideration; and 2) factors that enhance or detract from the suitability of specific alternative for the activity under consideration.

A *decision rule* is the procedure by which criteria are combined to arrive at a particular decision and by which evaluated data can be compared and acted upon. Decision rules are structured in the context of a specific objective, for example, to determine which area is suitable for a given activity. To meet a specific objective, it is frequently the case that several criteria will need to be evaluated (Multi-Criteria Evaluation).

The *decision-support field* is the "Development of approaches for applying information systems technology to increase the effectiveness of decision-makers in situations where the computer can support and enhance human judgement in the performance of tasks that have elements which cannot be specified in advance" (Sol, 1983).

2.2 Decision Process

According to Sol (1983), the decision-support field is a development of approaches for applying information systems technology to increase the effectiveness of decision-making, in particular in situations where PC-aided support can enhance human judgement in the performance of tasks that have elements, which cannot be specified in advance.

Decision-support systems must provide integration of information and feedback loops to support investigation in the quest for scientific discovery. The intangible factors in the decision-making process may be accounted for through information supplied and choices made by a decision-maker who operates the SDSS interactively or through an analyst. The above suggest that spatial decision-support systems may be developed as general-purpose tools for decision-making (Goodchild and Densham, 1990).

2.3 Spatial Decision-Support Systems (SDSS)

The SDSS have been extensively and adequately covered in literature (Craig and David, 1991, Densham, 1991, Goodchild and Densham, 1990, Moon, 1992, NCGIA, 1992). According to Densham (1991) and Geoffrion (1983), Decision-support Systems has six characteristics:

- Explicit design to solve problems;
- Powerful and easy-to-handle user interface;
- Ability to flexibly combine analytical models with data;
- Ability to explore the space analysis solution by building alternatives;

- Capability of supporting a variety of decision-making styles; and
- Allowing interactive and recursive problem solving.

The distinguishing capabilities and functions of SDSS are to provide mechanisms for the input of spatial data:

- Allow representation of the spatial relations and structures;
- Include the analytical techniques of spatial and geographical analysis;
- Provide output in a variety of spatial forms, including maps.

Notwithstanding in the specialized literature (Holsapple and Whinston, 1991) DSS is mainly viewed as a mathematical technique or a set of techniques for decision-making by optimising something under some specific constraints, we consider SDSS in its broad meaning as an information system that can be used to support decisions at spatial level. By SDSS we mean the integration of all the methods and tools that can be useful to build up a decision-support system for spatially related problems. The system needs the following components: GIS, data analysis and image processing, modelling and expert systems, simulation and optimisation, multi-criteria decision analysis and a suitable user interface. These components are discussed mainly following Fedra and Feoli (1998). The relationships between them are explained in Figure 1.

The ultimate objective of a computer-based SDSS for coastal zone resources management is, or should be, to improve planning and decision-making processes by providing useful and scientifically sound information to the actors involved in these processes, including public officials, planners and scientists, and the general public.

3. The Components of SDSS

3.1 Geographic Information System (GIS)

A Geographic Information System (GIS) is designed as a computer tool to efficiently capture, store, update, manipulate, analyse, and display all forms of geographically referenced information (e.g., IDRISI, 1997). A GIS typically links data from different sets, using geo-referencing, i.e., spatial co-ordinates, as a common key between the data set. The power of a GIS stems from 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 GIS on the market, commercial and public domain GIS and they are all different each other. They may answer more or less easily and completely to the following typical questions depending on how they have been designed:

- *Spatial identification*: find locations where certain conditions are satisfied, including the logical (Boolean) or arithmetic combination of multiple layers (overlay analysis);
- *Trends*: find the differences within an area over time or along spatial dimensions;
- *Patterns*: find correspondences between distributions of different attributes; calculate similarity between patches, fractal index, indices of fragmentation, and so on;
- *Modelling*: answer "What if" questions.

However, to answer more complex questions one need to combine (static) geographic data layers with dynamic and spatially distributed models. A progress toward this integration may be achieved by the object-oriented approach (Malczewski 1999). This can be considered as an alternative or a complement of the layer databases approach common in most of the GIS.

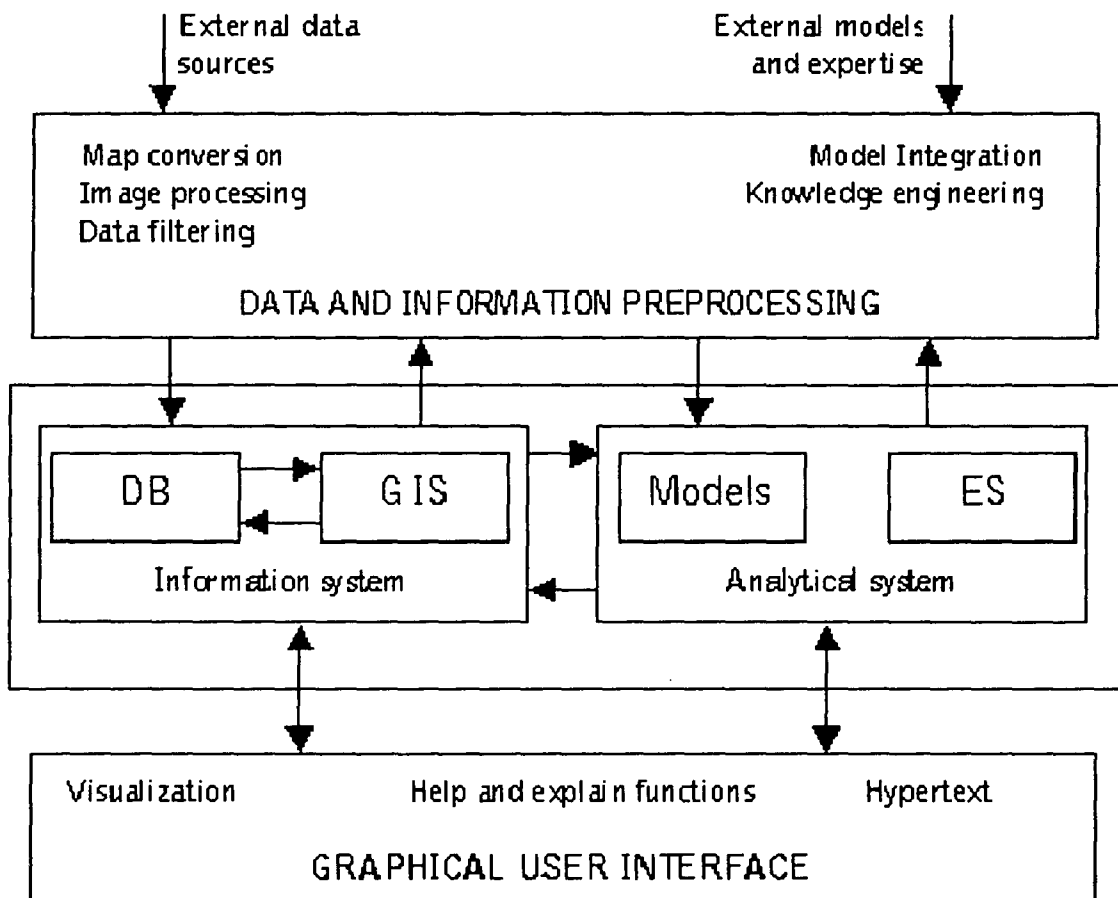


Figure 1: Graphical use interface

3.2 Data Analysis and Image Processing

The maps obtained by GIS may be seen not only as cartographic representations of a classification of the landscape at the end of an analytical process, but mainly as data sources for the landscape spatial pattern analysis through the many different indices of the landscape structure such as shape, fragmentation, fractal, diversity, etc. (Turner, 1989). Many GIS have internal data analysis and image processing systems that can calculate different pattern indices. Some GIS such as IDRISI, ILWIS, GRASS (see Malczewski, 1999 for a comparison between different GIS) have the possibility to treat remote sensing data (image processing) coming from LANDSAT, SPOT, NOAA, etc.; however there are not GIS including data analytical and statistical techniques that are able to classify specific Operational Geographic Units (OGU). The classification may be obtained by applying the clustering algorithms or other multivariate techniques. Feoli and Zuccarello (1996) treat this aspect. GIS can manage different OGUs to obtain maps. In GISs, raster or vector, the OGUs are stored in databasess generally structured according to the relational model. In the databases different characters may describe the OGUs. The probabilistic similarity functions proposed by Goodall (1964) that have been suggested and that have been included in the information system developed in ICS/UNIDO (Feoli 1993) would improve the interpretation by introducing the probabilistic aspect in the prediction. The functions can deal with 6 categories of characters: 1) binary; 2) qualitative, with more than two alternative values; 3) ordinal; 4) only small integer values; 5) quantitative grouped into classes; 6) quantitative not grouped into classes.

3.3 Modelling and Expert Systems

In GIS, the basic concept is one of location, of spatial distribution and relationship; basic elements are spatial objects. In environmental modelling, by contrast, the basic concept is one of state, expressed in terms of numbers, mass, or energy, of interaction and dynamics; the basic elements are "species", which may be biological, chemical and environmental media such as air, water or sediment. The overlap and relationship is apparent, and thus the integration of these two fields of research, technologies, or sets of methods, that is, their paradigms, is an obvious and promising idea (Fedra, 1995).

Simulation and optimisation modelling is a powerful tool of analysis, and forecasting. Modelling of marine systems has a considerable tradition in both physical and biological oceanography. For summary treatments, more recent model comparisons, and some classics in the field see, for example, Riley et al., (1949); Nihoul, (1975); Kremer and Nixon, (1978); Falconer et al., (1989); Fransz et al., (1991).

However, most of these approaches are designed to improve scientific understanding of physical and biological processes, with the notable exception of some of the fisheries models that have obvious management implications. Other

management oriented and model-based studies of marine systems include the RAND Corporation classic on the Oosterschelde or the recent study of the North Sea Management Analysis North Sea (MANS), (Klomp, 1990). Other important recent models for coastal zone management are ECOPATH, ECOSIM and ECOSPACE (Pauly et al., 2000) that are offering a set of tools for evaluating ecosystem impact of fisheries based on modelling the mass balance fluxes in the fish food-webs both in homogeneous and heterogeneous space conditions.

Quantitative numerical models and rule-based, qualitative expert systems provide another example of possible integration. *Expert systems* can be used just as any other model to assign a value to an output variable given a set of input variables; they do this, however, by using rules and logical inference rather than numerical algorithms.

In the context of models, expert systems are often used to help configure models (implementing an experienced modellers know-how to support the less experienced user) and estimate parameters. A number of these "intelligent front end systems" or model advisors have been developed in the environmental domain (Fedra, 1992).

A rule-based approach can also be a substitute for a numerical model, in particular if the processes described are not only in the physical and chemical, but also in the biological and socio-economic domain. An example could be the environmental impact assessment based on a checklist of problems, which can be understood as a diagnostic or classification task. A qualitative label is assigned to potential problems, based on the available data on environment and planned action, and a set of generic rules assessing and grading the likely consequences. And finally, a model can be integrated into the inference chain of an expert system (Fedra, 1992). Recent examples of environmental expert systems are given in Hushon (1990) and Wright et al., (1993).

The flexibility to use, alternatively or conjunctively, both symbolic and numerical methods in one and the same application allows the system to be responsive to the information at hand, and the user's requirements and constraints. This combination and possible substitution of methods of analysis, and the integration of databases, geographical information systems, and hypertext, allows to efficiently exploit whatever information, data and expertise is available in a given problem situation.

The approach is based on a model of human problem-solving that recursively refines and redefines a problem as more information becomes available or certain alternatives are excluded at a screening level. Learning, i.e., adaptive response to the problem situation and the information available, and the ability to modify function and behaviour, as more information becomes available, is a characteristic of intelligent systems.

3.4 Multi-Criteria Evaluation

To meet a specific objective, it is frequently the case that several criteria will need to be evaluated. Such procedures are called Multi-Criteria Evaluations (MCE) (Eastman et al., 1995). Two of the most common procedures for multi-criteria evaluation are weighted linear combination and concordance-discordance analysis (Carver, 1991). Weighted linear combination is very straightforward in a raster GIS. Indeed, it is the derivation of the weights, within the context of the decision objective that provides the major challenge. The weights are developed by providing a series of PAIRWISE comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated (Eastman, 1997). Figure 2 presents a suitability map for industrial site planning and urban settlement in the Tunisian coastal areas.

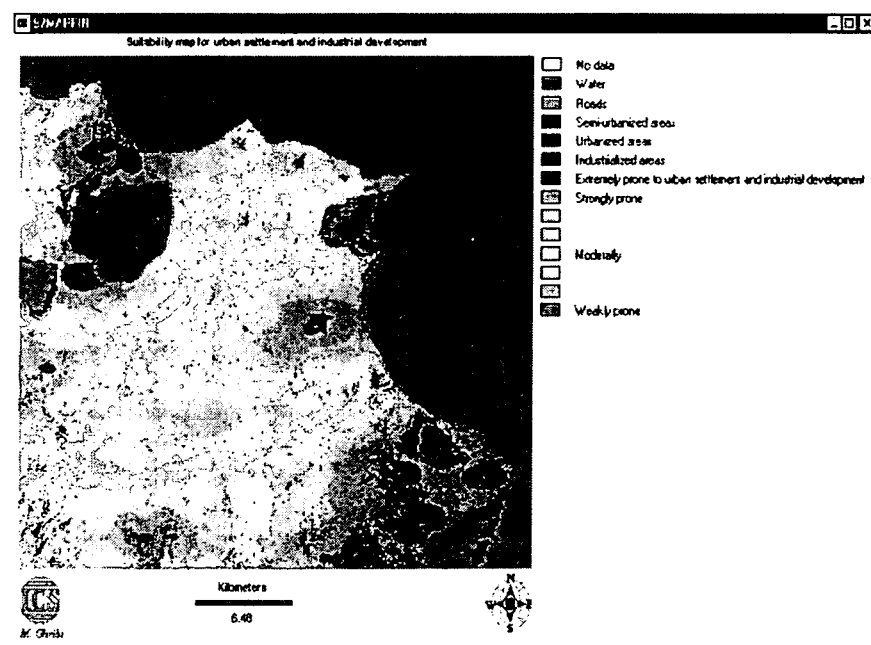


Figure 2: Suitability map

In a Multi-Criteria Evaluation, an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective (Eastman et al., 1995). During the last two decades, further support has emerged for the view that a decision is a multidimensional concept (Nijkamp et al., 1990; Paruccini, 1994). Decisions about the allocation of land typically involve the evaluation of multiple criteria according to several often conflicting-objectives (Eastman et al., 1995). Making-decisions about the allocation of land is one of the most fundamental activities of resource development. With the development of GIS, we now have the opportunity for a more explicitly reasoned process of land use evaluation. However, despite the wide range of analytical tools these systems provide, they are typically weak in the provision of decision-support procedures (Honea et al., 1991).

The advantage of MCE is that it provides a flexible way of dealing with qualitative multi-dimensional environmental effects of decisions (Munda, 1995). Even in the absence of monetary information, the point of departure of any multi-criteria analysis is the generation of a discrete set of alternatives, the formulation of a set of criteria, and the evaluation of an impact of each criterion for every alternative. Janssen (1992) and Munda (1995) provide a comprehensive review of multi-criteria decision-support for environmental management.

Although a variety of techniques exist for the development of weights, one of the most promising would appear to be that of PAIRWISE comparisons, developed by Saaty (1980), in the context of a decision-making process known as the Analytical Hierarchy Process (AHP). In the PAIRWISE comparison method the decision-maker is asked to select the most important of each possible pair effects (Janssen and Van Herwijen, 1992). Subsequently, a comparison must be established in qualitative terms to what extent one effect is more important than the other one (Saaty, 1980) to express the differences of importance.

3.5 Multi-Objective Evaluation

While many decisions we make are prompted by a single objective, it also happens that we need to make decisions that satisfy several objectives. A multi-objective problem is encountered whenever we have two candidate sets (i.e., sets of entries) that share members. These objectives may be complementary or conflicting in nature (Carver, 1991:332).

a) *Complementary Objectives*

With complementary or non-conflicting objectives, land areas may satisfy more than one objective, i.e., an individual can belong to more than one decision set. Desirable areas will thus be those, which serve these objectives together in some specified manner. For example, we might wish to allocate a certain amount of land for combined recreation and wildlife preservation uses. Optimal areas would thus be those that satisfy both of these objectives to the maximum degree possible.

b) *Conflicting Objectives*

With conflicting objectives, the objectives compete for the available land since it can be used for one or the other, but not for both. For example, we may need to resolve the problem of allocating land for timber harvesting and wildlife preservation. Clearly the two cannot coexist. Exactly how they compete and on what basis one will win out over the other will depend upon the nature of the decision rule that is developed.

In case of complementary objectives, multi-objective decisions can often be solved through a hierarchical extension of the multi-criteria evaluation process. For example, we might assign a weight to each of the objectives and use these along with the suitability maps developed for each to combine them into a single suitability map

indicating the degree to which areas meet all of the objectives considered (see Voogd, 1983). However, with conflicting objectives the procedure is more involved.

With conflicting objectives, it is sometimes possible to rank order to objectives and reach a *prioritised* solution (Rosenthal, 1985). In these cases, the needs of higher ranked objectives are satisfied before those of lower ranked objectives are dealt with. However, this is often not possible, and the most common solution to conflicting objectives is the development of a *compromise* solution. Undoubtedly, the most commonly employed techniques for resolving conflicting objectives are those involving optimisation of a choice function such as mathematical programming (Fiering, 1986) or goal programming. In both techniques, the concern is to develop an allocation of the land that maximises or minimises an objective function subject to a series of constraints.

3.6 The User Interface

Analysis in GIS is based on the map paradigm; maps in inherently static objects, and the basic level of analysis are (Boolean) map overlays. Complex relationships, and dynamic processes, may require another layer of tools, namely simulation models, to be integrated with a GIS.

The integration of GIS and environmental models can come in many forms. In the simplest case, two separate systems, the GIS and the model, just exchange files: the model obtains some of its input data from the GIS, and produces some of its output in a format that allows import and further processing and display with the GIS. This seems to be a rather common approach, since it requires little if any software modifications. Only the file formats and the corresponding input and output routines, usually of the model, have to be adapted. Depending on the implementation however, a solution based on files shared between two separate applications, usually with a different user interface, is cumbersome and possibly error prone if it involves a significant amount of manual tasks. Deeper integration provides a common interface and transparent file or information sharing and transfer between the respective components. One possible way is the use of higher level application language or application generators increasingly common as built-in features of commercial GIS packages as the basis of numerous integrated applications. Application generators and modelling capabilities with commercial GIS also offer the possibility of tight integration within the limits of the respective package options.

An alternative is to use an open GIS tool kit that uses a standardised interface, such as GRASS. Modules of the overall GIS system (which really is a set of tools with a standardised pipeline-type flexible coupling) can be included in modelling applications. The X Windows system and a number of interface-building toolkits make this a rather efficient integration strategy. Any integration at this level, however, requires a sufficiently open GIS architecture, that provides the interface and linkages necessary for tight coupling.

Using such predefined tools and components, while efficient for fast prototyping, can also be restrictive: investments in toolkits always carry the temptation to reformulate problems in terms of the available tools rather than the other way round. Another alternative is the use of do-it-yourself tool kits that provide both customised GIS functionality as well as interface components for simulation models. A relatively recent example of integration that draws together GIS, models, spreadsheet, and expert systems in a programmable system is RAISON (Lam and Swayne, 1991).

For having an efficient user interface we need:

- An interactive, menu-driven user interface that guides the user with prompts and explains messages through the application. No command language or special format of interaction is necessary, the computer assists the user in its proper use; help and explain functions can be based on hypertext and possibly include multi-media methods to add video and audio technology to provide tutorial and background information; in other words, they must be easy to use even for the non-specialist.
- Dynamic colour graphics for the model output and a symbolic representation of major problem components that allow easy and immediate understanding of basic patterns and relationships. Rather than emphasising the numerical results, symbolic representations and the visualisation of complex patterns support an intuitive understanding of complex systems behavior; the goal is to translate a model's state variables and outputs into the information requirements of the decision-making process; the coupling to one or several databasess, including geographical information systems, and distributed or remote sources of information in local or wide area networks, that provide necessary input information to the models and the user. The user's choice or definition of a specific scenario can be expressed in an aggregated and symbolic, problem-oriented manner without concern for the technical details of the computer implementation; data on chemical properties of the substances of concern, used in pollution fate and transport models, are one obvious example;
- Embedded Artificial Intelligence (AI) components, such as specific knowledge bases allow user specifications in allowable ranges to be checked and constrained, and ensure the consistency of an interactively defined scenario; as a special case this could also include QSAR methods that can be implemented in a combination of rule-based methods and algorithmic methods;

Interaction is a central feature of any effective man-machine system: a real-time dialogue, including explanation, allows the user to define and explore a problem incrementally in response to immediate answers from the system. Fast and powerful systems with modern processor technology can offer the possibility to simulate dynamic processes with animated output, and they can provide a high degree of responsiveness that is essential to maintain a successful dialogue and direct control over the software.

Visualisation provides the band-width necessary to communicate and understand large amounts of highly structured information, and permits the development of an intuitive understanding of processes and interdependencies, of spatial and temporal patterns, and complex systems in general. Also, many of the problem components in a real-world planning or management situation, such as risk or reliability, are rather abstract: a graphical representation of such concepts makes them tangible objects that can literally be manipulated and understood intuitively.

Intelligence requires software to be knowledgeable not only about its own possibilities and constraints, but also about the application domain and about the user, i.e., the context of its use. Defaults and predefined options in a menu system, sensitivity to context and history of use, built-in estimation methods, learning, or alternative ways of problem specification depending on the user can all be achieved by the integration of expert systems technology in the user interface and in the system itself.

Customisation is based on the direct involvement of the end-user, and the consideration of institutional context and the specifics of the problem domain in systems design and development. It is the users view of the problem and their experience in many aspects of the management and decision-making process that the system is designed to support. This then must be central to a system's implementation to provide the basis for user acceptance and efficient use.

REFERENCES

- Ajjour, M. and Drabih, S., 1997, Strategy for Coastal Zone Planning and Management in Gaza-Palestine, in: Özhan, E. (Ed.), Proceedings of the Third International Conference on the Mediterranean Coastal Environment MEDCOAST 97, 11-14 Nov. 1997, Qawra, Malta
- Carver, S. J., 1991, Integrating Multi-Criteria Evaluation with Geographical Information Systems, *International Journal of Geographical Information Systems*, 5(3), pp. 321-339
- Craig, W. J. and David M. D., 1991, Progress on the Research Agenda: URISA '90, *URISA Journal*, vol. 3, No. 1, Spring 1991, pp. 90-96
- Densham, P. J., 199, Spatial Decision-support Systems, in: Maguire, D. J., Goodchild, M.F. and Rhind, D.W., (Eds), *Geographical Information Systems: Principles and Applications*, vol.1, Langman, London, pp. 403-412
- Eastman, J. R., 199, IDRISI for Windows, Version 2.0, Tutorial Exercises 4.1, Graduate School of Geography, Clark University, Worcester, Massachusetts, U.S.A.
- Eastman, J. R., Jin, W., Kyem, P. A. K. and Toledano, J., 1995, Raster Procedures for Multi-Criteria/Multi-Objective Decisions, *Photogrammetric Engineering & Remote Sensing*, vol. 61, No. 5, May 1995, pp. 539-547
- Falconer, R. A., Goodwin, P. and Matthew, R. G. S. (Eds.), 1989, Hydraulic and Environmental Modeling of Coastal, Estuarine and River Waters, Proceedings of the International Conference held at the University of Bradford, 19-21 Sep. 1989, Gower Technical, Aldershot, UK, p. 694

- Fedra, K., 1992, Marine Systems Analysis and Modeling, Proceedings of the Symposium The Challenge to Marine Biology in a Changing World, 13-18 Sep. 1992, Heloland, Helgoländer wiss. Meeresunters, 49, pp. 617-632
- Fedra, K., 1995, Distributed Models and Embedded GIS: Strategies and Case Studies of Integration, in Goodchild, M. F., Steyart, L. Y., Parks, B. O., Johnston, C., Maidment, D., Crane, M. and Glendinning, S. (Eds.), GIS and Environmental Modeling: Progress and Research Issues, GIS World Books, Fort Collins Co. 1996, pp. 413-417
- Fedra K. and Feoli E., 1998, GIS Technology and Spatial Analysis in Coastal Zone Management, EEZ Technology, ICG publishing Ltd, UK, ISBN/ISSN 1369-5045, 3, pp. 171-179
- Feiring, R. B., 1986, Linear Programming, An Introduction to Quantitative Applications in the Social Sciences, 60
- Feoli, E., 1995, Data Analysis and Data Integration in Coastal Zone Management: the ICS Experience, Public Enterprise 15, pp. 65-73
- Feoli, E. and Zuccarello, V., 1996, Spatial Pattern of Ecological Processes: the Role of Similarity in GIS Applications for Landscape Analysis, in Fisher, M., Scholten H. J. and Unwin D. (Eds.) Spatial Analytical Perspectives on GIS, Taylor & Francis, London, pp. 175-185
- Fransz, H. G., Mommaerts, J. P. and Radach, G., 1991, Ecological Modeling of the North Sea, *Netherlands Journal of Sea Research*, 28(1/2), pp. 67-140
- Geoffrion, A. M., 1983, Can OR/MS Evolve Fast Enough?, *Interfaces*, 13, pp. 10-25
- Goodall, D. W., 1964, A Probabilistic Similarity Index, *Nature*, 203
- Goodchild, M. F. and Densham, P. J., 1990, Spatial Decision-support Systems: Scientific Report for the Specialist Meeting, Technical Report 90-5, National Center for Geographic Information and Analysis
- Gorry, A. and Scott Morton, M. S., 1971, A Frame Work for Information Systems, *Solan Management Review*, 13, pp. 55-77
- Holcomb Research Institute, 1976, Environmental Modeling and Decision-making-The United States Experience, Report by the Holcomb Research Institute, Butler University for the Scientific Committee on Problems of the Environment, Praeger Publishers, p. 152
- Holsapple, C. W. and Whinston, A. B. (Eds.), 1991, Recent Developments in Decision-support Systems, Nato ASI Series
- Honea, R. B., Hake, K. A. and Durfee, R. C., 1991, Incorporating GISs into Decision-support Systems: GIS Applications in Natural Resources, Heit, M. and Shortreid A. (Eds.), GIS World, Inc., Fort Collins, Colorado, U.S.A., in Eastman, et al., 1995, Raster Procedures for Multi-Criteria/Multi-Objective Decisions, *Photogrammetric Engineering & Remote Sensing*, Vol. 61, No. 5, May 1995, pp. 539-547
- Hushon, J. M. (Ed.), 1990, Expert Systems for Environmental Applications, *ACS Symposium Series*, 431, American Chemical Society, Washington, U.S.A.
- IDRISI, 1997, IDRISI for Windows User's Guide, Version 2.0, Clark Labs for Cartographic and Geographic Analysis, Clark University, Worcester, Massachusetts, U.S.A., Jan. 1997
- Janssen, R. and van Herwijnen, M., 1991, Decision-support Applied to Decisions Changing the Use of Agricultural Land, in Multiple Criteria Decision-support, Proceeding of the International Workshop held in Helsinki, Finland, 7-11 Aug. 1989, Korhonen, P., Lewandowski, A. and Wallenius J. (Eds.), Springer Verlag, Berlin, Germany, pp. 293-302
- Klomp, R., 1990, Modeling the Transport and Fate of Toxics in the Southern North Sea, The Science of the Total Environment, Elsevier Science Publishers B. V., Amsterdam, The Netherlands, 97/98, pp. 103-114
- Kremer, J. N. and Nixon, S. W., 1978, A Coastal Marine Ecosystem-Simulation and Analysis, Springer Verlag, Berlin-Heidelberg, Germany, p. 217

- Lam, D. C. L., and Swayne, D. A., 1991, Integrating Database, Spreadsheet, Graphics, GIS, Statistics, Simulation Models and Expert Systems: Experiences with the Raison System on Microcomputers, NATO ASI Series, Springer Verlag, Heidelberg, Germany, vol. G26, pp. 429-459
- Malczewki, J., 1999, GIS and Multicriteria Decision Analysis, Wiley J., New York, U.S.A.
- Nihoul, J. C. J. (Ed.), 1975, Models of Marine Systems, Elsevier Scientific Publishing Company, Amsterdam, The Netherlands, p. 272
- Moon, G., 1992, Capabilities Needed in Spatial Decision-support Systems, GIS/LIS '92, vol.2, pp. 594-600
- Munda, G., 1995, Multi-criteria Evaluation in a Fuzzy Environment, Physica-Verlag, Heidelberg, p. 255
- NCGIA, 1992, A Research Agenda of The National Center for Geographic Information and Analysis, Technical Report, pp. 92-99.
- Nihoul, J. C. J., 1975, Models of Marine Systems, Elsevier Scientific Publishing Company, Amsterdam, The Netherlands, p. 272
- Nijkamp, P., Rietveld, P. and Voogt, H., 1990, Multi-criteria Evaluation in Physical Planning, North-Holland, Amsterdam, The Netherlands
- Paruccini, M., 1994, Applying Multi-criteria Aid for Decision to Environmental Management, Kluwer, Dordrecht, The Netherlands
- Patrono, A., 1997, Introduction to Decision-support Systems, Paper from ICS Training Course on GIS and Water Management for Industrial Activity, Hanoi, Vietnam, 9-18 Jun. 1997
- Pauly, D., Christensen, V. and Walters, C., 2000, Ecopath, Ecosim and Ecospace as Tools for Evaluating Ecosystem Impact of Fisheries, *ICES Journal of Marine Science*, 57, pp. 697-706
- Riley, G. A., Stommel, H., and Bumpus, D. F., 1949, Quantitative Ecology of the Plankton of the Western North Atlantic, *Bull. Bingham Oceanogr. Coll.*, 12, pp. 1-169
- Rosenthal, R. E., 1985, Concepts, Theory and Techniques: Principles of Multi-objective Optimization, *Decision Sciences*, 16 (2), pp. 133-152
- Saaty, T. L., 1980, The Analytical Hierarchy Process, McGraw Hill, New York, U.S.A.
- Sol, H. G., 1983, Processes and Tools for Decision-support: Inferences for Future Developments, in Processes and Tools for Decision-support, Sol, H. G. (Ed.), North Holland, Amsterdam, The Netherlands, pp. 1-6
- Turner, M. G., 1989, Landscape Ecology: the Effect of Pattern on Process, *Ann. Rev. Ecol. Syst.*, 20, pp. 171-197
- Vallega, A., 1993, Mastering Resource Uses and Enhancing the Mediterranean Environment. Methodological Tools, in Management the Mediterranean, Information for Decision-Making, Proceedings of the Workshop, Istituto della Dinamica delle Grandi Masse (ISDGM), 18-20 Nov. 1993, Venice, Italy, pp. 40-45
- Voogd, H., 1983, Multi-Criteria Evaluation for Urban and Regional Planning, PION, London
- Wright, J. R., Wiggins, L. L., Jain, R. K. and Kim, T. J. (Eds.), 1993, Expert Systems in Environmental Planning, Springer, Berlin, Germany

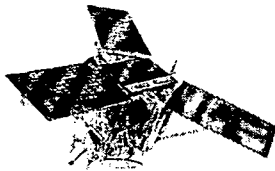


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GIS, remote sensing (RS) and spatial decision support systems (SDSS) for costal zone management (CZM)

Basic Concepts and practical case study in the coastal area of the
Gulf of Tunis, Tunisia

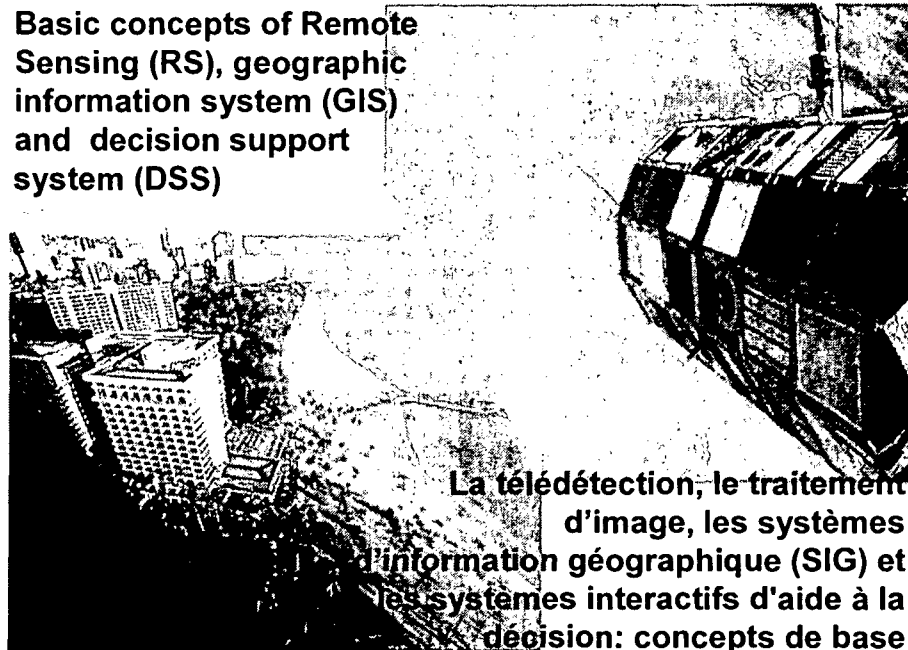


ICS-UNIDO GIS Lab

Mounir GHRIBI
Environmental Technologies Engineer
ICS-UNIDO
AREA Science Park, Padriciano 99
34012 Trieste, Italy
Tel. 0039-040-9228105, Fax. 0039-040-9228136
mounir.ghrabi@ics.trieste.it
<http://www.ics.trieste.it>

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**Basic concepts of Remote
Sensing (RS), geographic
information system (GIS)
and decision support
system (DSS)**



**La télédétection, le traitement
d'image, les systèmes
d'information géographique (SIG) et
les systèmes interactifs d'aide à la
décision: concepts de base**

Remote Sensing (Télédétection):

RS is the science (set of knowledge and techniques) of acquiring information about the earth's surface and its environment without actually being in direct contact with it.

This refers to a process of gathering data by sensing and recording electromagnetic energy, usually by aircraft and satellite sensors.

Examples range from aerial photography to multi-spectral scanning and radar.

Télédétection

La télédétection est la détection d'un objet à distance. Ce terme correspond plus spécifiquement à une technique qui utilise les ondes électromagnétiques (rayonnement) pour obtenir des informations concernant la Terre et l'atmosphère.

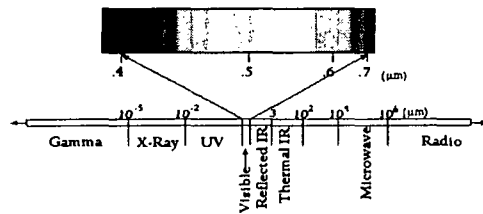
Le spectre électromagnétique comporte plusieurs parties distinctes, dont le rayonnement ultraviolet (UV), la lumière visible, le rayonnement infrarouge (IR) thermique, les rayons X, les micro-ondes, etc...

The Electromagnetic Spectrum:

The electromagnetic spectrum ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves)

Ultraviolet or UV portion of the spectrum has the shortest wavelengths

The visible wavelengths cover a range from approximately 0.4 to 0.7 μm

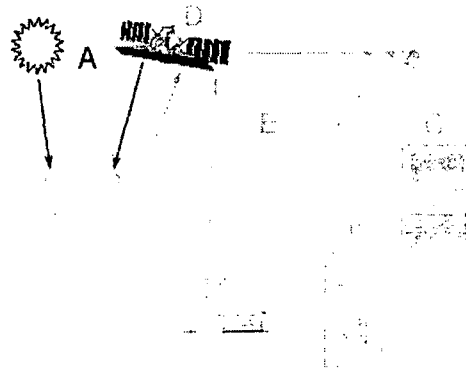


Violet: 0.4 - 0.446 μm
Blue: 0.446 - 0.500 μm
Green: 0.500 - 0.578 μm
Yellow: 0.578 - 0.592 μm
Orange: 0.592 - 0.620 μm
Red: 0.620 - 0.7 μm

Characteristics of Electro Magnetic Radiation:

- Wave length
 - The wavelength is the length of one wave cycle, which can be measured as the distance between successive wave crests
 - Wavelength is measured in meters (m)
- Frequency
 - Frequency refers to the number of cycles of a wave passing a fixed point per unit of time
 - Frequency is normally measured in hertz (Hz)

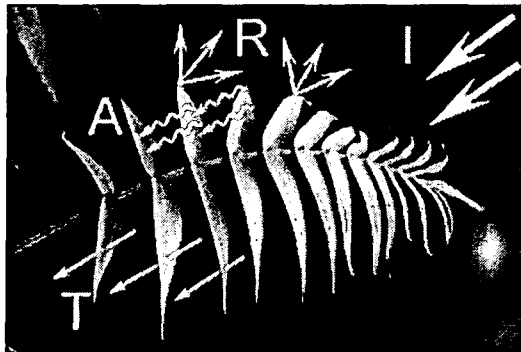
Interactions with the Atmosphere:



Particles and gases in the atmosphere can affect the incoming light and radiation. These effects are caused by the mechanisms of

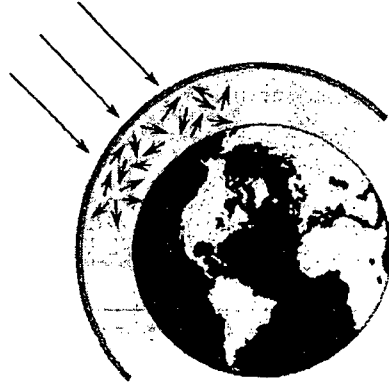
- ✓ Scattering
- ✓ Absorption

Radiation/ Target Interactions:



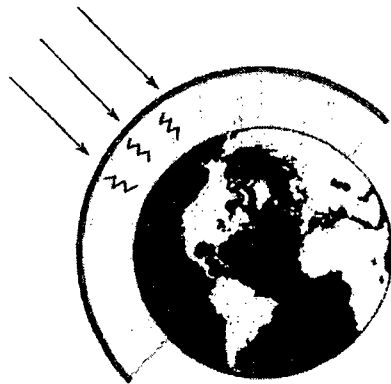
- **Absorption (A)**
(Absorption)
- **Transmission (T)**
(Transmission)
- **Reflection (R)**
(Réflexion)

Scattering (Dispersion):



- **Rayleigh scattering**
The particles are very small compared to the wavelength of the radiation
 - Blue light scatters
- **Mie scattering**
The particles are just about the same size as the wavelength of the radiation
 - Dust, pollen, smoke
 - water vapour
- **Non selective scattering**
The particles are much larger than the wavelength of the radiation
 - Water droplets and
 - large dust particles

Absorption (Absorption):

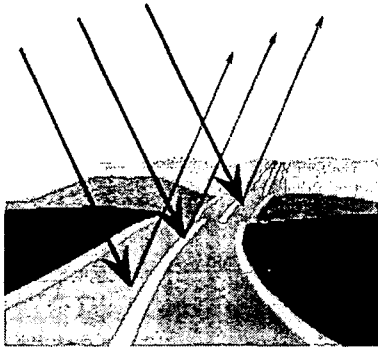


This phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths.

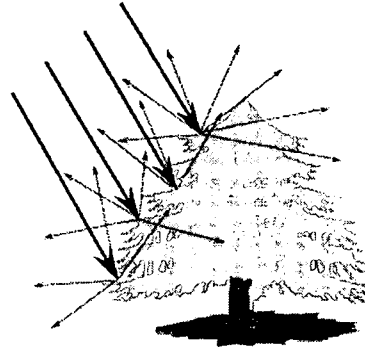
- Ozone (UV absorber)
- Carbon dioxide (IR absorber)
- Water vapour (long wave infrared and short wave microwave radiation)

Reflection (Réflexion):

Specular reflection
(Réflexion Spéculaire)

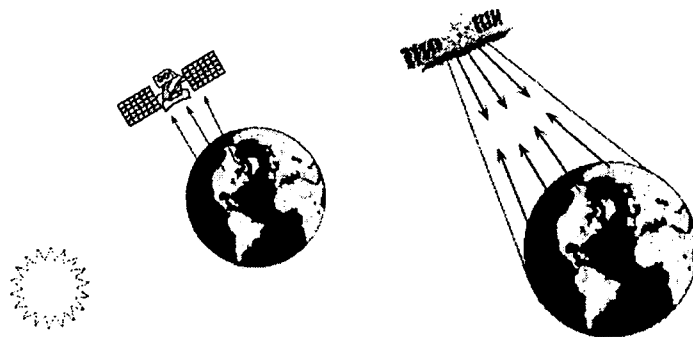


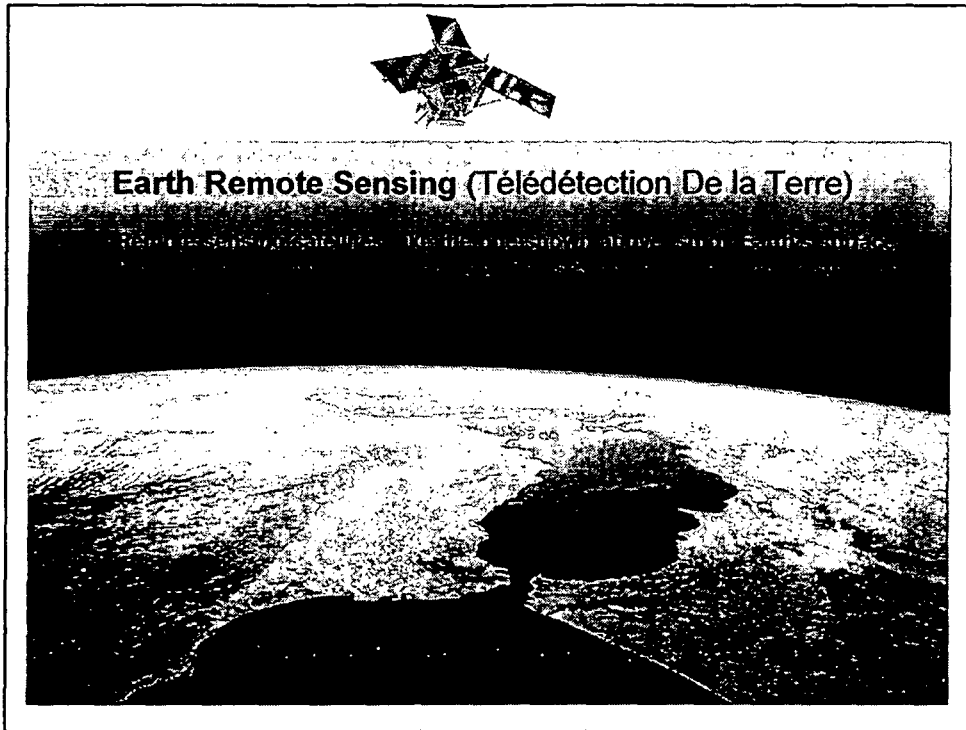
Diffuse reflection
(Réflexion Diffuse)



Passive & Active Sensing:

- Passive sensors can only be used to detect energy when the naturally occurring energy is available
- The Active sensor emits radiation which is directed toward the target to be investigated and receive the reflected energy

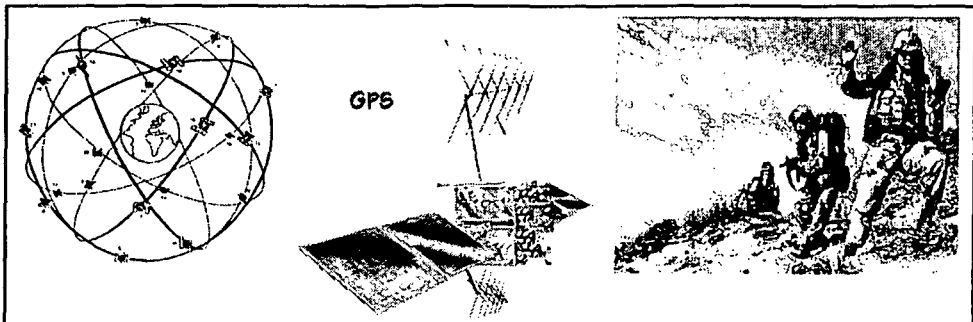




How we use Satellite Imaging?

(Comment utilisons-nous l'information obtenue?)

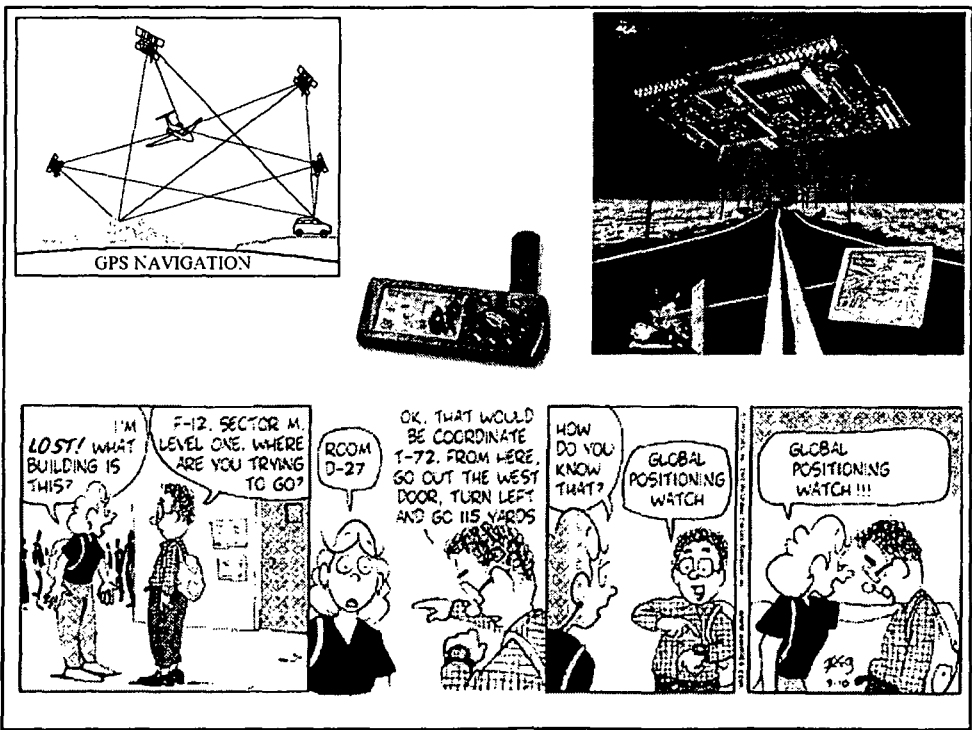
- The instruments on remote-sensing satellites study earth's plant cover and surface water, among many other features.
- People who work in farming, fishing, mining, and many other activities find this information very useful.
- We can also use remote sensing satellites to study changes in the earth's surface that are caused by people.



Global Positioning System (GPS)
(Le système de positionnement global)

This satellite is part of a group of satellites that can tell you your exact spatial coordinates (latitude, longitude and altitude).

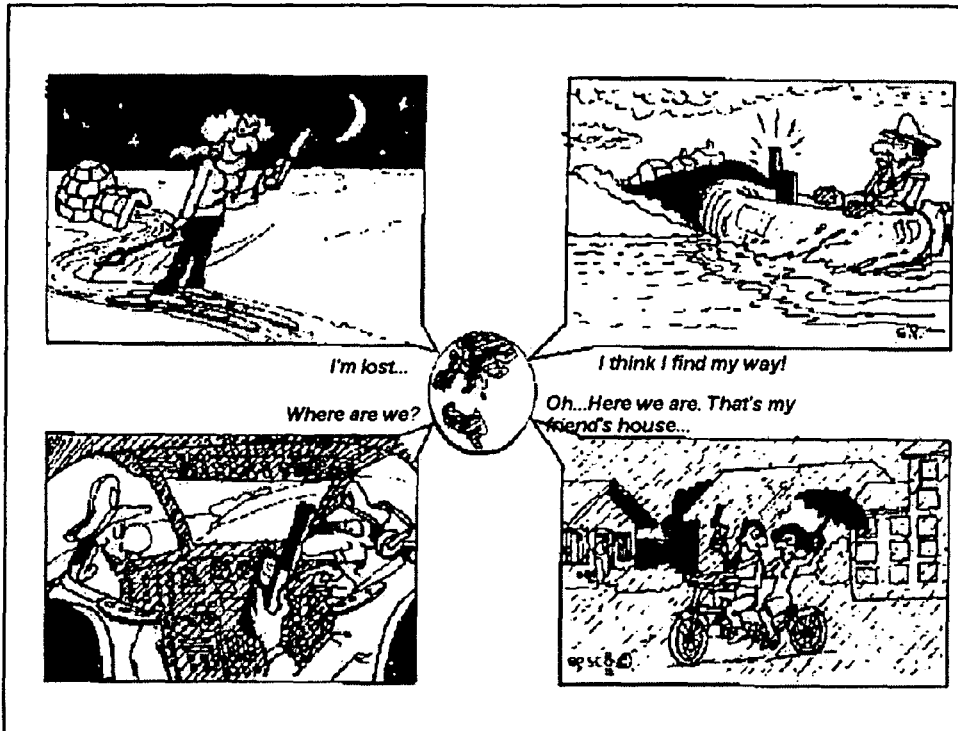
The Global Positioning System (GPS) was developed for military purposes, but now people everywhere can use these satellites to determine geo-referenced control points.



GPS NAVIGATION

GLOBAL POSITIONING WATCH !!!

LOST! WHAT BUILDING IS THIS? **I'M F-12, SECTOR M, LEVEL ONE. WHERE ARE YOU TRYING TO GO?** **ROOM D-27** **OK, THAT WOULD BE COORDINATE 1-72. FROM HERE, GO OUT THE WEST DOOR, TURN LEFT AND GO 115 YARDS** **HOW DO YOU KNOW THAT?** **GLOBAL POSITIONING WATCH** **GLOBAL POSITIONING WATCH !!!**



Links to GPS Sites on the WWW

There is plenty of additional information about the GPS on the WWW. In fact, you may easily lose yourself among the many sites which cater to a broad public at many different levels of complexity.

Before you start exploring on your own hand, you may like to have a look at the sites below. Most of them have very useful onward links:

<http://www.utexas.edu/depts/grq/gcraft/notes/gps/gps.html> - Global Positioning System Overview by Peter H. Dana (Department of Geography, University of Texas at Austin, USA) - Selected as the "Best GPS Site", one of GIS World's "Best of the Net" sites for 1996. Here you will find Map Projection Overview, Geodetic Datum Overview, Coordinate Systems Overview and Links to other related information.

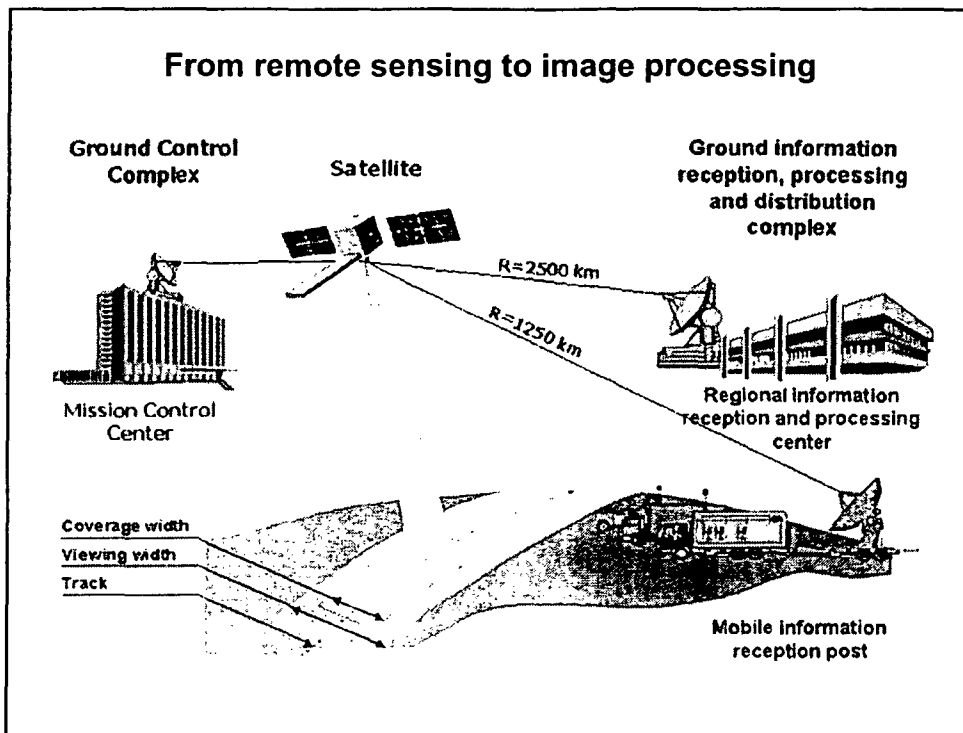
<http://galaxy.einet.net/editors/john-beadles/introgps.htm> - Introduction to the NAVSTAR and GLONASS Global Positioning Systems (GPS), Global Navigation Satellite Systems (GNSS) and their uses.

<gopher://unbmvs1.csd.unb.ca:70/hPUB.CANSPACE.GPS.INTERNET.SERVIC.ES.HTML> - Navstar GPS Internet Connections by Richard B. Langley

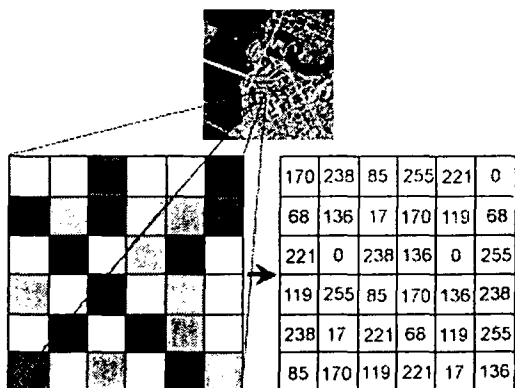
<http://www.navsys.com/gps.htm> - History of GPS - GPS Description- Links to other GPS Web Sites

<http://www.ion.org/redbookstoc.html> - The "Red Books" about the Global Positioning System: Papers Published in *NAVIGATION*

From remote sensing to image processing



Characteristics of a remotely sensed image (Caractéristiques d'une image):



- A digital format by subdividing an image into small equal-sized and shaped areas, called 'picture elements' or 'pixels'
- Pixel represents the brightness of each area with a numeric value or digital number (DN)

Image interpretation and analysis:

Interpretation and analysis of remote sensing imagery involves the identification and /or measurement of various targets in an image in order to extract useful information about them

» Manual interpretation

» Digital interpretation

- Manual interpretation is a subjective process, meaning that the results will vary with different interpreters
- Digital analysis is based on the manipulation of digital numbers in a computer and is thus more objective, generally resulting in more consistent results

Elements of Visual Interpretation:

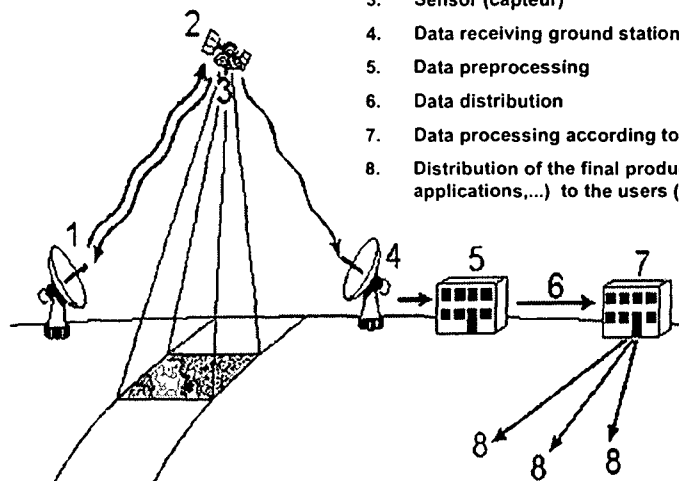
Recognizing targets is the key to interpretation and information extraction

- T one
- Shape
- Siz e
- Patt ern
- T exture
- Shadow
- Association

Digital Image Processing (Traitement d'Image):

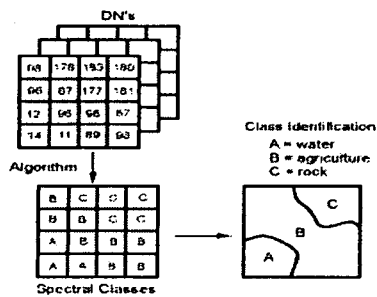
- **Preprocessing (Prétraitement)**
 - Correct for sensor and platform-specific radiometric and geometric distortions of data. The geometric correction is performed by giving each pixel of the image the correct place on the earth (geocoding).
- **Image Enhancement (Perfectionnement d'Image)**
 - Enhancements are used to make it easier for visual interpretation and understanding of imagery
- **Image Transformation (Transformation d'Image)**
 - Basic image transformations apply simple arithmetic operations to the image data
- **Image Classification and Analysis (Classification et Analyse)**
 - To identify homogeneous groups of pixels which represent various features or land cover classes of interest

Processing of satellite data



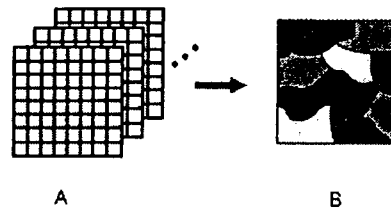
1. Satellite control ground station: programming & remote control of the flight of the satellite
2. Satellite
3. Sensor (capteur)
4. Data receiving ground station
5. Data preprocessing
6. Data distribution
7. Data processing according to the user's needs
8. Distribution of the final products (maps, GIS applications,...) to the users (utilisateur)

Image Classification and Analysis



Unsupervised classification

A computer-assisted interpretation



Supervised classification

A computer-assisted interpretation using more information layers and based on training sites for identification and verification of clusters

Unsupervised Classification

Unsupervised Classification is a technique for the computer-assisted interpretation of remotely sensed imagery. The computer routine does this by identifying typical patterns in the reflectance data. These patterns are then identified by undertaking site visits to a few selected examples to determine their interpretation. Because of the mathematical technique used in this process, the patterns are usually referred to as clusters.

Supervised Classification

Supervised Classification is a technique for the computer-assisted interpretation of remotely sensed imagery. The operator trains the computer to look for surface features with similar reflectance characteristics to a set of examples of known interpretation within the image. These areas are known as training sites.

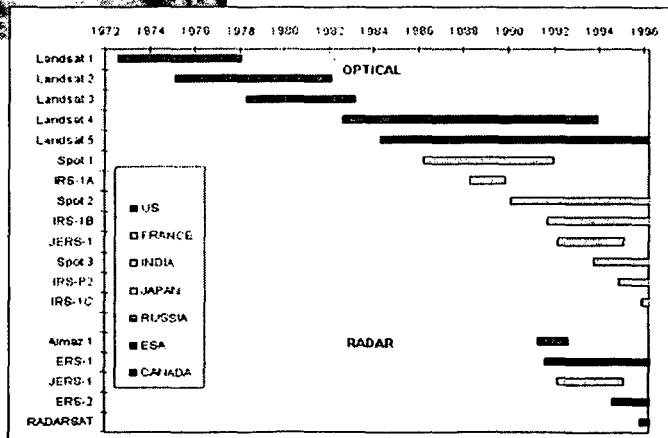
Data Integration and Analysis:

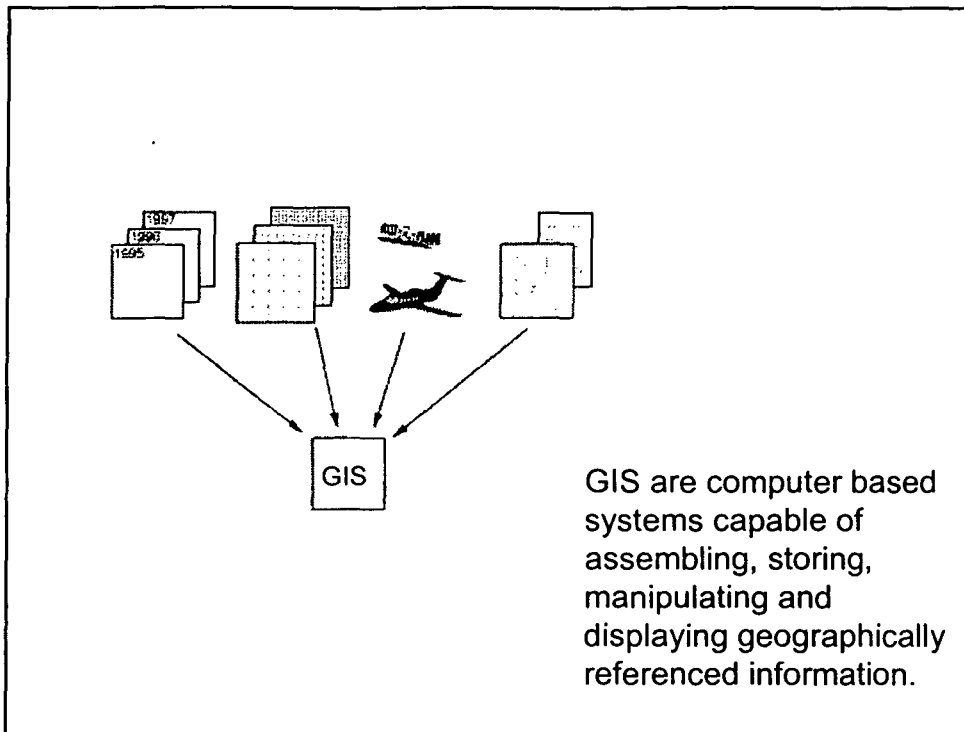
Data integration fundamentally involves the combining or merging of data from multiple sources in an effort to extract better and/or more information. This may include data that are:

- multi- temporal
- multi- resolution
- multi- sensor
- multi- data type in nature



Satellite missions



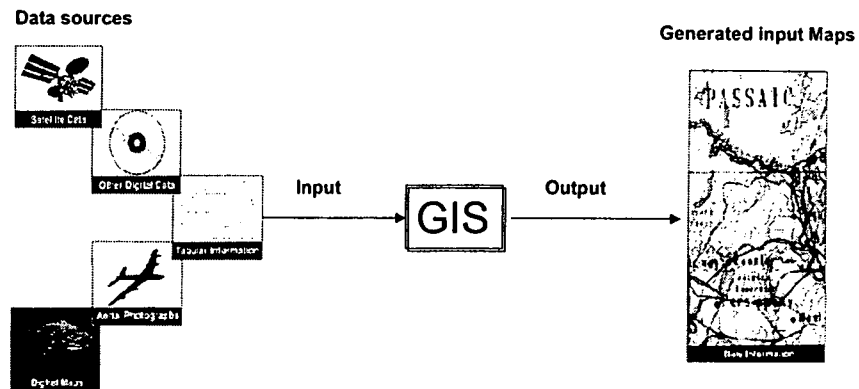


Les systèmes d'information géographique

Les systèmes d'information géographique (SIG) permettent de gérer sous forme numérique des couches d'information (rues, routes, trait de cote, etc.).

Ces données peuvent ensuite être analysées, combinées et visualisées pour produire des cartes.

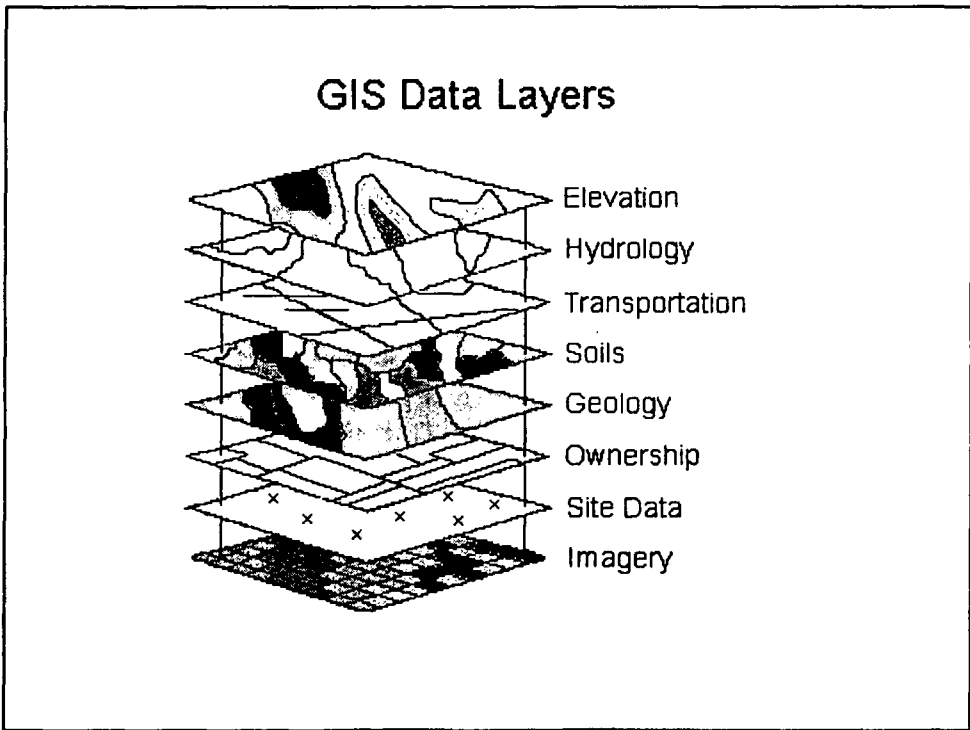
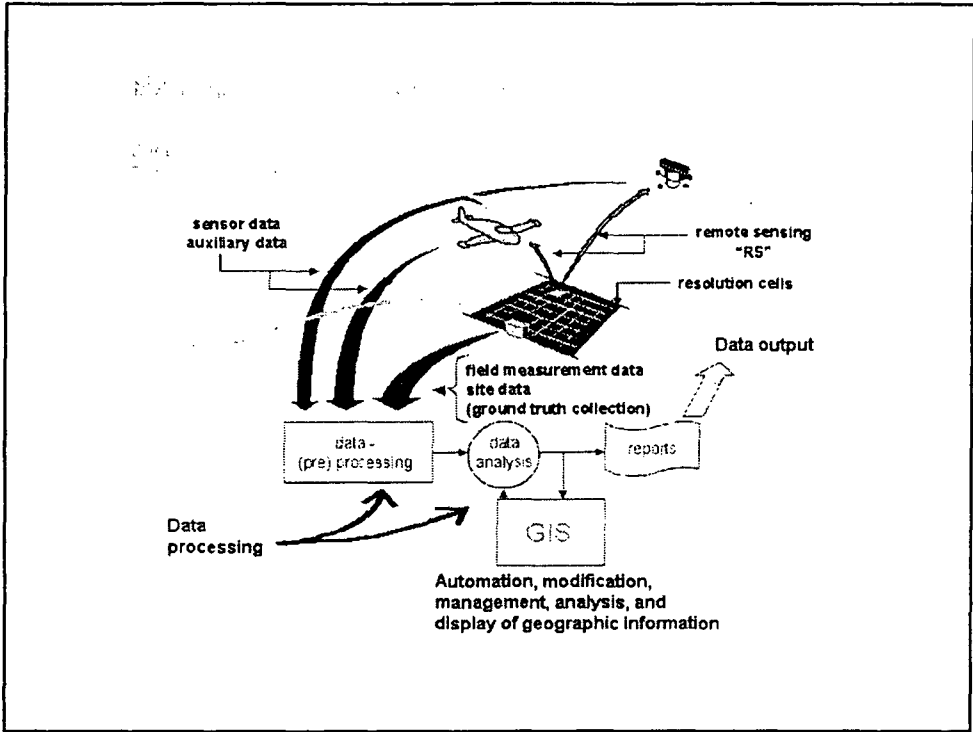
Spatial data management and information extraction



Relating information from different sources
Data capture and integration
Projection, geo-referencing and registration
Data processing, modeling and presentation

How does GIS work?

- Relating information from different sources
- Data capture
- Data integration
- Projection and registration
- Data structures
- Data modeling
- Data presentation



Map Projection



Projection refers to the representation of one surface onto another.

In the mapping sciences it is understood to refer to the representation of a **spherical** earth onto a **flat** medium such as paper or a computer screen.

Since it is physically impossible to flatten a globe without distortion, scale will vary across the projection surface with consequent distortions in **distance, area, and angular** relationships.

Geo-referencing

Geo-referencing refers to the location of an image or vector file in space as defined by a known coordinate referencing system.

With raster images, a common form of geo-referencing is to indicate the reference system (e.g., latitude/longitude), the reference units (e.g., degrees), and the coordinate positions of the left, right, top and bottom edges of the image.

The same is true of vector data files, although the left, right, top and bottom edges now refer to what is commonly called the bounding rectangle of the coverage -- a rectangle which defines the limits of the study area.

Some examples of reference system

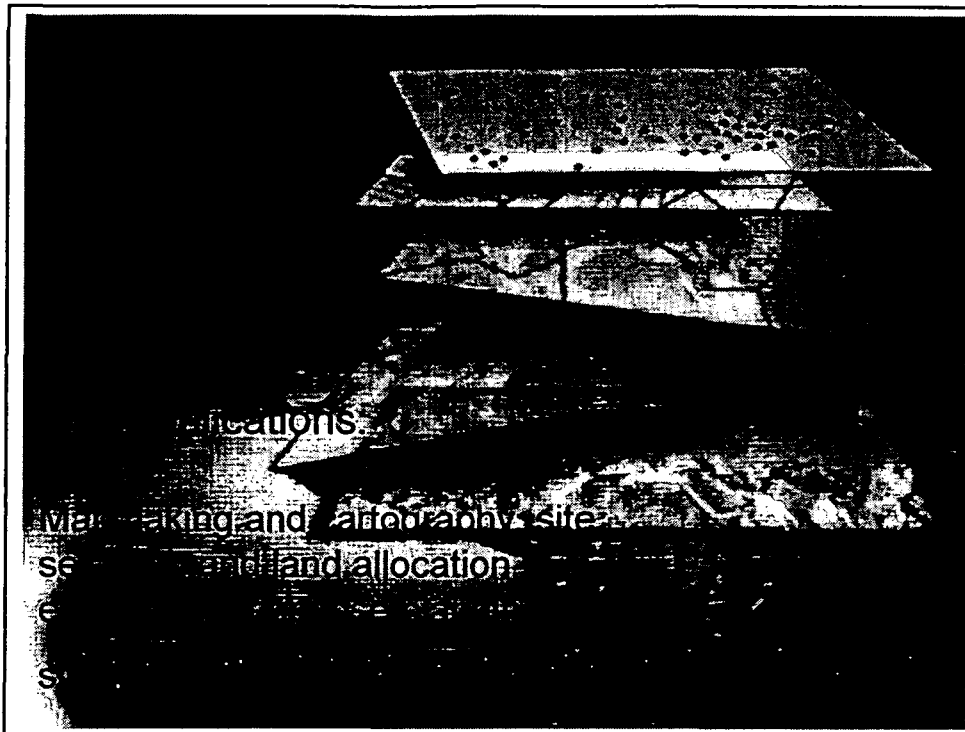
These include the geodetic coordinates **LATLONG** (latitude/longitude) using the decimal degrees as unit of measure, the **UTM** system (Universal Transverse Mercator) and **SPC** (State Plane Coordinate) systems based on the Lambert Conformal Conic and Transverse Mercator projections.

The UTM grid referencing system is frequently used for map projection. The unit of measure is meters or kilometres (m or km). It is usually necessary to know the UTM zone and datum used by the reference system.

What can GIS offer?

- Information retrieval
- Data input
- Data base construction
- Data manipulation
- Topological modeling
- Overlay operation
- Data analysis
- Data output
- Data exchange and Networks





GIS Applications (detailed):

- **Agriculture & Soil** (cropping pattern and soil occupation, biomass and crop yield...)
- **Archaeology** (site prediction and identification, database management...)
- **Biodiversity & Ecology** (wildlife management, conservation and planning...)
- **Business & Economy** (industrial site planning and tourism...)
- **Environment** (survey and monitoring...)
- **Forestry** (harvesting and foliage cover monitoring...)
- **Geology** (geological mapping...)
- **Geomorphology** (slope, fluvial and morphological analysis)
- **Health** (impact analysis...)
- **Military** (image resolutions...)
- **Natural Hazards** (earthquakes, floods, storms, drought, fire and landslides...)
- **Oceanography** (sea-level change and marine pollution...)
- **Urban Planning** (urban agglomeration and cultural resource management...)
- **Water Resources** (ground water assessment, water quality, watershed management, surface water management and water pollution)
- **Utility** (telecommunications, power, transport...)

Further environmental applications of GIS:

- Monitoring of areas that are sustained by the industrial activities; risk assessment and pollution control;
- industrial site planning and land allocation;
- Evaluation of the expansion of different industrial zones, their spatial distribution, their number, their infrastructure, their additional activities, etc;
- Definition of the homogenous areas to which specific concessions are assigned like degraded industrial areas;
- Evaluation of different degraded industrial areas and comparative analysis of industrial sites in alternative environments;
- Planning based on complete database of industrial plants (concentration and distribution, labor density and specialization) for each industrial zone and area at regional and national levels.

Significant images... Worldwide

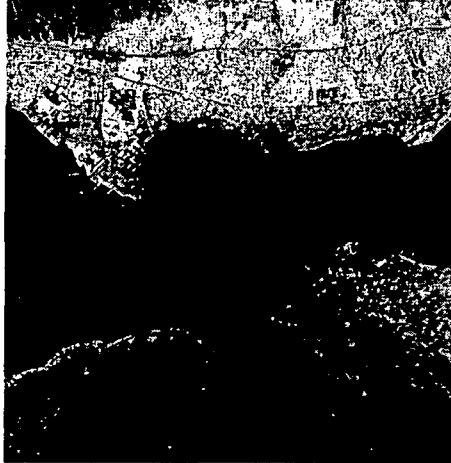
...Chosen from the SPOT, Eurimage and IKONOS satellite images



Earthquake in Turkey

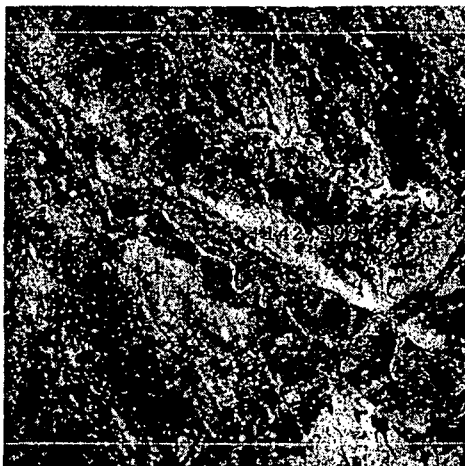


Izmit, Turkey on July 9, 1999

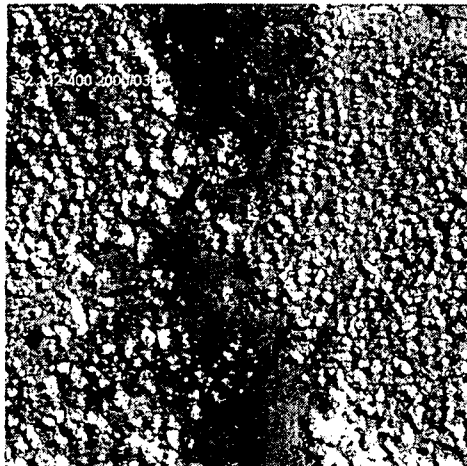


Izmit, Turkey on August 20, 1999
(smoke from oil refinery fire creates haze visible in this image)

Mozambique Floods

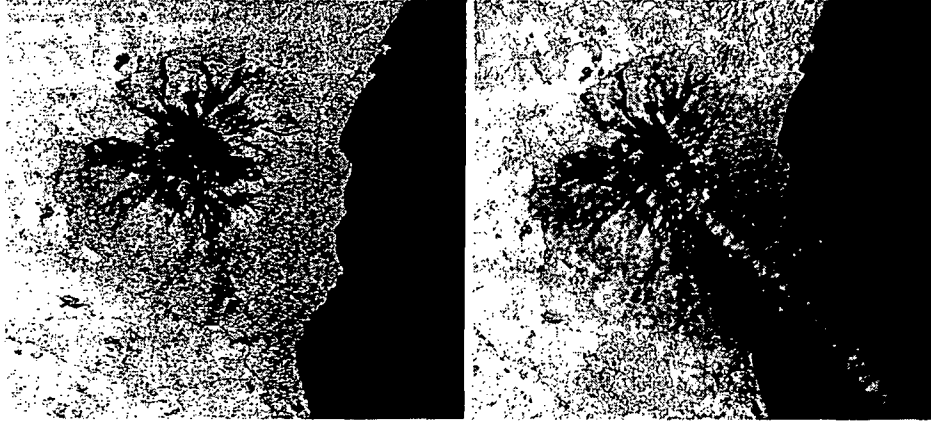


November 15, 1998 – Although the rainy season of Mozambique begins November 1, the bed of the Limpopo River is clearly visible as it snakes diagonally across the northern image (142, 399).



March 4, 2000 – After torrential rains in late February and early March, the Limpopo River has greatly overrun its banks and engulfed the lakes to the northeast. The river has also merged with the lake to the south.

Etna explosion, Italy



On this image acquired on July 19th, 2001 by SPOT 4, old lava flows can be seen in dark shades while the most recent lava flows stand out in red (image processing using the SWIR band).

SPOT Satellite Image acquired on July 23rd, 2001. Sicily's Mount Etna continued to spew lava and ash, forcing the international airport in Catania to shut.

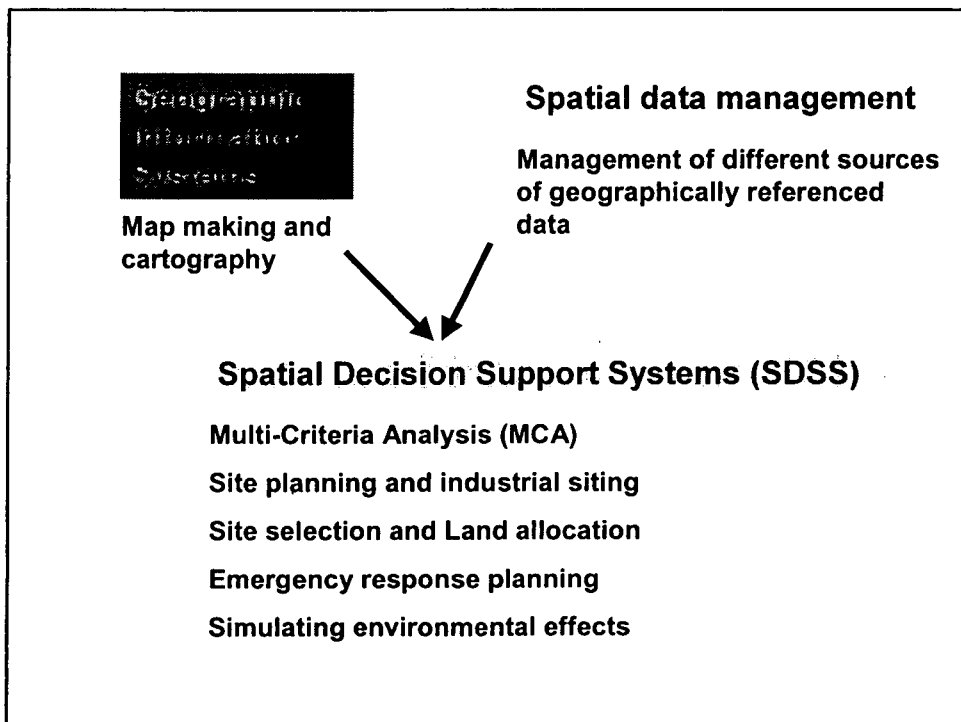
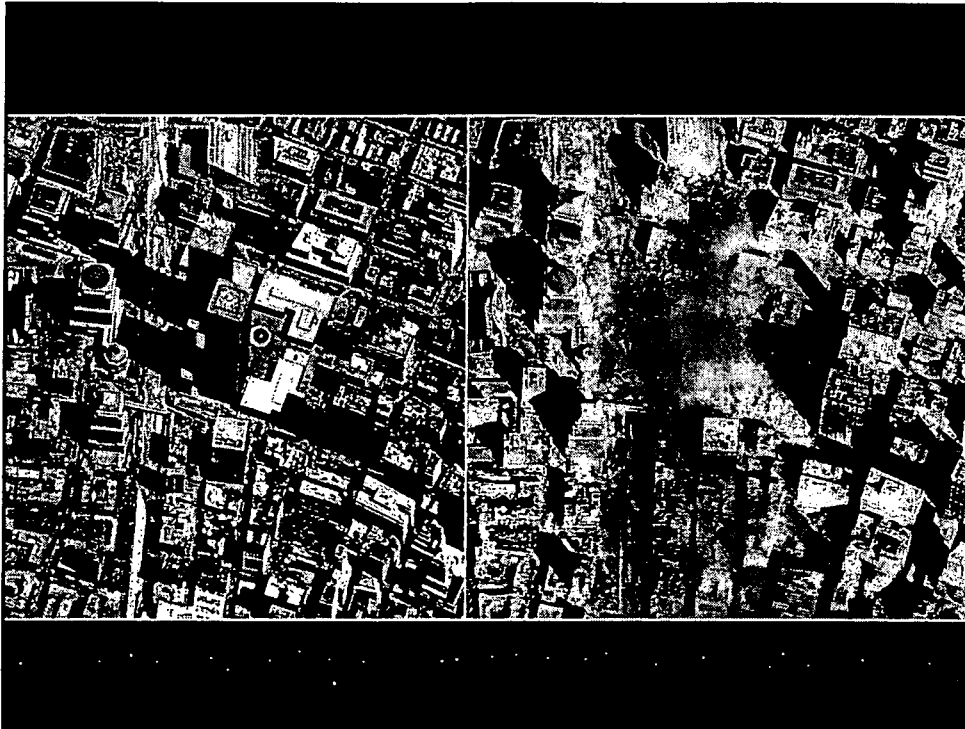
Olympic Games 2000, Sydney from space



An image of Sydney captured on November 8, 1994 illustrates bare ground and undeveloped land surrounding the location for the Olympic Village and the Sydney Showground & Exhibition Center.



Six years later, on July 25, 2000, Sydney has added a number of venues for the 2000 Olympic Games. A waterway has been expanded and a bridge built between the Olympic Village and the athletic stadiums.



Decision Support Systems (DSS) (systèmes interactifs d'aide à la décision)

- A decision is a choice between alternatives.
- The alternatives may represent different courses of action or different hypotheses.
- Rational human behaviour involves the evaluation of choice alternatives based on some criteria.
- A criterion is some basis for a decision that can be measured and evaluated.

Criteria can be of two kinds:

- Factors that enhance or detract from the suitability of specific alternative for the activity under consideration
- Constraints which serve to limit the alternatives under consideration

What is DSS?

Definitions of decision support systems range from:

“Interactive computer based systems that decision makers utilize data and models to solve unstructured problems” (Gorry & Morton, 1971)

to

“Any system that makes some contribution to decision making” (Sprague & Watson, 1986)

‘The decision support field is the development of approaches for applying information systems technology to increase the effectiveness of decision makers in situations where the computer can support and enhance human judgment in the performance of tasks that have elements which cannot be specified in advance’

Multi-Criteria Evaluation:

- To meet a specific objective, it is frequently the case that several criteria will need to be evaluated. Such procedure is called Multi-Criteria Evaluation (MCE)
- In a 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
- The advantage of MCE is that it provides a flexible way of dealing with qualitative multi-dimensional environmental effects of decisions

Decision Support Systems (DSS) has six characteristics:

- Explicit design to solve problems;
- powerful and easy-to-handle user interface;
- ability to flexibly combine analytical models with data;
- ability to explore the space analysis solution by building alternatives;
- capability of supporting a variety of decision-making styles; and
- allowing interactive and recursive problem-solving

The distinguishing capabilities and functions of Spatial Decision Support Systems (SDSS) are to:

- provide mechanisms for the input of spatial data ;
- allow representation of the spatial relations and structures ;
- include the analytical techniques of spatial and geographical analysis ; and
- provide output in a variety of spatial forms, including maps

Example: Multi-Criteria Evaluation for industrial siting

- Decisions about the siting of industries on certain land areas typically involve the application of Multi-Criteria Algorithm based on logical PAIRWISE comparison.
- With the advent of GIS, we now have the opportunity to apply decision-making processes, in more enhanced and integrated context

Mise en place d'un système d'information géographique (SIG)

Objectif

L'objectif est de donner aux ingénieurs, techniciens et cadres en charge, les bases nécessaires à:

- la saisie des données localisées ou géographiques (scannerisation, digitalisation, GPS...);
- la structuration de l'information (modèle et équation);
- la mise en œuvre des applications informatiques de gestion de l'information géographique;
- le traitement des données (requêtes, analyse, traitement d'image...);
- l'édition des données (cartes, tableaux...)

Procédure

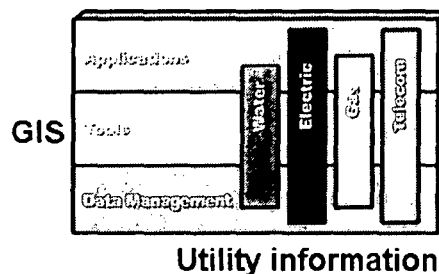
La mise en œuvre d'un système d'information géographique ne saurait se limiter au simple apprentissage de l'outil logiciel qui n'en constitue que l'interface d'accès et de manipulation des données. Il faut replacer le sujet dans une vision globale du système d'information alliant la représentation cartographique à une véritable banque de données.

GIS Application for utility information Management

GIS are powerful tools for the integration, maintenance, modelling and data management of utility information. GIS are used:

- to support the vertically integrated utilities (electric, gas, water and telecommunications networks);
- to view, design, map, manage and maintain spatial data in a multi-utility context.

GIS can be applied to share common data models and user interfaces to create an integrated solution across utilities.



Telecommunication GIS & Information data management

- **Land Base Created from Geographically Correct Sources**
- **GPS tracking compatible Land Base**
- **Land Base Built on the Applicable Coordinate System**
- **Data Management and marketing Information Interface Utilizing Network Schematics and Base Maps**

Example: GIS and database of wireless locations

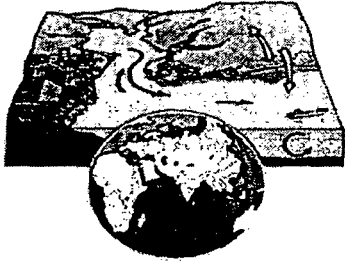
Database contents: Site Name, Latitude/ Longitude location (decimal degrees), AGL (Above Ground Level) Height, AMSL (Above Mean Sea Level) Height, Ground Elevation, Site ID, Owner/Manager Name, Leasing Agent Telephone, Type of Structure, Street Address, etc.

GIS and Mapping for Mobile Systems

GIS technology and GPS functionality may play an important role for:

- mobile mapping and field data collection;
- data accuracy and real time information;
- immediate data availability and validation;
- data access via Wireless Technology (to download images or map layers via wireless technology using a TCP/IP connection, such as a wireless LAN, cellular phone, or a wireless modem).

Coastal Zone Management (CZM)



Coastal zone management is the management of coastal resources.

Resources are common to other areas (residential settlement, agriculture, forestry, military base, tourism and recreation, quarrying, dumping and waste disposal, etc.)

Resources are also specific to coastal area (fishing, navigation, port and harbor, desalination and salt production, etc.)

Environmental Planning and Coastal Zone Management

“Planning and management are based on a generic problem-solving process”.

It involves various forms of analysis including simulation and modeling.

Based on these concepts, some requirements are necessary for environmental management:

- human & environmental safety
- efficient use of resources & waste management
- addressing societal expectations & concerns
- regulatory compliance
- respect towards habitats, biota and physical environment on which ecosystems depend

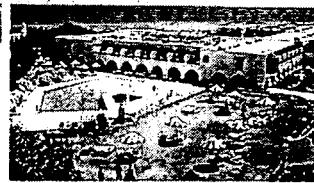


The coast and human society



“the real conflict of the beach is not between sea and shore but between man and nature”. Bartlett (1993)


Coastal zone is of extreme significance to human affairs. Management of coastal zones should be based on the ecosystem approach, which considers the physical, chemical and biological interaction among various components of the system in relation to anthropogenic exploitation.



Integrated Coastal Zone Management (ICZM) deals with the management of the coastal zone as a whole in relation to local, regional, national and international goals.

Given the complexities of coastal systems and the multi-disciplinarity required for sound ICZM, integration of technologies including Remote Sensing, GIS and DSS is especially useful for optimal coastal management solutions.

www.NetCoast.nl

NetCoast  **A Guide to Integrated Coastal Zone Management**

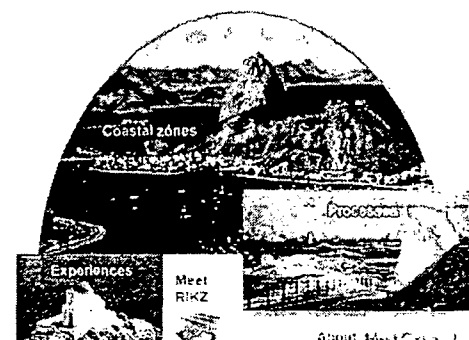
Home | About | Contact us | Feedback | News | Publications | Projects | Publications | Publications | Publications | Publications


Search

Feedback | Tell a friend | Full screen

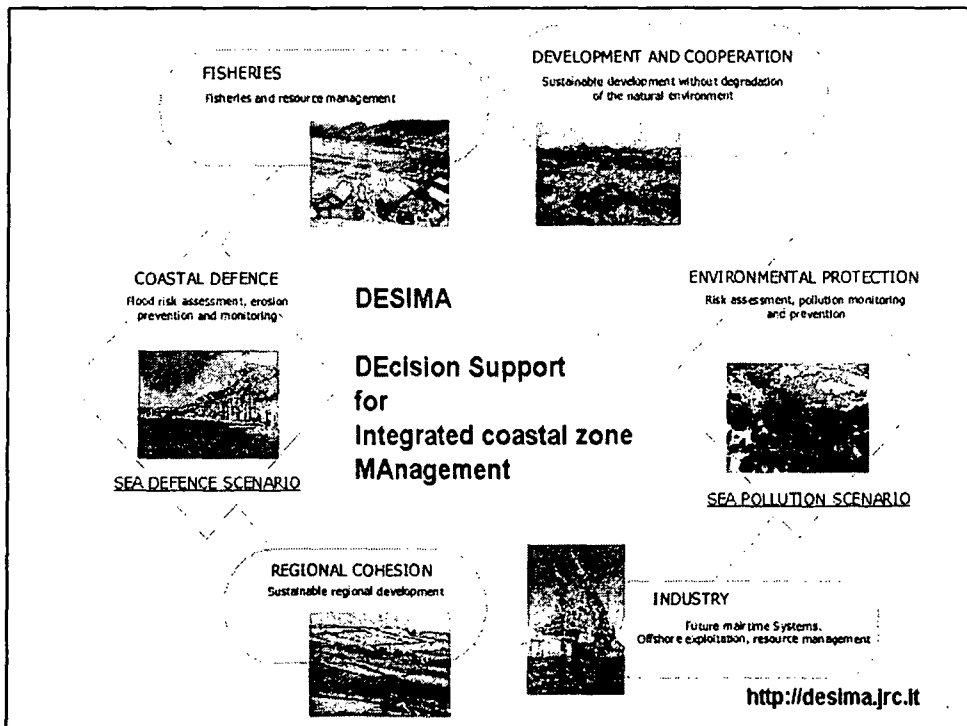
Thursday, 22 May 2002

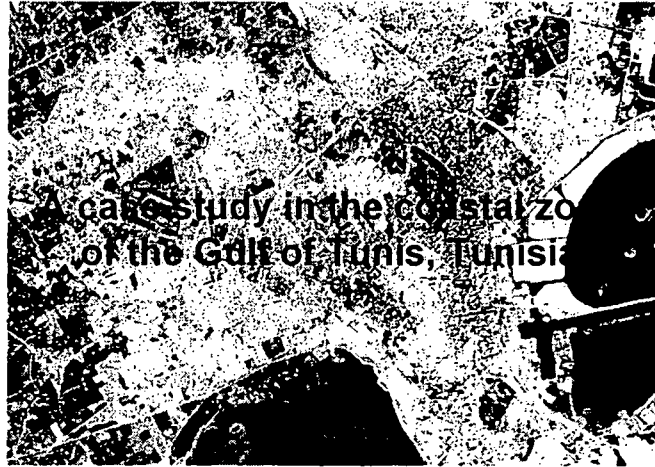
Project Erosion
ICZM funding guide
MPA Training East
Africa
About ICZM Centre
Projects
Publications
Tools
Delcasnetwork



Coastteam EU funded project 

2001 NetCoast. Contact address: Carla Bennink
Optimised for IE (IE6.0+95)





ABSTRACT

The Tunisian coastal area, as for many other coasted countries of the Mediterranean Basin, is subject to an increasing pressure from a wide variety of activities such as recreational and tourism projects, industrial development and urban settlement.

Environmental managers are faced with the challenge of balancing this pressure using an integrated coastal area management (ICAM) approach.

An integrated system adopts the integration of information technologies to incorporate data from a variety of sources and should be built on: the collection and the analysis of socio-economic and climatic data, the use of remote sensing data, the development of models and the use of advanced techniques and tools.

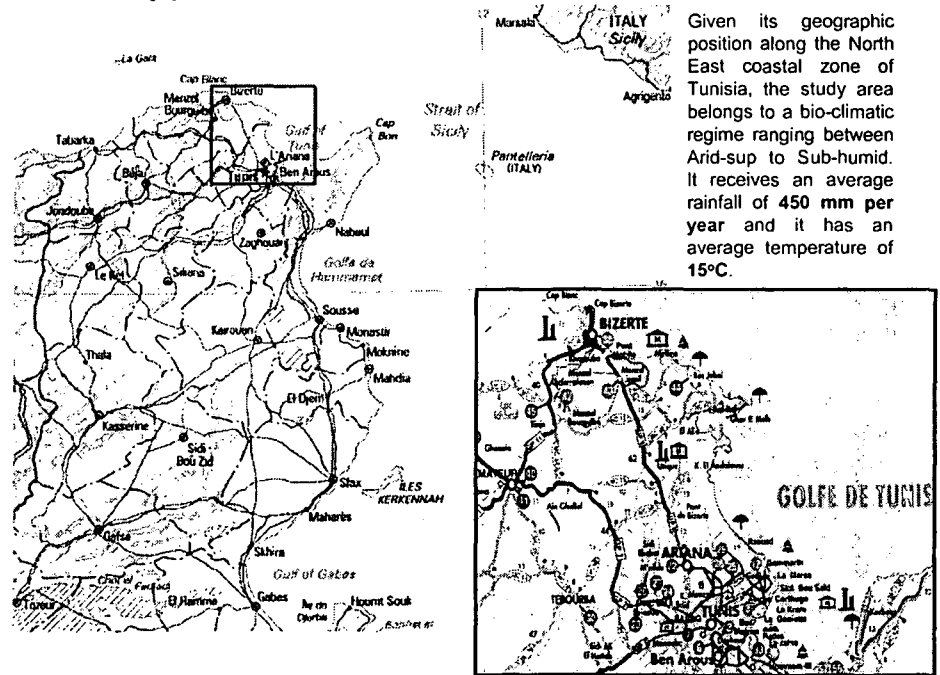
The present research will focus on the importance of those tools including geographic information systems (GIS), remote sensing (RS) and decision-support systems (DSS) and will illustrate the many advantages of spatial decision support systems (SDSS) through the application of Multi-Criteria Evaluation (MCE). From conventional approaches to urban mapping and industrial siting taking in considerations the indicator value of the vegetation for monitoring and analysis.

This will be addressed to the indicator value of different vegetation indices such as: the standard normalized difference vegetation index (NDVI), the soil adjusted vegetation index (SAVI) and the green vegetation index (GVI) and will evaluate the impacts of anthropogenic activities on the landscape.

Subsequent resource mapping will be realized through the application of Landsat TM and other remotely sensed imagery (NOAA/AVHRR for NDVI values and RADAR/SAR using ERS1-2 for digital elevation model (DEM extraction and land use mapping) followed by field trip survey and statistical data gathering and analysis.

The potential use of GIS technology to contribute as a decision-support methodology and the many applications of remote sensing techniques for vegetation monitoring, represent the two converging streams of this research.

Case study presentation and criteria of selection



Selection Criteria



It is a Mediterranean Coastal Area

The Area encompasses multiple patterns of vegetation bio-diversity

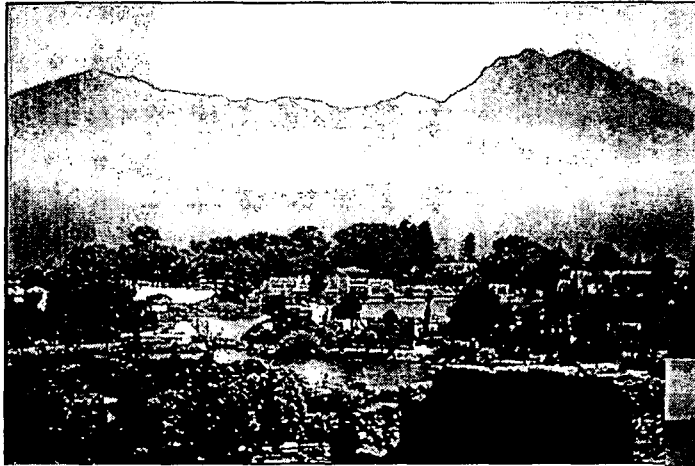
Artificial crops (orange groves, vineyards, olive orchards, etc.)
Wild vegetation (grasses, shrubs and forest) spread throughout different ecological sites (mountains, marshes and salty lakes).



A continuous and frequently spontaneous Urban settlement

A large set of Industrial activities





**And tourism among
other activities**



NDVI Data Extraction And Analysis

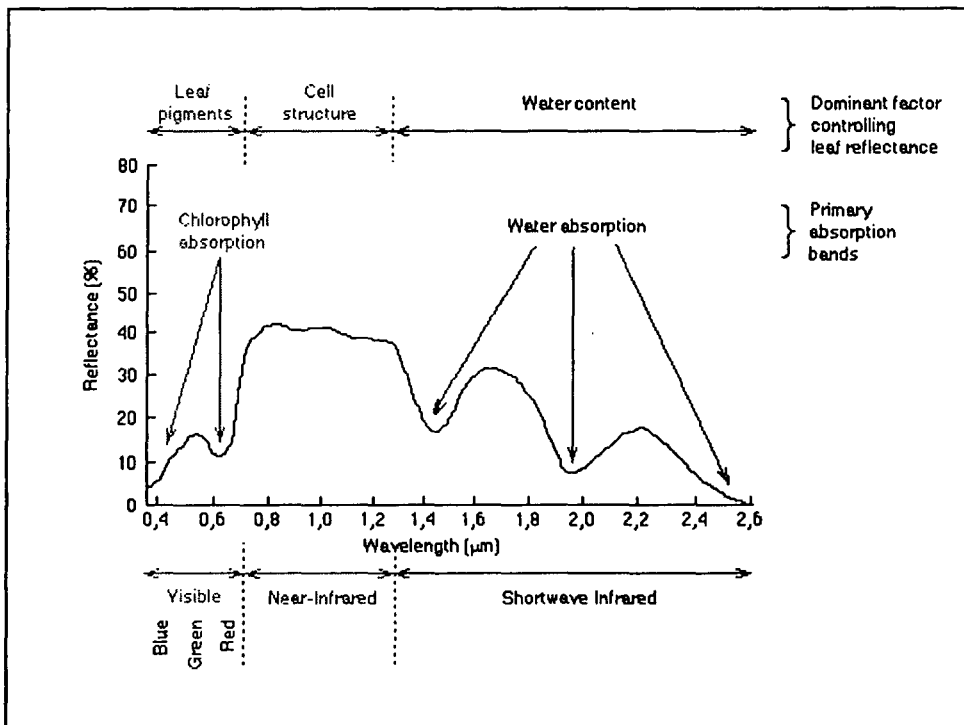
Access to land processes data, including satellite and aircraft acquired data stored in the Earth Resources Observation Systems (EROS), plays an important role to promote the interdisciplinary study and understanding of the integrated Earth system (USGS, 1998). Since 1983, **Advanced Very High Resolution Radiometer (AVHRR)** of the **National Oceanic and Atmospheric Administration (NOAA)** satellites has given a continuous spatial cover on regular time scale of the photosynthetic potential activity. This can be expressed by vegetation indices such as the **Normalized Difference Vegetation Index (NDVI)** (Richard et al., 1998).

The NDVI, referred to the greenness index, is used as a measure of vegetation health and density. A healthy vegetated area will have a high NDVI value, while a sparsely vegetated or unhealthy area will have a lower value. The values of NDVI will range from -1 (the lowest possible value indicating areas void of vegetation, ice, water, barren ground etc.), through +1 (the highest value indicating highly vegetated, healthy environment). In the real world, useful values fall between 0 and +1. The NDVI values are often rearranged from 0 to 255 in order to make use of the full 8-bit nature of the graphics.

The NDVI is derived from the reflected solar radiation in the near-infrared (NIR) and red (RED) wavelength bands via the algorithm:

$NDVI = (NIR - R) / (NIR + R)$, Example $NDVI = (band4 - band3) / (band4 + band3)$ for Landsat TM

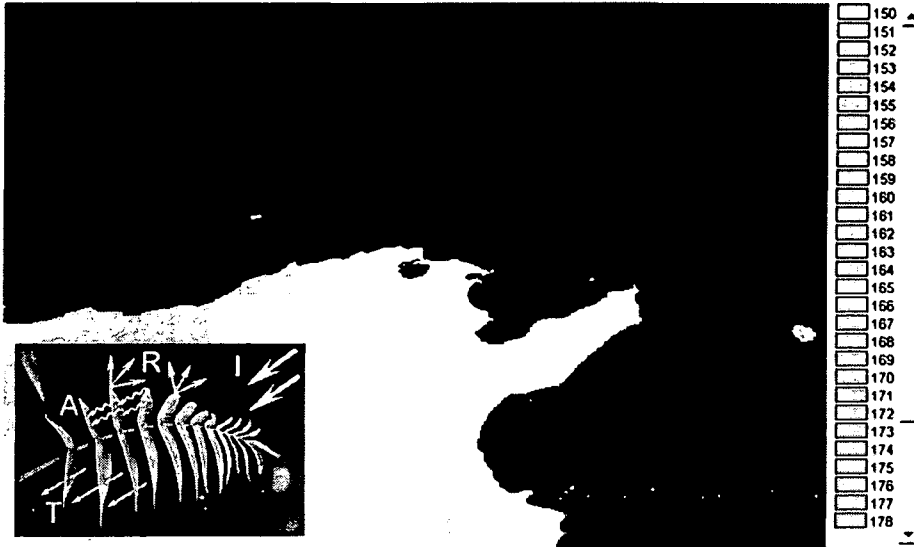
The NDVI is a nonlinear function which is undefined when RED and NIR are zero. The NDVI values vary with absorption of red light by plant chlorophyll and the reflection of infrared radiation by water-filled leaf cells.



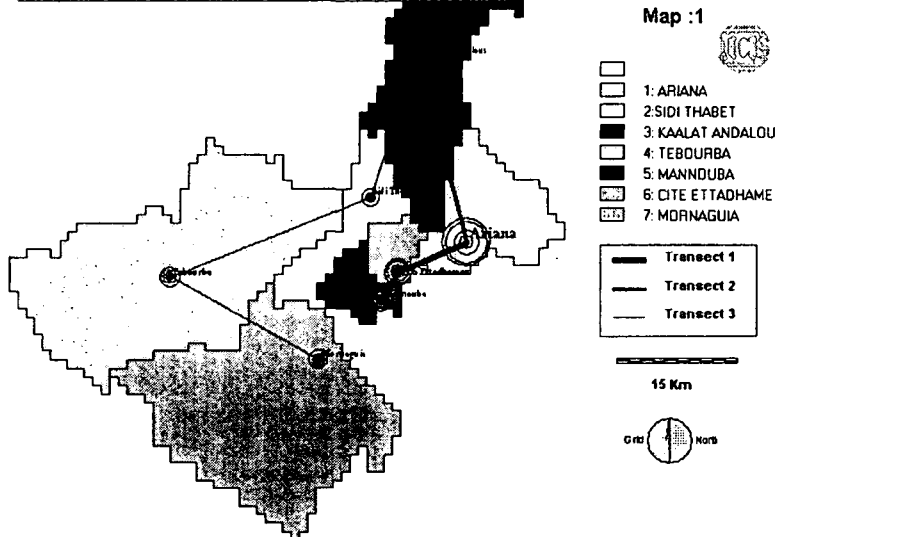
METHODOLOGY

By FTP access to global 1-km AVHRR 10-day composite data, the NDVI data was extracted from the following Internet site: <http://edcwww.cr.usgs.gov/1Km/comp10d.htm>

Only data from 1992 to 1996 are available in this public domain.



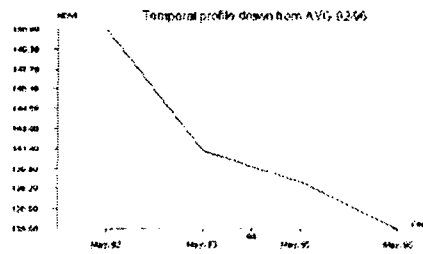
The three spatial transects for NDVI assessment



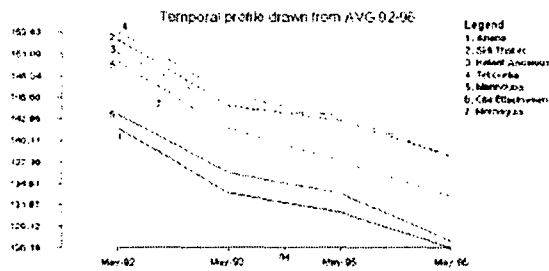
NDVI change and Time Series Analysis

Time series analysis concerns the examination of change over a sequence of ten-days images obtained for the 3 decades of May for 1992, 1993, 1995 and 1996 (data for 1994 was not available).

To measure the global changes over profiles of time, the vegetation dynamics of the whole study area, by each province (délégation) and by main residential sites was measured taking the normalized difference vegetation index (NDVI) as the numerical indicator.



NDVI change from 1992 to 1996 for the whole area



NDVI dynamics from 1992 to 1996 by provinces

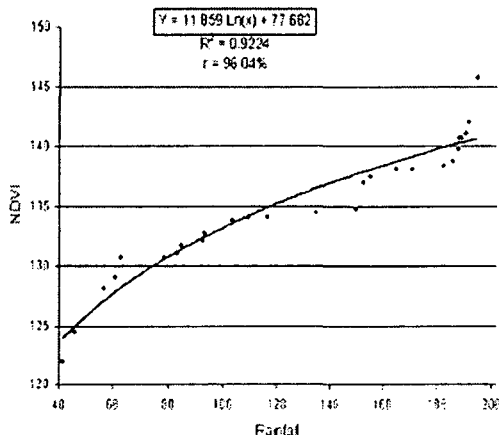
INTERPRETATION

As mentioned earlier, NDVI is a measure of the greenness or vegetation health. High values indicate presence of healthy vegetation while lower values indicate less vegetation or stressed vegetation. The graphs clearly indicate the vegetation change over time characterized by a global decline of NDVI for the whole area and by each province.

There are some justifications to the change of the NDVI values corresponding reasonably well with the season and the rainfall period but also the man effect is a crucial factor affecting the NDVI dynamics. For instance, Ariana and Mannouba represented the lowest NDVI average values (this can be explained by their proximity to the capital), while Tebourba and Sidi Thabet are covered by more green areas thanks to the dominant agriculture vocation.

NDVI sensitivity to rainfall, urbanization, industrialization and elevation

Using the "Idrisi" module "Analysis/ Statistics/ Regress", some simple linear regression models between the NDVI average as a dependent variable and the rainfall, the industrial growth ratio, the urban growth ratio and the altitude as independent variables were carried out successively. To enhance their statistical relationship, some mathematical transformations of the variables were done.



The spatial distribution of the vegetation cover is strongly related to severe climatic conditions (Saugier, 1996). As a vegetation indicator, the NDVI can be considered as a climatic recorder, and mainly a rainfall recorder. In fact, it has been shown that NDVI was highly sensitive to an extended rainfall anomaly, like the 1984 Ethiopian drought (Henricksen, 1986).

The evolution of the amount of rainfall is followed by an increase of NDVI and this is explained by a positive correlation between the two variables (positive slope and a high correlation expressed by a relatively high coefficient (96.04 %).

Correlation NDVI/ Urban growth ratio

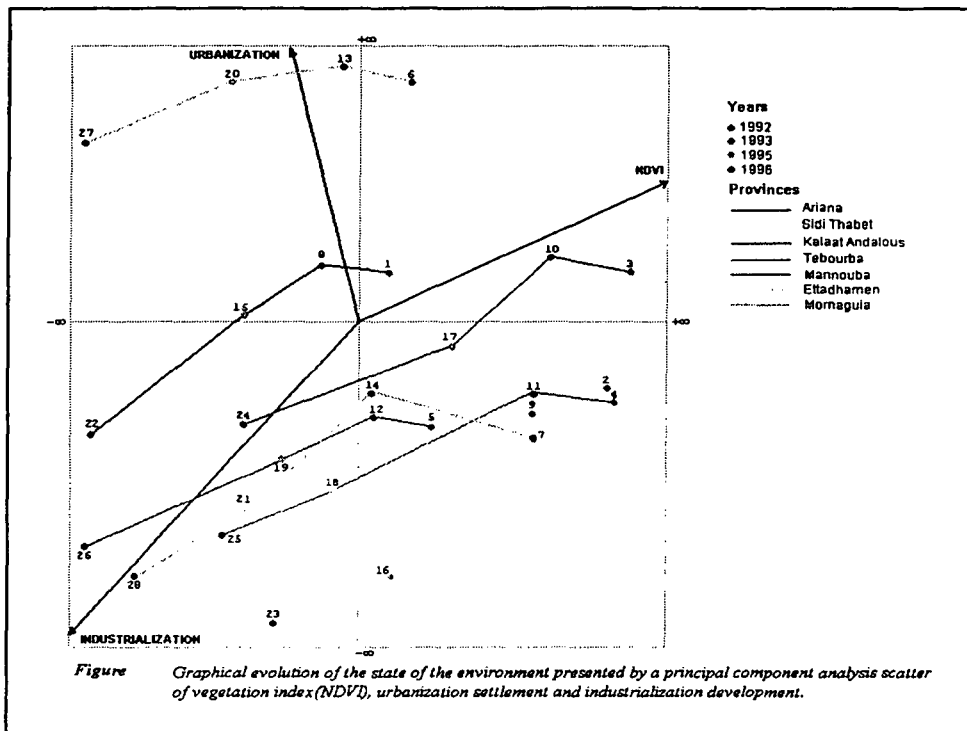
The expansion of urban settlement is followed by a **decrease of NDVI** and this is explained by a higher negative correlation between the two variables (negative slope -0.021935 and relatively high coefficient of determination $r^2 = 55.61\%$). According to statistical table forms, the model is significant at 1% level.

Correlation NDVI/ Industrial growth ratio

The industrial development is followed by a **decline of NDVI** and this is explained by a higher negative correlation between the two variables (negative slope -0.02195 and relatively high coefficient of determination $r^2 = 55.98\%$). The model is significant at 1% level.

Correlation NDVI/ DEM

For both dates, there is a positive correlation between the altitude and the NDVI explained by a moderate coefficient of determination (70.08 % in May-92 and 71.76 % in May-96). An increase of elevation is followed by an **increase of NDVI**.



Multiple linear regression

Using the "Idrisi" module "Analysis/ Statistics/ MULTIREG", some multiple linear regression models between the NDVI average as a dependent variable and the yearly industrial growth ratio, the yearly urban growth ratio, the altitude and the amount of rainfall as independent variables were carried out.

Interpretation

The NDVI is positively correlated with rainfall and DEM and negatively correlated with the yearly urban growth ratio and the industrial growth ratio.

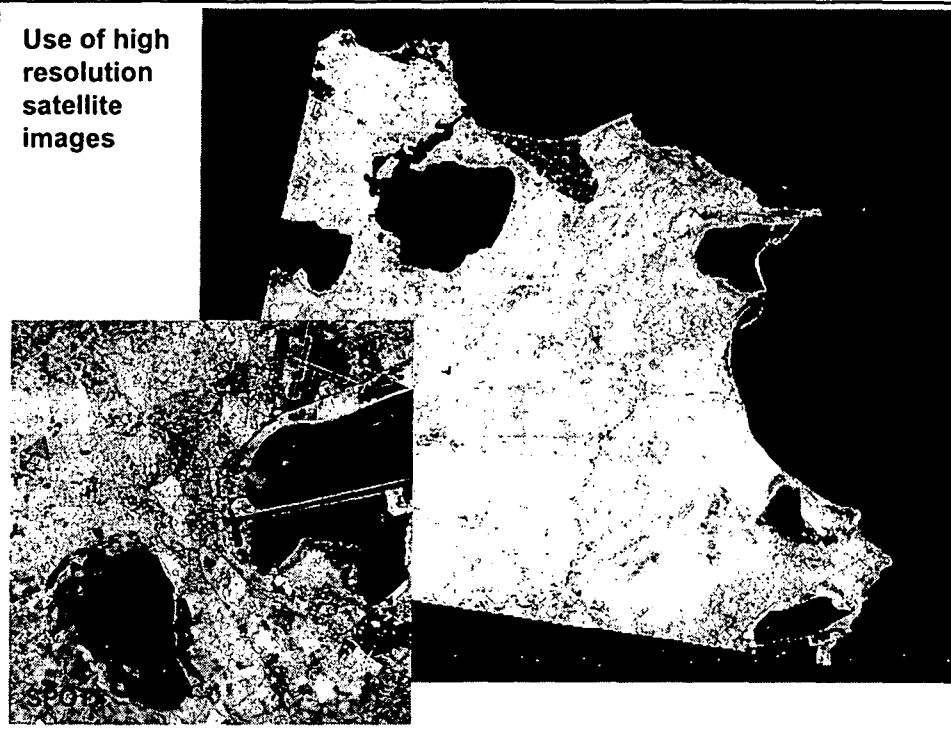
According to F values (F Statistical at 5% = 2.84, F Calculated = 40.881172 and F Statistical <<< F Calculated), the multiple regression's model is significant at 5%.

Concerning the partial correlation and according to t values: t at 5% confidence level = 1.684, the NDVI is significantly negatively correlated with the urban growth ratio since -3.397961 belongs to the interval $]-\infty, -1.684]$ and significantly correlated with the industrial growth ratio since -3.371853 belongs to the interval $]-\infty, -1.684]$, significantly positively correlated with the altitude since 3.827727 belongs to $[1.684, +\infty[$.

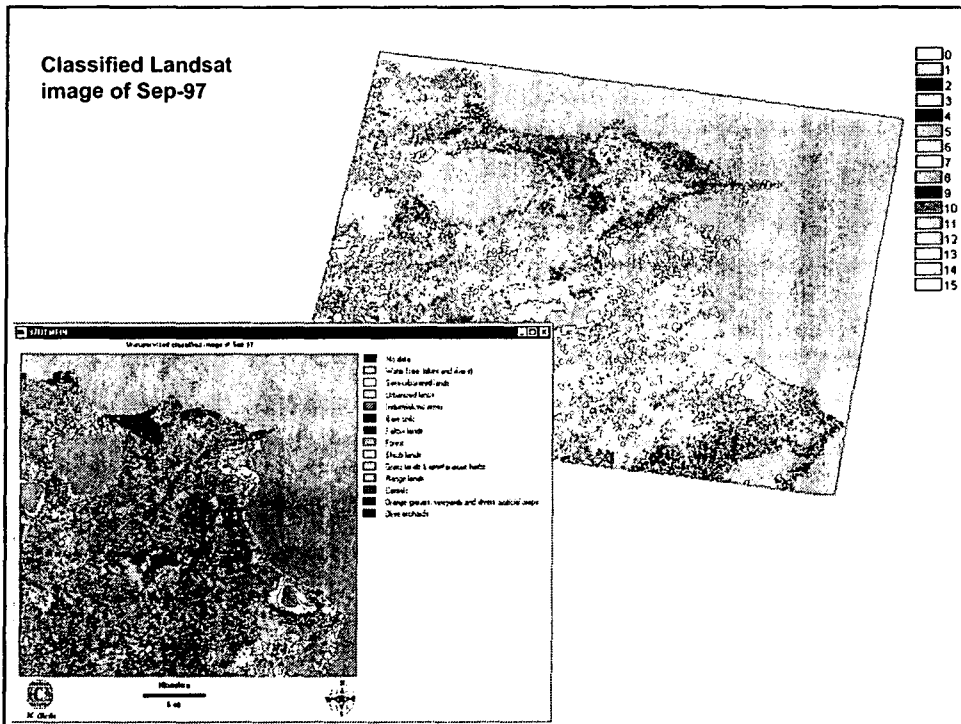
The analysis of the state of vegetation through the Normalized Difference Vegetation Index correlation with the industrial growth, the urban growth, the altitude and the quantity of rain, shows that the vegetation is more affected negatively by the human factors (urban and industrial development) than the natural parameters (rainfall and DEM).

While the changes in the vegetation are noticeable in time and over space, there is a gap of information obtained from the NOAA images of 1km resolution. A more detailed analysis involving LANDSAT images of 30 m resolution acquired for Sep-89, Sep-93 and Sep-97 would give a more meaningful representation of the actual vegetation patterns in this region of Tunisia.

Use of high resolution satellite images



Classified Landsat image of Sep-97



Multi-criteria evaluation for industrial siting

Concept

Decisions about the siting of industries typically involve the application of Multi-Criteria algorithm based on logical PAIRWISE comparison. GIS offers the opportunity to apply decision-making processes in a more enhanced and integrated context.

Aim

To design suitability map of industrial sensitivity of the coastal zone of the study area.

Methodology

Investigation of interactive effects by contributing factors and constraints that may enhance or decrease industrial susceptibility. Factors contributing to the change of industrial susceptibility include:

- ✓ Proximity to main industrial zones
- ✓ Proximity to main residential sites
- ✓ Proximity to main roads
- ✓ Proximity to water (sea, lakes and rivers)
- ✓ Proximity to protected forest & national parks
- ✓ Proximity to bares lands

The output will consist of a number of categories, each reflecting its susceptibility to the installation of new industries.

Weighted Linear Combination (WLC) is the most often used technique in multi-criteria decision making.

Criteria here may include weighted factors and constraints.

Calculating the product of weight and factor multiplied with all constraints at any location, and then summing up all products yields a total overall score.

The score for each alternative A is:

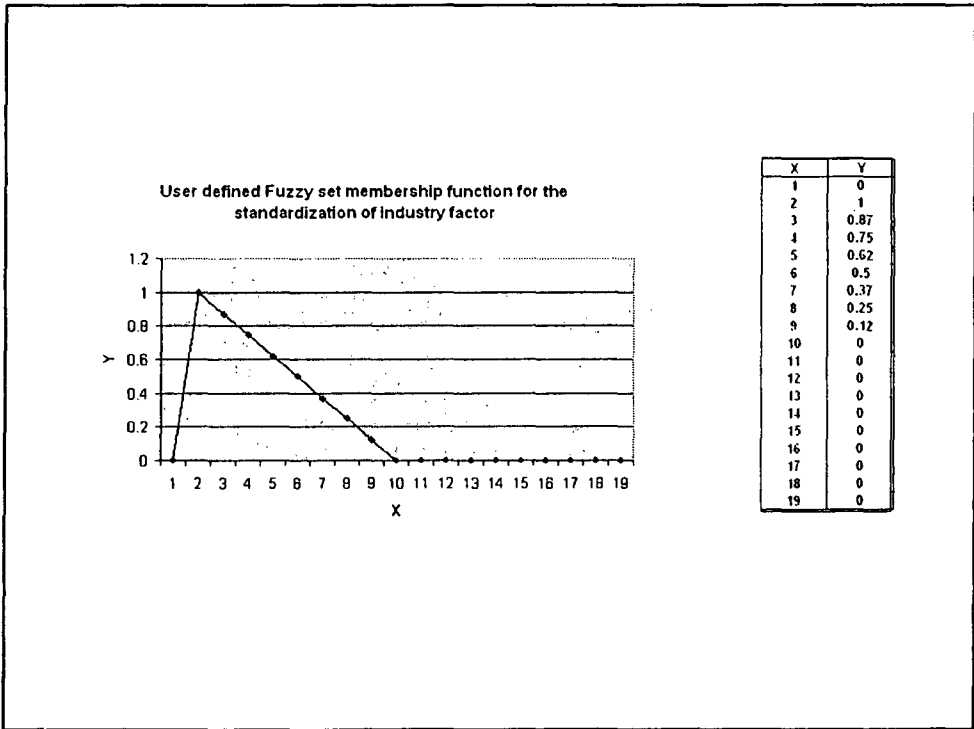
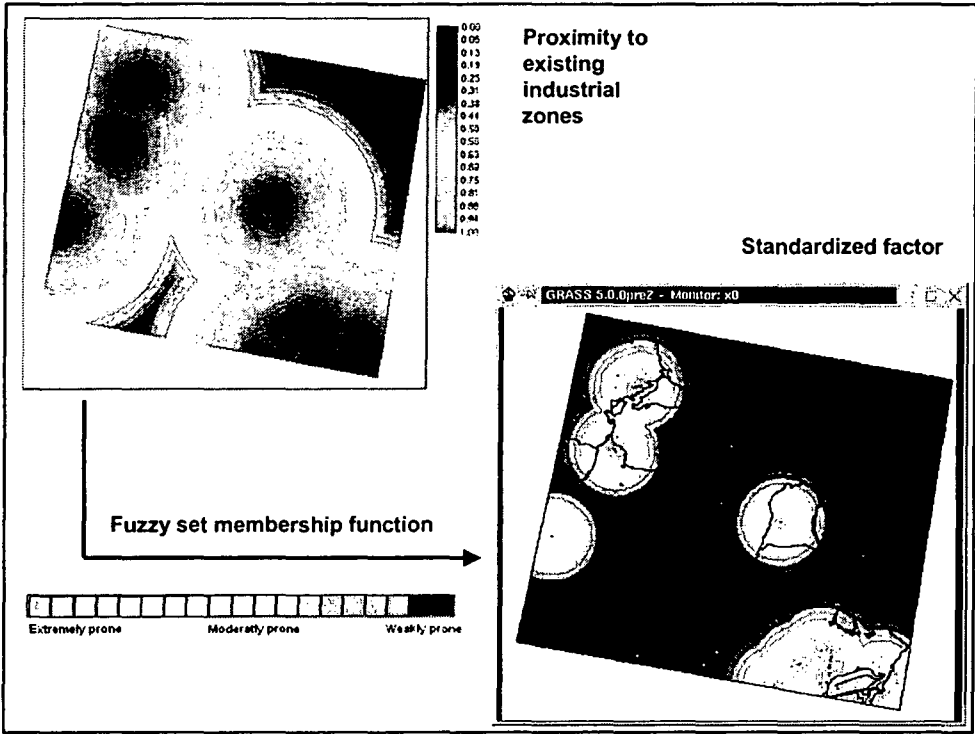
$$A = \sum w_i x_i \quad \text{or} \quad A = \sum w_i x_i \quad \cap \quad c_j \quad \text{if a constraint is part of the decision}$$

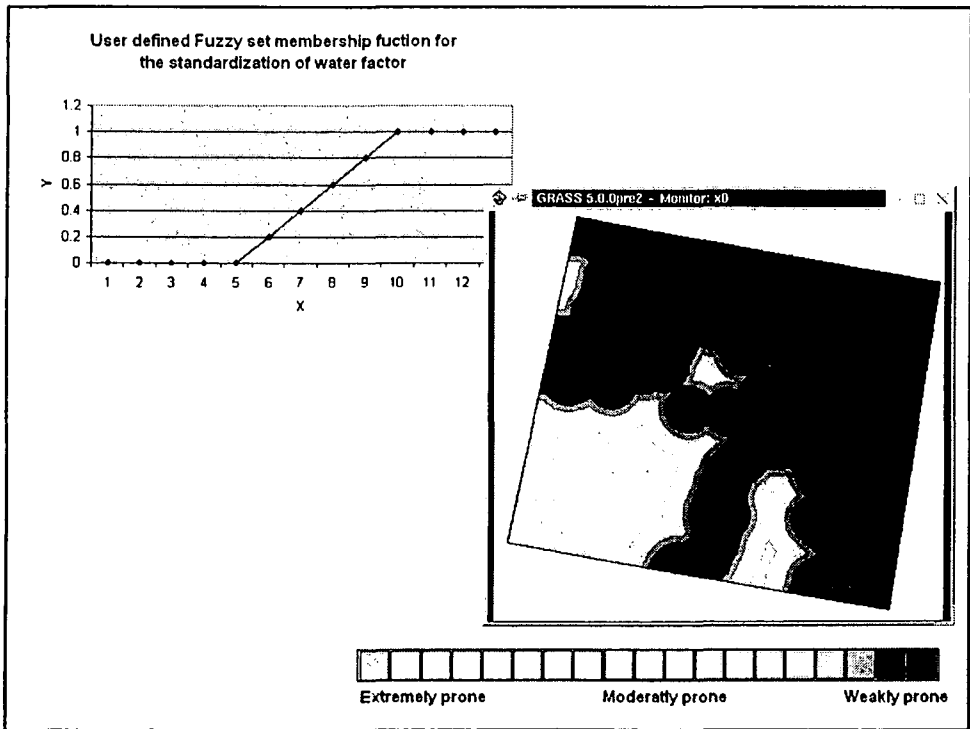
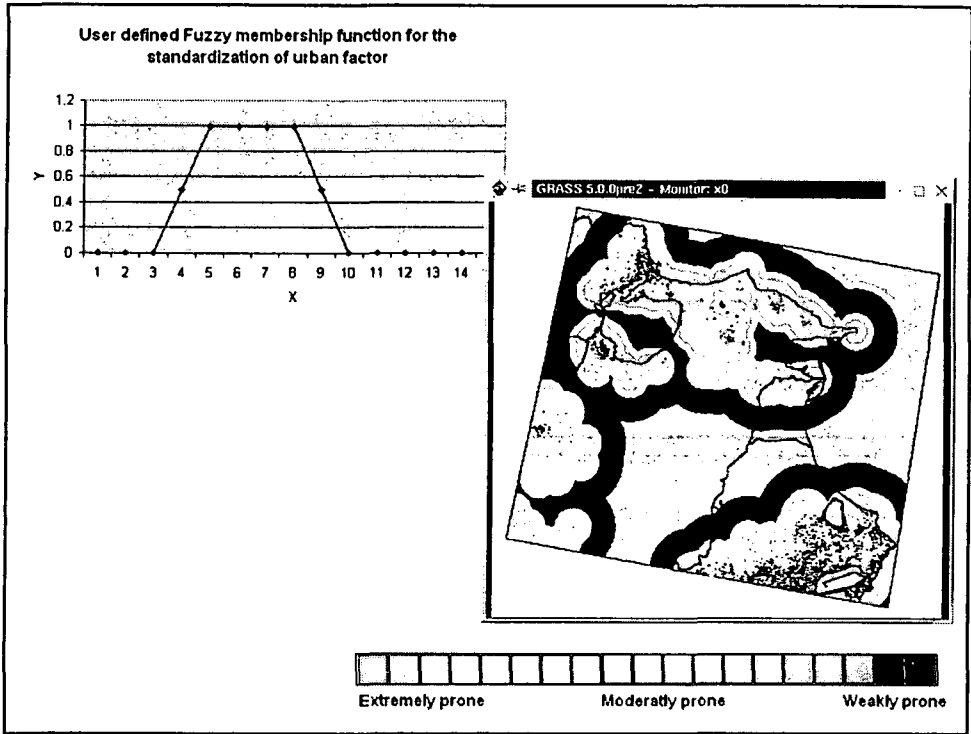
Where:

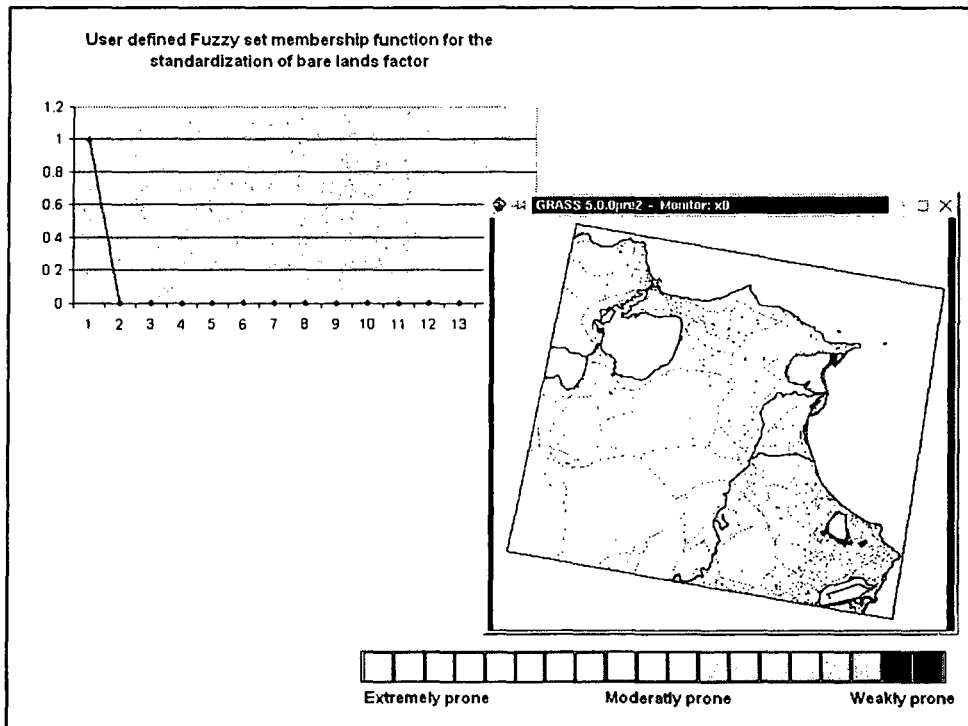
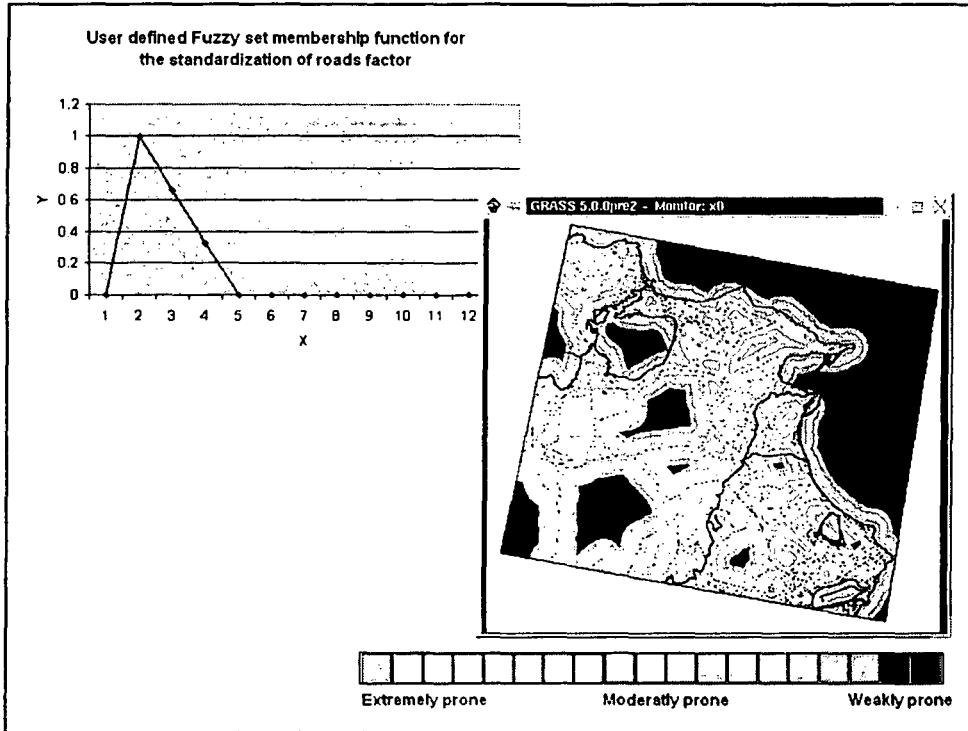
x_i = criterion score of factor i ;

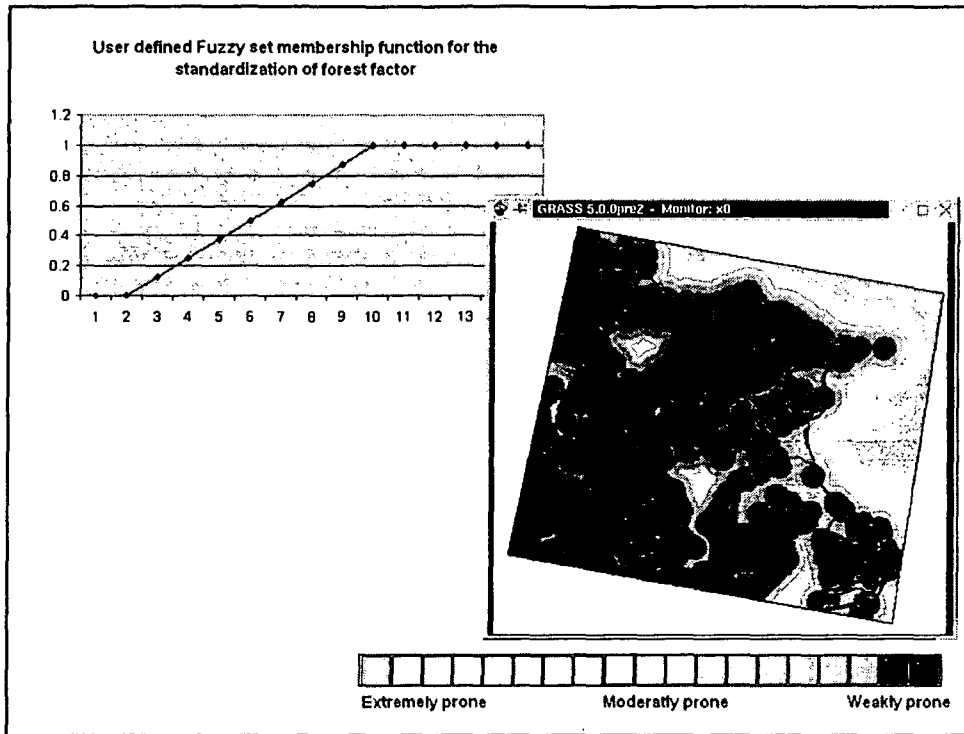
w_i = weight of factor i ;

And c_j = criterion score of constraint j .







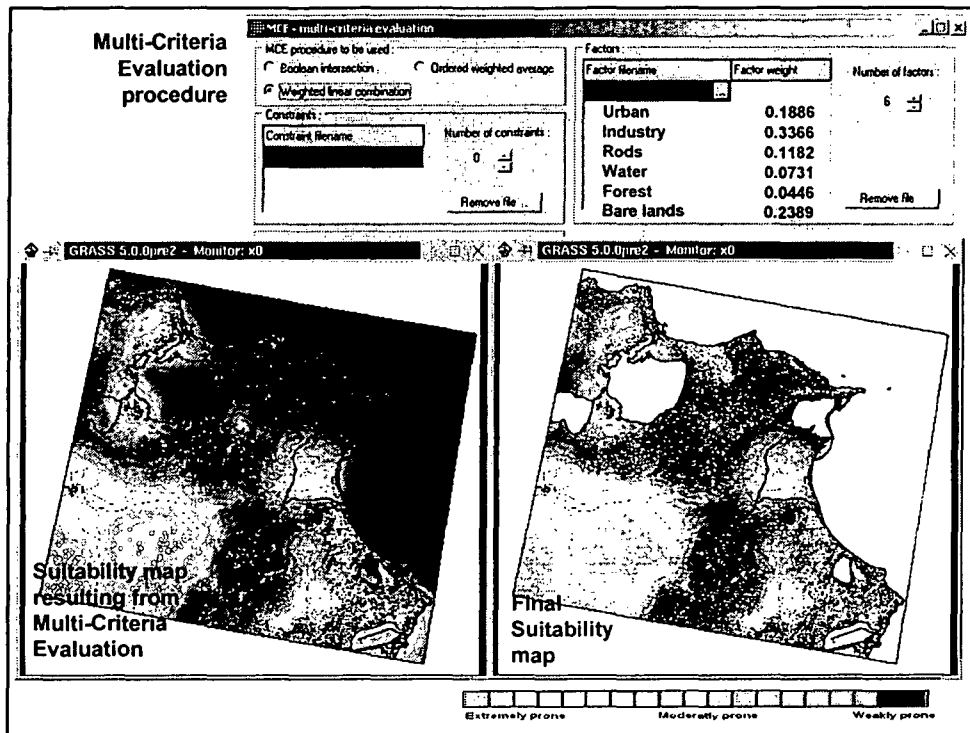


The continuous rating scale used for the PAIRWISE comparison between factors

Pairwise Comparison 9 Point Continuous Rating Scale									
1/9	1/7	1/5	1/3	1	3	5	7	9	
extremely	very strongly	strongly	moderately	equally	moderately	strongly	very strongly	extremely	
Less important						More important			
Pairwise comparison file to be saved: <input type="text"/> ... <input type="button" value="Calculate weights"/>									
	Urban	Industry	Roads	Water	Forest	Bare lands			
Urban	1								
Industry	2	1							
Roads	1/2	1/3	1						
Water	1/3	1/4	1/2	1					
Forest	1/5	1/5	1/3	1/2	1				
Bare lands	2	1/2	2	3	5	1			

The eigenvector of weights is:

- Urban : 0.1886
- Industry : 0.3366
- Roads : 0.1182
- Water : 0.0731
- Forest : 0.0446
- Bare lands : 0.2389



Interpretation

The suitability map resulting from a Multi-Criteria Evaluation shows different classes for which the degree of susceptibility to accept new industrial plants vary from extremely prone areas to weakly prone.

The strongly prone areas are concentrated around the main existing industrial sites ("Echarguia", "Ariana", "Ettadhamen" and "Mannouba") and in the sub-urban (rural-urban interface) areas of the main cities.

This put in evidence the proximity to main roads and its good connection with the market (access to transportation is an important consideration) and also its natural location (coast, rivers, lakes, slope, forest, etc...) which can represent an environmental limitation.

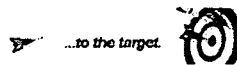
Conclusion

GIS has the capacity to integrate information from a variety of sources into a spatial context in particular from remotely sensed (RS) data.

GIS is well suited to support decision making procedures and can act as a tool in helping the decision-makers in evaluating certain alternatives.

In the end, it is the decision maker, who determines the criteria, the factors, the constraints, the individual weighting and the decision rules.

...But also who takes decision.



Thanks for Your Attention



References

ICS-UNIDO (2000) Training package entitled "Introduction to Geographic Information Systems for Industrial Development", version 1.0, January 2000.

ICS-UNIDO (2001) Training package entitled "Integrated Coastal Area Management", version 1.0, February 2001.

ICS-UNIDO (2001) Proceedings, IT-supported services within the context of sustainable development, International conference on science and technology for sustainable technological development in Central European Countries, Belgrade, 9-10 May 2001.

ICS-UNIDO (2002) Proceedings, International workshop on "Industrial Development in Coastal Areas of South-East Asia", Hanoi, 25-27 June 2001.

Eastman, J.R. (1999) Multi-criteria evaluation and GIS, Longley, Goodchild, Maguire and Rhind (Eds.) Geographical Information systems: Principles and Technical Issues, Vol. 1, pp 493 -502

Fisher, P.F. (1994) Probable and fuzzy models of the viewshed operation Innovations in GIS 1, pp. 161-175

Fisher, P.F. (1999) GY 705 Geographical Decision Making, University of Leicester, Lecture notes and practical tutorials

Jones, C. (1997) Geographical Information Systems and Computer Cartography, pp. 215 – 230

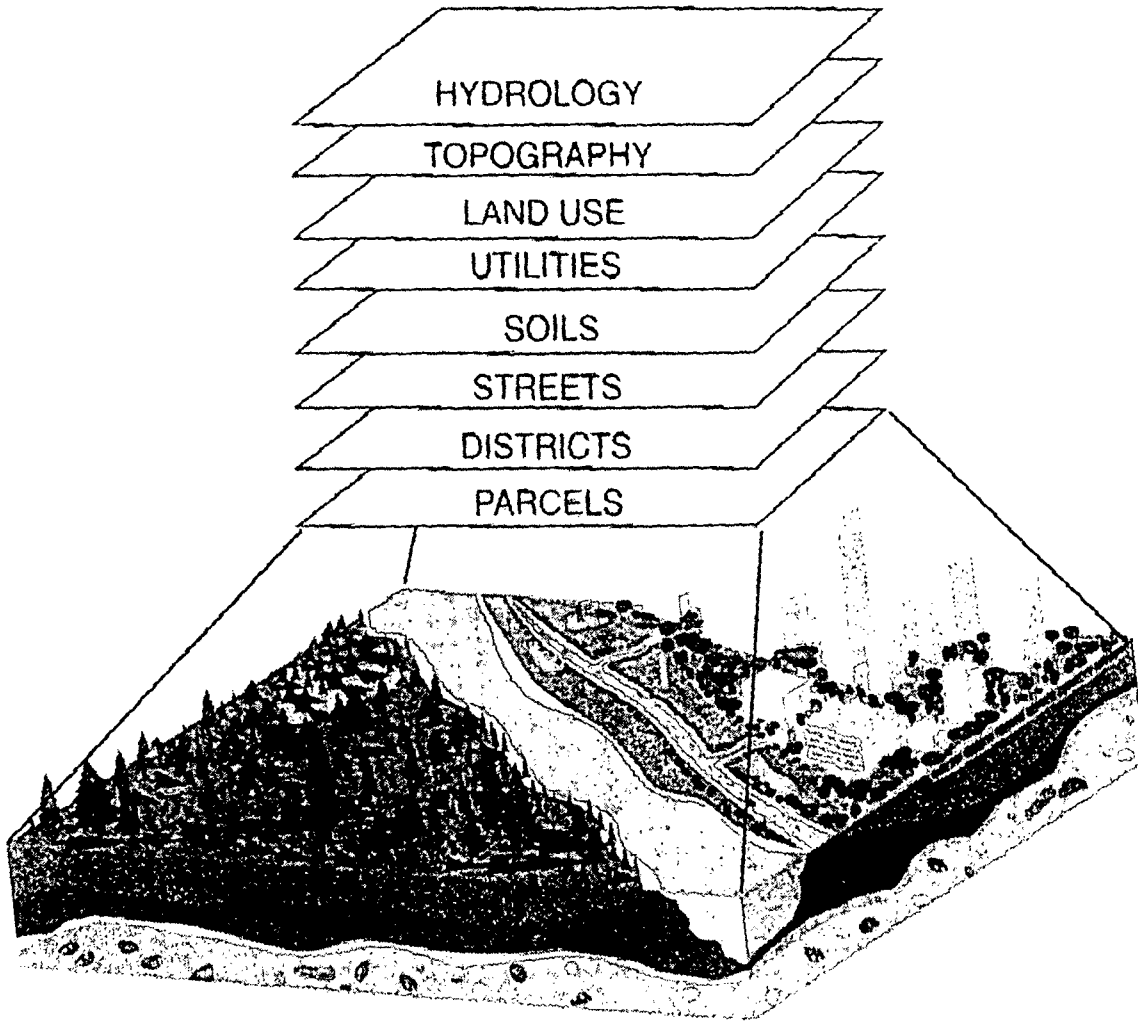
Malczewski, J. (1999) GIS and Multi-criteria Decision Analysis

*Practical Exercises on Image Processing and Multi-Criteria
Evaluation (MCE) Using IDRISI Software Package
by M. Ghribi*



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Mounir Ghribi
Environmental Technologies Engineer
Earth, Environmental & Marine Sciences and Technologies
ICS-UNIDO
AREA Science Park, Building L2
Padriciano 99, 34012 Trieste, Italy
Tel. +39-040-9228105, Fax. +39-040-9228136
E-mail: mounir.ghribi@ics.trieste.it

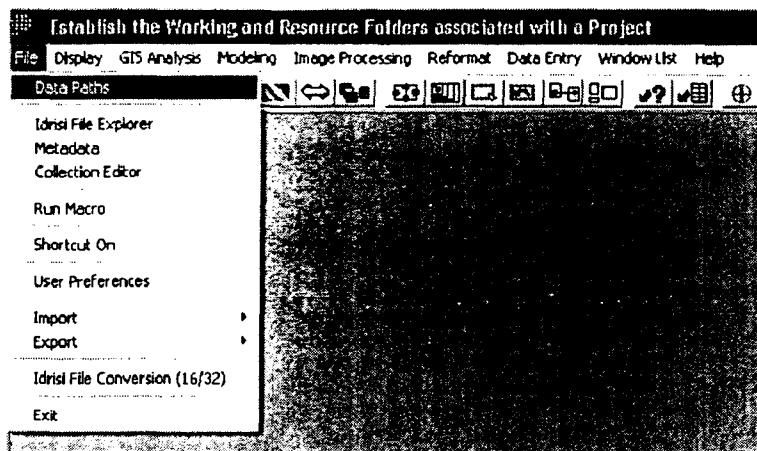
Exercises

1. Getting started with IDRISI

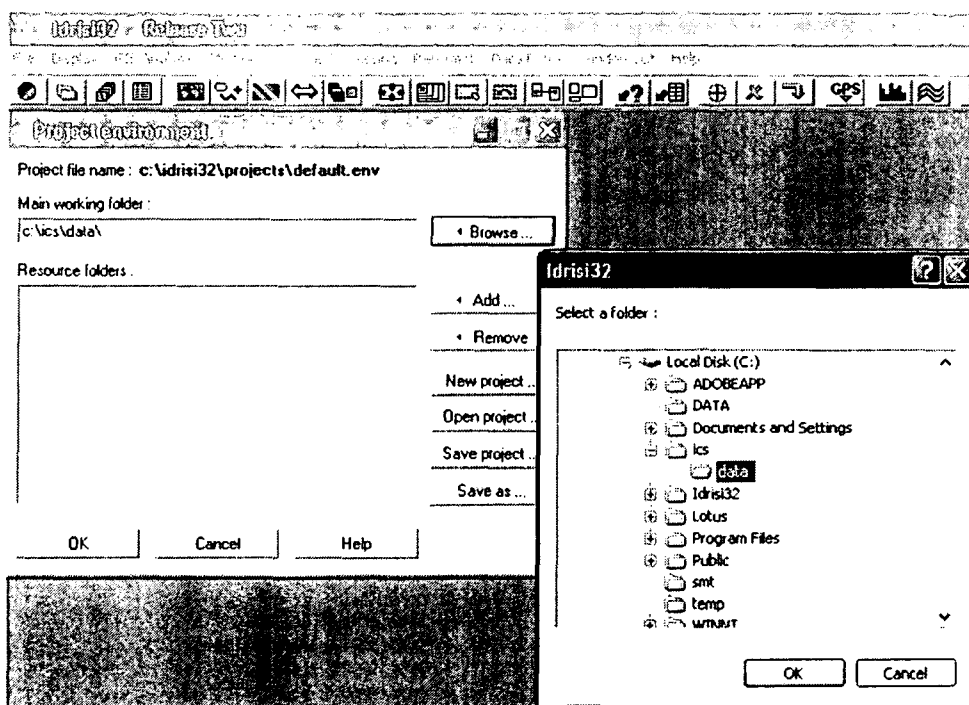
IDRISI for Windows consists of a main interface program (with a menu and toolbar system) and a collection of over 150 program modules that provide facilities for the input, display and analysis of geographical and remotely sensed data. These data are described in the form of map layers.

1.1. Start IDRISI

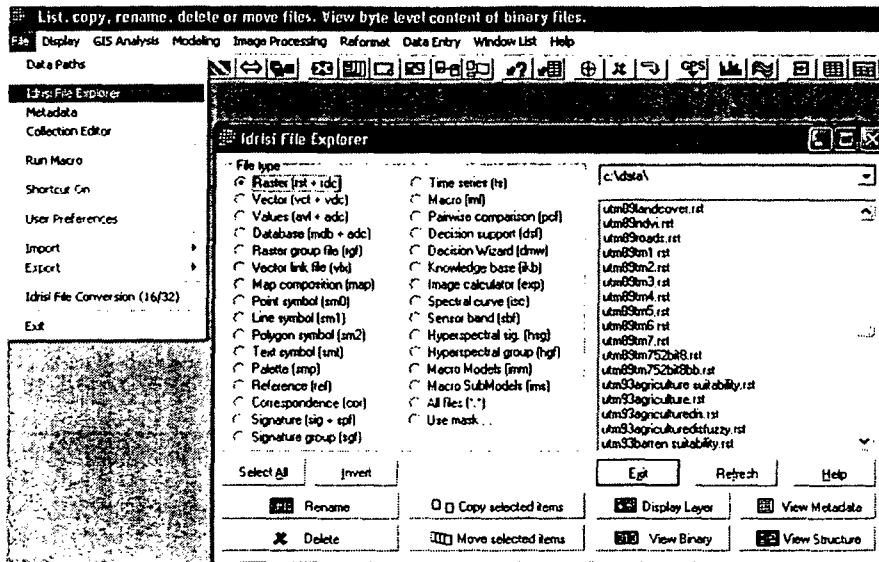
From the Desktop double-click on the IDRISI GIS Software Version 32, release2, shortcut to start the program. After the start up process, you should establish a working directory. From the menu bar choose **File**, and then **Data Paths**.



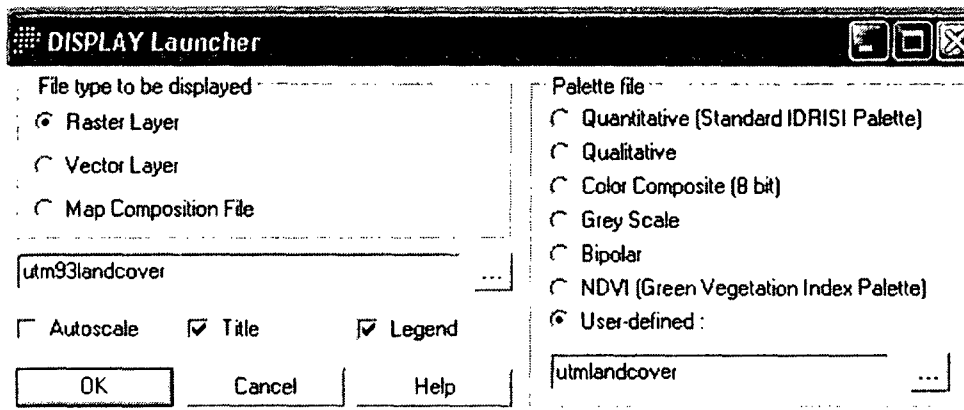
The Operating Environment dialogue box will appear. Directories are shown on the right. Move to the `c:\ics\data` directory by double-clicking each folder successively.



To explore the existing data, go to **File/ Idrisi file explorer**

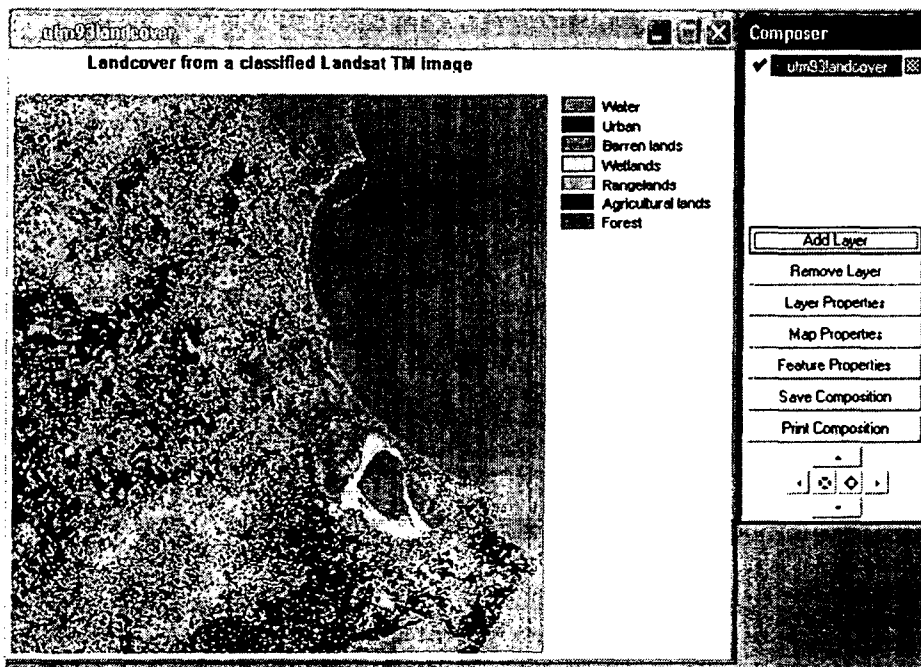


To open an existing project, choose a raster file name from the list, for example **utm93landcover** and then click **Display Layer** or click on **Display** in the menu bar and choose **DISPLAY Launcher**.



1.2. Open an existing raster file and overly vector files

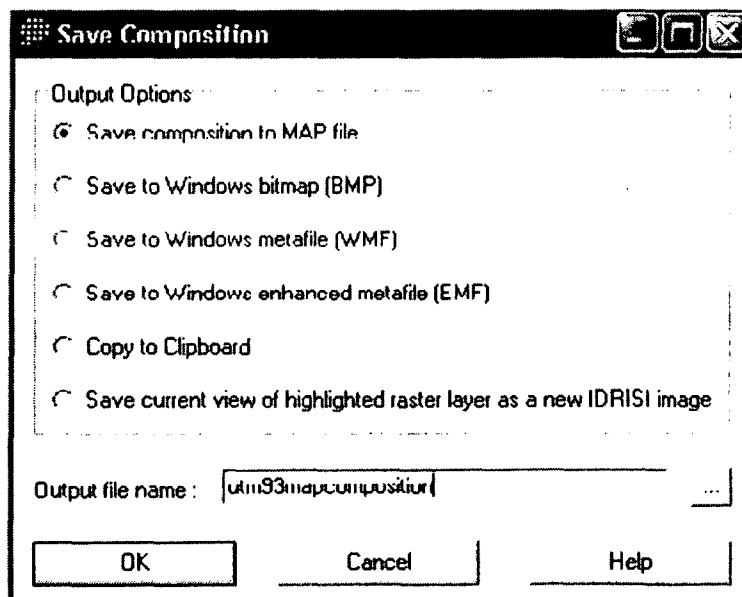
In the Display Map Composition Launcher dialogue box, double-click on the input image file box and choose **utm93landcover**. Select the palette file **utm93landcover** and click the map components boxes to add the Title, Legend, Logo, etc. To display the raster map layer click OK in the icon field.

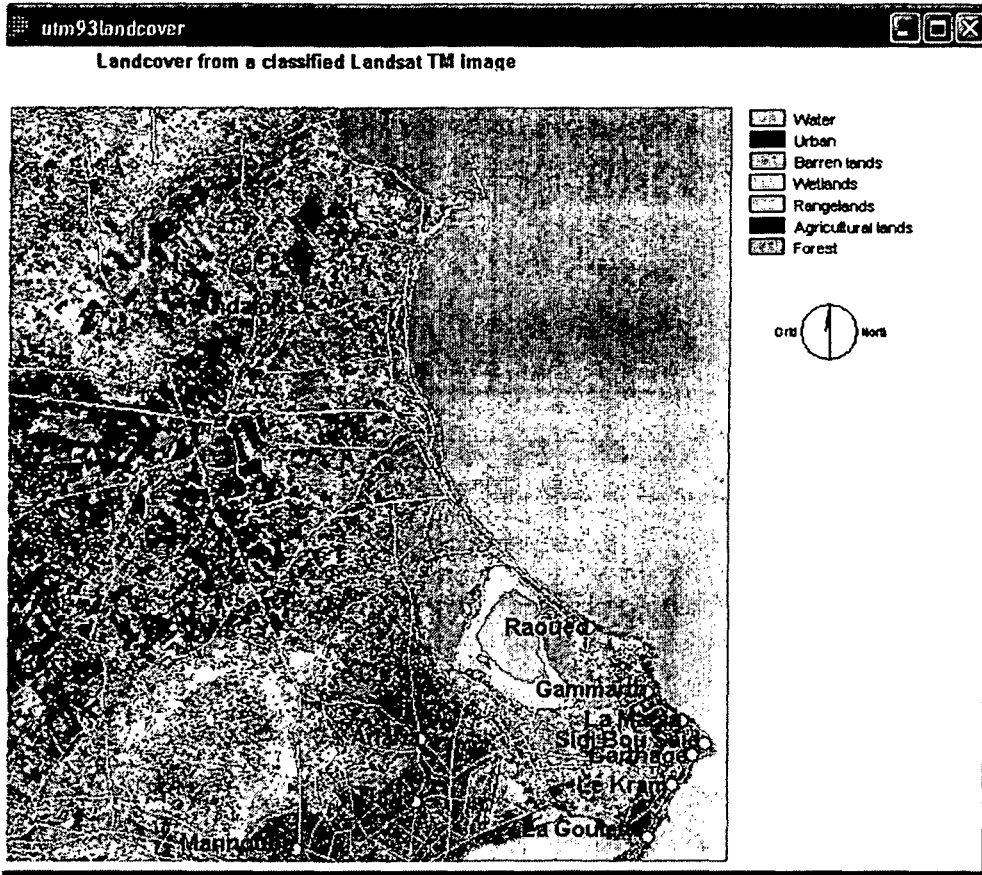


Once the raster map layer is displayed, go to the Composer dialogue box and press Add Layer icon to add vector map layers. Double-click on the input file window and choose **utm93roads** with **uniwhite** as symbol file, the **utm93cities** with **utm93cities** as symbol file and **utm93citiestext** with **utm93text** as symbol file. This will provide respectively: the main roads, the main cities and the names.

To add other components of your map, click on Add Layer in the Composer dialogue box and choose some components: **scale bar**, **n orth arrow**, etc.

To **Save composition**, in the composer go to **Save composition** then save composition as MAP File and give a file name to your final map composition for example **utm93mapcomposition**.

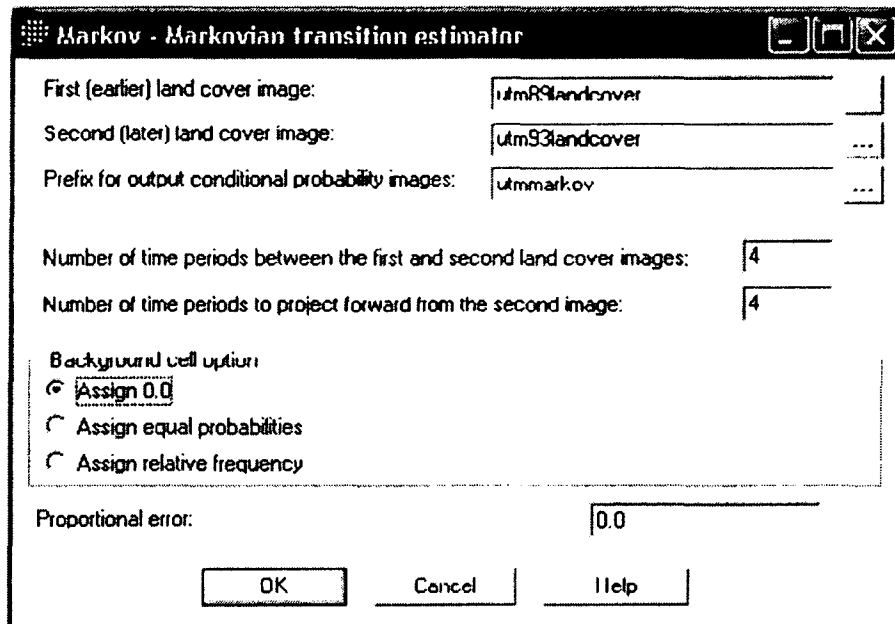




2. Markovian Transition Estimator, cellular automata and Markov change land cover prediction

Since we have 3 sets of data (3 Landsat TM satellite images of the same period for 1989, 1993 and 1997), we will use the **Markovian Transition Estimator** to compare the first 2 land cover images of 89 and 93 (4 years time period) and we will project the results for 1997. And since we have already the 97 land cover, we will be comparing the predicted and the classified land cover images.

Go to **GIS Analysis/Change-Time Series/Markov**

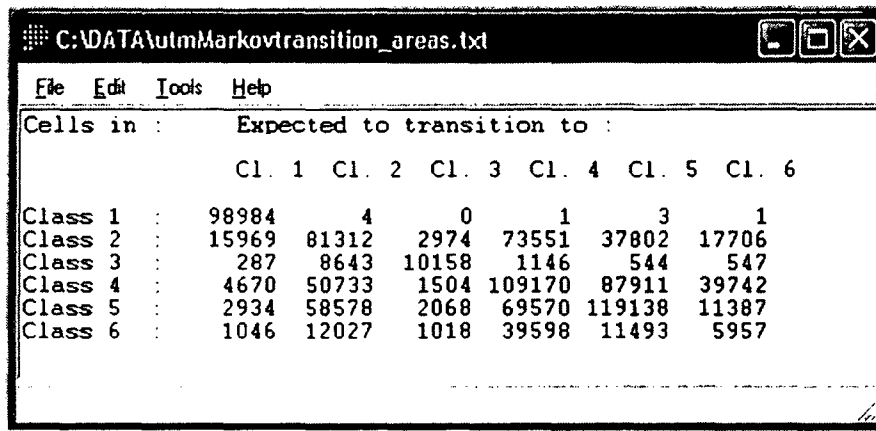


The MARKOV module analyzes a pair of land cover images **utm89landcover** and **utm93landcover**. The output is a transition probability matrix, a transition areas matrix, and a set of conditional probability images (having **utmmarkov** as prefix).

The transition probability matrix is a text file that records the probability that each land cover category will change to every other category.

Given :	Probability of changing to :					
	C1. 1	C1. 2	C1. 3	C1. 4	C1. 5	C1. 6
Class 1 :	0.9999	0.0000	0.0000	0.0000	0.0000	0.0000
Class 2 :	0.0696	0.3546	0.0130	0.3207	0.1648	0.0772
Class 3 :	0.0134	0.4053	0.4764	0.0530	0.0255	0.0256
Class 4 :	0.0159	0.1727	0.0051	0.3717	0.2993	0.1353
Class 5 :	0.0111	0.2222	0.0078	0.2638	0.4518	0.0432
Class 6 :	0.0147	0.1691	0.0143	0.5566	0.1616	0.0837

The transition areas matrix is a text file that records the number of pixels that are expected to change from each land cover type to each other land cover type over the specified number of time units.



The screenshot shows a text file window titled "C:\DATA\utmMarkovtransition_areas.txt". The window contains a table with the following data:

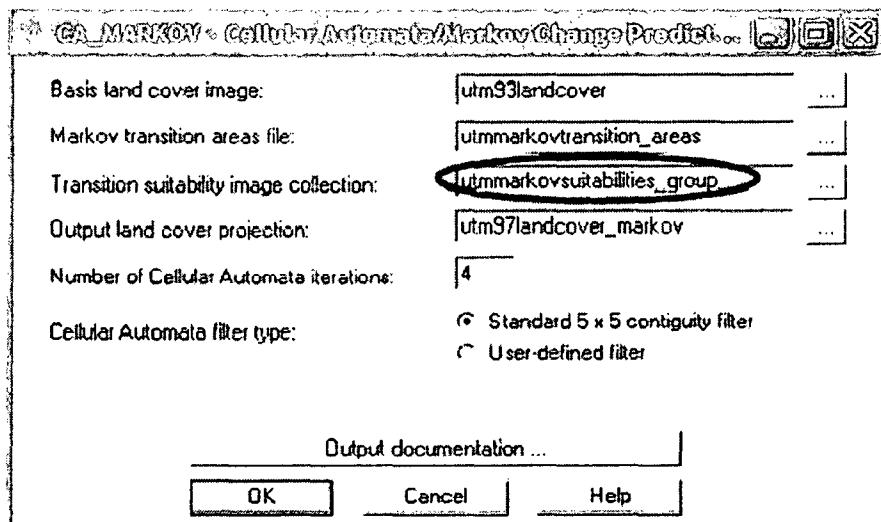
Cells in :	Expected to transition to :					
	Cl. 1	Cl. 2	Cl. 3	Cl. 4	Cl. 5	Cl. 6
Class 1 :	98984	4	0	1	3	1
Class 2 :	15969	81312	2974	73551	37802	17706
Class 3 :	287	8643	10158	1146	544	547
Class 4 :	4670	50733	1504	109170	87911	39742
Class 5 :	2934	58578	2068	69570	119138	11387
Class 6 :	1046	12027	1018	39598	11493	5957

In both of these files, the rows represent the older land cover (1989) categories and the columns represent the newer categories (1993).

CA_MARKOV

CA_MARKOV is a combined cellular automata / Markov change land cover prediction procedure that adds an element of spatial contiguity as well as knowledge of the likely spatial distribution of transitions to Markov change analysis. For our case we will predict the change for **4 years** period. The basic land cover image is **utm93landcover**, the Markov transition areas file is **utmmarkovtransition_areas** and a transition suitability image collection **utmmarkovsuitabilities_group**. The cellular Automata filter is the standard 5x5 contiguity filter. The output is a projected land cover image of 1997 (**utm97landcover_markov**).

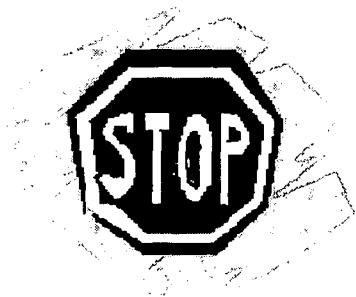
Go to GIS Analysis/Change-Time Series/CA_MARKOV



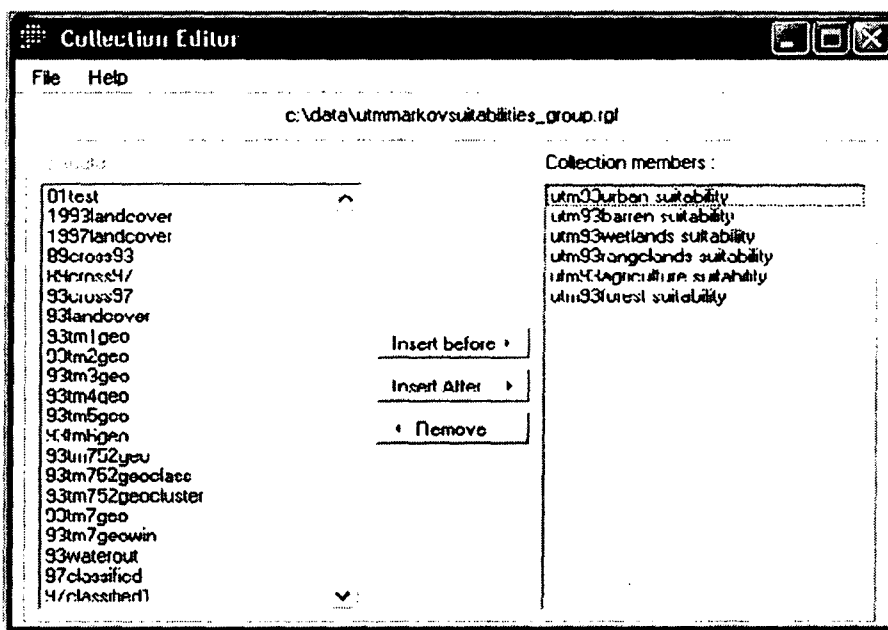
The screenshot shows the "CA_MARKOV - Cellular Automata/Markov Change Predict..." dialog box. It contains the following fields and options:

- Basis land cover image: utm93landcover
- Markov transition areas file: utmmarkovtransition_areas
- Transition suitability image collection: **utmmarkovsuitabilities_group** (circled in red)
- Output land cover projection: utm97landcover_markov
- Number of Cellular Automata iterations: 4
- Cellular Automata filter type: Standard 5 x 5 contiguity filter, User-defined filter

At the bottom, there is an "Output documentation ..." field and three buttons: "OK", "Cancel", and "Help".



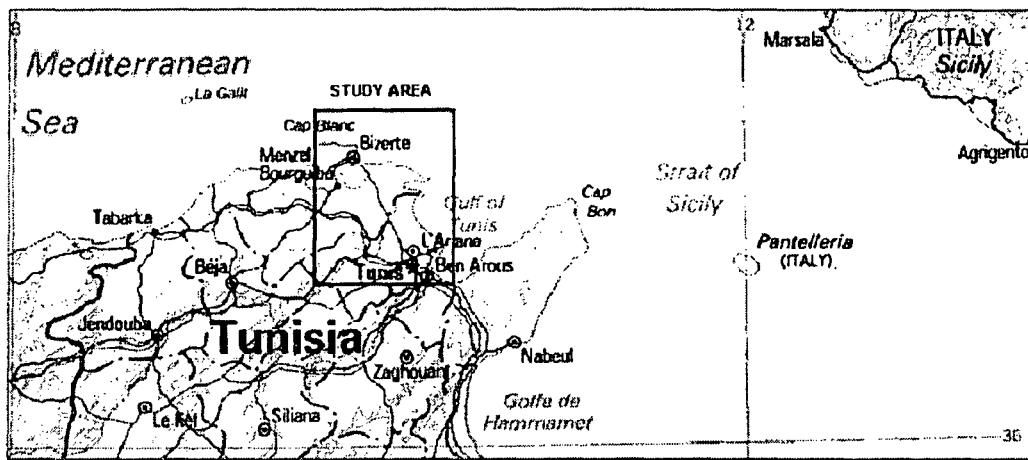
We should first create the `utmmarkovsuitabilities_group` file.



3. Multi-criteria evaluation for urban settlement

3.1. Description of the study area

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



3.1. Purpose

In the present exercise, we will try to design a suitability map depicting the sensitivity of the coastal areas of the study area to the expansion of urban settlement. It consists of landscape evaluation for urban planning and includes a GIS technology developed for the IDRISI geographic information system software.

3.2. Procedural steps

A GIS-based methodology is integrated by using **Weight** IDRISI module. The concept consists of inserting interactive effects of several contributing factors and constraints that may contribute in enhancing or decreasing the susceptibility.

```

C:\DATA\utm93urban pairwise.pcf
File Edit Tools Help
7
utm93slopedisfuzzy
utm93forestdisfuzzy
utm93waterdisfuzzy
utm93barrendisfuzzy
utm93industrydisfuzzy
utm93roadsdisfuzzy
utm93urbandisfuzzy
1
1/3 1
1/2 1/3 1
3 5 3 1
5 7 5 3 1
5 7 3 2 2 1
7 9 7 2 2 3 1
cursor position: 1,18

```

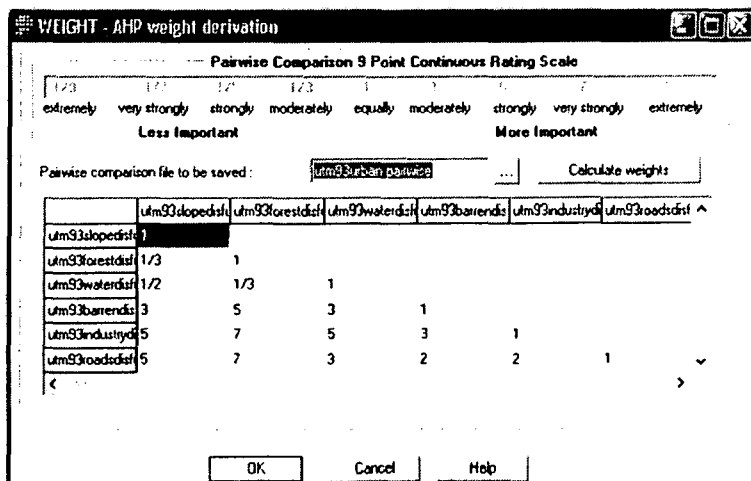
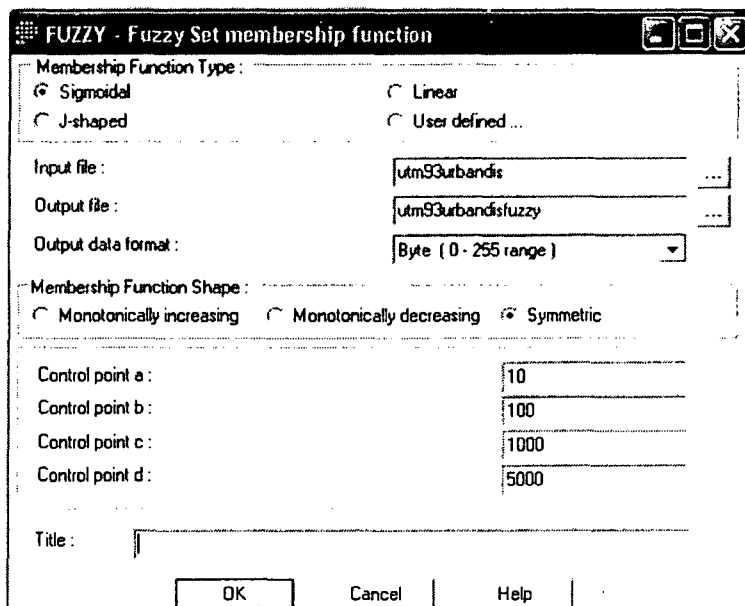
The factors are raster images containing the target features from which distance is measured thanks to Distance IDRISI module. The constraint, on the other hand, is to exclude certain areas from consideration, such as water and reserved lands (urban and roads).

Go to **GIS Analysis/Distance Operators/Distance** to create distance files to all selected factors that contribute to the final suitability map.

Table: Factors contributing to the change of urbanization susceptibility

Factors	File name	Description
1	Utm93urbandisfuzzy	Proximity to main urbanized areas
2	Utm93industrydisfuzzy	Proximity to main industrialized sites
3	Utm93roadsdisfuzzy	Proximity to main roads
4	Utm93waterdisfuzzy	Proximity to water (sea, lakes and rivers)
5	Utm93forestdisfuzzy	Proximity to protected forests and national parks
6	Utm93barrendisfuzzy	Proximity to bares soils
7	utm93slopedisfuzzy	Proximity to hills and high slope

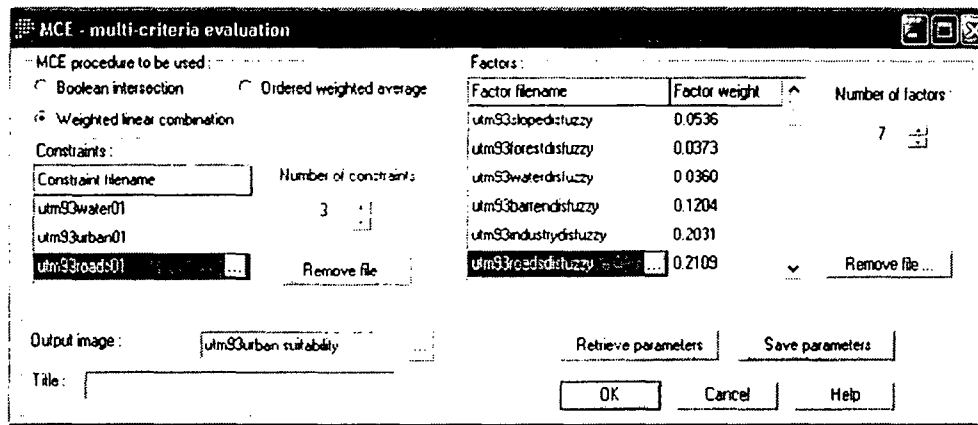
To standardize factors, we will use a fuzzy set membership for each category. Go to **GIS Analysis/Decision Support/Fuzzy**



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.

Select GIS Analysis/Decision Support/MCE.

MCE is a decision support tool for Multi-criteria evaluation. A decision is a choice between alternatives (such as alternative actions, land allocations, etc.). In a 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.



The result is a set of factor weights used by a weighted-linear combination in the multi-criteria evaluation.

3.4. Suitability map and Interpretation



The suitability map produced from a multi-criteria evaluation shows different degrees of susceptibility to new industrial plants. As shown in figure 2.8, 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. Highly prone areas to industrial development are characterized by:

- Proximity to an existing industrial zone in which there is a high probability that infrastructure and organized industrial system exist;
- Proximity to residential and commercial sites fulfilling the requirement for social activities. The availability of high number of workers will satisfy labour requirements for industrial activities;
- Proximity to main roads and connection with markets;
- Natural allocation (coast, rivers, lakes, slope, etc.), which can represent an environmental constraint.

REFERENCES

Carver, S. J. (1991) Integrating Multi-Criteria Evaluation with Geographical Information Systems, *International Journal of Geographical Information Systems*, 5(3): 321-339.

Craig, W.J. and David M.D. (1991) Progress on the Research Agenda: URISA '90. *URISA Journal*, Volume 3, Number 1, Spring 1991, pp.90-96.

Densham, P.J. (1991) "Spatial Decision Support Systems". In: Maguire, D.J., M.F. Goodchild, and D. ... eds. *Geographical Information Systems: Principles and Applications*, vol.1, ... , 403-412.

Eastman, J. R. (1997) "IDRISI for windows, version 2.0, tutorial exercises", 4.1. Worcester, MA: Graduate school of Geography, Clark University

Eastman, J.R., Jin, W., Kyem, P. A. K. and Toledano, J. (1995) Raster Procedures for Multi-Criteria/ Multi-Objective Decisions. "Photogrammetric Engineering & Remote Sensing", Vol. 61, No. 5, May 1995, pp. 539-547.

Feiering, R.B. (1986) Linear Programming, An introduction to Quantitative Applications in the Social Sciences 60

Geoffrion, A.M. (1983) Can OR/MS Evolve Fast Enough? *Interfaces* 13: 10-25.

Goodchild, M.F. and Densham, P.J. (1990) Spatial Decision Support Systems: Scientific Report for the Specialist Meeting, technical Report 90-5, National Center for Geographic Information and Analysis.

Gorry, A. and Scott Morton, M. S. (1971) A frame work for information systems, *Solan Management Review* 13: 55-77

Honea, R.B., Hake, K.A. and Durfee, R.C. (1991) Incorporating GISs into Decision Support Systems: *GIS Applications in Natural Resources*, (M. Heit and A. Shortreid, editors), GIS World, Inc., Fort Collins, Colorado. In: (Eastman, et al., 1995). Raster Procedures for Multi-Criteria/ Multi-Objective Decisions, *Photogrammetric Engineering & Remote Sensing*, Vol. 61, No. 5, May 1995, pp. 539-547.

IDRISI (1997) *IDRISI for windows User's Guide*, Version 2.0, January 1997, Clark labs for Cartographic and Geographic Analysis, Clark University.

Janssen R. and van Herwijnen, M. (1991) Decision Support Applied to Decisions Changing the Use of Agricultural Land, In Multiple Criteria Decision Support. Proceeding of the International Workshop held in Helsinki, Finland, 7-11 August 1989, edited by P. Korhonen, A. Lewandowski and J. Wallenius (Berling, Springer Verlag), p. 293-302.

MEAT (1995) National Report, THE STATE OF THE ENVIRONMENT IN TUNISIA, Ministry for the Environment and land use planning (MEAT), pp.66-67.

Moon, G. (1992) Capabilities Needed in Spatial Decision Support Systems. GIS/LIS '92, vol.2: 594-600.

Munda, G. (1995) Multi-criteria Evaluation in a Fuzzy Environment, Physica-Verlag, Heidelberg, pp. 255

NCGIA (1992) A Research Agenda of The National Center for Geographic Information and Analysis. Technical Report: 92-7.

Nijkamp, P., Rietveld P. and Voogt H. (1990) Multi-criteria Evaluation in Physical Planning, North-Holland, Amsterdam

Patrono, A. (1997) Introduction to Decision Support Systems, ICS training course on GIS and water management for industrial activity, Hanoi, Vietnam, 9-18 June, 1997

Paruccini, M. (1994) Applying Multi-criteria Aid for Decision to Environmental Management, Kluwer, Dordrecht

Rosenthal, R.E. (1985) Concepts, theory and techniques: Principles of multi-objective optimization, *Decision Sciences* 16 (2): 133-152.

Saaty, T. L. (1980) The Analytical Hierarchy Process, McGraw Hill, New York

Sol, H. G. (1983) Processes and tools for decision support: Inferences for future developments. In Processes and Tools for Decision Support, (ed. Sol, H. G.), North Holland, Amsterdam, the Netherlands, pp 1-6

Sprague, R.H. and Watson, H.J (1986) Decision Support Systems: Putting Theory into Practice. Prentice Hall, New Jersey

UNESCO (1993) *Environment and Development BRIEFS*, United Nations Educational, Scientific and Cultural Organization, Paris, 1993

Voogd, H. (1983) Multi-Criteria Evaluation for urban and regional planning, PION, London

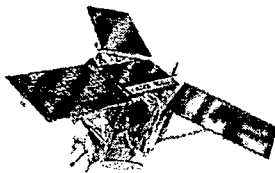
ICS Case Studies Presentation
by M. Ghribi



International Centre for Science and High Technology

An autonomous body of the United Nations Industrial Development Organization

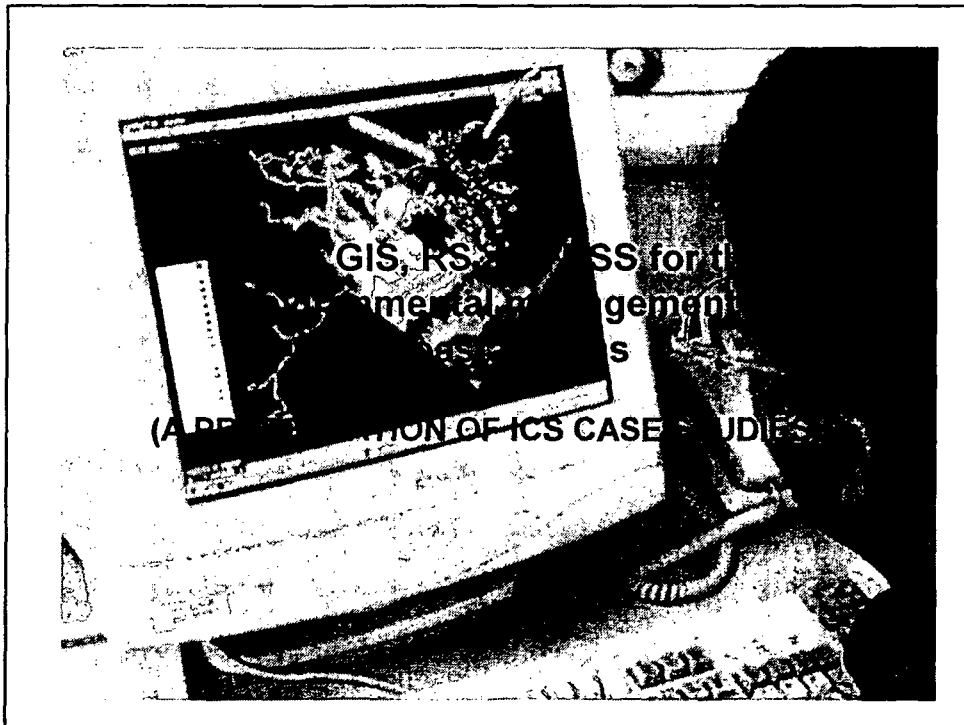
ICS Case Studies Presentation



ICS-UNIDO GIS Lab

Mounir GHRIBI
Environmental Technologies Engineer
ICS-UNIDO
AREA Science Park, Padriciano 99
34012 Trieste, Italy
Tel. 0039-040-9228105, Fax. 0039-040-9228136
mounir.ghribi@ics.trieste.it
<http://www.ics.trieste.it>

ICS-UNIDO is supported by the Italian Ministry of Foreign Affairs



ICS GIS lab software packages

GRASS (GIS) Geographic Resources Analysis Support System, is a public domain (free) Geographic Information System used for data management, image processing, spatial modeling , etc.

MultiSpec, is a processing system for interactively analyzing Earth observational multi-spectral image data such as that produced by the Landsat series of Earth satellites and data from current and future airborne and space borne systems such as AVIRIS (free).

IDRISI (GIS) is a pc-based, (mostly) raster GIS from Clark labs. It couples the extensive analytical capabilities of the GIS and Image Processing System with a highly interactive graphical user interface. It provides raster analytical functionality covering the full spectrum of GIS and Remote Sensing needs from database query, to spatial modeling, to image enhancement and classification.

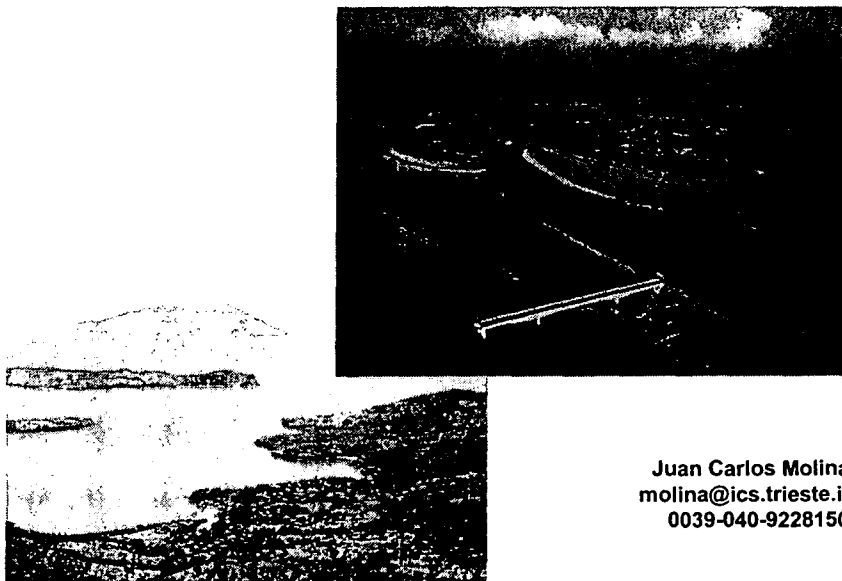
ArcGIS (GIS) ESRI products containing ArcView and ArcInfo. It is a desktop mapping and a complete GIS software. Has hundreds of mapping and spatial analysis capabilities.

ERDAS IMAGE (Image Engineering) offers a flexible and scalable solution for mage input, management, display and enhancement, spectral analysis, digital photogrammetry, GIS data integration and map composition. Imagine provides a robust set of tools for geo-correction, image analysis, visualization, and map output.

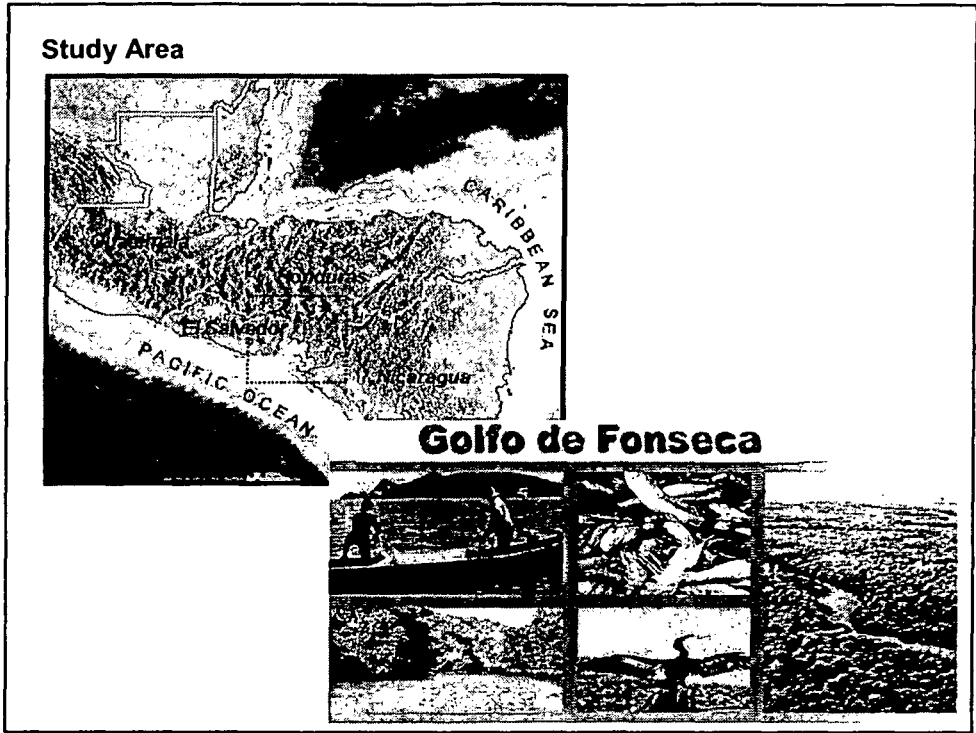
Delft-3D (Environmental Simulation) is a framework of software modules for 2 and 3-dimensional flow, water quality, ecology, short wave propagation and morphology and their interactions. The software has been developed over the passed 15 years and still being extended and improved in functionality's and application.

SPSS & STATISTICA (statistics) generate decision-making information using powerful statistics, tabular and graphical output, and offer results to other packages using a variety of reporting methods, including secure Web publishing.

A case study in the Gulf of Fonseca, Honduras



Juan Carlos Molina
molina@ics.trieste.it
0039-040-9228150



Geo-referencing Landsat TM

Introduction:

It is crucial to register the map with the real world coordinates in order to correct it for systematic or random distortions

MULTISPECW32:

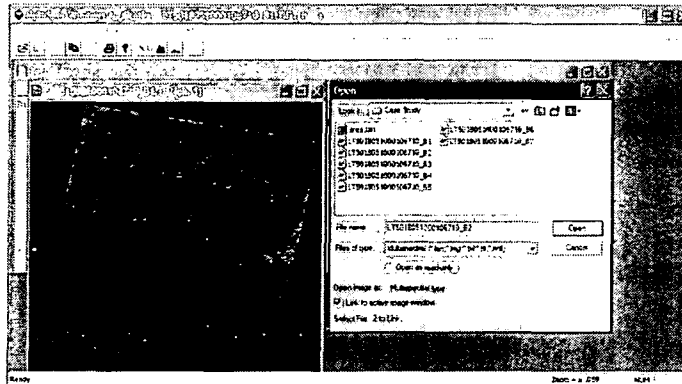
Is a processing system for interactively analyzing Earth observational Multispectral image data

Multispectral images are composed of a series of images at differing optical wavelengths. Hyperspectral images are composed of a large number of measured wavelength bands

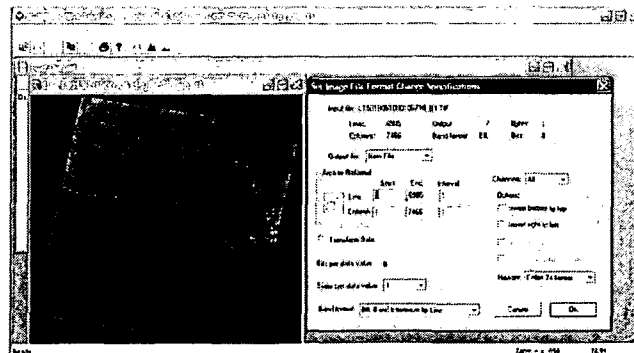
Discrete Georeference

Multispectral file:

In MultispecW32 click on **file > open image > band1**, now go and open band 2 but this time check in the box "link to archive image window", do this for all the bands, when the last band has been added just click cancel to the dialog box



Now we have to change the image format, in the main menu go to **processor > reformat > Change image file format** in the dialog box revise if the data is correct and if the header selection is "Erdas" format and click ok



IDRISI:

consists of a main interface program (the one with the menu and toolbar system) and a collection of over 150 program modules that provide facilities for the input, display and analysis of geographic data.

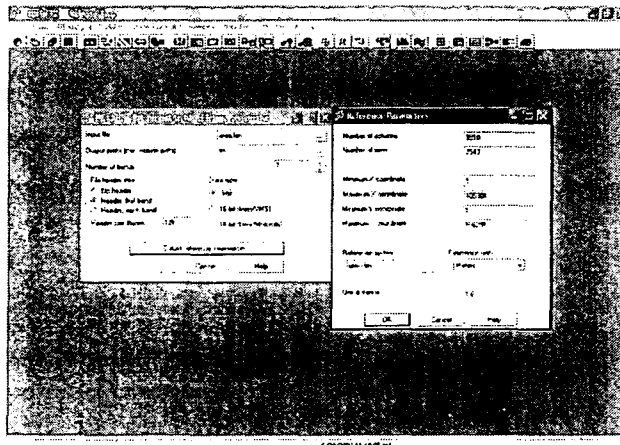
Importing the Multispectral file:

In IDRISI's main menu go to click on **File > Import > General Conversion Tools > BILIDRIS (BIL with/without header)**

When introducing the Maximum and Minimum "x" and "y" coordinates you have to be careful, first check if resolution is 30 if not apply the following formulas to find the real coordinate values

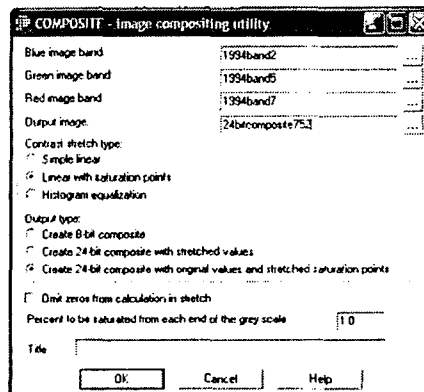
# Columns	# Lines
$(\text{Max "x"} - \text{Min "x"}) / \text{Resolution}$	$(\text{Max "y"} - \text{Min "y"}) / \text{Resolution}$
Max "x"	Max "y"
$\# \text{Columns} * \text{Resolution} + \text{Min "x"}$	$\# \text{Lines} * \text{Resolution} + \text{Min "y"}$
Max "x"	Max "y"
$3510 * 30 + 1$	$3543 * 30 + 1$
Max "x" = 105301	Max "y" = 106291

Now you should input the corrected Max "x" and "y" coordinate data



24 bit Composite 752:

Introduce the RGB bands, name this file and select the contrast stretch type "linear with saturation points" in the output type options check in the last option, the 24 bit image will give us a clearly looking for the ground control points. Create the same composite for the georeferenced image



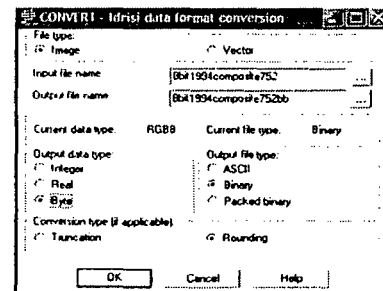
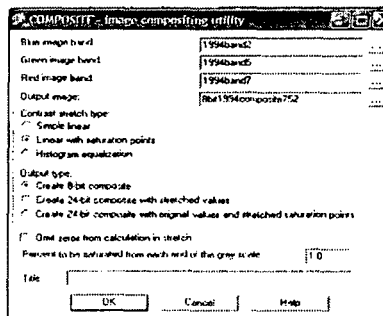
Correspondence file:

This file contains the coordinates of specific points termed Ground Control Points in two different reference systems, the first pair of coordinates correspond to the locations in an arbitrary plane reference system, the second corresponds to the same locations in the desired georeferencing system

E1	E2	E3	E4
155253	106460	132274	491655
168920	638219	137954	541454
170764	815656	395450	449424
166889	617482	174162	058236
163549	451576	380461	639629
113729	132723	184411	443158
131608	184924	156521	359824
128789	854187	125479	847611
234919	725084	177382	518546
194870	707521	135771	417722
197560	172871	135346	374863
160659	893348	131206	116640

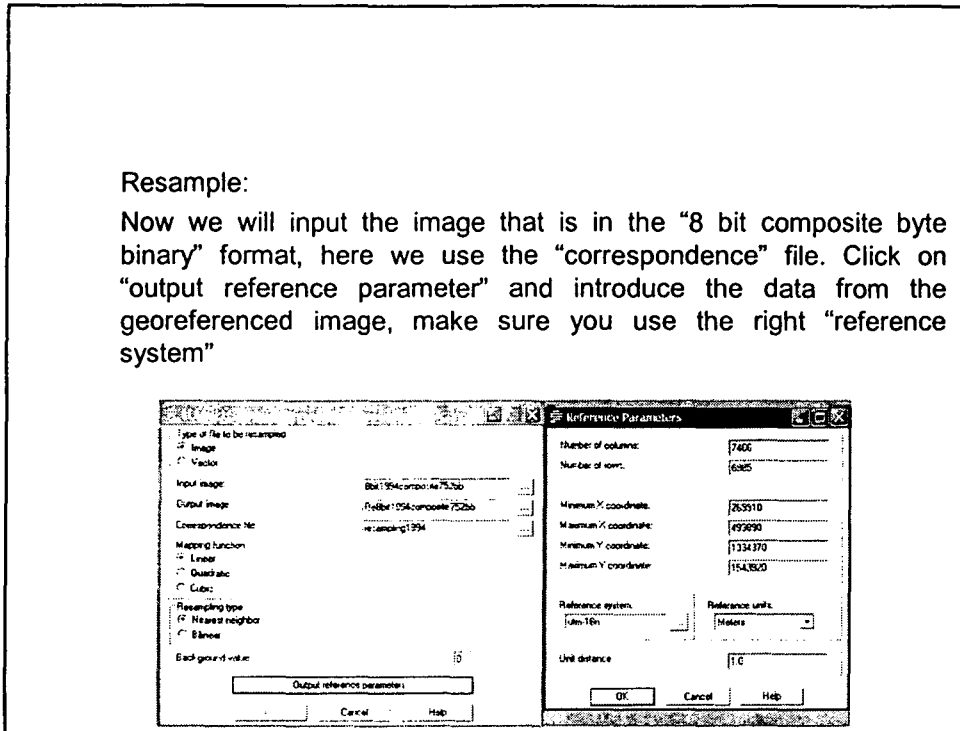
Byte Binary:

Since the default format of IDRISI is "8bit byte binary" we should change our image to that format, after you have done this you should proceed to the last step in order to run the statistical test and create the resample file.



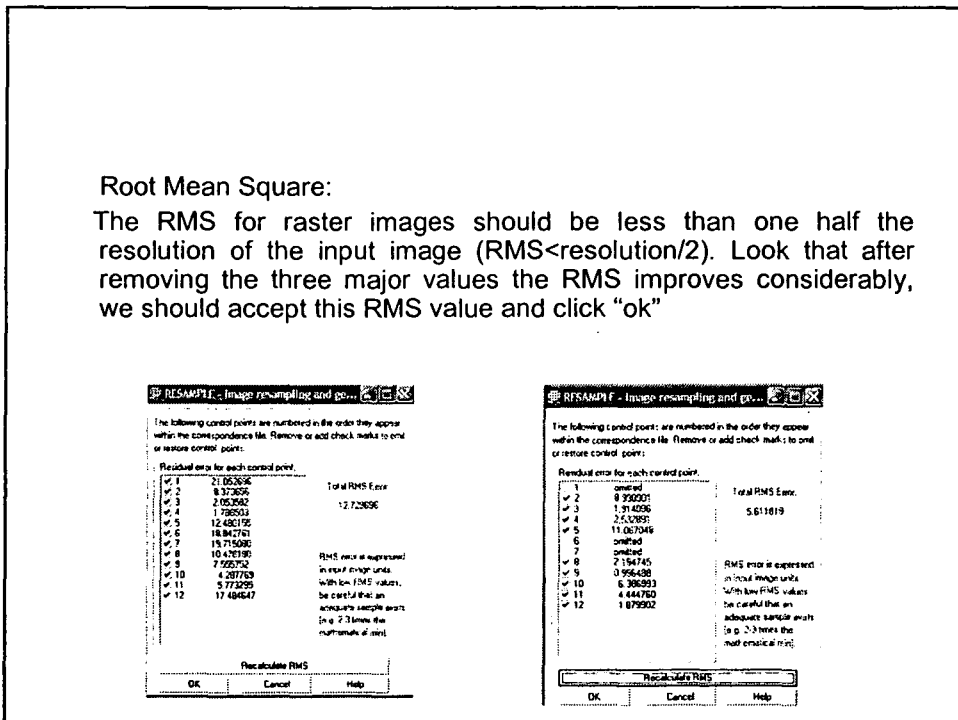
Resample:

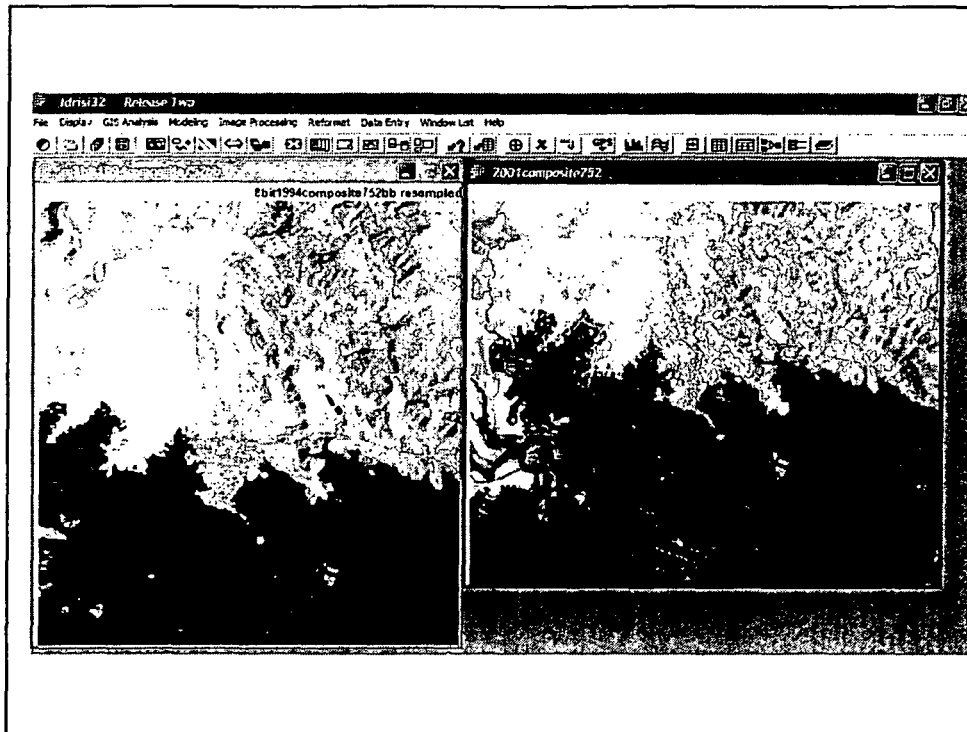
Now we will input the image that is in the "8 bit composite byte binary" format, here we use the "correspondence" file. Click on "output reference parameter" and introduce the data from the georeferenced image, make sure you use the right "reference system"



Root Mean Square:

The RMS for raster images should be less than one half the resolution of the input image ($RMS < resolution/2$). Look that after removing the three major values the RMS improves considerably, we should accept this RMS value and click "ok"





Hai phong case study summary

Simulation of pollutants spreading in water body

(A case study in Hai Phong coast of Vietnam)

Rajeeb Ghimire
Rajeeb.ghimire@ics.trieste.it
0039-040-9228149

Objectives of the case study :

- To develop an hydrodynamic model for the coastal area of Hai Phong.
- To use the model for simulation of hydrodynamics behavior and pollutant spreading

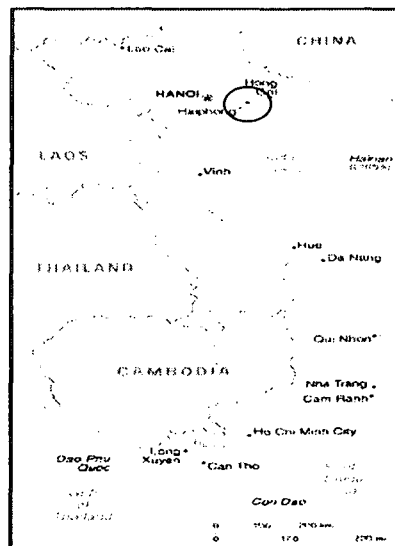
Introduction to study area :

Hai Phong, Vietnam

Area: 1,507.6 km²

Population: 1,677,465

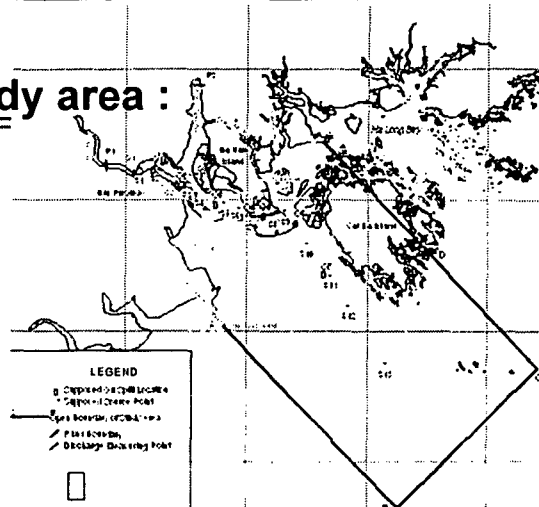
Location: 20° 52' N and 106° 41' E



Hai phong case study summary

Physics of Study area :

- Size: 1808 square km, Length 63.45 km and breadth of 28.5 km.
- Depth varies from 0 m to 27 m.



- There are two rivers joining the sea: Cam river and Bach Dang river.
- The boundary of the study area contains small part of South China sea, a part of Cat Ba Island, Qua Xoai Island and Ha Nam Island.
- The tidal flow is weak, the highest tidal range of the M2 constituent is just 0.1 m

Hai phong case study summary

Nature of data :

- The site map: It contains the land boundary, supposed oil spill location, open boundary of sea and river boundary.
- The depth points: There were a total of 80370 depth points in ASCII format. Points were rotated in 45 degree. The depth points were distributed in 190*423 grid with 150m*150m grid cell size.
- Sea boundary condition: The harmonic values of all 588 sea boundary points
- River boundary conditions: The time variation of velocity at river boundary.
- Location and amount of release: The location and amount of pollutants release for 13 source points were given

Tools used :

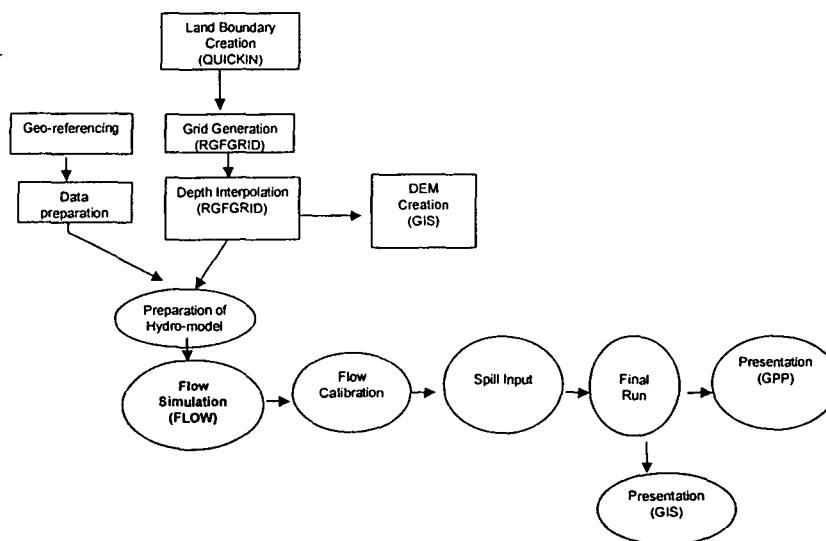
Delft3D-RGFGRID: This is a pre-processing program used to create, manipulate and visualize orthogonal curvilinear model Grid for the Delft 3D program.

Delft3D-QUICKIN: This is a pre-processing program used to create, manipulate and visualize model bathymetries for The Delft3D program.

Delft3D-GPP: This is post-processing program used to read, plot and export the results of Delft3D modules.

Delft3D-FLOW: This is a multidimensional (2D or 3D) hydrodynamic and transport simulation program which calculates non-steady flow and transport phenomena that results from tidal and meteorically forcing on a curvilinear grid.

Methodology :



Detail work process :

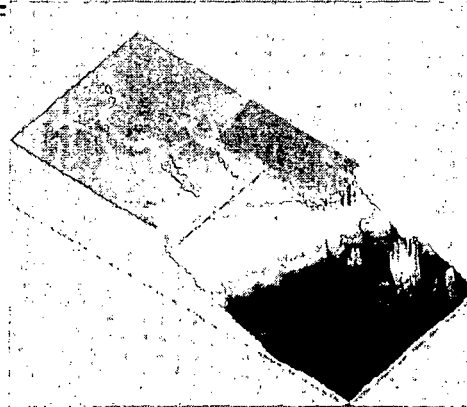
• Reviewing and formatting of existing data:

Excel sheet and text editor were used to reformat the provided data to Delft 3D formats. Some VBA macros were created.

Georeferencing Data:

The provided *.tiff map was georeferenced for latlong projection system. Idrisi was used.

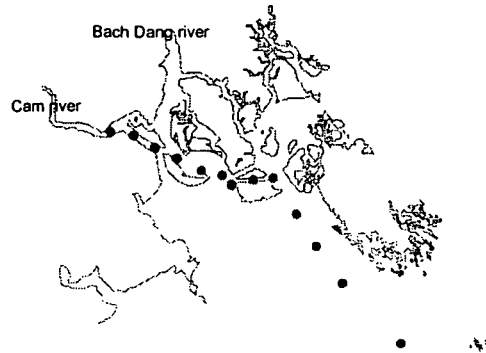
Detail work process :



3D view generation:

To have the better knowledge of the study area the 3D view was generated with the help of Idrisi (Figure 4).It clearly shows the location of rivers, channels, sea and land.

Detail work process :



Creating land boundary:

The geo-referenced map was on-screen digitized for land boundary in IDRISI and exported to Arc view and then to Delft-QUICKIN. The thirteen points of oil spill location were also digitized.

Detail work process :



Grid creation and bathymetry interpolation:

Orthogonal grid was created with Delft-RGFGRID and bathymetry interpolation were done using Delft-QUICKIN. The number of grid cell were reduced as compared to the original grid but the grid cells are fine towards the area of interest, it helps to save the time of computation

Case Study in Trinidad & Tobago



Anjana Dayal

Fellow

anjana.dayal@ics.trieste.it

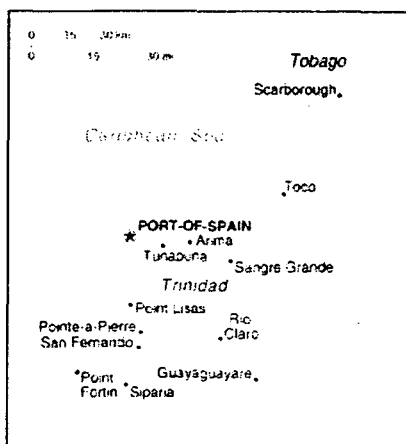
0039-0409228151

Coastal Zone Management Issues in Trinidad & Tobago

*Using Geographic Information
Systems (GIS)*

Trinidad and Tobago

For our purposes,
we will be solely
focusing our
activities on the
mainland of the
two islands,
Trinidad.



Part I: NDVI using NOAA images

- By entering the geographical coordinates, images for the study area were downloaded using available data from the National Oceanic Atmospheric Administration (NOAA)
- This image represents the time period of July, 1992

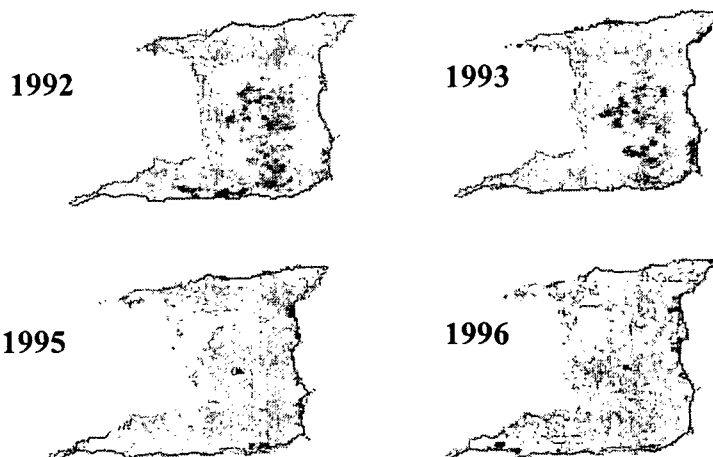


Reformatted window

- The following image is a reformatted window taken from the original study area in the previous slide
- The next slide illustrates the changes in NDVI over a time period of 4 years



NDVI dynamics from 1992-1996



Part II: Digitizing

- Using a reliable map source from the internet, the 8 administrative borders of Trinidad were digitized
- Dividing the study area into units allows one to observe and analyze the differences in vegetation dynamics within a region by a 'data extraction process'
- The figure on the next page represents a raster image of the island, digitized into 8 units

Digitized Study Area



Tabular Data Extraction

- Now we will combine Parts I & II by using the NDVI image and the digitized image of administrative borders to extract data
- Using **Administrative borders** as the 'Feature definition image' and **NDVI 1992** as the 'Image to be processed', tabular results were produced for each administrative unit (see next slide)
- The 'Maximum NDVI' values for each area were used in the data extraction process

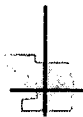
NDVI tabular extraction data for administrative units of Trinidad

Module Results		
Maximum values extracted from newyear1992utm based on bordersutm		
Category	Maximum	Legend
0	1.000000	No Data
1	149.851868	St. David
2	154.592590	St. Andrew
3	157.777771	Nariva
4	156.666656	Mayaro
5	158.296295	Victoria
6	156.888885	St. Patrick
7	156.370377	Caroni
8	156.185181	St. George



Data extraction for whole area

- The previous 'administrative borders' image proves that data may be extracted for each individual unit of a study area
- As well, a '**Mask image**' may be created so one can observe the NDVI dynamics over the study area as a whole (not divided into units)
- The Mask image only has 2 values; 0 for water and 1 for land



The Mask Image

To extract data in this case, the **Mask** is used as the 'feature definition image' while the same **NDVI 1992** image is used as the 'image to be processed'.



NDVI tabular extraction data for the whole study area

This table shows data extracted from 'All listed summary types' instead of only the 'Maximum'

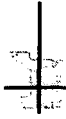
Note: We are interested here in the land statistics (i.e. Value 1)

Module Results		
Summary statistics from newyear1992utha based on askutha		
Category	Summary Type	
0	Minimum	0.000000
	Maximum	140.000000
	Total	933.000000
	Average	0.068563
	Range	140.000000
	Population Std Dev	3.024579
	Sample Std Dev	3.024690
1	Minimum	0.000000
	Maximum	158.296295
	Total	708290.110836
	Average	145.379744
	Range	158.296295
	Population Std Dev	9.050130
	Sample Std Dev	9.051059

Print Contents | Save to File | Copy to Clipboard |

Correlation between NDVI and Population

	NDVI Maximum	Population
1992	158.3	1,268,000
1993	165.0	1,282,000
1995	203.2	1,287,000
1996	175.5	1,297,000



Relation of NDVI & Population

- It is observable from the previous table that there is an overall increasing NDVI trend from 1992 to 1996 (the calculated NDVI growth ratio is actually 10.9%)
- As well, there is an increase in population over the years to consequently prove a positive correlation between the NDVI and population in Trinidad

Case Study for the municipality of Koper, Slovenia

M. Russi

INTRODUCTION

•Slovenia is mainly a continental state. The total length of the **coastline**, all facing the Bay of Trieste, **is only 46 km**. This small coastal area is of strategic economic and political importance for the whole country.

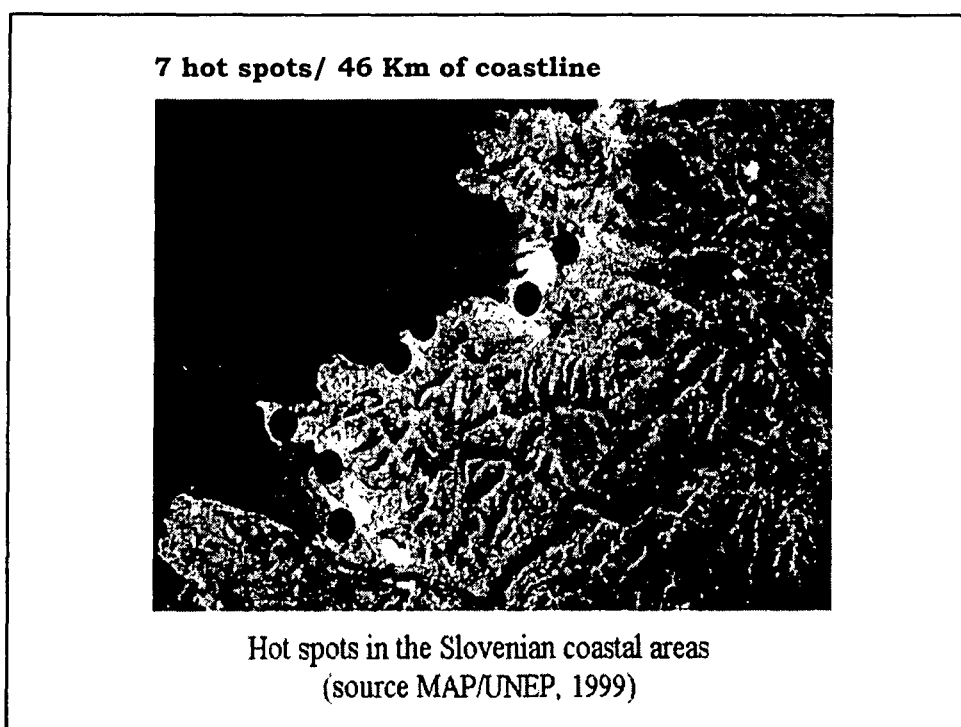
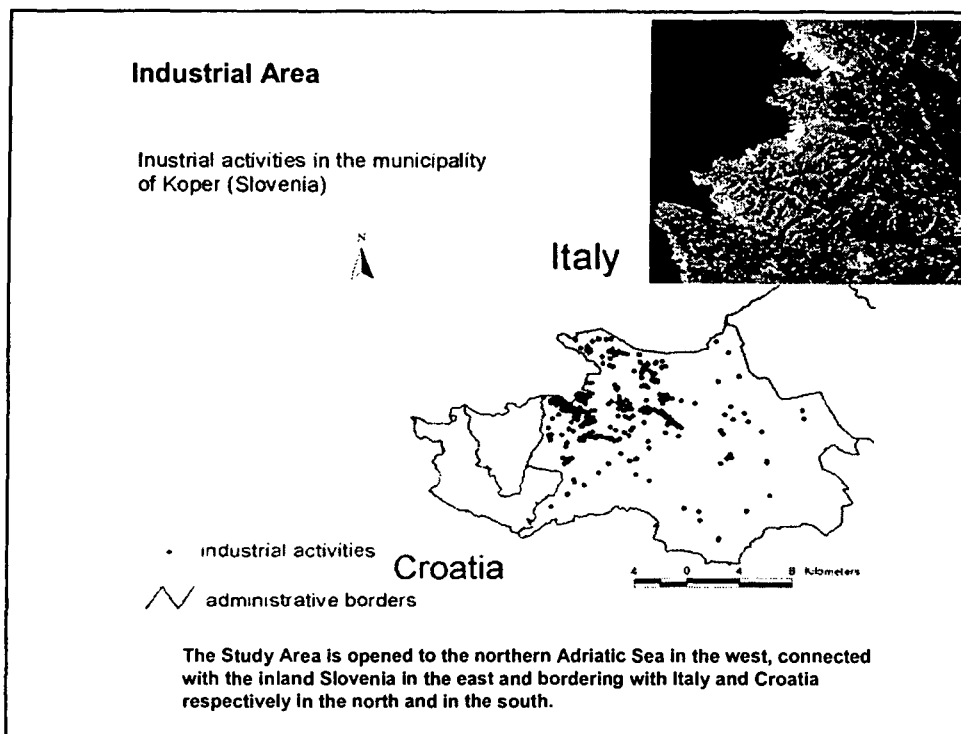
•Along this coastal area Three towns have developed there: Koper (administrative center of the area, industry and harbour activities), Izola (tradition in the fishing industry (cannery)), Piran and neighbouring Portorož (highly developed tourist center) and smaller settlements and tourist facilities between them, so the entire coast is one large urban area.

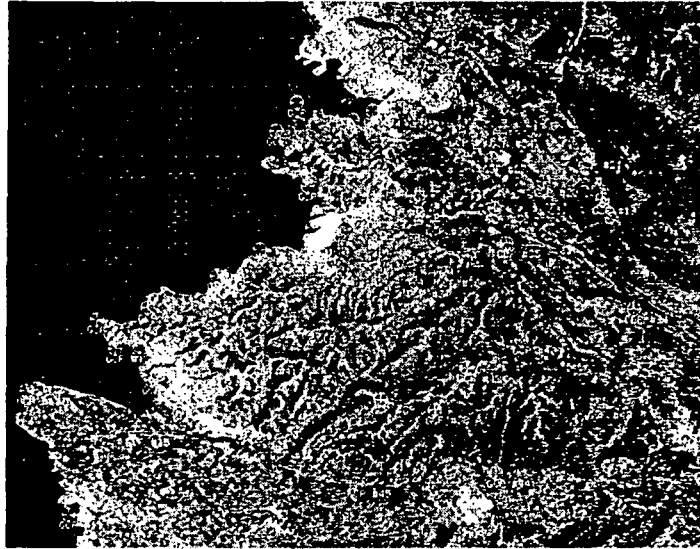
•For this reasons competition for the land use among housing, marine activities, tourism and industry is strenuous. However, close to this large urban area, environmentally valuable - unique - locations are located (ex. the Valley of Dragonja).

•As a result of these conflicts **seven hot spots** have been identified in the Slovenian coastal zone in the frame of the Mediterranean Action Plan (MED POL programme) survey. They are located in all the three municipalities.

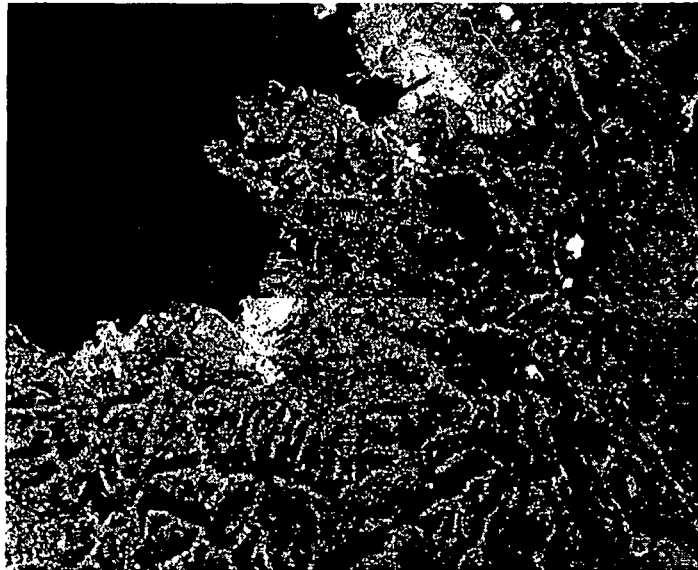
•Surface flows, numerous urban wastewater outlets and one submarine outfall are the main sources of pollution of the coastal sea. Untreated industrial (three hot spots) and urban wastewater in the rivers are among the biggest problems.

•The contribution of land-based sources of pollution situated on the Slovenian coastal zone is much smaller than the overall value for the entire Bay of Trieste. The Italian side contribution must be -also- considered.

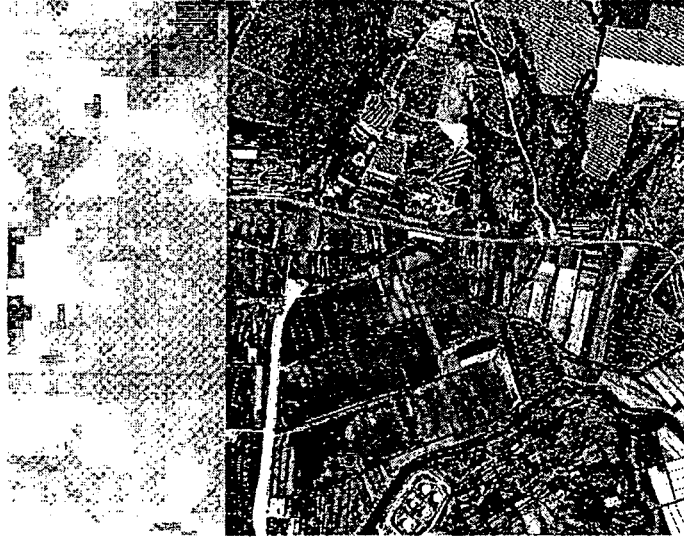




False color composite image of the Slovenian coastal zone
with ground control points (Landsat 5-TM image, summer 1997)

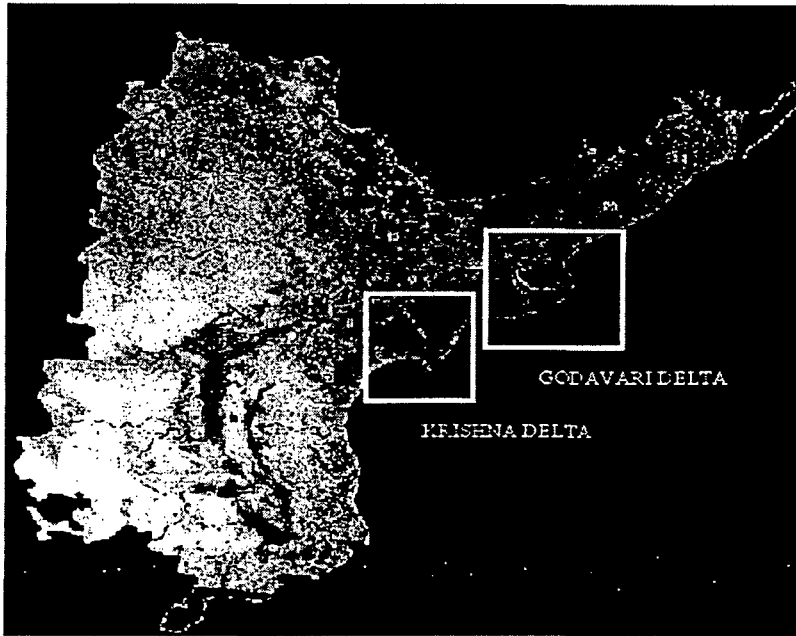


Layer 1: color composite image, Layer 2: orthophoto
(Georeferenced Landsat 5-TM, summer 1997)

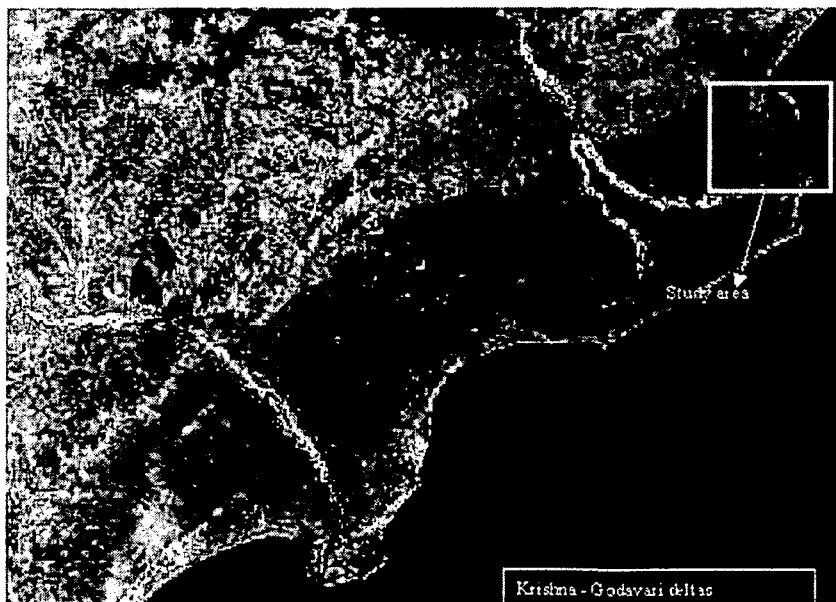


Layer 1: false color composite image; Layer 2: orthophoto
(Georeferenced Landsat 5-TM, summer 1997)

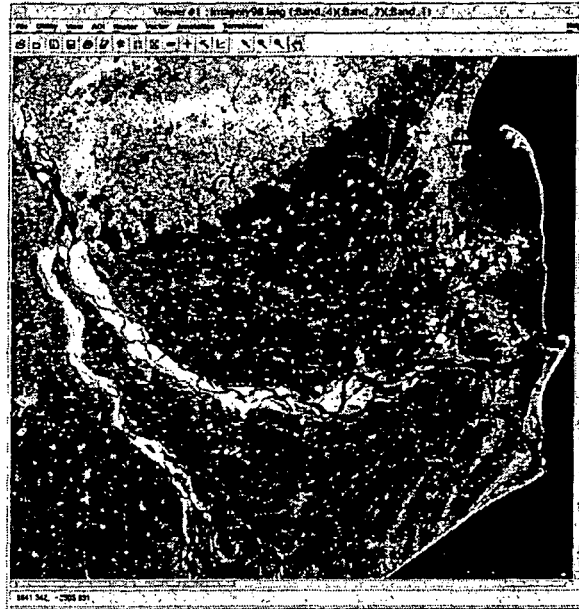
Godavari delta



Krishna - Godavari Deltas



The Godavari Delta -IRS LISS-III imagery



Objectives

- To study the land use and land cover dynamics over the years
- A quantitative study of landscape ecology/metrics
- Assessing the land use and land cover variations using landscape metrics
- To study the impact of anthropogenic activities on the LUCC dynamics

The Data

- Indian Remote Sensing Satellite (IRS 1-C) Linear Imaging Self-Scanner (LISS-III) 23.5m resolution 4 bands image data
 - 12th February 1999 image
 - 17th February 1998 image
 - 03rd January 1997 image
- NOAA-AVHRR NDVI 1.1KM data
 - 1992 to 1996
- USGS Digital Elevation data
- Survey of India toposheet No: 65L/5
- Ancillary data

Methodology

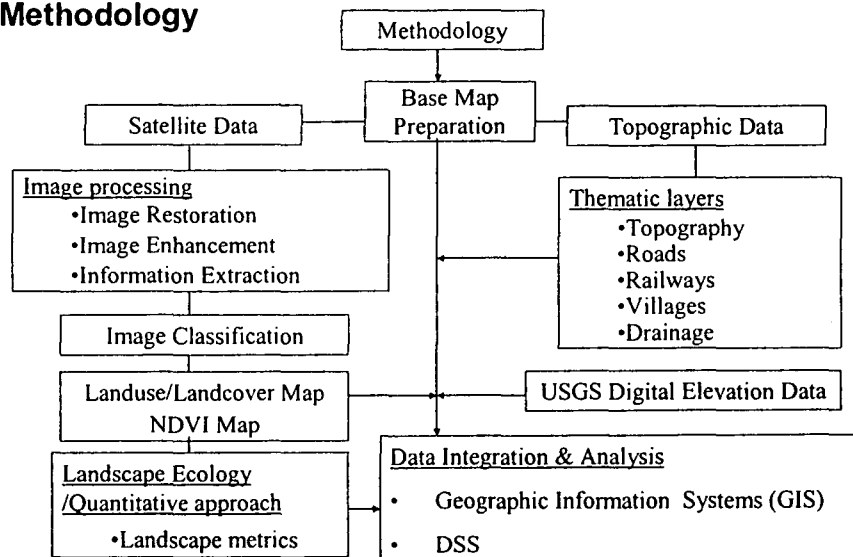
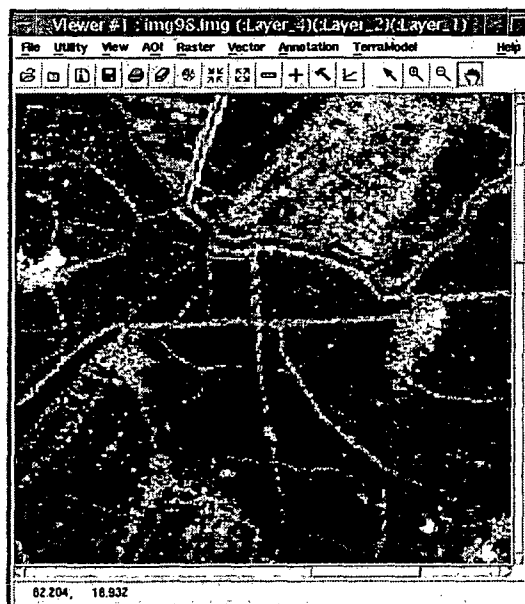


Image Processing

- Image processing
 - Geometric correction
 - Image enhancement
 - » Spectral
 - » Spatial
 - » Fourier analysis
- Image classification
 - Unsupervised
 - Supervised
 - NDVI Classification

Contd.....

IRS 1C LISS-III image of 17th Feb. 1998



Rectified image

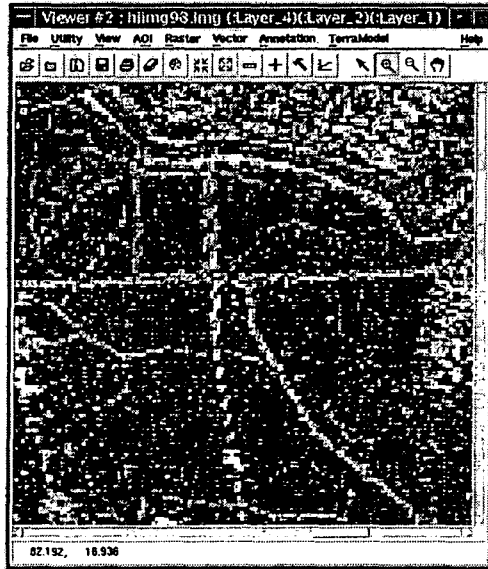






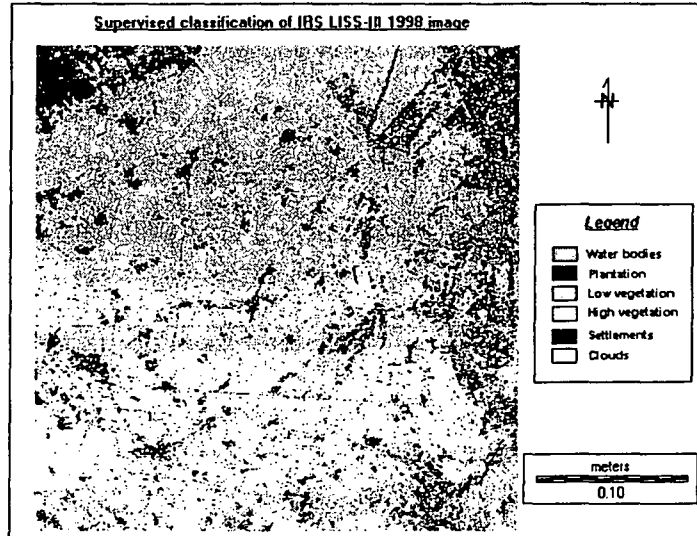


Image Classification - Training sites

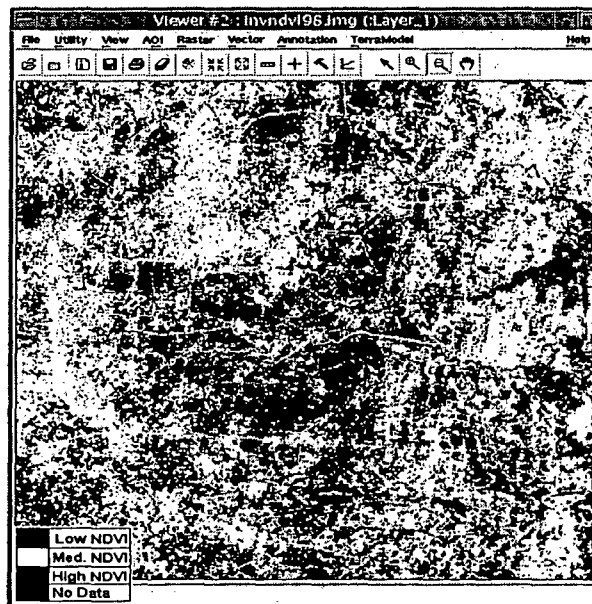
Class #	Signature Name	Color	Red	Green	Blue
1	>water		0.000	0.000	1.000
2	settlements		0.000	1.000	1.000
3	plantation		1.000	0.000	0.000
4	high vegetation		0.000	0.392	0.000
5	low vegetation		0.000	1.000	0.000
6	clouds		1.000	1.000	1.000

The Signature Editor Cellarray

Supervised Classification

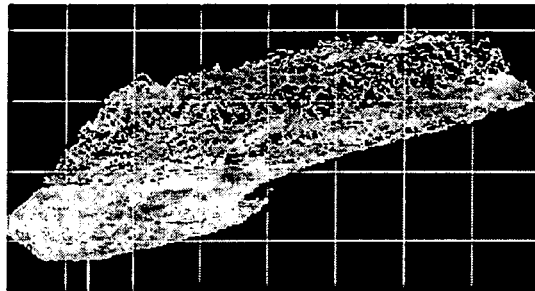


NDVI Classification



DEM Generation

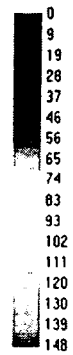
Orthoimage generated by using DEM (USGS)



meters
100.56



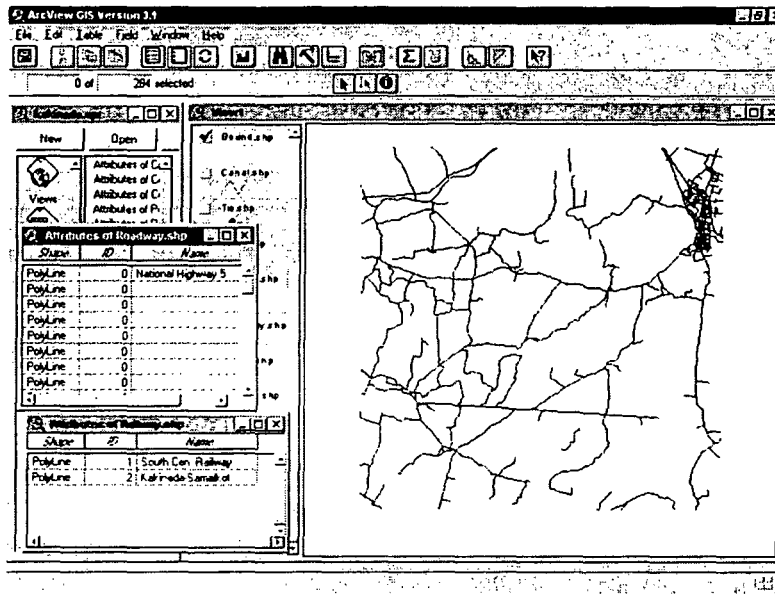
NDVI



Geographic Information Systems(GIS)

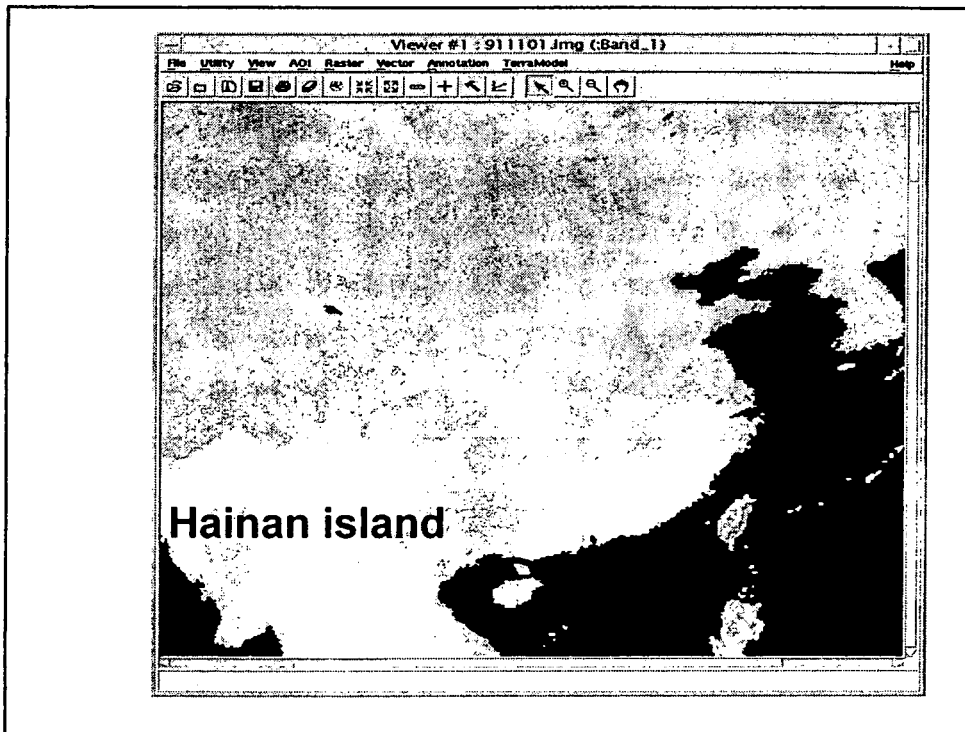
- Data base generation
 - Base map preparation
 - Scanning
 - R ectification & mosaicing
 - On Scr een digitization
 - » Arcview
- Topology
 - Er ror rectification
 - Building
 - Attr ibute assignment

Railway and Road map



Case study in Hainan island, China

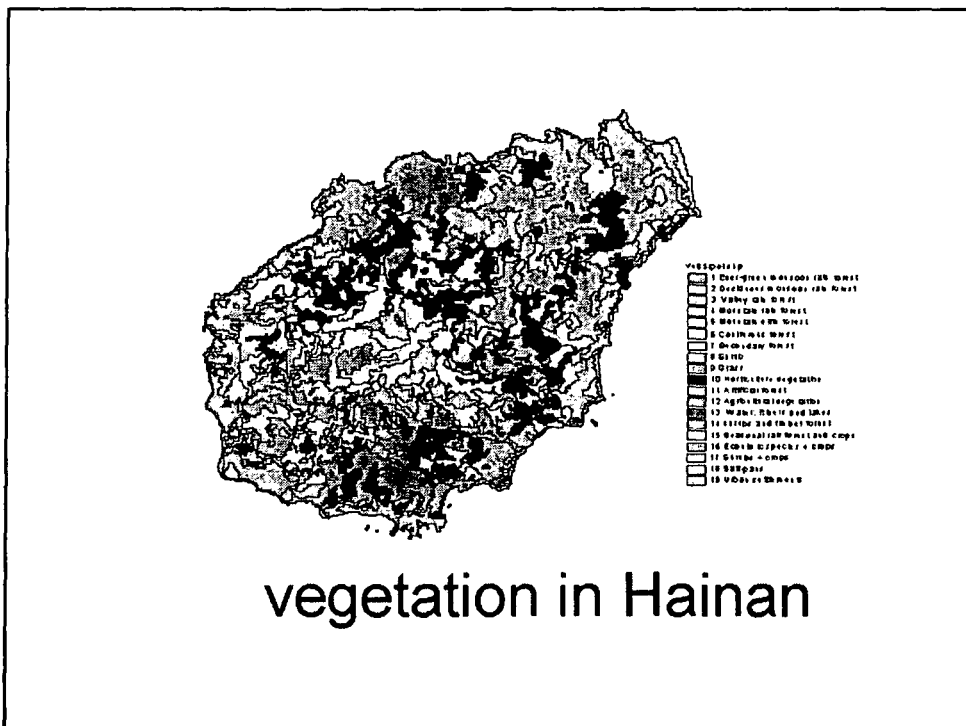
Xiaobo Wu

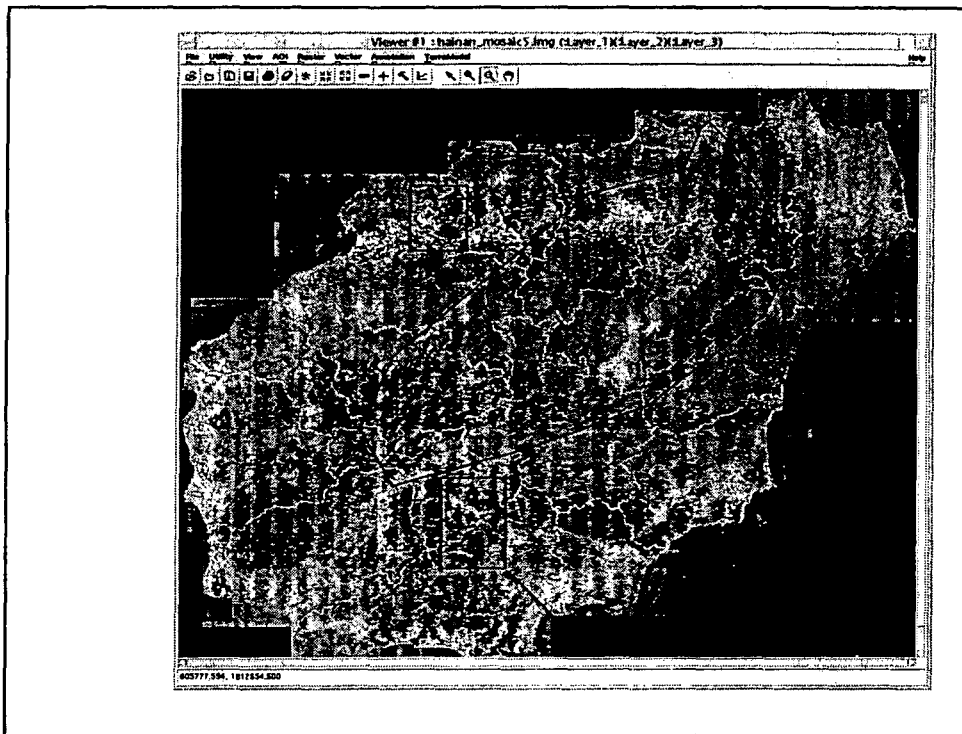


Study Area: Hainan Island

- Location: N 18 ° 10 ' 04 " -- 20 ° 09 ' 40 "
E 108 ° 36 ' 43 " -- 111 ° 02 ' 31 "
- Area: 34,000 km²
- Population: 7,245,289 (end of 1997)
- Temperature: year average 23 °C - 25 °C
 - yearly sunshine time 1750 - 2750 hours
 - coldest month temperature average 17 °C - 20 °C
- Wind: typhoon season is from May to November.
- Rainfall: eastern 2000 – 2500 mm/year
western <1000 mm/year
- Geo-morphological feature: multi level circular structure. Upheaval in center and gradually lower in surrounding.

- The highest peak: 1867.1m
- From center outward is middle mountain - low mountain - high hill - low hill - terrace - plain.
- Vegetation
 - tropical evergreen monsoon rain forest
 - defoliate monsoon rain forest
 - valley rain forest
 - mountain rain forest
 - mountain evergreen broadleaf forest
 - tropical coniferous forest
 - coastal mangrove
 - tropical tree-scattered shrubs
 - tree-scattered steppe
 - damp steppe
 - low hill and tableland steppe
 - hill and mountain steppe





Objective of my study

- **find out the relationship between land cover change and socio-economic development**
- **establish a system to monitor the ecosystem change, make warning to prevent from human activity damaging the ecosystem balance**

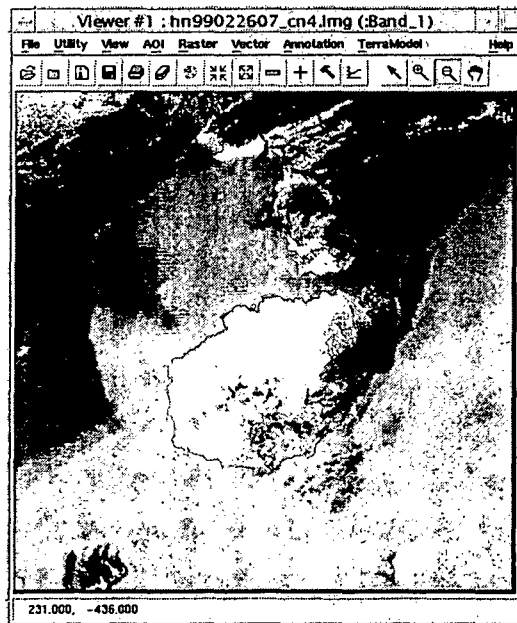
Data

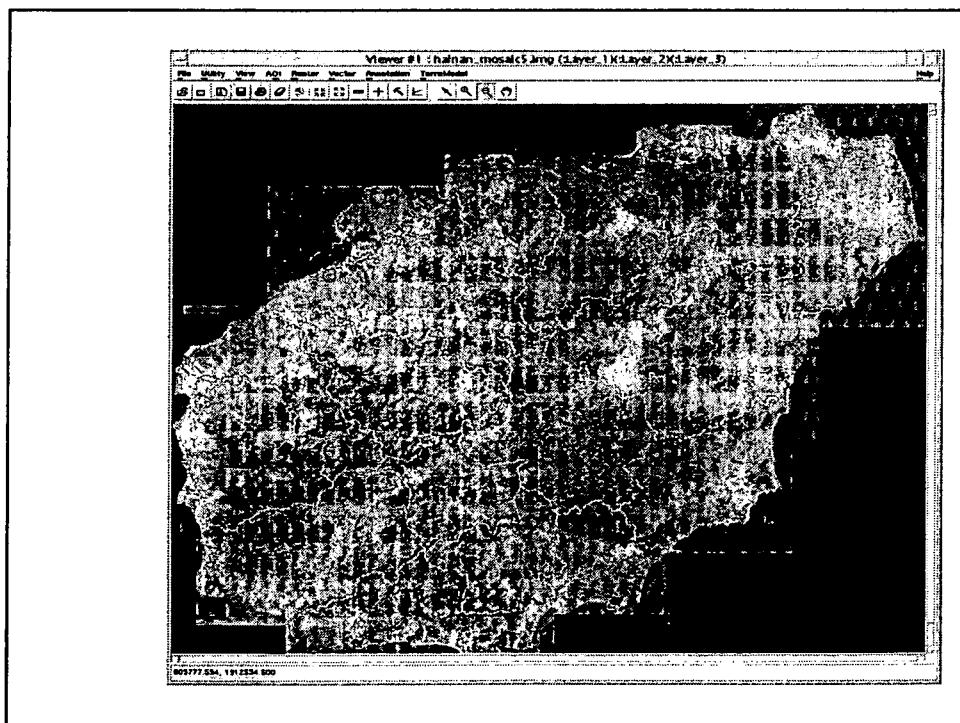
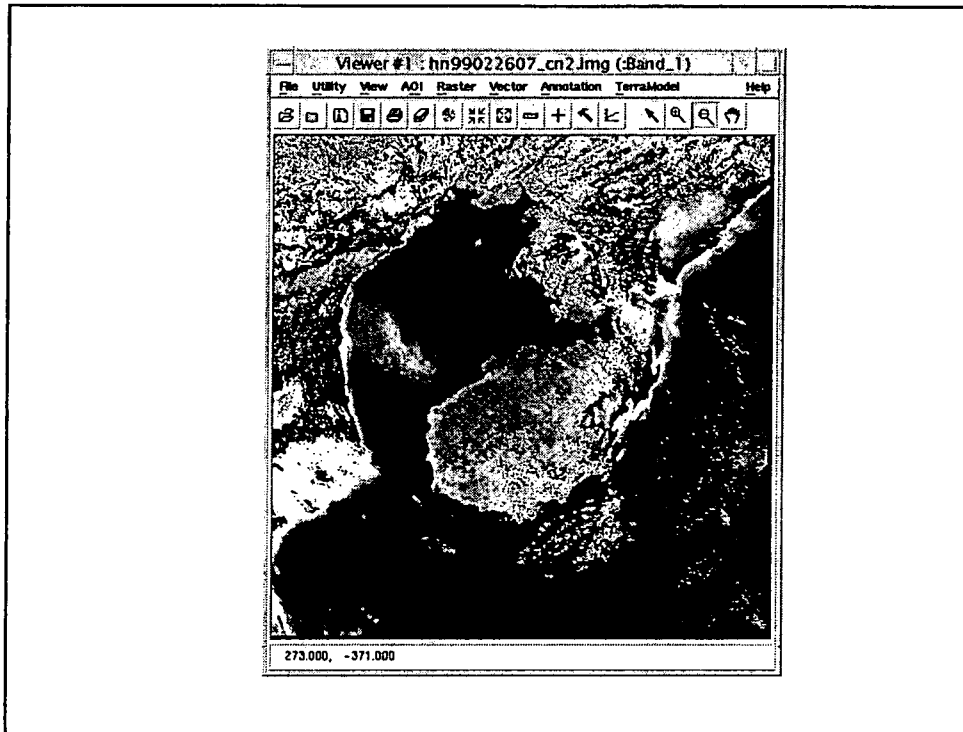
NOAA/AVHRR

- time period: 92,93,95 and 96
- resolution: 1.1 km
- range: whole island

TM

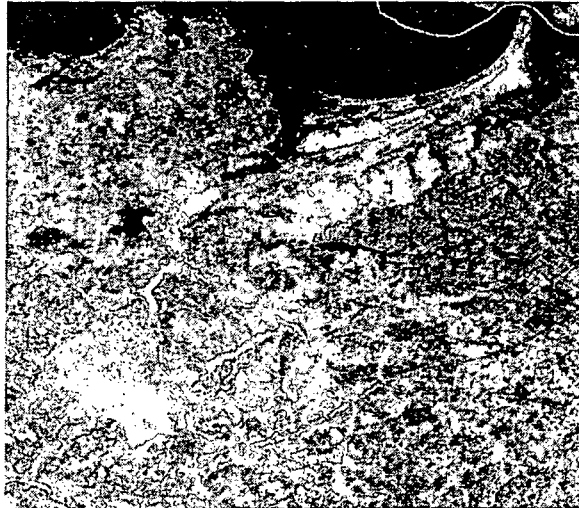
- range: whole island
- time period: 1996
- band: 2,3,4



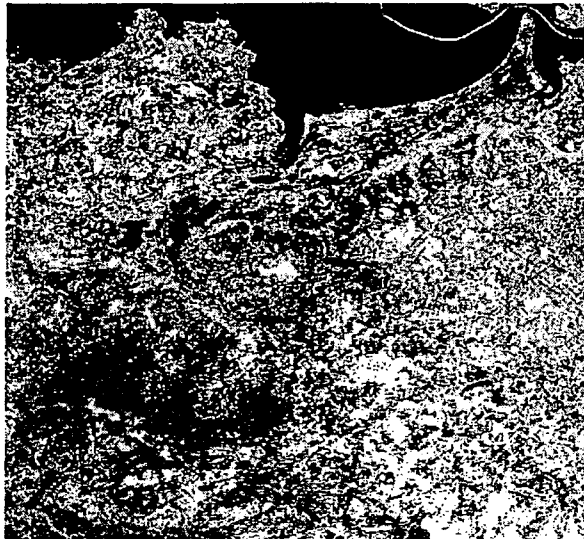


ancillary data (Chinese)

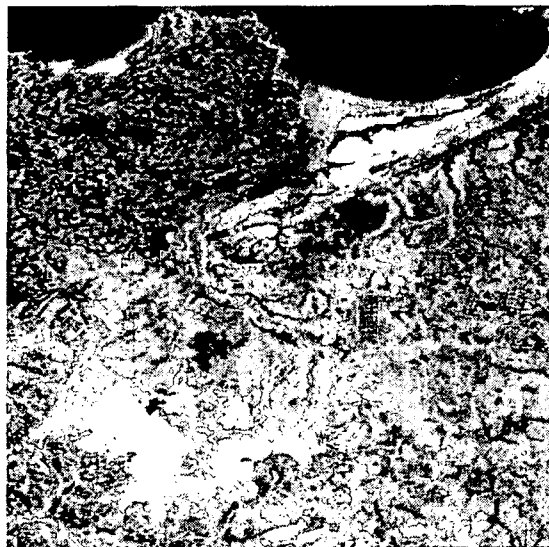
- some published papers and books on soil, landscape, geological structure, geomorphologic feature, climate etc in Hainan Island.
- forest distribution map of Dan Zhou and Tong Zha (scale: 1: 50,000 1:100,000)
- DTM of Nan Du River Basin
- forest distribution of Nan Du River Basin in digital format
- socio-economic data on county level from 1987 - 1999



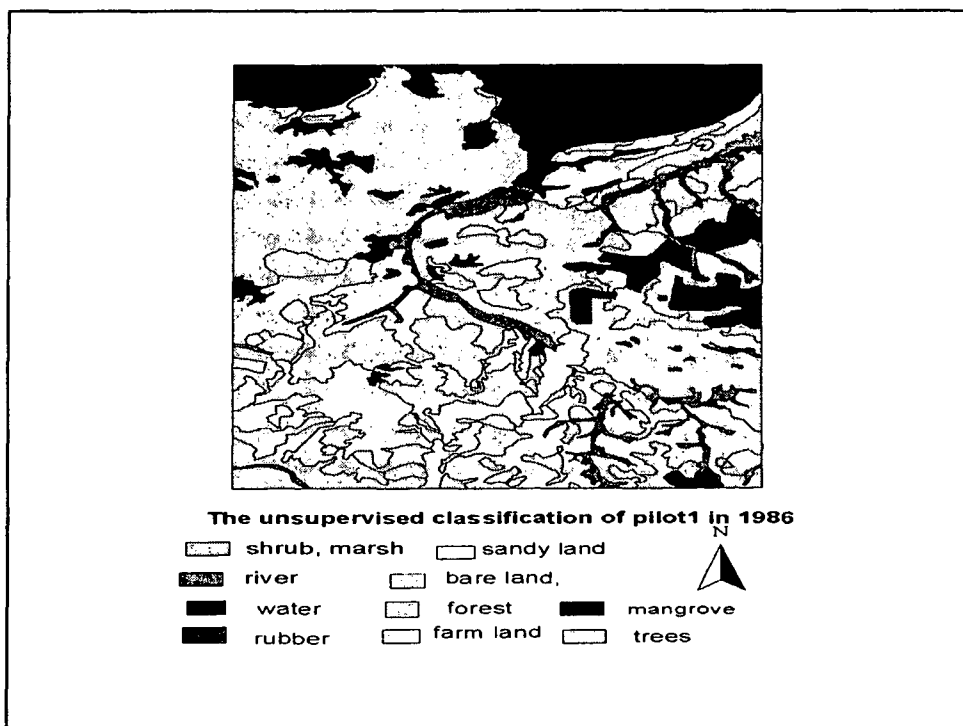
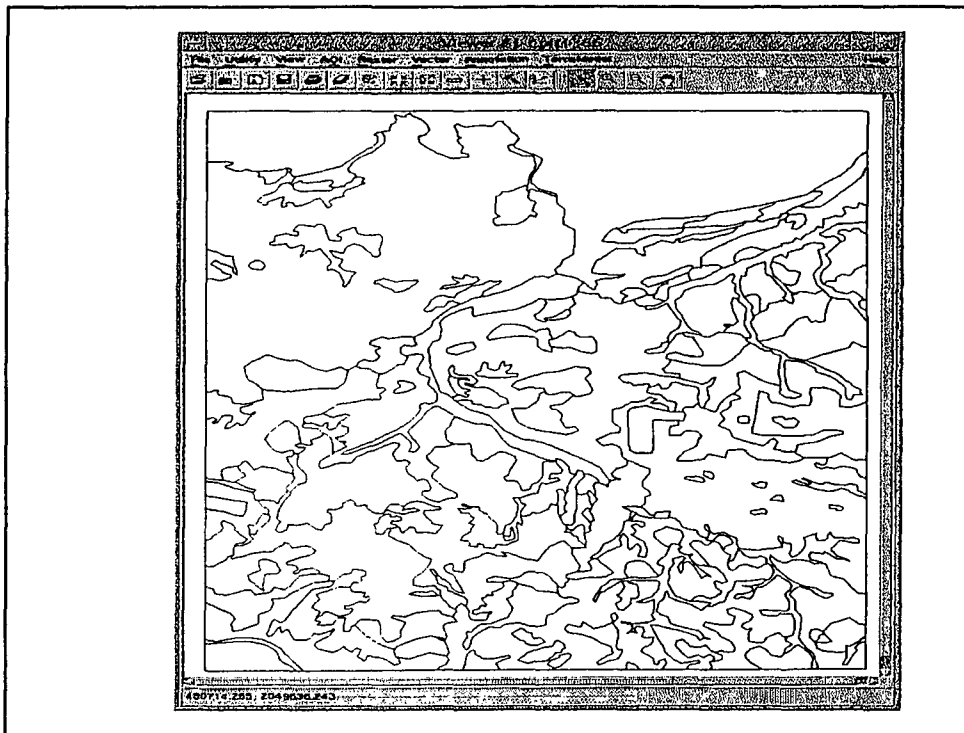
natural color image of pilot1 in 1996



unsupervised classification
on PCA image of pilot1 in 1996



interpreting on screen



Case study in Morocco



Anjana Dayal

Fellow

anjana.dayal@ics.trieste.it

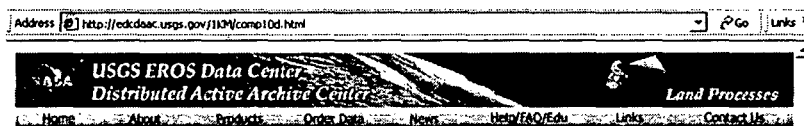
0039-0409228151

Data extraction from Internet public domain

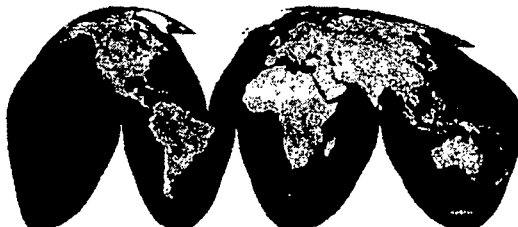
Purpose: This exercise emphasizes the utilities of the Worldwide Web as a source for data. It explains the steps involved in selecting the desired data and how to import it to GIS software.

Procedure: Using an Internet browser, access the following URL site:

<http://edcdaac.usgs.gov/1KM/comp10d.html>



FTP access to Global AVHRR 10-day composite data

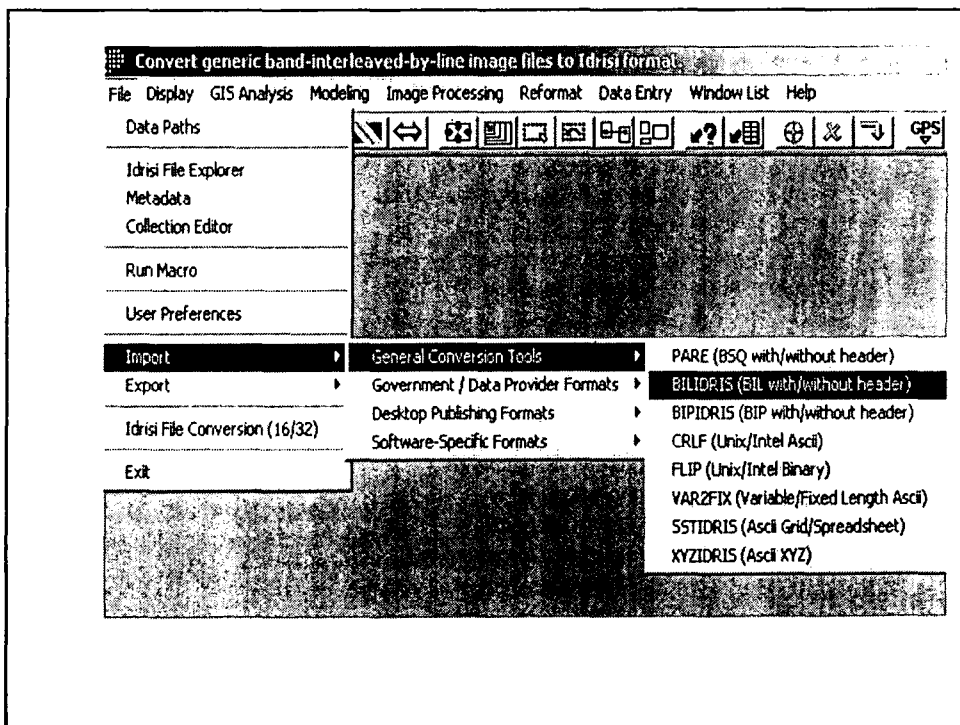
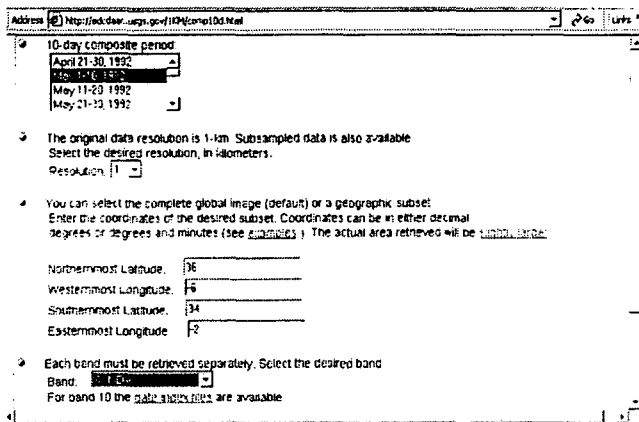


New Notice to Global 1-km AVHRR Data Users

Select the following criteria for this specific exercise (case study for Morocco):

- 10-day composite period: May 1-10, 1992
- Resolution: 1.1Km
- Latitude/Longitude geographical coordinates: Northernmost Latitude 36, Westernmost Longitude -6, Southernmost Latitude 34, Easternmost Longitude -2.
- Bands to be retrieved: NDVI

Press 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.



The image data can be arranged inside the files in many ways. Most common ones are:

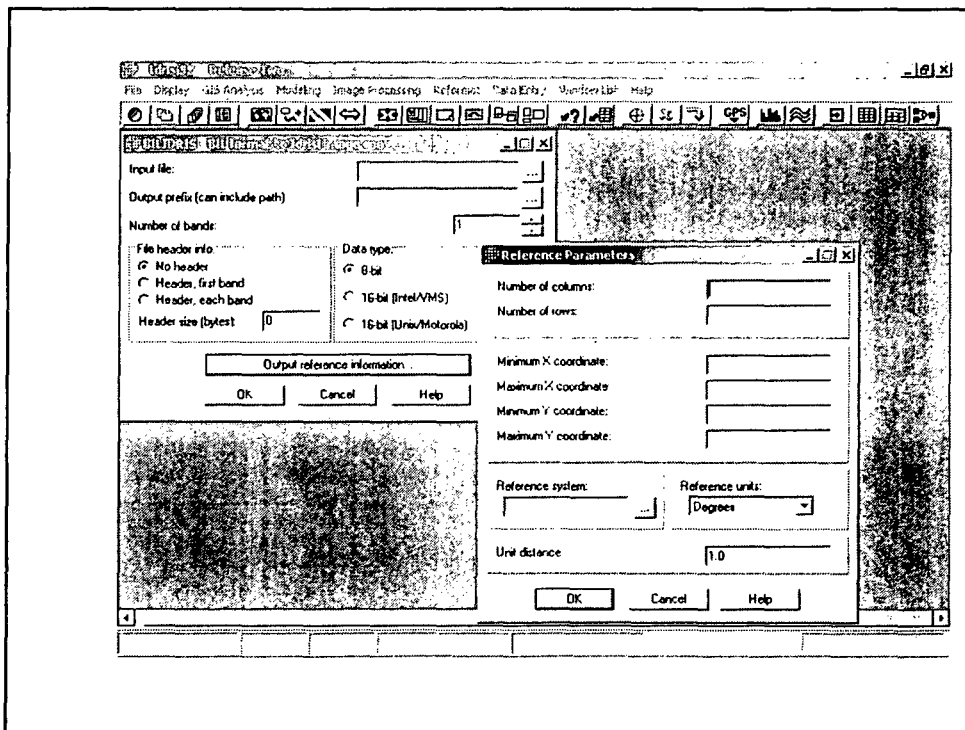
- BIP, Band Interleaved by Pixel
- BIL, Band Interleaved by Line
- BSQ, Band SeQuential

If the pixels of the bands A, B, C and D are denoted a, b, c and d respectively then:

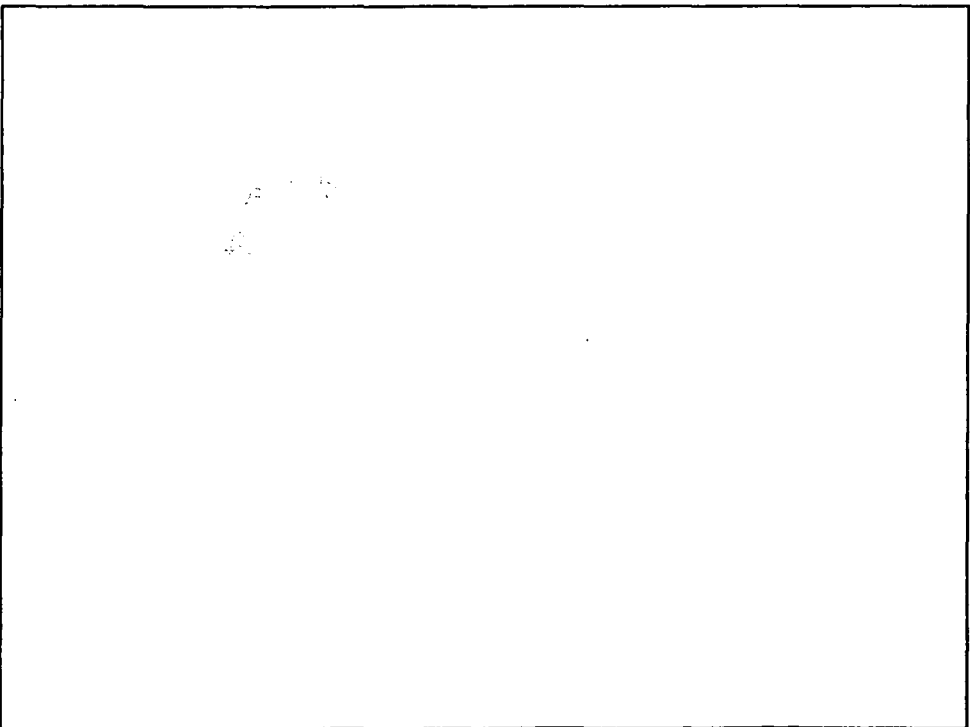
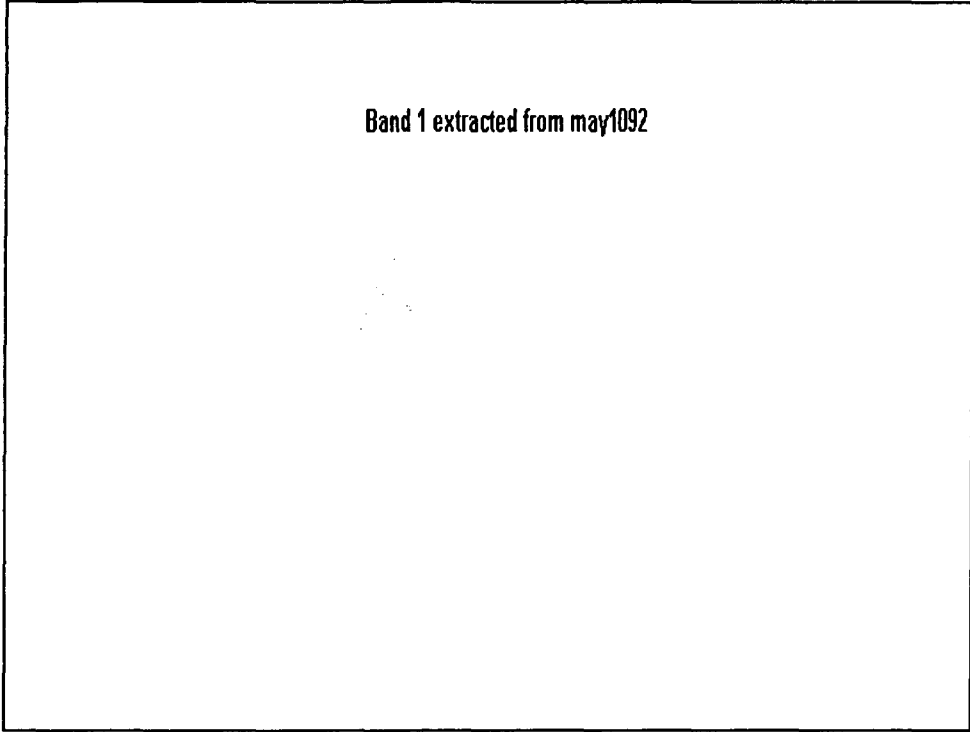
BIP is organized like abcdabcdabcdabcdabcdabcdabcdabcd... line 1/
abcdabcdabcdabcdabcdabcdabcdabcdabcd... line 2/
abcdabcdabcdabcdabcdabcdabcdabcdabcd... line 3/ ...
abcdabcdabcdabcdabcdabcdabcdabcdabcd...
abcdabcdabcdabcdabcdabcdabcdabcdabcd...

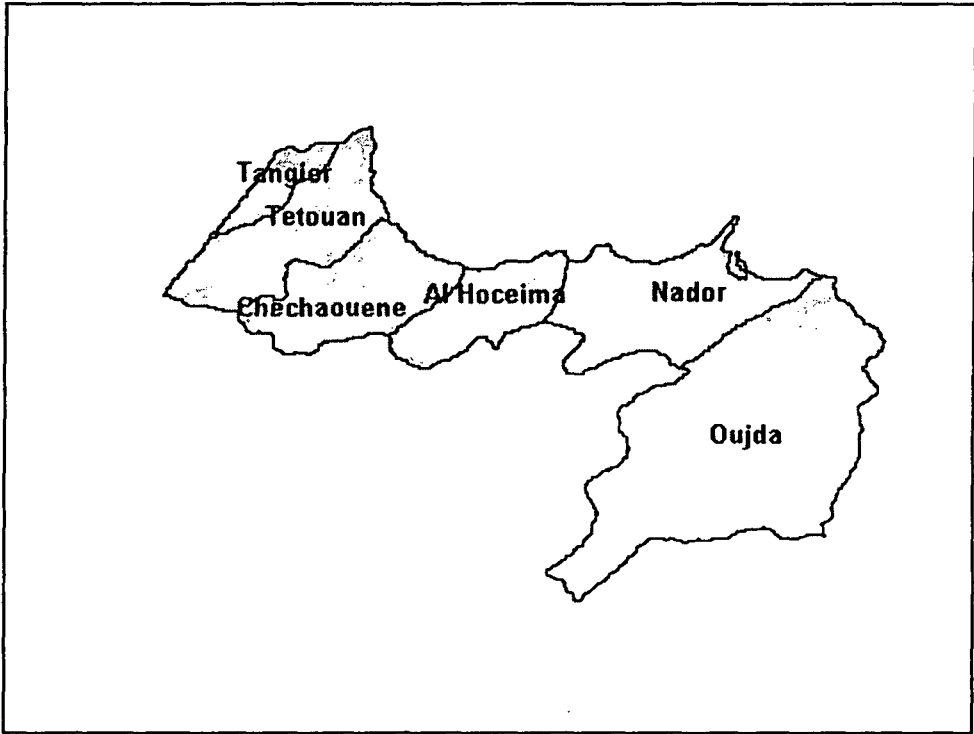
BIL looks like aaaaaaaaaa... band 1, line 1 bbbbbbbbbbbb... band 2
cccccccccc... band 3 dddddddddddd... band 4 aaaaaaaaaaaa... band 1, line 2
...

BSQ shows aaaaaaaaaa... line 1, band 1 aaaaaaaaaaaa... line 2
aaaaaaaaaaaa... line 3 ... bbbbbbbbbbbb... line 1, band 2 bbbbbbbbbbbb... line 2
bbbbbbbbbbbb... line 3 ... cccccccccc... line 1, band 3 cccccccccc... line 2
cccccccccc... line 3 ... dddddddddddd... line 1, band 4 dddddddddddd... line 2
ddddddddddd... line 3 ...



Band 1 extracted from may1092





A case Study in the coastal areas of Tunisia

Mounir GHRIBI
Environmental Technologies Engineer
Mounir.ghribi@ics.trieste.it
0039-040-9228105

Hazardous waste analysis



Purpose

The aim is to improve the decisions concerning prioritization of sites for a remedial response to hazardous waste. In course to achieve this goal a cluster analysis was made to reflect the degree of similarity between the main industrial sites.

Identification of Main Industrial Sites using satellite image (LANDSAT 5 TM) of September 1997



- 1: Ariena
- 2: Echarguia
- 3: Mennouba
- 4: Ettadhemen
- 5: Douar Hicher
- 6: El Mnihla
- 7: Koleet Andalous



Kilometers
5.84

International Centre for Science and High Technology

Existing activities per main industrial sites

Industrial sites	Activity								
	Textile & Garment / Leather & shoes	Agro-alimentary	Mechanical & Electrical	Construction materials / Glass & ceramics	Chemical	Miscellaneous			
						Pharmaceutical works	Hospital and medical clinics	Municipal or/and industrial landfills	Scientific laboratories etc...
Ariena	29	16	10	3	2			13	
Echarguia	125	73	44	13	11			53	
Mennouba	30	17	11	4	3			13	
Ettadhemen	19	12	6	3	1			6	
Douar Hicher	43	26	15	5	4			19	
El Mnihla	10	6	3	1	1			5	
Koleet Andalous	5	3	2	1	1			3	
Typical hazardous waste	Sludge containing heavy metals	Pesticides & manure / contaminated filters	Sludge containing heavy metals	Building and soil material	Solvents/ halogenated residues/ sludge/ tars aqueous waste	Halogenous & halogen free solvents	Infectious waste, radioactive material	Domestic or industrial wastes	Wide range of hazardous materials usually in relatively small quantities
Nature of hazards	Pollution by toxic	Pollution by toxic/ infection	Pollution by toxic	Pollution by toxic & odorous substances	Fire/ explosion/ pollution by toxic	Pollution by toxic	Pollution by toxic/ micro-organisms/ radiation	Fire/ explosion/ pollution by toxic	Pollution by toxic/ infection/ radiation
Potential impact	Soil and water contamination	Soil and water contamination, bio-accumulation & persistence in environment	Soil and water contamination	Soil and water contamination	Soil, water & air contamination	Soil, water & air contamination	Soil and water contamination	Soil, water & air contamination	Soil, water & air contamination
Potential health impacts	Chronic & acute illnesses through intake of pollutants through water supply and food chain	Chronic & acute illnesses through inhalation and intake of pollutants through water supply and food chain	Chronic & acute illnesses through intake of pollutants through water supply and food chain	Chronic & acute illnesses through intake of pollutants through water supply and food chain	Chronic & acute illnesses through inhalation and intake of pollutants through water supply and food chain	Chronic & acute illnesses through intake of pollutants through water supply and food chain	Chronic & acute illnesses through inhalation and intake of pollutants through water supply and food chain	Chronic & acute illnesses through inhalation and intake of pollutants through water supply and food chain	Chronic & acute illnesses through inhalation and intake of pollutants through water supply and food chain

Tunisian Ministry of International Cooperation and External Investment (1996) Inventory.

IAEA (1996) Manual for the classification and prioritization of risks due to major accidents in process and related industries, International Atomic Energy Agency (IAEA).

International Centre for Science and High Technology

Matrix A (Industrial sites, Activity)

		Activity					
		Textile & Garment / Leather & shoes	Agro-ellimentary	Mechanical & Electrical	Construction materials / Glass & ceramics	Chemical	Miscellaneous
Industrial Sites	Ariana	29	16	10	3	2	13
	Echaroua	125	73	44	13	11	53
	Mannouba	30	17	11	4	3	13
	Ettadhamen	19	12	6	3	1	8
	Douer Hicher	43	26	15	5	4	19
	El Minhia	10	6	3	1	1	5
	Kalazat Andalous	5	3	2	1	1	3

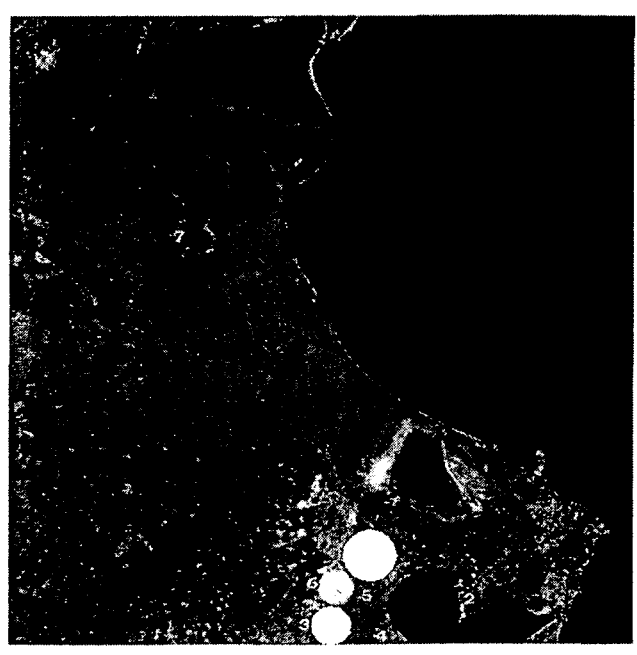
Matrix B (Activity, Potential Impact)

	Sludge containing heavy metals	Pesticides & manure / contaminated filters	Building and soil material	Solvents/ hydrocarbonated materials/ sludge/ tars aqueous waste	Wide range of hazardous materials usually in relatively small quantities Domestic or industrial	Pollution by toxic	Infection	Odorous substances	Fur explosion	Radiation	Soil and water contamination	Bioaccumulation & persistence in environment	Soil, water & air contamination		
Textile & Garment / Leather & shoes	1	0	0	0	0	1	0	1	0	0	1	0	0	1	0
Agro-ellimentary	0	1	0	0	0	1	1	0	0	0	1	1	0	0	1
Mechanical & Electrical	1	0	0	0	0	1	0	0	0	1	1	0	0	1	0
Construction materials / Glass & ceramics	0	0	1	0	0	1	0	1	0	0	1	0	0	1	0
Chemical	1	0	0	1	0	1	0	1	1	0	1	0	1	0	1
Miscellaneous	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1

Matrix AB = Matrix A x Matrix B (Industrial Sites, Potential Impact)

	Sludge containing heavy metals	Pesticides & manure / contaminated filters	Building and soil material	Solvents/halogenated residues/ sludges/ tars aqueous waste	Wide range of hazardous materials usually in relatively small quantities Domestic or	Pollution by fossils	Infection	Odorous substances	Fire explosion	Radiation	Soil and water contamination	Bio-accumulation & persistence in environment	Soil, water & air contamination		
Ariana	41	16	3	44	13	73	29	47	15	23	73	16	15	55	31
Echarguia	180	73	13	169	53	319	126	202	64	97	319	73	64	235	137
Mannouba	44	17	4	46	13	78	30	50	16	24	78	17	16	58	33
Ettadhamen	26	12	3	28	8	49	20	31	9	14	49	12	9	36	21
Douar Hicher	62	26	5	66	19	112	45	71	23	34	112	26	23	82	49
El Mnhla	14	6	1	16	5	26	11	17	6	8	26	6	6	19	12
Kalaat Andalous	8	3	1	9	3	15	6	10	4	5	15	3	4	11	7

Potential impact for each industrial site



- Industrial Sites**
- 1: Ariana
 - 2: Echarguia
 - 3: Mannouba
 - 4: Ettadhamen
 - 5: Douar Hicher
 - 6: El Mnhla
 - 7: Kalaat Andalous

Potential Impact

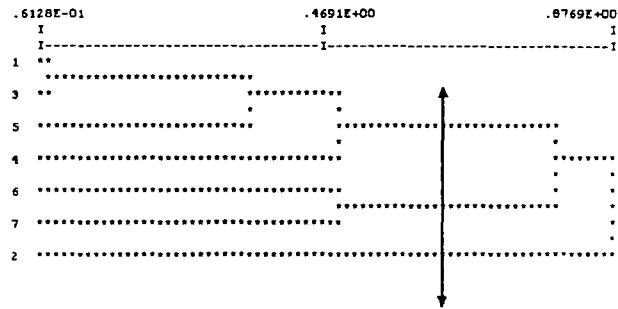
- Low
- Moderate
- High



Kilometers
5.04

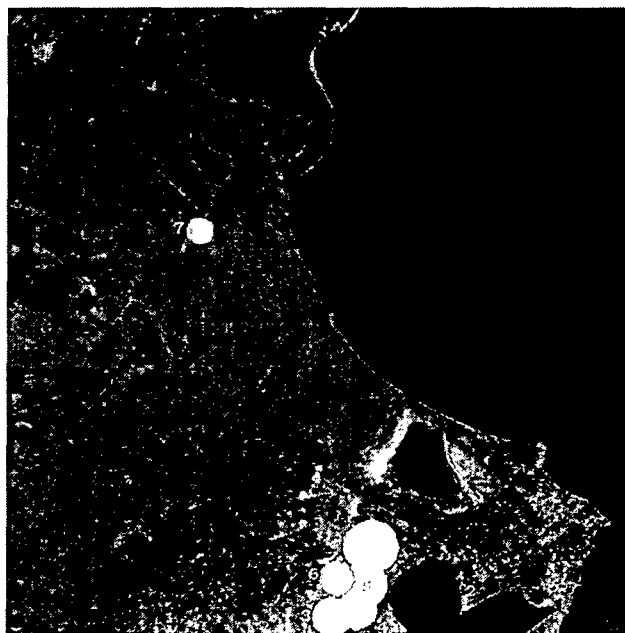
Hierarchical clustering classification

Dendrogram of objects



- 1. Ariana
- 2. Echarguia
- 3. Mannouba
- 4. Douar Hicher
- 5. Ettadhamen
- 6. El Mnhila
- 7. kalaat Andalous

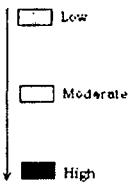
Potential impact per each cluster



Industrial Sites

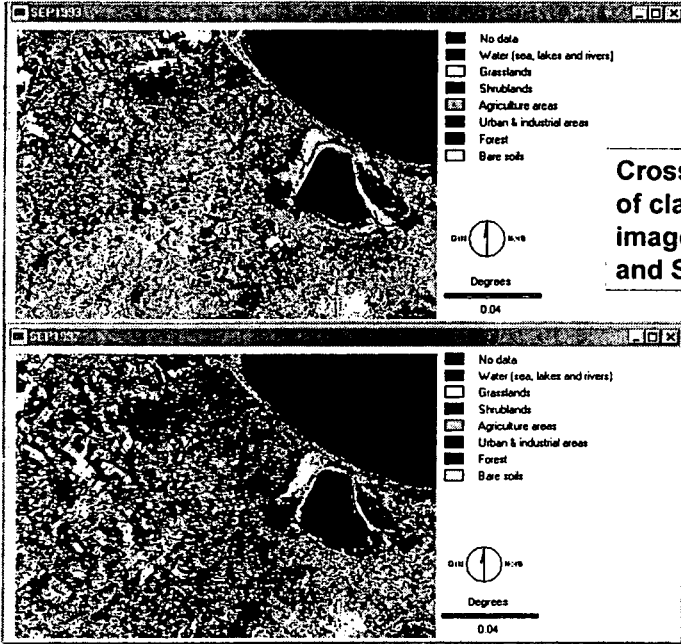
- 1: Ariana
- 2: Echarguia
- 3: Mannouba
- 4: Ettadhamen
- 5: Douar Hicher
- 6: El Mnhila
- 7: Kalaat Andalous

Potential Impact



Kilometers

5 04



**Cross Tabulation
of classified
images of Sep93
and Sep97**

Crosstabulation of Sep1993 (columns) against Sep1997 (rows)

	1	2	3	4	5	6	7	Total
1	93835	178	240	4	0	358	2241	96856
2	295	37062	14339	14542	0	13002	591	79831
3	262	31067	53305	38635	0	5888	4122	133279
4	43	6681	7082	42180	0	3787	110	59883
5	2	2025	7268	21878	43757	716	436	76082
6	1733	9962	1992	2111	0	17207	892	33897
7	858	4883	4824	403	0	1704	9484	22156
Total	97028	91858	89050	119753	43757	42662	17676	501934

- Legend**
- 1 Water (sea, lakes and rivers)
 - 2 Grasslands
 - 3 Shrublands
 - 4 Agriculture lands
 - 5 Urban & industrial areas
 - 6 Forest
 - 7 Bare soils

Chi Square = 1032103.75
 df = 36
 Cramer's V = 0.5854

Proportional Crosstabulation

	1	2	3	4	5	6	7	Total
1	0.1869	0.0004	0.0005	0	0	0.0007	0.0045	0.1929
2	0.0006	0.0738	0.0286	0.029	0	0.0259	0.0012	0.159
3	0.0005	0.0619	0.1062	0.077	0	0.0117	0.0082	0.2665
4	0.0001	0.0133	0.0141	0.084	0	0.0075	0.0002	0.1193
5	0	0.004	0.0145	0.0436	0.0872	0.0014	0.0009	0.1516
6	0.0035	0.0198	0.004	0.0042	0	0.0343	0.0018	0.0675
7	0.0017	0.0097	0.0096	0.0008	0	0.0034	0.0189	0.0441
Total	0.1933	0.163	0.1774	0.2386	0.0872	0.085	0.0356	1

Multi-Objective Decision Making in GIS

Aim

Solving a multi-objective land allocation problem with conflicting objectives.

Procedure

Based on the information from two suitability maps, we attempt to maximize the suitability of lands for each objective given the weights assigned.

Objectives

- .To find lands that are best for industrial development
- .To protect lands for forestation

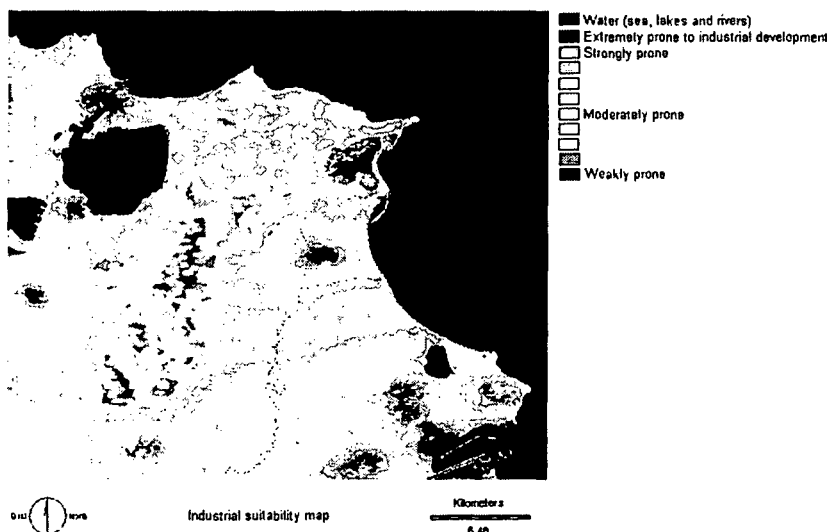
Conflict

Since lands can be allocated to only one of these two uses, the objectives are viewed as conflicting.

Data Requirements

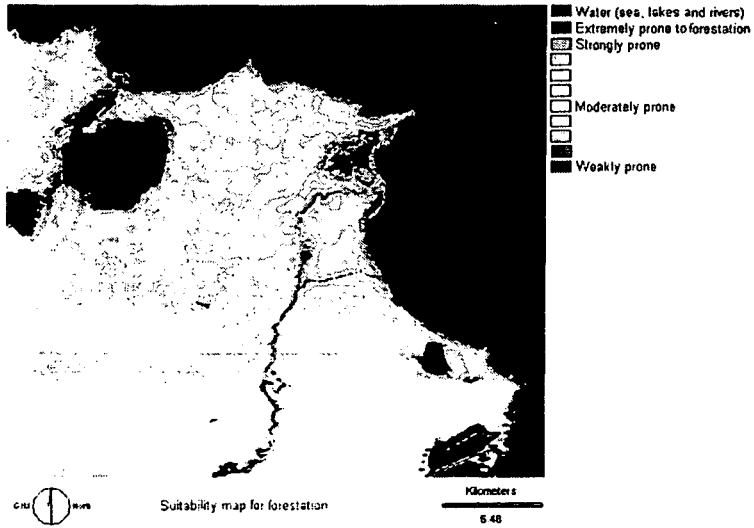
2 ranked suitability maps for each objective that have been produced by means of the multi-criteria evaluation.

Objective 1: To find lands that are best suited for industrial development



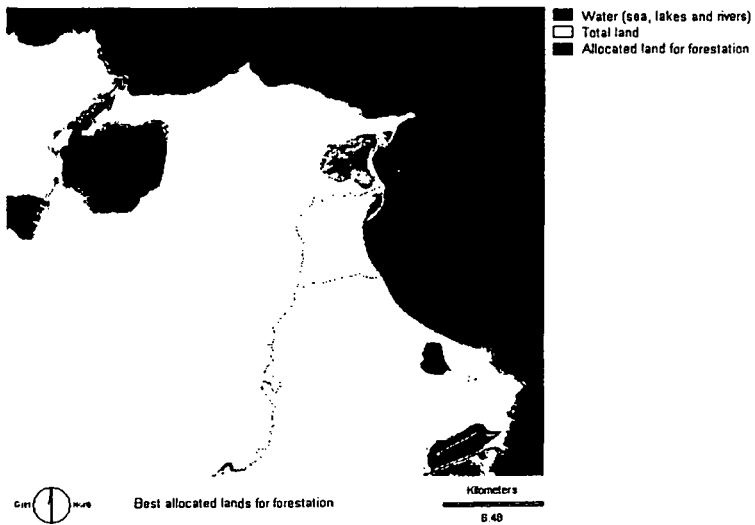
Objective 2: To protect lands that are best for forest

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Solving the Multi-Objective Land Allocation (MOLA) problem

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Conclusion for ICS case studies presentation

Industry and Sustainable development in coastal areas

Industrial component

Existing
Extension
New

Place
Number
Activity
Technology

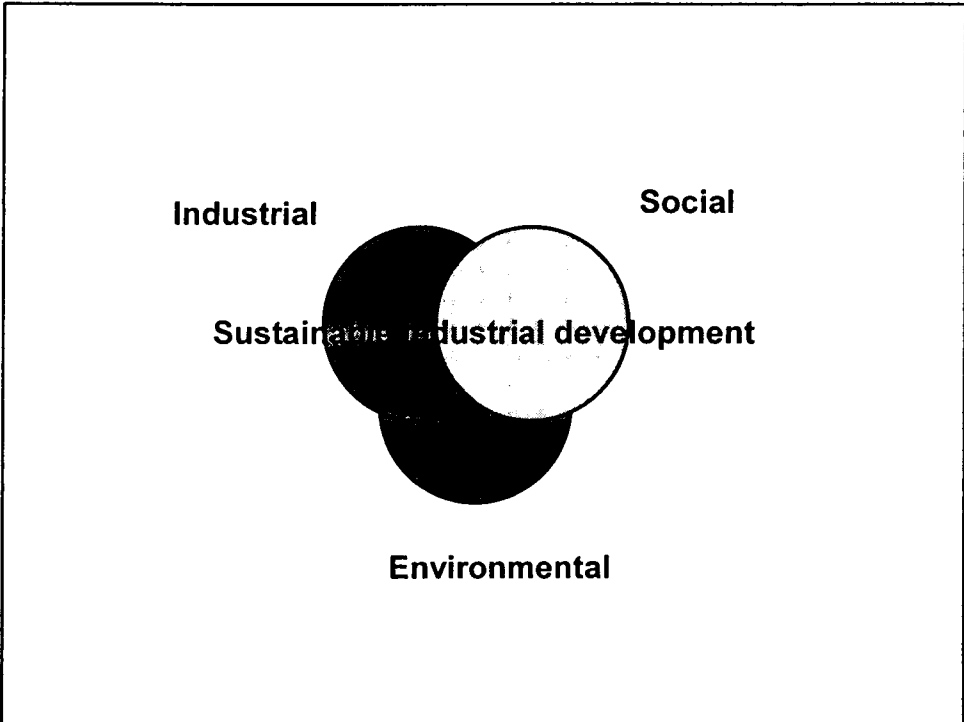
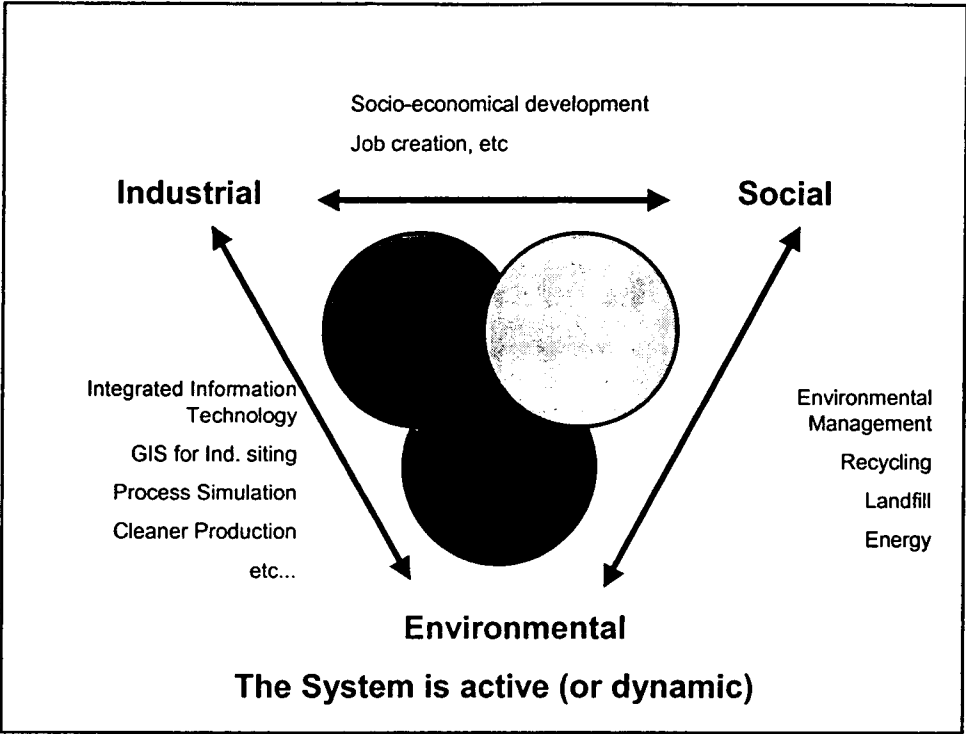
Social component

Education
Job creation
Social development

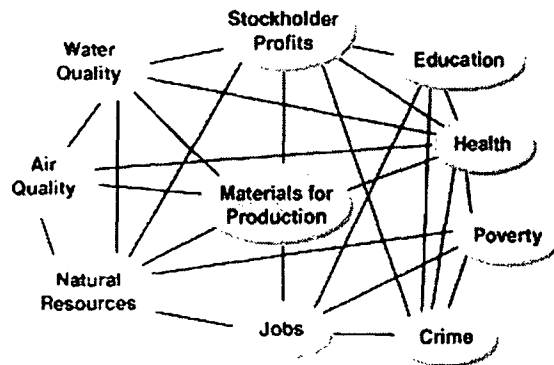
Environmental component

Land degradation
Pollution (water, air and soil)
Over use of coastal areas
etc.

The System is inactive (or passive)



Sustainability requires...



...interactions among multidimensional indicators that show the links among the environment, the economy (industry) and society.

As the figure illustrates, the natural resource base provides the materials for production on which jobs and stockholder profits depend.

Jobs affect the poverty rate and the poverty rate is related to crime.

Air quality, water quality and materials used for production have an effect on health. They may also have an effect on stockholder profits: if a process requires clean water as an input, cleaning up poor quality water prior to processing is an extra expense, which reduces profits.

Likewise, health problems, whether due to general air quality problems or exposure to toxic materials, have an effect on worker productivity and contribute to the rising costs of health insurance.

*Application of Classification and Ordination Methods
in Landscape Assessment
by E. Feoli*

Application of Classification and Ordination Methods in Landscape Assessment

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by

Enrico Feoli

*ICS Senior Scientific Consultant
Earth, Environmental and Marine Sciences and Technologies*

ICS-UNIDO

AREA Science Park, Bldg. L2

Padriciano 99, Trieste, Italy

Tel.: +39-040-9228109

Fax: +39-040-9228136

Abstract

The data describing the landscape system in terms of pattern and/or landscape elements are giving rise to multidimensional spaces. For understanding pattern and processes in the landscape and to model them it is necessary to represent in efficient way such multidimensional spaces by few dimensions. Exploring multidimensional spaces on the basis of spectral and singular value decomposition theorems (SVD) and eigenanalysis (EA) is an exercise that can be useful to get information on landscape patterns and can be used for modeling complex systems in iterative way without feeling too much restricted to precision problems. The idea of modeling clusters of points, rather than lines is suggested. Fuzzy set theory can be used as a useful data interpolation method and data transformation before EA.

1. Introduction

Some definitions are necessary before to start to discuss on the application of singular value and spectral decomposition theorems (SVD) and eigenanalysis (EA) that are used and could be used to explore the multidimensional spaces generated by matrices describing the landscape system:

1) *Landscape* is a complex system with states determined by all the interactions between man, plants, other living organisms and the chemical-physical environmental factors.

2) *Landscape ecology* is the discipline aimed to understand all the aspects of landscape system concerning its composition (diversity), structure (spatial pattern and spatial relationships), functions and dynamics (the ways and the the causes of landscape changes in space and time). It uses the concept of

multidimensional space (*ecological space*) defined by all the ecological factors influencing the human life and the life of the other organisms.

3) *Landscape* is sampled and described by Operational Geographic Units (OGU). They are sampling units, which are supposed to represent in a satisfactory way a landscape at a given time in a given place. These sampling units may be defined by the user in a GIS procedure, or defined automatically by remote sensing techniques (pixels). The variables that are sampled and described in each OGU may be of different nature such as spectral bands, environmental chemical-physical factors and/or human and other biological factors that are supposed to influence the landscape states. OGUs can be sampled following some sample design or by preferential sampling as it may happen in vegetation science (Orloci 1991a,c; Orloci and De Patta Pillar 1991). It must be clear that an OGU is an operational concept, which is useful to integrate in a GIS the remotely sensed data with other multisource data.

The concept of Operational Geographic Unit (OGU) was defined as the basic cartographic element for understanding biogeographical patterns by classification and ordination techniques (Crovello 1981). It is analogous to the concept of Operational Taxonomic Unit in numerical taxonomy (Sneath and Sokal 1973), with the only difference that OGU is a georeferenced unit. The concept of OGU has been already introduced in GIS context by Feoli and Zuccarello (1996), to describe ecological processes in space and time. OGUs may be used to store information in data bases following what Peuquet (1984) calls geographical data models, however we prefer to use the concept to integrate and extract georeferenced data already stored in GIS data bases. The data integration is achieved when each OGU is described by remotely sensed data (average values, class frequencies, min-max values, etc. of bands) and by other landscape multisource data not directly attributable to the single pixels (e.g. population density, urbanisation density, yield production, biodiversity, etc.), usually called ancillary data. OGUs can be obtained by a GIS in a very flexible way. They, as adjacent or non adjacent polygons (or points), may be easily defined by administrative boundaries or by superimposing to the maps regular or irregular tessellated structures (grids, triangulated networks, quadtree patterns, hexagonal mesh, Thiessen polygons, etc., see Peuquet, 1984; Skole et Al. 1993).

4) OGUs that are considered similar enough are grouped into the same land cover type or class, which is used for cartographic purposes. A GIS can easily show the results of OGUs classifications by maps showing the spatial distribution of the classes of OGUs. Since these classes may be characterized by the character states, used for the OGUs classification, the maps show the spatial pattern of those character states in the landscape. In this sense OGUs are useful tools of the Dobson's "macroscope".

5) In a given landscape a land cover type is spread within the geographic ranges of the combination of characters that are characterising it (Characteristic variables) as a different type from other land cover types present in the landscape. The extension and the shape of the area occupied by a land cover type depend on the extension of the environment favourable to the

combination of its characteristic variables in the geographical space. The environment hosting a land cover type defines, in analogy with the community niche concept (Feoli, Ganis and Zerihun 1988), the land cover type niche. However the concept of niche is not only related to environmental variables, if socio-economic variables are only used the multidimensional space will represent a socio-economic multidimensional space and the niche of a land cover type will be a socio-economic niche. The niches may be wide or narrow in the multidimensional space irrespective its extension in the geographic space, the niche width depends on the heterogeneity of the land cover type.

6) Once defined the land cover types on the basis of a set of characters (variables), landscape can be studied on the basis of other sets of variables. The classification of landscape based on a set of land cover types can be used as a reference system on which to overimpose other kind of classifications or other information.

7) Land cover type niches are partially or completely represented in a matrix X given by a set of OGUs (almost always disposed as column vectors). Matrix X represents partially the multidimensional ecological space (it is just a sample of it). In this each variable has a number of co-ordinates equal to the number of OGUs and each OGU has a number of co-ordinates equal to the variables that are describing it. Variables and OGUs may be seen as vectors with a common origin, namely the origin of the space. Their length and direction are determined by their co-ordinates in X . The dimensionality of the space represented by X is, however, equal or lower than the minimum number among the number of OGUs and the number of variables.

The dimensionality (rank of the matrix) is, in fact, the minimum number of orthogonal axes that are able to get the projections of all the OGUs and all the variables. Only the variable or OGU with all the co-ordinates equal to the co-ordinates of the origin of the space do not have axes where to be projected. These orthogonal axes are the reference system for variables and OGUs. They give the minimum number of co-ordinates necessary to correctly positioning variable and OGUs in the multidimensional space. These axes are also used to represent the space by a reduced number of dimensions. Their efficiency in doing this is measurable. X may be divided into sub-matrices on the basis of the kind of variables used to describe the OGUs: e.g. $X(1)$ matrix of biological variables, $X(2)$ matrix of environmental variables, $X(3)$ matrix of socio-economic variables, $X(4)$ matrix of human impacts, etc.

Each matrix X is the matrix representing the states of landscape system according to some set of variables. To study the correlation between different matrices is possible by many mathematical methods.

2. Spectral and Singular value decomposition theorems

The spectral and singular value decomposition theorems of matrix algebra are generally mentioned in the Appendix of multivariate data analysis textbooks addressed to applications (Jongman, Ter Braak and Van Tongeren 1995). However it would be more appropriate to present them at the beginning of

these books since they are essential for understanding why multidimensional space of a given matrix X may be represented by few orthogonal dimensions. The theorem of spectral decomposition says that a symmetric matrix S of rank p can be decomposed by the following three matrices:

$$S = T \Lambda T' \quad (1)$$

where T is an orthogonal matrix ($m \times p$), i.e. $T_i' T_i = 0$, Λ is a diagonal matrix ($p \times p$) and T' is the transposed of T . Λ is the matrix of the p positive eigenvalues of S that are disposed in decreasing order. T is the matrix of standardized eigenvectors of S .

Λ may be calculated by the characteristic equation of eigenvalues:

$$\det (S - \lambda I) = 0$$

where *det* means the determinant of the matrix $(S - \lambda I)$, λ is a scalar and I is the identity matrix (i.e. a matrix with ones along the diagonal and zeros outside). Out of this equation only the positive p solutions are considered in the diagonal matrix Λ . Once calculated the p positive eigenvalues ($\lambda_i, i=1, \dots, p$), T may be obtained by solving p times the system of equations:

$$(S - \lambda_i I) T_i = 0 \quad (2)$$

The singular value decomposition theorem says that given a rectangular matrix X of m rows and n columns ($m \times n$) of rank p it can be decomposed in the following product of three matrices:

$$X = U \Lambda V' \quad (3)$$

where U is an orthonormal matrix ($m \times p$) ($U'U = I_p$, identity matrix), V is an orthonormal matrix ($n \times p$) ($V'V = VV' = I_p$) and Λ is a diagonal matrix ($p \times p$) with positive elements.

If we consider that:

$$X'X = (U \Lambda V')' U \Lambda V'$$

it follows that

$$X'X = V \Lambda' (U'U) \Lambda V'$$

and since $U'U = I_p$ it follows that

$$X'X = V \Lambda^2 V'$$

on the other hand

$$XX' = U\Lambda^2U'$$

and since both $X'X$ and XX' are symmetric matrices (S) the theorem of spectral decomposition holds true. From this it follows that the eigenvalues of the two symmetric matrices are the same.

The relevant implications of these two theorems for exploring multidimensional spaces of X (or $X(1)$, $X(2)$, $X(3)$, etc.) are the following:

1) Each numeric matrix X , i.e. a matrix for which it is possible to apply the product matrix ($X'X$) or (XX'), may be represented by two sets of orthogonal axes that may be used to order column vectors (objects) and the row vectors (variables) simultaneously by biplot graphs (Gabriel 1971; ter Braak 1995). The efficiency of the representation is given by the ratio between the sum of the eigenvalues corresponding to the eigenvectors used for ordination and the total sum of eigenvalues;

2) For any numeric symmetric matrix S obtained in some way from X it is possible to compute its eigenvalues and eigenvectors by equation 2). T_i may be adjusted in several ways, e.g. $T_i'T_i = 1$ or $T_i'T_i = \lambda_i$ or $T_i'T_i = \lambda_i^{1/2}$;

3) If S is the symmetric matrix for the rows, T_i is an axis of ordination for the elements in rows. If S is a symmetric matrix for the columns, T_i is an axis of ordination for the elements in columns. For better clarity we can indicate with R the symmetric matrix for rows and with Q the symmetric matrix for columns (in analogy with the well known terminology R-mode and Q-mode algorithms, ter Braak 1995), and respectively we can indicate by α_i the eigenvectors of R and by β_i the eigenvectors of Q . Only in some circumstances the matrix of the β_i can be computed by multiplying the matrix of the α_i by X . This happens when R is obtained by XX' . When Q is obtained by $X'X$, α_i can be obtained by multiplying X by β_i (Orloci 1967, 1978). Not always the R and Q matrices can be obtained by scalar products between row or column vectors. If the matrix X is ordinal or alphanumeric, other measures of similarity or correlation (association) rather scalar products should be applied, e.g. Gower's and/or Goodall's and Burnaby's indices (Goodall 1964; Dale 1991; Carranza et Al. 1998). In this case only the SVD of the symmetric matrix makes sense.

3. Ordination methods and gradient analysis

In landscape analysis, as in ecology, the methods able of positioning objects (OGUs, or variables) in a reference system of orthogonal or obliques axes are called ordination methods (Orloci 1966, 1967, 1978, ter Braak, 1995). Ordination methods are used to display the relationships between variables and objects with the aim to discover clusters, trends of variation (gradients) and/or trajectories. More in general they are used to study patterns (spatial, temporal,

structural) of landscape and gradients, i.e. the way in which landscape is changing in function of environmental factors. Gradient analysis is playing an important role in landscape ecology. Its primary aim is to reconstruct the sequence of response curves of variables along single environmental variables (primary or secondary ecological factors), or combination (linear or non-linear) of them. Two methods of gradient analysis have been so far distinguished: direct gradient analysis and indirect gradient analysis (Whittaker 1967, Whittaker 1978, Prentice and ter Braak 1988).

- Direct gradient analysis

In direct gradient analysis two matrices of data are considered: the matrix of independent variables (causal or explanatory variables, e.g. chemical-physical variables in ecology) $X(2)$, and the matrix of dependent variables of our interest that have been used to describe landscape features $X(1)$. Direct gradient analysis may be done by two approaches: one considers only $X(2)$ and uses it to order $X(1)$ the other considers both the matrices simultaneously.

Let us consider the first approach. The following procedures are used:

1) $X(1)$ is rearranged (ordered) according to environmental axes given by the single environmental variables or according to some combination (linear or non-linear) of all of them or only some of them. $X(2)$ is subjected to SVD after having standardized the variables. The T axis are used to rearrange $X(1)$. If according to the scattergram of T axes, a curvilinear pattern of points is evident, than the curve interpolating the points, or an angular seriation, can give the non-linear combination of the variables in $X(2)$ (Feoli and Orloci 1991). The new axis so obtained is used to plot the response values of the variable.

2) Graphs are produced by simply plotting the variable scores against the environmental axis, and/or by curves fitting the scores by regression analysis (ter Braak 1995).

3) A model of response curves is described and used for predicting landscape composition all along the gradient.

In the second approach $X(2)$ and $X(1)$ are used simultaneously following two main procedures. In the first one the two matrices may be fused in one with $m+s$ rows and n columns, where m (number of environmental variables) are the rows of $X(2)$ and s (number of variable) the rows of $X(1)$. This matrix (X) after standardization of row vectors may be decomposed according to SVD. This gives the simultaneous ordination of variable, environmental variables and OGU's. This procedure includes the methods known as Principal Component Analysis (PCA) and Correspondence analysis (CA). They differ only because in PCA the variables are centered and/or standardized ($z_{ij} = (x_{ij} - \xi_j) / \sigma_j$), where ξ_j is the mean of i -th variable and σ_j is its standard deviation, while in CA the variables are transformed according to the deviation of the scores from the expected scores calculated as the product of the marginals (row totals and column totals) divided by the grand total of the matrix X .

In the second procedure the two matrices are kept together by multiplying $X(2)$ by $X'(1)$ in order to obtain a matrix of scalar products $C(m \times s)$. When the s variable and the m variables are standardized by the z variable this matrix is a non-symmetric correlation matrix. $C(m \times s)$ can be decomposed by SVD. The resulting matrix U' of p eigenvectors corresponding to the p positive eigenvalues may be multiplied by $X(2)$ (standardized by rows) in order to obtain $\beta(2)$, namely the p ordination axes for the n OGU's. This gives ordinations based on the m variables under the constraint of their correlation with the s variable. The multiplication of matrix of V' by $X(1)$ (standardized by rows) gives $\beta(1)$, namely the p ordination axes of the n OGU's based on the s variable under constraint of their correlation with the m variables. Scattergrams can be obtained by using $\beta(2)$ or $\beta(1)$ and also by using $\beta_j(2)$ against $\beta_j(1)$, i.e. j -th axis of $\beta(2)$ against j -th axis of $\beta(1)$. This type of scattergrams show the pattern of correlation between $X(2)$ and $X(1)$. The methods of multivariate data analysis known as canonical correlation analysis, canonical correspondence analysis and redundancy analysis are based on this procedure. They differ only by the way in which the variables are transformed or combined into the two matrices before the multiplication in order to get C . In terms of equation $(S - \lambda I_p)T_i = 0$ they differ only by the way in which S is computed based on C . In canonical correlation analysis:

$$S = R_{11}^{-1} R_{12} R_{22}^{-1} R_{21}$$

for obtaining $\beta(1)$, $\beta_1(1) = T_1' X(1)$

or

$$S = R_{22}^{-1} R_{21} R_{11}^{-1} R_{12}$$

for obtaining $\beta(2)$, $\beta_1(2) = T_1' X(2)$

where R_{11} is the correlation matrix between the variable in $X(1)$, R_{22} between the variables in $X(2)$ and R_{12} or R_{21} is the C matrix. R_{11}^{-1} and R_{22}^{-1} are respectively the inverse matrices of R_{11} and R_{22} .

In redundancy analysis R_{11} is the identity matrix. In Canonical correspondence analysis the data are transformed as in correspondence analysis and centered, then the equation for getting $\beta(2)$ is equal to that of canonical correlation analysis (ter Braak 1995).

If the variables cannot be standardized, because measured in different scales (e.g. variable in ordinal scale and environmental variables in ratio scale), the two matrices have to be both transformed in symmetric matrices (resemblance matrices), namely $Q(1)$ and $Q(2)$, by suitable resemblance functions (Dale 1991, Podani 1991a). Both the matrices can be decomposed by SVD. $\beta(1)$ and $\beta(2)$ are

respectively the matrices of eigenvectors of $Q(1)$ and $Q(2)$. $X(1)$ can be ordered and response curves of variables detected by using $\beta(2)$ as ordination axes (first procedure above). In order to get the second procedure, i.e. constrained ordination, $\beta(1)$ is multiplied by $\beta(2)$ and the resulting matrix decomposed by SVD. In this case the constrained ordination axes are obtained respectively by multiplying U' by $Q(1)$ and V' by $Q(2)$.

The proper direct ordination is always the one based on $X(2)$. To constrain the ordination by matrix $X(1)$ it means to keep into consideration all the factors that have determined the matrix $X(1)$ included those in $X(2)$. The constrained ordination axes of $X(2)$ obtained based on matrix $C(m \times s)$ are always axes that in some way maximize their linear correlation with the axes obtained from $X(1)$, irrespective the type of relationship between the variables. Scattergrams obtained by plotting $\beta(1)$ axes versus $\beta(2)$ axes may show linear correlation between $X(1)$ and $X(2)$ notwithstanding the correlation between variable, between environmental variables and between variable and environmental variables may be non-linear.

In direct gradient analysis constrained ordination axes can be obtained by Procrustes analysis (see Podani 1991b and Feoli, Podani and Sun 1993, for applications and for references). By it, given k axes of $\beta(2)$, in a matrix called for convenience $X(k \times n)$, and k axes of $\beta(1)$, in a matrix $Y(k \times n)$, the k axes of $\beta(2)$ are transformed in such a way to fit as much as possible the configuration of OGU's in the space defined by Y . This means that the new axes of X are adjusted in such a way to "absorb" the effects that other environmental factors have and/or have had in defining the ordination of n OGU's in $\beta(1)$.

The required rotation of X is obtained by its multiplication with the $n \times n$ (n =number of OGU's) orthogonal transformation matrix:

$$H(n \times n) = V(n \times p)U'(p \times n)$$

where U and V result from SVD of

$$Y'X(n \times n) = U(n \times p) \Lambda(p \times p) V'(p \times n)$$

Rescaling parameters should be necessary for measures the goodness of fit of the rotation (Podani 1991b). This would be useful to measure what variables in $X(2)$ are better related to $X(1)$ in a step-wise process followed according to some suitable criterion.

- Indirect gradient analysis

Indirect gradient analysis is based on the assumption that the variables describing the landscape are good indicators of the landscape states. It is assumed that the landscape pattern is determined by all the environmental and historical factors that can be and that cannot be measured and that the pattern is indicating both the environmental situation and the environmental impact of human activities.

Indirect gradient analysis uses only the matrix $X(1)$ to get ordination axes. The explanatory matrix $X(2)$ is only used to try to explain the pattern of $X(1)$. Indirect gradient analysis does not require that the explanatory matrices have the same number of columns of $X(1)$. Their number of columns can be less than the number of columns in $X(1)$. The ordination axes obtained by SVD of $X(1)$, or of Q matrices obtained by different resemblance functions applied to $X(1)$, are used for detecting gradients and for what ter Braak (1995) calls calibration, i.e. the prediction of scores of explanatory variables. In this case $X(2)$ is rearranged according to the ordination axes obtained by $X(1)$. Along these axes, or along non-linear combination of them (projections of OGU's to curves or angular seriations) the scores of variable and/or those of environmental variables are plotted (Feoli and Feoli Chiapella 1980).

4. Ordination based on classification and fuzzy set theory

The ordination methods based on SVD and eigenanalysis of a matrix X (or of its submatrices obtained by separating groups of variables) are generally maximizing dispersion or correlation. When the OGU's are classified into groups by explanatory variables, a direct ordination can be obtained by Discriminant Analysis. In terms of equation 2), Discriminant Analysis (DA) is:

$$(W^{-1}B - \lambda I_p)T_i = 0$$

where W^{-1} is the inverse of the matrix of covariance of the variables within the sets of OGU's and B is the matrix of covariance of the same variables between the sets of OGU's.

$\beta(2)$ ordination axes are obtained by $\beta(2) = T'X(2)$. These axes maximize the separation between the sets of OGU's. Discriminant analysis allows to find what are the variables that better discriminate the OGU's sets and also gives the probability of each OGU to belong to the sets under the assumption of normal distribution, linear correlation and equality of variance-covariance of the variables within the clusters. All these limitations are rarely met in data matrices, however they can be tested and the tests can be useful to understand landscape patterns rather than to prove hypothesis (Feoli and Lagonegro 1991). Discriminant analysis (DA) can be also used as an indirect ordination method when W^{-1} and B are obtained by the dependent variables. To avoid singularity problems, the number of variable should be always less than the number of OGU's in the sets. This is rarely met. A way to overcome this problem is to group variable in sets before DA. In this way OGU's are described by variable groups (average scores of the variable in each group).

Another method of ordination based on classification is the one proposed by Feoli and Zuccarello (1986, 1988). This is based on fuzzy set theory since the ordination axes are given by the degree of belonging of OGU's to sets of OGU's. According to fuzzy set theory a fuzzy set is given by a set of elements with their degrees of belonging to the set (see Feoli and Orloci 1991 for references). In this method the similarity matrix Q is considered a fuzzy matrix, where each OGU

represents a set. The similarity measures (ranging between 0 and 1, with 0 no similarity, 1 identity) in the i -th row or j -th column ($i=j$, being the matrix symmetric) are the degree of belonging of all the OGUs to the set represented by i -th OGUs. On the other way, they are also the degrees of belonging of the i -th OGU to all the sets represented by all the other OGUs. Fuzzy axes can be obtained by averaging the values of similarity in a matrix of similarity after having rearranged its rows and columns according to some classification. The Q matrix becomes a rearranged $Q_p(n \times n)$ that is transformed in a $Q_p(n \times c)$ matrix where c is the number of clusters (sets). The c clusters can be obtained by any classification method, provided, and this is essential for fuzzy set theory, they are well characterized, i.e. "conceptualized". Each set has to be described by variables that have been used for classification or that have been added later. For doing this it is essential to rearrange the original data matrix X according to $Q_p(n \times n)$ and discovering what are the discriminating variables. Once discriminat variables have been defined the sets are characterized according to them. In this way each j -th vector of the c vectors in $Q_p(n \times c)$ is associated to a variable or to a set of variables highly correlated and represent the degree of belonging of all the OGUs to that set, each j is a fuzzy set. If the values in $Q_p(n \times c)$ are adjusted to the row totals in order to get $\sum_j \xi_{ij} = 1$ (with ξ_{ij} = degree of belonging of i -th OGU to j -th fuzzy set) $Q_p(n \times c)$ represent a fuzzy partition, let call it $F_p(n \times c)$. SVD of $F_p(n \times c)$ gives the representation of the fuzzy system space where the n OGUs and the c fuzzy sets find their mutual position. This method of ordination can be applied to any kind of matrices and it is not confined, as DA, to variables measured in ratio scale. When the data are mixed (alfanumeric, ordinal, etc.) Q matrices can be obtained by suitable similarity measures that are not based on scalar product, such as Gower, Burnaby or Goodall's similarity indices. Direct gradient analysis can be done using the matrix $\Phi(n \times m)$ obtained, as was suggested by Feoli and Zuccarello (1988) by multiplication $F_p(n \times c)E'(c \times m)$. $\Phi(n \times m)$ is a matrix that describes the OGUs by the variables in $E(m \times c)$. There are many ways to put values in $E(m \times c)$: average values, maximum values, the most probable value, etc. The result in $\Phi(n \times m)$ depend on the way chosen. $\Phi(n \times m)$ represents a new description of all the n OGUs, (notwithstanding data were not collected for all the OGUs in E) in this sense fuzzy set ordination can be considered an interpolation method in the fuzzy system space. If the values in $\Phi(n \times m)$ are adjusted in such a way that the row totals are equal to 1, than $\Phi(n \times m)$ is a fuzzy partition with m environmental fuzzy sets. Each column represents the degree of belonging of OGUs to the sets defined by the j -th environmental variable. The SVD of $\Phi(n \times m)$ represents the fuzzy system space where OGUs and environmental variables find mutual position. Once defined a fuzzy partition, let say $F_p(n \times c)$, many other fuzzy partitions can be obtained by matrix multiplication. Keeping the c fuzzy sets as axes all the objects that may belong to the c sets (environmental variable, morphological characters, chorological, etc.) can be overlapped into a single ordination, examples are given by Feoli and Zuccarello (1988, 1992, 1994) and Banykwa, Feoli and Zuccarello (1990).

5. Conclusions

Mapping multidimensional spaces described by X matrices is a good exercise to study niches of land cover types and to study relationships between variables or sets of variables and between them and land cover types. Data analysis is often criticised for not being enough explanatory: elements of deductive approach are considered missing and the methods are considered not predictive. This criticism is not realistic. It is true that the mechanistic element in landscape studies is weak, but it is also true that cannot be stronger owing to the complex nature of landscape. Landscape is a self-organizing system, objects or entities that can be described by several variables (characters) are in a certain area for historical and ecological reasons that cannot be modelled in a mechanistic way. Shapes of features are the results of many interactions. Based on SVD we are able to model clusters in multidimensional space by creating new data by interpolations or extrapolations in the space defined by V in $X = UAV'$. Iterative calibrations according to ter Braak (1995) can be done accordingly. The space defined by V based both on real or fuzzy data, can be used to find the position and width of the ecological niches of variable and communities in the ecological space (Zerihun et Al. 1989) and can be used for detect or simulating gradients by direct or indirect methods.

Extended References

Banyikwa, F.F., Feoli, E. and Zuccarello, V. (1990) Fuzzy set ordination and classification of Serengeti short grasslands, Tanzania. *Journal of Vegetation Science* 1, pp. 97-104.

Carranza L. , E. Feoli and P. Ganis. 1998. Analysis of vegetation diversity by Burnaby's similarity index. *Plant Ecology* 138: 77-78.

Dale M.B. (1991) Mutational and nonmutational similarity measures: a preliminary examination, in Feoli, E. and Orlóci, L. (eds) *Computer assisted vegetation analysis*, pp. 123-135. Kluwer, Dordrecht.

De Patta Pillar, V. and L. Orloci. 1993. Character-based community analysis: the theory and an application program. SPB Academic Publishing, The Hague.

Feoli, E. (1984) Some aspects of classification and ordination of vegetation data in perspective. *Studia Geobotanica* 4, pp. 7-21.

Feoli, E. and L. Feoli Chiapella. 1980. Evaluation of ordination methods through simulated coenoclines: some comments. *Vegetatio* 42:35-41.

Feoli, E., Ganis, P. and Zerihun Woldu (1991) Community niche an effective concept to measure diversity of gradients and hyperspaces, in Feoli, E. and Orlóci, L. (eds) 1991 *Computer assisted landscape analysis*, pp. 273-277. Kluwer, Dordrecht.

Feoli, E. and Lagonegro, M. 1991. Testing for elliptical clusters in ecological multidimensional spaces. in Feoli, E. and Orlóci, L. (eds) *Computer assisted vegetation analysis*, pp. 291-297. Kluwer, Dordrecht.

Feoli E., M. Lagonegro and L. Orłóci. 1984. Information analysis of vegetation data. Dr. W. Junk, The Hague.

Feoli E. and L. Orłóci (eds.). 1991. Computer Assisted Vegetation Analysis. *Kluwer*. Boston.

Feoli, E. and Orłóci, L. 1991 The properties and interpretation of observations in vegetation study, in Feoli, E. and Orłóci, L. (eds) *Computer assisted vegetation analysis*, pp. 3-13. Kluwer, Dordrecht.

Feoli E., Podani J. and Sun Cheng Yong. 1993. Correspondence between climatic and geographical spaces by Procrustes analysis. *Abstracta Botanica* 17: 141-146.

Feoli E. & V. Zuccarello. 1986. Ordination based on classification: yet another solution?! *Abstracta Botanica* 10: 203-219.

Feoli E. & V. Zuccarello. 1988. Syntaxonomy, a source of useful fuzzy sets for environmental analysis?. *COENOSES* 3: 65-70.

Feoli E. and Zuccarello V. 1992. Fuzzy sets and structural changes in forest succession: an example from broad leaved forests of N.E. Italy. *COENOSES* 7: 81-90.

Feoli E. and Zuccarello V. 1994. Naivete of fuzzy system space in landscape dynamics? *COENOSES* 9: 25-32.

Gabriel, K.R. (1971) The biplot graphic display of matrices with application to principal component analysis. *Biometrika* 58 pp. 453-467.

Goodall, D.W. (1964) A probabilistic similarity index. *Nature* 203 pp. 1098.

Greig-Smith P. 1983. Quantitative plant ecology. 3rd ed. Blackwell, Oxford.

Jongman, R.H.G., ter Braak, C.J.F. and van Tongeren O.F.R. (eds.) 1995 *Data analysis in community and landscape ecology*. "2nd ed. Cambridge University Press. Cambridge.

Mueller-Dombois, D. and Ellenberg, H. (1974) *Aims and methos of vegetation ecology*. Wiley, New York.

Orłóci, L. (1966) Geometric models in ecology. I. The theory and application of some ordination methods. *J. Ecol.* 54 pp. 193-215.

Orłóci, L. (1967) Data centering: a review and evaluation with reference to component analysis. *Syst. Zool.* 16 pp. 208-212.

Orłóci, L. (1978) *Multivariate analysis in vegetation research*. Junk, The Hague.

Orłóci, L. (1988) Detecting landscape patterns. *ISI Atlas of Sciences, Plants and Animals*, Vol 1. pp. 173-177.

Orłóci, L. (1991a) Statistics in ecosystem survey: computer support for process-based sample stability tests and entropy/information inference, in Feoli, E. and Orłóci, L. (eds) *Computer assisted vegetation analysis*, pp. 47-57.

Orłóci, L. (1991b) On character-based plant community analysis: choice, arrangement, comparison, in Feoli, E. and Orłóci, L. (eds) *Computer assisted vegetation analysis*, pp. 81- 86.

Orłóci, L. (1991c) Poorean approximation and fisherian inference in bioenvironmental analysis. *Advances in Ecology*, 1: 65-71.

- Orlóci, L. and De Patta Pillar, V. (1991) On sample size optimality in ecosystem survey, in Feoli, E. and Orlóci, L. (eds) *Computer assisted vegetation analysis*, pp. 41-46.
- Podani, J. 1991a On the standardization of Procrustes statistics for the comparison of ordinations. *Abstracta Botanica* 15, pp. 43-46.
- Podani, J. (1991b) SYN-TAX IV. Computer programs for data analysis in ecology and systematics, in Feoli, E. and Orlóci, L. (eds) *Computer assisted vegetation analysis*, pp. 437-452.
- ter Braak, C.J.F. Ordination. In Jongman, R.H.G., ter Braak, C.J.F. and van Tongeren O.F.R. (eds.) 1995 *Data analysis in community and landscape ecology*. "2nd ed. Cambridge University Press. Cambridge. pp. 91-173.
- ter. Braak, C.J.F. and I.C. Prentice. 1988. A theory of gradient analysis. *Adv. Ecol. Res.* 18: 271-317.
- Westhoff, V. and E. van der Maarel 1978. The Braun-Blanquet approach. In: Whittaker R.H. (ed.), *Classification of Plant Communities*. 2nd ed. Junk, The Hague.
- Whittaker, R.H. (1967) Gradient analysis of landscape. *Biol. Rev.* 42, pp. 207-264.
- Whittaker, R.H. (1978) Direct gradient analysis, in Whittaker, R.H. (ed.), *Ordination of plant communities*, pp. 7-50. Junk, The Hague.
- Zerihun W., E. Feoli & L. Nigatu. 1989. Partitioning an elevation gradient of landscape from Southeastern Ethiopia by probabilistic methods. *Vegetatio* 81: 189-198.
-
- Arnold G. W., 1995. Incorporating landscape pattern into conservation programs. In: L., Fahring L. & Merriam G. (eds.). *Mosaic landscape and ecological processes*, 309-337. Chapman & Hall, London.
- Baret F., 1995. Use of spectral reflectance variation to retrieve canopy biophysical characteristics. In Danson, F.M. and S.E. Plummer (eds.) "Advances in Environmental Remotely Sensing". J. Wiley, pp.33-51.
- Barseley M.J. and Barr S.L., 1996. Inferring Urban Land Use From Satellite Sensor Images Using Kernel-Based Spatial reclassification. *Photogrammetric Engineering & Remotely Sensing*, 8, 949-958.
- Bezdek, J.C., Keller J. Krisnapuram R. and Pal N.R. 1999. *Fuzzy models and algorithms for pattern recognition and image processing*. Kluwer Academic Publishers, Dordrecht. pp. 776.
- Choudhury B.J., 1987. Relationships between vegetation indices, radiation absorption, and net photosynthesis evaluated by a sensitivity analysis. *Remotely Sensing of Environment* 22: 209-233.
- Crovello, T.J. (1981). Quantitative biogeography an overview. *TAXON* 30(3): 563-575.
- De Jong S.M., 1993. An application of spatial filtering techniques for land cover mapping using TM images. *Geocarto International*, 8(1), 43-49.
- De Jong S.M. and Burrough P. A., 1995. A fractal approach to the classification of Mediterranean vegetation types in remotely sensed images. *Photogrammetric Engineering & Remotely Sensing*, 8, 1041-1053.

- De Cola L. 1989. Fractal analysis of a classified Landsat scene. *Photogrammetric Engineering and Remotely Sensing*, 55, 601-610.
- Dobson, J.E. (1993) Commentary: a conceptual framework for integrating remotely sensing, GIS and geography. *PE&RS* 59 (10) pp. 1491-1496.
- Emberger L. 1955. Afrique du Nord- Ouest. In: *Plant ecology: review of research /ecology v`ÈgÈtale: co mpte rendu de recherche*. Paris Unesco (Recherche sur la Zone aride 6).
- Feoli E. and Zuccarello V., 1996. Spatial pattern of ecological process: the role of similarity in GIS applications for landscape analysis. In: Fisher M., Sholten H.J.,
- Unwin D. (eds) *Spatial analytical perspectives on GIS*, GIS DATA 4, Taylor and Francis, London, 175-185.
- Frohn R.C., 1998. *Remotely sensing for landscape ecology. New metric indicators for monitoring, modeling, and assessment of ecosystem*. Lewis Publishers.
- Kenkel N.C. and Walker D.J., 1996. Fractals in the biological sciences. *Coenoses*, 2, 77- 100.
- Krummel J.R., Gardner R.H., Sugihara G., OfNelle R.V. and Coleman P.R., 1987. Landscape Patterns in a disturbed environment, *Oikos*, 48, 321- 324.
- Klinkenberg B. and Goodchild M.F., 1992. The fractal properties of topography: comparison of methods. *Earth surface process and landforms*, 17, 217-234.
- O'Neill R.V., Krummel J.R. Gardner R.H., Sugihara G., Jackson B., De Angelis D. L., Milne B. T., Turner M.G., Zygmunt B., Christensen S.W., Dale V.H. and Graham R. L., 1998. Indices of landscape pattern. *Landscape Ecology*, 1, 153-162.
- Peuquet D.J., 1984. A conceptual framework and comparison of spatial data models. *Cartographica*, 21 (4): 66-113.
- Podani J., 1993. SYN-TAX-PC. Computer programs for multivariate data analysis in ecology and systematics. Version 5.0. User' s guide. Scientia Publishing, Budapest.
- Purevdorj T., Tateishi R., Ishiyama and Honda Y., 1998. Relationships between percent vegetation cover and vegetation indices. *Int. J. Remotely Sensing*, 19 (18): 3519-3535.
- Qiu H.L., Siu-Ngan Lam N., Quattrochi D.A. and Gamon J.A., 1999. Fractal Characterization of Hyperspectral Imagery *Photogrammetry Engineering & Remotely Sensing* Vol. 65, No.1, pp 63-71.
- Rescia A.J., Schmitz M.F., Martin de Agar P., de Pablo C.L. & Pineda F.D., 1997. A fragmented landscape in northern Spain analyzed at different spatial scale: implications for management. *J. Veg. Sci.*, 8, 343-352.
- Rex K.D., and Malanson J.P., 1990. The fractal shape of the riparian forest patches. *Landscape Ecology*, 4, 249-258
- Ricotta C., Olsen E.R., Ramsey R.D. & Winn D.S., 1997. A generalized Non regression Techniques for Evaluating the fractal Dimension of Raster GIS Layer consisting of non square cells. *Coenoses*, 1, 23-26
- Rouse, J.W.Jr., Hass, R., Schell, J. A. and Deering, D. W., 1974. Monitoring the vernal advancement and retrogradation (green wave effect) of natural vegetation. NASA/GFSC Type III Final Report, Greenbelt, MD. 371.

● Skole, D.L. Moore III, B. and Chomentowski, 1993. Global geographic Information Systems and Databases for Vegetation Change Studies. In Solomon A.M. and H.H. Shugart (eds) "Vegetation Dynamics and Global Change" pp.168-189. Chapman & Hall, New York, London.

Sneath, P.H.A. and Sokal, R.R., 1973. Numerical Taxonomy. Freeman, San Francisco.

● Snow R.S., and Mayer L. (editors), 1992. Fractals in geomorphology. *Geomorphology*, 5, PP. 194

Turner M.G. & Gardner R., 1990. Quantitative Methods in Landscape Ecology. *Ecological studies*, Vol.82 analysis and synthesis.

Zhao, S.X. 1986. Discussion on Fuzzy Clustering. 8th Int. conference on Pattern recognition, IEEE Press, New York, pp. 612-614.

● Zimmerman H.J. 1985. Fuzzy Set Theory and its Applications. Kluwer, Dordrecht. pp. 363.

**Training Course on
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Enrico Feoli

Multicriteria Analysis:

Establishing priorities

(notes from the book of T. Saaty 1999 Decision making for leaders: The analytic hierarchy process for decisions in a complex world. RWS Publications University of Pittsburg, 322 Mervis Hall)

Calculating the priorities using an approximation method

Let have a Saaty’s matrix of pairwise comparison between three criteria:

	C	T	L
C	1	1/2	1/4
T	2	1	1/2
L	4	2	1
Column total	7	3.5	1.75

A normalized matrix is computed by dividing each element in the matrix by the corresponding column total

	C	T	L
C	1/7	1/7	1/7
T	2/7	2/7	2/7
L	4/7	4/7	4/7

The priority of each criterion is calculated by averaging the row scores of the normalized matrix

In the present example it is:

Priority C = $(1/7 + 1/7 + 1/7)/3 = 1/7 = 0.14$

Priority T = $(2/7 + 2/7 + 2/7)/3 = 2/7 = 0.29$

Priority L = $(4/7 + 4/7 + 4/7)/3 = 4/7 = 0.57$

The concept of consistency:

In the example we can see that $C = 1/2 T$ and that $C = 1/4 L$ so that $1/2 T = 1/4 L$ which brings $T = 1/2 L$ that is what we have in the Saaty matrix. This proves that the matrix is consistent. Another proof of consistency is given by the fact that L is 2 T, and C is 1/2 T so L should be 4 C, that is actually what happen in the Saaty matrix.

Calculating the priorities using the exact method

This is based on the idea of consistency. If the matrix is consistent all its powers (multiplication of the matrix by itself 1 time = power 2, 2 times = power 3, etc.) give the same priority or dominance pattern.

When the matrix is consistent, the normalized sum of each row tells us how much each element dominates the others in relative terms. The sum of the entries in each column tells us how much each element is dominated by other elements.

To derive the priorities from the matrix we add the numbers in each row and divide each of the results by their total sum to obtain the normalized scores. The operation is repeated till results are stabilized. (In the approximation method each value in the row is divided by the sum of the corresponding column!). The resulting vector is approximating the first eigenvector of the matrix, i.e. the eigenvector corresponding to the first eigenvalue of the matrix.

If the matrix is consistent the product of the vector of the sum of the elements in columns by the vector of the normalized scores is equal to n , where n is the number of elements (criteria). If the product is higher than n it means that the matrix is not consistent.

The inconsistency is assumed to be generated when the scores in the pairwise comparison matrix the values are generated by random.

The ratio $CI = (\text{eigenvalue} - n) / n - 1$ is the consistency index, the consistency ratio is given by the ratio between CI and CIR where CIR is the consistency index corresponding to a completely random judgement (there are tables for this!!!). If the consistency ratio $CR = CI/CIR$ is less than 0.05 the matrix of Saaty can be considered good!

There are computer programs for calculating priorities, CI and CR. IDRISI is calculating them automatically within a GIS environment. EXPERT CHOICE is doing out of a GIS environment.

*Focus on the Impacts of Industrial Development on Marine
Environment and Landscape
by N. Candeloro*

Focus on the Impact of Industrial Development on Marine Environment and Landscape

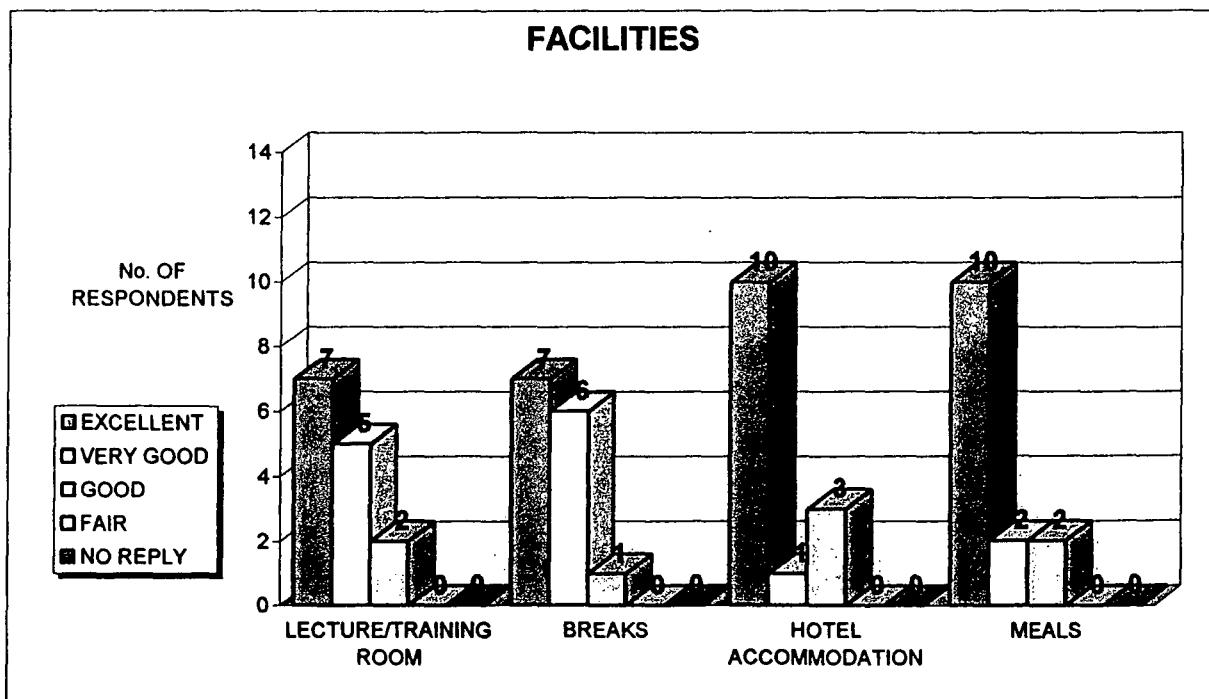
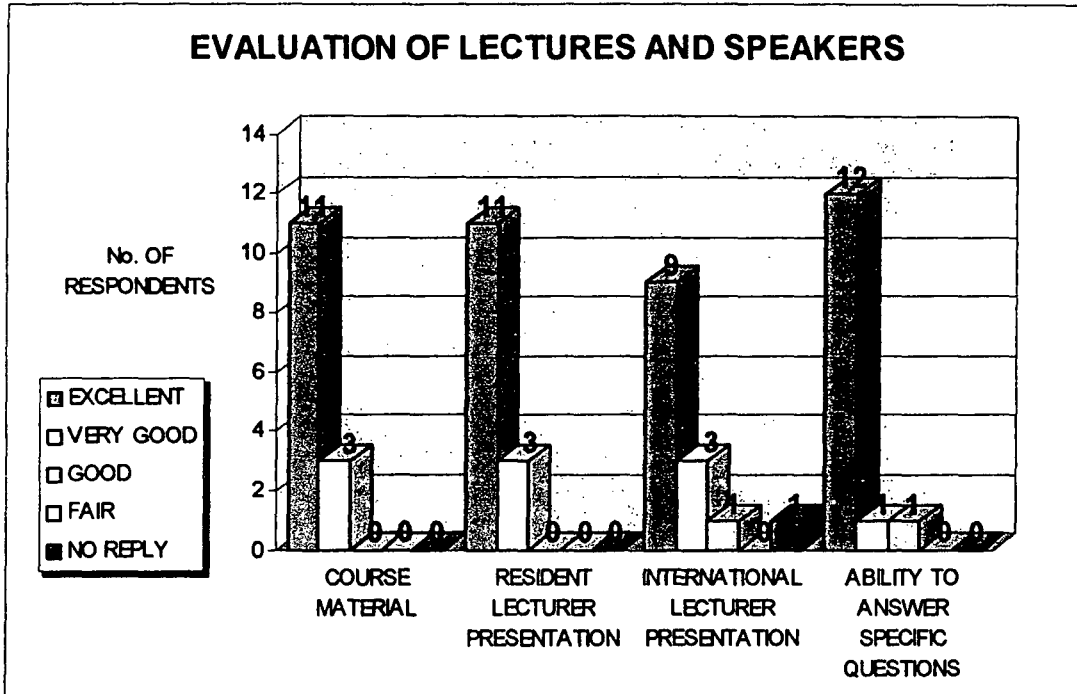
by Nicola Candeloro

At the end of second world war, more than 50000 of people worked into the lead and zinc mines of the areas of Sulcis-Iglesiente. When the Italy State has opened its market to abroad trade, the lead and zinc production became not economic convenient. The companies started to reduce the employees and, in the same time, the unemployment was going to increase in the area. The Unions and the local authorities required an alternative to the mine production to reduce the level of unemployment. The government decided to transform the land of Portoscuso, a village of farmers and fishermen, in industrial zone. The state companies havebeen required supporting the government decisions. They designed and set up the Alumina refinery, aluminium smelter, lead and zinc refinery and the facilities to support the activities of plants. The chimneys of plants replaced the vineyards. More of 5000 people were employed during the phase of the construction and the same number were involved to run the plants. Fishermen and farmers have been transformed in workers. Portoscuso transformed itself and in few years the residents increased from 500 to 7000. At the beginning all the people were satisfied of the situation. The problems started when the company reduced the number of employs and the environment issues became actual. During the first phase of production the waste material of alumina and lead and zinc refineries has been put in the open pond. When the resident of Portoscuso became to protest against the companies, the authorities imposed the construction the new ponds and reduced the limits to the emissions and the area has been declared "Area ad alto rischio ambientale". This declaration imposed to the companies the recovery of the polluted areas. Actually the companies are involving to burn the low sulphur oil, cover the stock pile to reduce the dust, increase the efficiency of process to reduce the off sets and design the recovery of polluted areas. In the same time it is nearly impossible to construction new ponds. The future of plants of areas is uncertain and depends of the public opinion that prefers now the tourism to the industry. The history of Portoscuso shows it is very important to consider the interest of the stakeholders before those of shareholders in marine environment.

Annex IV
STATISTICS

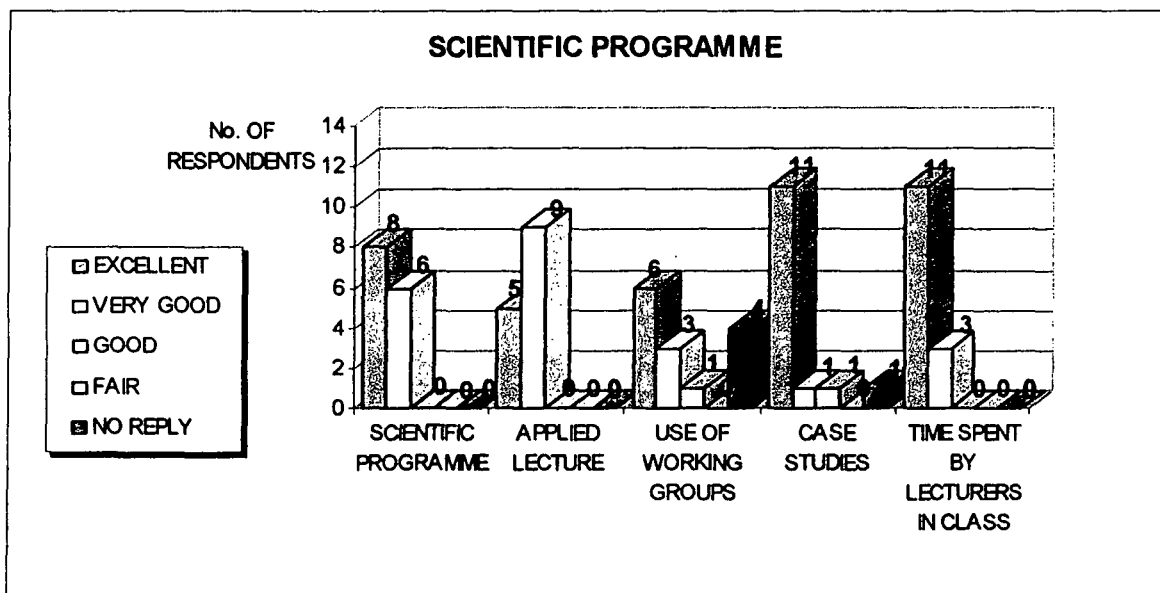
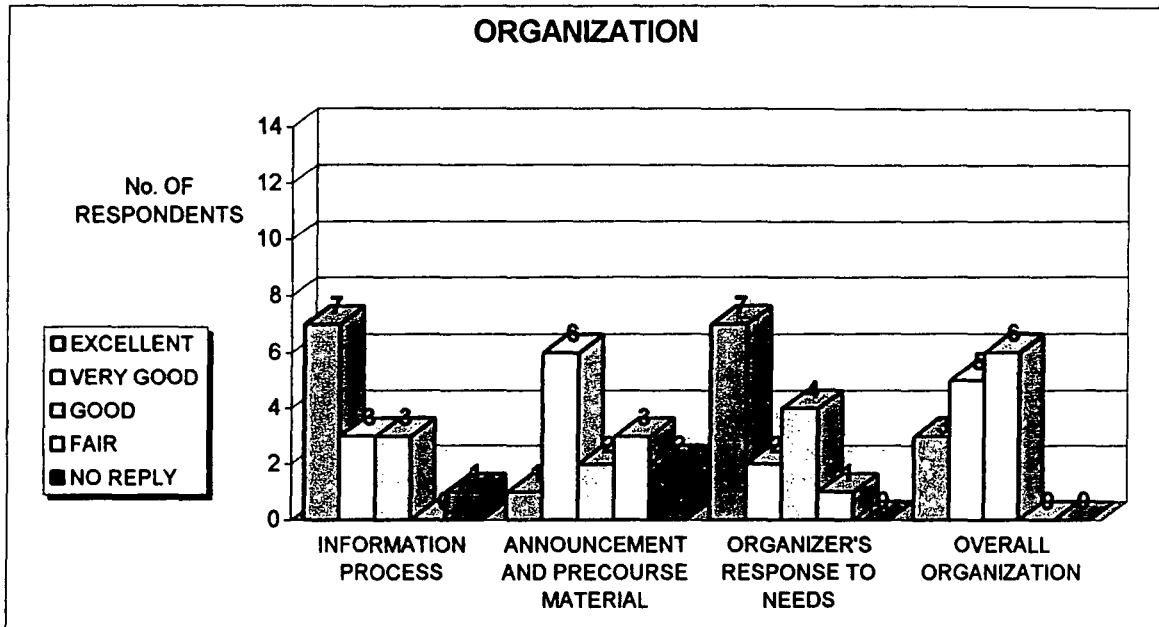
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