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Paper 7

FROM ENVIRONMENTAL INFORMATION SYSTEMS TO ENVIRONMENTAL INFORMATICS - EVOLUTION AND MEANING

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ABSTRACT

Environmental Information and Environmental Information Systems play a major role in environmental decision making. The development of these systems is tightly connected to the environmental awareness of the last three decades. This working paper is a review of the historical development and state-of-the-art of environmental information systems. It focuses on the creation, management and use of Environmental Information Systems (EISs). It is based on the World Wide Web and computerised databases research of the term "environmental information". The paper explores the typology of EISs and examined the common definitions of them in the light of these findings. The major issues in this paper include:

- The concepts of data, information and knowledge in EISs
- The connection between EISs and Geographical Information Systems (GISs).
- Problems and obstacles to the development of EISs.
- Scale, jurisdiction and EISs.
- And finally, the emerging demand for public access to environmental information.

The paper includes a list of major WWW sites that are relevant to this field.

1. Introduction and Outline

Environmental Information and Environmental Information Systems play a major role in environmental decision making. This working paper is a review of the historical development and state-of-the-art of environmental information systems. It focuses on the creation, management and use of Environmental Information Systems (EISs). Instead of focusing on the technical attributes of EIS (although they are taken into consideration and analysed), the paper explores those cases where the term EIS was used. The aim of this is to try to understand the reasons for declaring a certain set-up of computerised technology and data sets as an “Environmental Information System”. By doing so, it is possible to scrutinise definitions of EIS in the light of existing systems.

This paper is based on the World Wide Web and computerised databases and some meta-analysis of the syntactical use of the term “environmental information” research (described in Annex 2).

The discussion starts with a description of systems that have been called “Environmental Information System” (EIS) in order to identify and pinpoint the shared attributes of these systems. The review includes systems that have been developed by the United Nations Environmental Program (UNEP), and also a set of various systems that cover different scales from the national (hence the term National EIS or NEIS), to the regional and the metropolitan level. The review also considers the group of EISs which relate to processes - usually industrial - and the need to monitor and regulate the use of hazardous materials. Each type of EIS identified is explained and, in some cases, demonstrated with a “best practice” example.

Following the description, the existing definitions of environmental information systems are examined - in the practical sense (as in the case of job descriptions) and in the more theoretical sense (for example in textbooks). This discussion includes the description of the emerging field of “environmental informatics”.

EIS are divided into two groups - those that are information systems in the strictest sense (they are used to store and retrieve information) and those that are geared toward analysis and simulation of environmental information. Among the latter, the predominance of Geographical Information System (GIS) is striking. Moreover, it seems that in many cases the term EIS is used to refer to a GIS (or vice versa).

The discussion then turns to common and known problems in existing EIS - some of which are common to GIS in general. The problems include:

- The high costs of building and maintaining EIS.

- Information overload and the need to balance between the urge to “bridge the knowledge gap” and the need to have a meaningful and useful database.
- Information sharing, and as information becomes a valuable asset, the issues of copyright and cost influence the ability to share (and later to use) it.
- In relation to GIS, the problems of lack of base mapping and expertise, weak analytical capabilities in GIS packages and integrity, reliability and accuracy of spatial databases.

Why is there strong coupling between EIS and GIS? The customary claim is that as most environmental problems are spatial, GIS is the most appropriate technology for dealing with these problems. However, this explanation is not complete. It is possible to find other spatially related research fields that have not relied on GIS as their main computing environment. Therefore, a more complete explanation is needed to relate the development of GIS and EIS and their shared history.

Next, the question “Is it worth it?” is explored and the delicate balance between worthwhile systems and the rush to use the latest technology is examined. Some examples where the technical development was considered more important than the environmental content of the system are identified. Even though these examples should not be used as a reason to stop the development of EISs, they are a cause of concern and should be taken into account during the evaluation and decision of new projects.

In the last section of the paper, the issue of scale and jurisdiction is explored in detail. On the basis of the review, some aspects on the relationship between the system owners, their juridical area and the extent of the system coverage are explained, but also other aspects - the level and need for public access and the ways in which this access is achieved are discussed.

A list of major web sites that contain relevant information about EIS is presented as an annex to the paper.

2. Background

By most historical accounts, the closing years of the 1960s mark the beginning of the environmental movement, and the arrival of the “Environment” on the international agenda (Castells, 1997). The Stockholm conference on the Human Environment (1972) is commonly used as the “starting point” for this awareness. The main outcome of this conference was the creation of the United Nations Environmental Programme - UNEP (Strong, 1997). From its inauguration, UNEP saw the collection of data and information about the state of the environment as its most urgent task (Wallen, 1997). Since then, UNEP has been a catalyst and co-ordinator in the field of environmental data collection and exchange[1]. As commonly happens in this situation, considerable “knowledge gaps” have been found, and UNEP have focused on filling them - a project supervised by the Global Environment Monitoring System (GEMS) unit. By the end of the 1970s, GEMS had created INFOTTERA - the International Environmental Information System - probably the first of its kind. However, the use of computers for environmental research can be traced back to the late 1960s (Munn, 1975). The ever increasing computing power was exploited to create new environmental models - from local meteorological forecasting to global warming, from bio-diversity to hydrology to noise from traffic – it is hard to find an aspect of environmental sciences that does not use computer modelling.

As computers became more available (both in term of cost and ease of use) and as more and more environment-related data was collected through various remote sensing programmes - ranging from satellites to air pollution sensors - the need to handle, store, analyse and present this information gained importance. Today, it’s virtually impossible to think about environmental research without relying heavily on digital technology. Information Technology (IT)[2] casts a shadow over almost every aspect of the “Environment” debate: research, monitoring, management and, ultimately, decision making and public involvement in decision-making.

From the outset of the research that lead to this paper, it became clear that there is a distinct difference between the use of the singular form (Environmental Information System) which is used to describe a specific system and the plural (Environmental Information Systems) which is used to describe the generic type of such systems (in the same way that the term “information systems” is used). Since this paper examines the plural (denoted by EISs) in the light of the singular (EIS), I will start with the latter. To avoid confusion, I will not use the plural form when EIS is discussed (even if the sentence refers to a group of specific systems).

3. Types of EIS

According to the survey, an appropriate definition of EIS is “a collection of data sets and information that have some relevance for the study and/or monitoring and/or exploration of the environment”. The term EIS is used to describe a collection of socio-economic indicators; a contact list of consultants or a list of chemicals that are used in the production cycle. It can be a set of data

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[1] The definitions of “data” and “information” in EIS are blurred. Even though the two are quite different, many texts use them interchangeably. This issue will be examined later.

[2] The term IT will be used here in its broadest sense, encompassing all forms of technology used to create, store, exchange, and use information in its various forms (business data, voice conversations, still images, motion pictures, multimedia presentations, and other forms, including those not yet conceived). It's a convenient term for including telephony, computer technology and embedded systems in the same word. (Whatis.com, 1998)

files, or a highly integrated information system; a standalone system, running on a personal computer; or a sophisticated system, based on super-computers. It can rely on “proven” technology - such as database management system running on a mainframe computer or based on the latest “hot” technology (currently the WWW). Its scale can be as wide as the globe, national, local, or it might not relate to any geographical scale. To set some order in what seems to be “chaos of EIS”, it might be beneficial to try and give a typology of EIS. The presentation order follows (fairly loosely) the historical “evolution” of EIS, while categorising groups according to the declared functionality of the system. The most influential family of EIS is presented in Figure 1 – systems that were developed by UNEP. As we shall see later, these systems epitomise the main trends in EIS.

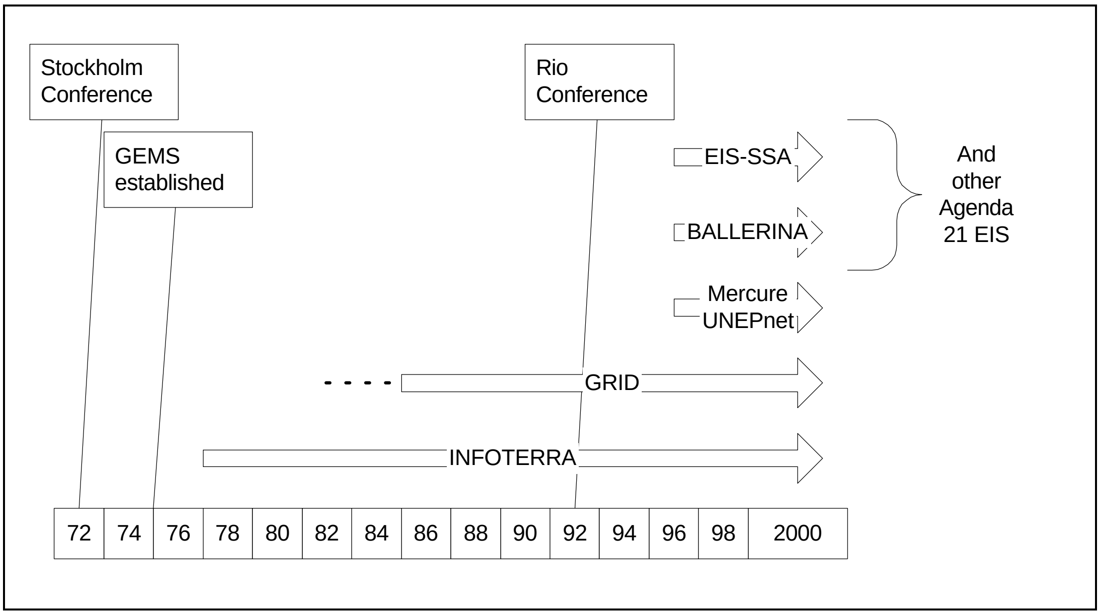

Figure 1 - Time Line of UNEP EIS

EIS and UNEP/Earthwatch

As mentioned earlier, INFOTERRA is probably the first EIS. The “Earthwatch” concept was on the UNEP agenda from its inception: a mission to evaluate, monitor, research and exchange data and information about the global environment. As time went by, the Global Environment Monitoring System (GEMS) unit became the pivotal body within UNEP. GEMS is in charge of collecting, validating, storing and systematising the data from various monitoring programmes at a global scale. To help co-ordinate the sources of environmental information GEMS developed INFOTERRA, which first came on-line in 1977 after 5 years of development. It serves as a repository of contacts and expertise on every aspect of environmental research. The system operates through several regional centres, with National Focal Points (affiliated bodies in the national level that act as INFOTERRA contact points). INFOTERRA was intended for researchers and professionals and was run by the environmental data unit of UNEP which also collected various data and statistics about the environment:

> *"...Infoterra is thus responding to an increasing world demand for accurate, quality information on environmental planning, development ... Its achievement has been to reduce wrong decision on environmental issues made more from ignorance than ill-will."* (UNEP, 1979)[3]

A typical query to INFOTERRA would focus on the "meta" level (exchange of information about information - "Where can I find knowledge/information about air pollution modelling? " and the system would give answers in the form of providing contact points and references. The next major UNEP EIS is the Global Resource Information Database (GRID). It was conceived around 1981-1983, with a mission to co-ordinate, within a common geographical reference system the numerous data sets that GEMS, UNEP and other specialised agencies already had. It is noteworthy that in the heart of GRID there is a GIS and that digital geographical information is the main resource that GRID provides. GRID is based on ARC/INFO GIS - donated by ESRI back in 1983, two years after the package was released.

> "*...Existing technology now makes possible the development within GEMS of the global resource data base (GRID), which will be a data management service within the UN system designed to convert environmental data into information usable by decision makers ... The technical feasibility of GRID has been assessed by expert groups...* " (UNEP, 1985)[4]

> "*...GRID technology allows us ... initially to describe, but eventually to understand, and ultimately to predict and manage... GRID is also providing practical introduction to GIS technology for application in the national level ... data transmission rates were very low, and for cost-effective telecommunication between GRID nodes, direct satellite links will clearly have to be established ... UNEP looks forward to the day when GRID data and technology will be routinely and easily available to the entire world community to help sharpen the process of environmental assessment and guide the forces of environmental management*" (UNEP, 1986)

A look at GRID Arendal (the north European GRID centre) WWW site provides an idea about the role of GIS in this system (Figure 2). GRID has grown by its own momentum, and became a separate unit (Programme Activity Centre - PAC) of the UNEP in 1991(Wallen, 1997).

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[3] This was the second year of INFOTERRA operation. The total fund spent on it was 973,136 $US while the number of queries was about 2,000. Each query cost about 500 $. Later in the paper, the costs of EIS are examined.

[4] Investment in GRID 2,000,000 $US - partially from donations, most notably by ESRI – ARC/INFO developers.

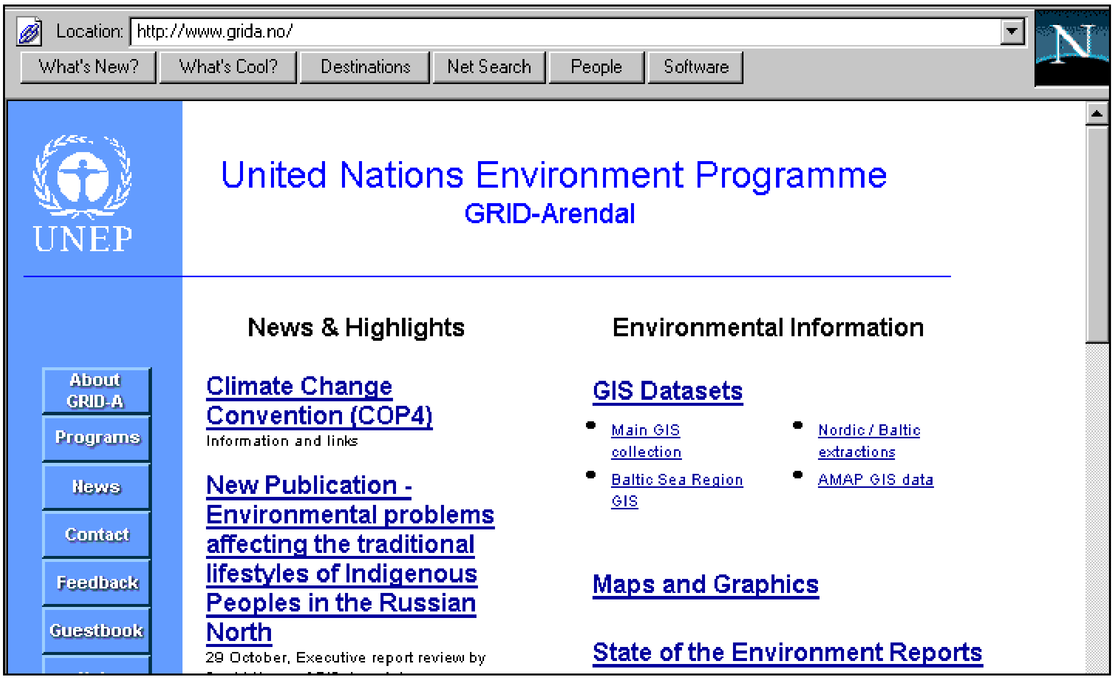

Figure 2 - UNEP/GRID Arendal home page

The next major event in the UNEP EIS story is the Rio Conference 1992 and "Agenda 21" (A21). EIS are first mentioned in chapter 12 of Agenda 21, which focuses on desertification:

> "*Governments at the appropriate level, with the support of the relevant international and regional organizations, should:*
> ***One****. Establish and/or strengthen environmental information systems at the national level;*
> ***Two****. Strengthen national, state/provincial and local assessment and ensure cooperation/networking between existing environmental information and monitoring systems, such as Earthwatch and the Sahara and Sahel Observatory;*
> ***Three****. Strengthen the capacity of national institutions to analyse environmental data so that ecological change can be monitored and environmental information obtained on a continuing basis at the national level*." (Article 12.7)

Chapter 40 of Agenda 21 is dedicated to the role of information in sustainable development:

> Article 40.1 "*In sustainable development, everyone is a user and provider of information considered in the broad sense. That includes data, information, appropriately packaged experience and knowledge. The need for information arises at all levels, from that of senior decision makers at the national and international levels to the grass-roots and individual levels. The following two programme areas need to be implemented to ensure that decisions are based increasingly on sound information:*
> *1. Bridging the data gap;*
> *2. Improving information availability*."

And under the header "activities":

> "*Relevant international organizations should develop practical recommendations for coordinated, harmonized collection and assessment of data at the national and international levels. National and international data and information centres should set up continuous and accurate data-collection systems and make use of* ***geographic information systems****, expert systems, models and a variety of other techniques for the assessment and*

analysis of data. These steps will be particularly relevant, as large quantities of data from satellite sources will need to be processed in the future. Developed countries and international organizations, as well as the private sector, should cooperate, in particular with developing countries, upon request, to facilitate their acquiring these technologies and this know-how." (Article 40.9, *Emphasis added*)

and

"*Countries, international organizations, ... should exploit various initiatives for electronic links to support information sharing, to provide access to databases and other information sources, to facilitate communication for meeting broader objectives, such as the implementation of Agenda 21, to facilitate intergovernmental negotiations, to monitor conventions and efforts for sustainable development to transmit environmental alerts, and to transfer technical data. These organizations should also facilitate the linkage of different electronic networks and the use of appropriate standards and communication protocols for the transparent interchange of electronic communications. Where necessary, new technology should be developed and its use encouraged to permit participation of those not served at present by existing infrastructure and methods. Mechanisms should also be established to carry out the necessary transfer of information to and from non-electronic systems to ensure the involvement of those not able to participate in this way*." (Article 40.25)

With the new agenda and the availability on computer and telecommunication networks, the number of UNEP related systems proliferated. UNEP established an Internet backbone (UNEPnet) and a set of regional systems - such as BALLERINA for the Baltic sea area, EIS-SSA for the Sub Saharan Africa region and others.

EIS and the World Bank

Unlike the rest of the UN system, the World Bank started to assimilate the need for environmental appraisal of projects only during the 1980s[5]. The World Bank has an internal EIS - a database system that contains three components:

- Project Monitoring and Tracking System
- Country Module with information on protected areas, Environmental Legislation, Environmental and Economic Bibliography etc.
- Data and Information Management.

This internal system is part of the management information systems of the World Bank. The World Bank is also involved in supporting projects for the development of EIS in the developing countries. The Bank has been focusing on the collection of geographically referenced information, and the promotion of EIS in different regions (such as the aforementioned EIS-SSA to which the World Bank seems very keen to claim "ownership").

[5] However, current World Bank documents are re-writing history and mentioning that the position of Environmental Advisor was established in 1970. It took the World Bank another 14 years to issue the first significant policy statement about environmental aspects of the bank work ... (The World Bank, 1993)

EIS as a national project (or the role of National EIS)

Another outcome of Agenda 21 are National Environmental Information Systems. As mentioned above, chapter 12 of Agenda 21 explicitly encourages the creation of National EIS (NEIS). Yet, NEIS *predates* Agenda 21. The "first NEIS" is also the first GIS - the Canada GIS (CGIS). Developed between 1960 and 1969, CGIS became a main repository of various data sets about the environment. The system was managed as the "Canada Land Data System", which was subsequently replaced with "Environmental Information Systems Division". The system is:

> "…*A generalized GIS with a very complete range of functional capabilities to capture, validate, edit, store, manipulate, retrieve and display geographically-based data. Throughout 20 years of operation, an enormous bank of digital data holdings has been captured, now totalling about 10,000 map sheets and encompassing over 200 data coverages (themes*)" (The Inter-Agency Committee on Geomatics, 1989)

Another example of pre-Agenda 21 systems are the Indian ENVIS that stems from INFOTERRA and serves as the National Focal Point for it. ENVIS is somewhat similar to INFOTERRA and serves as a repository and dissemination centre for environmental knowledge in various fields.

Nevertheless, the roll of Agenda 21 cannot be undermined. Agenda 21 reinforced the concept of NEIS and was a major influence on the creation of NEIS - especially in developing countries. One example to the influence of Agenda 21 is a project for the development of a framework for NEIS, initiated in 1996 by the Special Interest Group on Environmental Information of the International Federation for Information and Documentation (FID SIG/EI). The project aim is to develop a framework that could assist developing countries in the implementation of NEIS. The elements of this project are a clear specification of the requirements from NEIS - data, management structure, common problems and pitfalls and so on (FID SIG/EI, 1996).

Sub-National EIS

Sub-National EIS can be found mainly in Western countries where a sub-national governance arrangement exists. In most cases, it is the environmental function within this governance that initiate and manage the EIS. Examples can be found in Portugal (the Alentejo region), Switzerland (with GENIE - EIS for Geneva canton), Spain (Andalucia), the UK (Cornwall). The most prominent example for a set of sub-national EIS is in Germany - with the system of Umweltinformationssystemen (UIS). Every German State (Lander) has a UIS. These systems have been developed since the early 90s, and the environmental authority at the State level runs it. The UIS is based on GIS, and contains information about various aspects of the environment. They are used to analyse and model the state of the environment and to manage the environmental resources of the state. The systems are mainly for the use of the environmental professional and researchers, but some are already developing a WWW interface with the aim to provide access to the general public.

EIS - management tool for regional projects

In many countries some geographical areas have earned a special importance in their environmental amenities. Due to their special virtues, it is common to find a concerted effort to manage and monitor them. In some cases these efforts have led to the creation of dedicated EIS for the region. As the jurisdiction over the region is usually divided between more then one authority, an "environmental oriented" body is assigned to create and run the system (the UNEP regional systems, such as BALLERINA, have the same roots: supra-national bodies who can overcome the juridical barriers). In the United States such systems exist in Cheaspeake Bay, the US-Mexico border region, the Virginia coast and the Great Lakes region. Other examples are Canada (the Crown of the Continent) and Vietnam (Red River - sponsored by Canada).

The Great Lakes Regional EIS (GLREIS) will serve as an example for these systems. GLREIS can be accessed through the WWW (http://epawww.ciesin.org/). As Figure 3 demonstrates, the Great Lakes area falls under the jurisdiction of 5 US states and 2 Canadian provinces. The whole area forms one integrated and interconnected ecosystem. In 1992 the Great Lakes Programme Strategy was launched, with the aim to reduce releases of toxicants to the environment, to protect and restore the habitat, and to protect the ecosystem's living resources. To help the co-ordination between the various bodies and to enable them to share information, the US Environment Protection Agency (EPA) commissioned GLREIS. The system is based on a WWW interface that provides access to data sets - statistics, GIS, documents and WWW links. The system also provides data exploration utilities - such as a tool to create thematic maps based on census data.

Figure 3 - Great Lakes EIS area (source: GRLEIS web site)

Municipal/Metropolitan EIS

The urban environment has its own set of environmental issues and authorities. Just like their colleagues in the regional and national environmental services, the municipal environmental professionals have created a range of information systems to manage and monitor the environment. Among the reviewed EIS, the municipal systems seem to be the ones that try to contact the wider public by providing “environmental atlases” and “interactive information kiosks”. With the growth of the WWW, public access through the Internet to environmental data and information is an inseparable part of these EIS. The Berlin UIS can serve as an example for this type (http://www.sensut.berlin.de/SenSUT/umwelt/uisonline/index_e.html).

The Berlin UIS was developed between 1984 and 1989, as an internal project at the “Berlin Ministry of Urban Development and Environmental Protection”. Later, as the “environmental atlas“ was developed, it was decided to provide the information to the public through various technical means - from CD-ROM to WWW. Figure 4 provides an overview of the main components in the Berlin UIS. As the figure shows, the Berlin UIS have a GIS component which plays a pivotal role. Other components of the systems are technical data banks with statistical information about soil, water, air, climate, biotopes, land use and transportation.

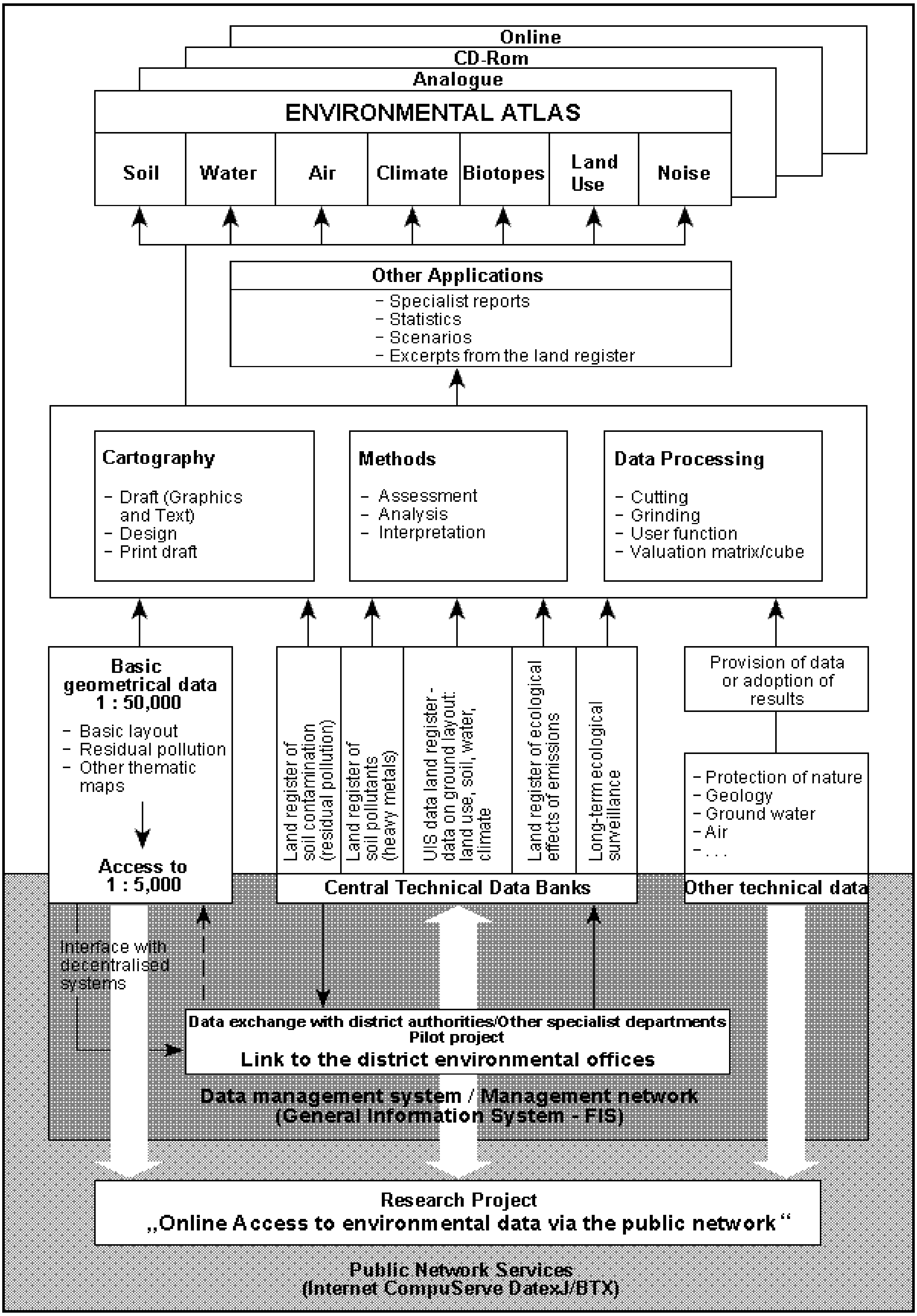

Figure 4 - Berlin UIS: Main Components (Source: Berlin UIS web site)

EIS as an answer to ISO 14000

Yet another outcome of Agenda 21 is the International Standards Organisation (ISO) "ISO 14000" standard and its EIS. ISO 14000 is a rather unusual member in the ISO standards family. Until the creation of the new "management standards", ISO focused on physical and tangible standards (such as size of containers, credit cards or the definition of the A4 paper size). ISO 9000 (which focus on quality management) and ISO 14000 can be considered as the response of ISO to the information age and the need for standards in information work. ISO 14000 is based on the general structure of the ISO 9000 standard, and introduces a range of methods and techniques that can help the organisation in combining the environmental aspects into the general decision making process. The standard is called the "Environmental Management System" (EMS).

> "*ISO 14000 is primarily concerned with "environmental management". In plain language, this means what the organization does to minimize harmful effects on the environment caused by its activities*." (ISO web site)

The standard was developed as ISO's response to the Rio Conference (1992) and provides a framework for the inclusion of the "sustainable development"[6] principles in the management process. ISO 14000 was published in the autumn of 1996.

The framework of ISO 14000 (known as ISO 14001) gives the guidelines to the EMS - the organisation should establish environmental policy, identify the environmental aspects of its operation, set targets and objectives, manage a programme to achieve them and set the system for internal and external reporting. As expected, software vendors have seized the new opportunity, and there are several software packages that support EMS, some of which are called EIS. The ISO 14000 EIS is mainly a document management system. They offer a database to store the information, and some means to arrange, restore and explore it. According to one vendor setting up an EIS is a very easy process:

> "*Now you can set up your own Environmental Information System in 4 easy steps:*
>
> *choose which information modules you want to integrate in your EIS*
> *choose a hardware server platform (NT or Macintosh) or have Ecotopia host your EIS*
> *feed the information into the database, incl. data from remote locations, using a simple web browser*
> *select from a number of report templates or create your custom lay-outs*
> *That's it!*" (Source: Ecotopia Web Site)

If only it was possible to use a simple four step plan to reduce emissions that the Ecotopia system holds in their databases…

EIS and Industry

ISO 14000 is not the only reason for the development of industrial EIS. As a response to industrial accidents - such as Seveso (1977) Bophal (1984) or Chernobyl (1986) - the regulations that control factories and installations that deal with hazardous materials (nuclear power plants, chemical storage facilities and so on) have been tightened. The ever-growing demand for reporting and inspection encouraged the operators to create a dedicated computerised system to follow the movement and use of those materials. The term EIS is used for these systems, probably because their reports are sent to the environmental authorities.

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[6] The quotes appear in ISO documents and its WWW site.

These systems can range from a database system which stores the inventory of chemicals to a highly integrated system (which includes a GIS component) that helps in risk assessment and quick response in case of emergencies. The latter exist at the Pantex Plant - the main nuclear weapons disassembly facility of the US.

Other EIS

There are some EIS that don't fall into any of the above categories. However, they are noteworthy, as they demonstrate the wide application of the term EIS. These include (in their creators' own words):

Statistics Canada EIS:

> "Statistics Canada made available its Environmental Information System to all interested users in June 1991. The system contains a wide variety of socio-economic data series, and provides the facility to combine this data with external environmental data. The system's outputs can be readily structured, tabulated and displayed to suit the specific needs of environmental consultants and researchers.
>
> Data is available from the system in geographic units, as follows: river basins, ecological zones, soil zones, and wetland regions. Forms of system output include:
>
> spreadsheets, ASCII files, micro-computer data bases, tables on paper, export files, PC screen formats, and hard-copy maps on paper or film (The Inter-Agency Committee on Geomatics, 1992)."

GAIA:

> "Overall, GAIA aims to provide innovative tools and methods to promote the conservation and the sustainable use of natural resources, ... At the same time, and through the methodology used to address the first objective, it aims to integrate developing countries ... into the global information society; to combine research skills established in developing countries institutions with their EU counterparts and to facilitate the growth of an information and communications area allowing developing countries to participate in solving their regional problems with regard to development.
>
> The primary vehicle of GAIA is information technology, and in particular, a multi-media information system accessible through the Internet. Designed to support both classroom teaching as well as distance learning, the system combines a workstation based server part with a WWW information system, addressing environmental issues and problems both at a global scale as well as through a number of local and regional case studies."(GAIA web site)

Put simply, GAIA is a set of case studies and data sets, aimed to provide educational material for distance learning about environmental issues.

HOLIT - Israel ecological and environmental information system:

> "The HOLIT project at the Hebrew University of Jerusalem, provides a central location for Israeli environmental information. HOLIT also provides the tools for the public at large to obtain online access to this information and other information which exists elsewhere in the world (via the Internet lines).

The local information in Holit is gathered by the cooperative efforts of the Ministry for the Environment, The Nature Reserves Authority and other environmental agencies in Israel.

The system provides several services that help users retrieve information from local or remote databases, and enter information manually. These include:

- Access to local discussion groups in Hebrew and English that concentrate on environmental issues.
- Access to a local Bulletin board in Hebrew and English that let the user enter short notices or messages.
- Access to HOLIT local database which includes reports written by various environmental agencies in Israel.
- Access to online news reports gathered daily from newspapers and environmental agencies in Israel.
- Access to environmental law database on Israel.
- Access to on-line bulletin board about grants and funding agencies in Israel and elsewhere.
- Access to library information systems which exist in Israel (Aleph library system) and elsewhere.
- Access to any Gopher, WWW, Ftp, or Wais database that exists on the Internet lines.
- Access to UseNet news service.

The Holit system uses the WWW (World Wide Web) browser adapted to support Hebrew dialog. The system also uses software designed to let the user enter his own data easily.

A network of VMS and UNIX based computers, and high speed networking infrastructure support the system software and communications. The system is equipped with a **high speed modem (14,400)** which enables users from remote destinations to log onto the system. The system is also available to users working via internet lines by telneting to WWW.HUJI.AC.IL Username: TEVA (no password needed).”(HOLIT web site, *Emphasis added*)

HOLIT was developed in the early 90s, and was not updated since 1994.

4. When “Environmental Information Systems” is used?

As the previous sections demonstrated, there is a wide array of systems that are described as “environmental information system”. In many cases, the GIS is the special “environmental component”. Therefore, it is not surprising to find that in most cases, the environmental merit of the EISs is - GIS. There are many examples for this observation:

- The title “Environmental Information Systems Department” at the Joint Research Centre of the European Commission, (Ispra, Italy) is used to describe expertise in GIS. Looking at the CV and the publications of the EIS department, it is clear that what they define, as EIS is - GIS. However, Ispra is not alone. The faculty of Land Reclamation and Environmental Engineering in Warsaw Agricultural University (Poland) have an “Environmental Information System Laboratory” (again, GIS is the specialised “environmental software”) as does Houston Advanced Research Center (Texas, USA), and the Department of Geography at the University of Texas at Austin.

- The term is also used in job vacancy advertisements - where it is easy to discover the meaning of EIS. An example from the USA will show the content of EISs:

> “*Job title: Data Analyst/Specialist*
> *Location: Scitutate, MA and Charleston, SC*
> *The Data Analyst/Specialist supports senior project staff in analyzing and presenting environmental data. Works with Database/Programmer Analysts to define effective data formats and structures for* ***environmental information systems****. Data from multiple sources may be integrated to evaluate specific statistical models. Assists with the development of new innovative ways for interpreting and portraying trends in data, including coordinating with* ***GIS Analysts*** *to create effective visualization techniques…*” (*emphasis added*)

5. Definitions for Environmental Information Systems

To complete the exploration of EIS/EISs, it is worth examining how others have described EISs.

The International Symposium on Environmental Software Systems (ISESS) define EISs as:

> “*Environmental Information Systems is the umbrella term for those systems used for:*
>
> *Monitoring*
> *Data storage and access*
> *Disaster description and response*
> *Environmental Impact Reporting*
> *State of the Environment Reporting*
> *Planning*
> *Simulation modelling and decision making*” (ISESS web page)

and in the ISESS 97 web site:

> “*Environmental Information Systems (EIS) are an important factor in environmental research, decision support, management and policy. EIS implementations have a number of requirements which are hard to satisfy, even with the information technology of today. After a period of 10 years of trial and error, of failures and successes, the study of EIS has matured. The subject is still growing, in a mutlidisciplinary work environment which changes quickly, both in the IT and the environmental sector*.”

ESSA technologies, a Canadian company who offer expertise in environmental consultancy and environmental software development define EISs as:

> “*Environmental Information Systems (EIS) are computer systems that use a variety of tools and technologies to facilitate the management and use of environmentally-related data and information*.” (ESSA web site)

The next definition is taken from the synopsis of “Environmental Information Systems” (Gunter, 1998)

> “*Environmental information systems are concerned with the management of soil, water, air and species in the world around us. This textbook describes a framework for systems*

based on four phases of data processing: data capture, aggregation, storage, and analysis. The first part of the text concerns the collection of environmental raw data. The second part explains how this raw data is condensed and enriched to extract semantically meaningful entities. How aggregated data is then stored in a file or database is described in the third part of the text. In the final section the available information is prepared for decision support purposes. "

Since the early 90s, a new field of research has been created for EISs research, coined "environmental informatics". A shorthand definition: "environmental informatics is the field that deal with the development, management and research on Environmental Information Systems" or:

"*Environmental informatics is a field of applied computer science that develops and uses the techniques of information processing for environmental protection, research, and engineering. ... basic methodological issues and typical applications across a wide range of topics, including monitoring, databases and information systems, GIS, modeling software, environmental management systems, knowledge-based systems, and the visualization of complex environmental data. A sampling of topics: networking protocols and tools for the environmental science community, an adaptable architecture for river quality monitoring, and CRAMD--a database for validation of models used in chemical risk assessment*." (Avouris and Page, 1995)

By searching the WWW for the context in which "informatics" is used, it is clear that it is used over a wide range of fields - from "healthcare informatics" and "genome informatics" to "agriculture informatics" and "legal informatics" (with a concentration around medicine). Usually the term is used as an umbrella definition for computer, telecommunication and embedded systems. It seems that there is a relation between the centrality of IT to the specific topic and the use of the term. Using this scale, it is possible to conclude that IT is central to environmental research.

6. Types and definitions of EISs

In reviewing the range of EISs, it is possible to divide them into two broad groups – systems that store information *about* the environment, and those that store information and measures *from* the environment.

The first group includes systems that store and retrieve various types of document and/or information that relate to the environment. INFOTERRA, ISO 14000, industrial EISs and systems like GAIA or HOLIT belong to this group. The information that they store does not relate to measurements that came from the environment. The information does fall under the title environment (e.g. a list of consultants in the field, inventory of potentially hazardous materials or a database of legal references) - hence the "environmental" in the system name.

However, the majority of EISs belong to the second group. It is quite safe to conclude that GIS is the nucleus of these EISs. In some cases, GIS is the only technology that is used. These systems are characterised by data and information that relate directly to the environment. The information is gathered through different means - from satellite imagery to noise level probes. The GIS is usually used as an overarching framework that brings the various data sets into an integrated database. These systems also focus on monitoring, analysing and modelling.

While the first type belong to the general group of "information systems" (like management information systems etc.), the second is not exactly dealing with information in the strict sense.

They are environmental data processing systems. These tools are used to collect environmental data and to analyse it. If we look back at Gunter's definition (1998) it is apparent that data is the main "raw material". The production of information might be the goal of these systems, but they are not explicitly "information systems". It is interesting to note that the same situation exists with GIS. The first GIS were information systems – they relate information to a geographically referenced object. It was prohibitively expensive to store "non-meaningful facts" (i.e. unprocessed data) in them. Today, many GIS are geared toward analysis, and they do operate on data sets.

7. Issues with EISs

Before turning to the discussion, it is worth mentioning the common pitfalls and obstacles in the development of EISs. By now, the reader should be aware of the overwhelming role of GIS within EISs. Many of the obstacles have been discussed in parallel in the GIS literature (and some that are cited here are taken from this branch of the scientific literature).

Lack of money - the cost of EIS

Information Technology is expensive. On top of the costs of hardware and basic software (such as the operating system), software development (custom application development) and maintenance, IT is becoming obsolete faster then any other similar product or service. In many cases, system upgrades are not an option – they are mandatory; therefore considerable maintenance costs are a continuous burden. Agenda 21 gives some idea about these costs: the collection of digital geographic information for environmental applications is estimated by GRID at about 2 billion $US annually. The cost of the systems themselves is 165 millions $US annually (and that is just in supporting the UN system and partially helping developing countries!). To make things worse, most EIS are developed by public organisations that have limited resources.

Information Overload

"*We have an ocean of data but only drops of information*!" (Tveitdal, 1996)

Since 1972, literally billions of dollars have been spent on environmentally related data collection programmes. Over the years, the theme of "bridging the knowledge gap" continuously echoes. Even Agenda 21 mentions this theme. However, recent papers mention the other side of the coin - the problem of getting meaningful information out of the huge[7] amount of environmental information that is being collected every day. NASA predicts that the daily data volume will reach 1 terabyte[8] by 2000, and NASA is not the only producer of environmental data.

Information sharing

Information sharing can be divided into two aspects: organisational and technical.

On the organisational side, there is a problem of accessing information that was collected by private organisations. It is possible to speculate that the oil companies (Shell, BP etc.) hold the most comprehensive geological data sets. However, these data sets are beyond reach for the rest of us. This is just part of the problem. Even between scientific institutions there isn't too much enthusiasm

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[7] Maybe gigantic or monstrous are more appropriate adjectives for the amount of environmental data.

[8] Terabyte is 1,000,000,000,000 bytes, or about 200 times the size of the latest PC hard drive.

in data sharing. A scientist or a group who have spent many years and resources in collecting environmental information usually regard it as their “own” and are reluctant to share it (Porter and Callahan, 1994).

The technical aspect is a combination of issues, including:

- Data Format - every software has its own data structures and file formats. Data sharing is impossible without knowing the full details about the data format. To make things worse, most software vendors tend to change their file formats from time to time.
- Different observation sets - data sets vary in scale, projection, datum and time. Even when the information is accessible, incorporating the data sets into one comprehensive framework is laborious work.
- Lack of documentation - if the data sets are not documented properly, it’s virtually impossible to assess their value and to integrate them into a coherent set. This topic has received a lot of attention in the last 10 years and is now termed as “metadata” (information about information).
- Data volumes - Some data sets tend to be very large (for example satellite images). With very large data sets, there is a physical problem of sharing data sets - it’s very difficult technically to transfer the data set between research centres.

GIS related problems

<u>Lack of base mapping</u>

The cost and availability of digital geographic information plays a crucial part in the feasibility and creation of EISs. This problem poses an obstacle in areas of the world where accurate base mapping is not available - a common situation in developing countries (Tveitdal, 1996) or in the creation of “grass roots” EISs (Pipes and Maguire, 1997).

<u>Lack of expertise</u>

Efficient, productive and useful operation of GIS requires a fairly high level of knowledge and skills - ranging from basic knowledge in geomatics, to computer maintenance and programming. In the case of EIS, there is an added demand for knowledge in the specific domain - such as ecology or pollution control. In many cases these requirements make it fairly difficult to recruit and train adequate staff.

<u>Integrity, reliability and accuracy</u>

EIS models tend to rely on multiple data sources and the problem of error propagation in environmental models has been recognised and received attention by researchers (Heuvelink, 1998). To reduce the errors in the output (which are then used to support a decision) the data sources must be reliable and complete. This, naturally, raises the cost of collecting the information and reinforces the need for metadata, as it serves as the main source for assessing the quality of the data set.

<u>Weak analytical capabilities</u>

In many environmental applications, there is a need to create and integrate sophisticated models. However, the current software products lack functionality and can not “keep up” with the innovations in the field of environmental modelling. As a result, the EIS developer must programme the specific models with the software development tools that come with the GIS. This, of course, increases the total costs of the EIS even further (Joao and Fonseca, 1996).

8. Discussion

Data, Information, Meaning and Knowledge

As mentioned earlier, one of the main “push” factors and justification for the investment in EIS, is the continuos theme of “Bridging the knowledge gap”. It is plausible to argue that decision and policy makers and those in charge of managing the environment, want to **know** more about the environment. The knowledge is needed to achieve sound decisions. If we use Checkland and Holwell (1998) definition that “Information” is “data + meaning” it is possible to evaluate how much “information” is stored in EIS.

Computers are not “intelligent machines” – they are no more then data processors. I believe that it is now clear, that while the early stages information systems did store information, now they store data. This can be related to the changes in “computer generations” and the cost of computing. INFOTERRA was born to the age of mainframe computing – an age where data storage devices were expensive and every operation with computers was considered carefully. As a result, only meaningful (and therefore valuable) data could be stored and used on-line. Meaningful data is equal to information and indeed that is what INFOTERRA stores.

GRID belongs to another age of computing – it was conceived with the age of minicomputers and became operational in the age of powerful workstations. The cost of computing was reduced by that period, and it was possible to plan storage of data sets on a global scale. The words that describe GRID use the term data as the main material of the system. The continuous drop in computing costs, especially in storage, make it more and more likely that many current EISs, store uninterpreted data and information is produced “on the fly” as the end users interact and query the system.

As the storage capacities of computers grow (especially in the last 5 years), more and more systems tend to solve the problem of due selection of data sources with creation of large databases of raw data. Again, Gunter’s definition (1998) alongside ISESS definitions show that EIS became a repository of environmental raw data. This approach raises many new issues and questions. Among them: How to find meaningful and relevant information out of these systems? How to display the analysis results in a meaningful way? (i.e. to convert the data to information). How to manage these repositories? Some of the questions are not unique to EISs. For example, finding meaningful information links EISs with “data mining”. The nature of the datasets and the special attributes of environmental decision making add a special slant to the solutions to those questions.

However, a full discussion of data, information, meaning and knowledge in the content of EISs is beyond the scope of this study and will be investigated in a future paper.

Why GIS?

The role of GIS in (or as) EIS introduces the question “why?” The usual argument is that GIS is the only technology that offers computerised spatial analysis, and considering the inherently spatial nature of environmental problems, we shouldn’t be surprised by the active role of GIS in EIS (Fedra, 1993). However, we shouldn’t take this argument at face value, there are other examples. In transportation modelling GIS doesn’t have the same role and dedicated software tools are widely used. No one will argue that transportation has a very strong spatial dimension and yet, it exhibits far less dependence on GIS technology.

Looking back at Fedra (1993) and others in "Environmental Modeling with GIS" (Goodchild et al., 1993, Goodchild, 1996) it is clear that GIS wasn't the major tool in environmental modelling from the beginning. The transition to GIS centred modelling happened during the 80s, and slowly but surely, GIS became *the* tool for environmental modelling. I believe that we need to resort to a sociological explanation for this attribute. The connection between environmental studies and GIS can be traced back to the 60s with the seminal work of Ian McHarg "Design with nature" (McHarg and American Museum of Natural History, 1969). McHarg advanced the ideas about environmentally sensitive planning while using the overlay technique that later became one of the major analysis techniques in GIS. In the early 70s, a computerised implementation of his methods was developed (GIS World, 1995). Other evidence appears in the proceedings of the first symposium on Geographical Information Systems (titled "environment information system"):

> "*...throughout the symposium, "geographical data" and "environmental data" were used* ***synonymously as were the terms "geographical information system" and "environment information system"***"(Tomlinson, 1970, P. 1, emphasis added)

Several GIS products have clear environmental origins. One of the leading vendors of GIS software is called "Environmental Systems Research Institute", and started in 1969 as a consultancy with a focus in using GIS related technologies for environmental planning. GRASS (Geographic Resources Analysis Support System), another GIS product was originally written by the U.S. Army Construction Engineering Research Laboratories (USA-CERL) branch of the US Army Corp of Engineers as a tool for land management and environmental planning by the military.

Do we really need EISs?

While exploring the information about EISs, it is almost unavoidable to reach the conclusion that (at least in some cases) EISs exhibit "computer fetishism". Researchers feel that computers are powerful instruments, they are "captured" by their capabilities, and they want to use this awesome power to their research. Sometimes, the reason for the use of computers has nothing to do with the problem solving issue that the system was built for. It is possible to follow evidences that reinforce this "accusation" from the beginning of GIS. This is how Ian McHarg describes the first printouts from computers (from a line printer using Xs and Os) :

> "*McHarg: {it was} absolutely terrible. I mean there wasn't a left-handed, barbarous, mentally retarded technician who couldn't do better than the best computer. Terrifying. It has come a long way.*
> *GIS World: the analytical process was rather crude, even with early computers, wasn't it?*
> *McHarg: Primitive beyond description...*"(GIS World, 1995)

The question is then: "Why use computers in the first place?" the answer, I would guess is "because its there".

Another example comes from UNEP. After two years of operation INFOTERRA has a database with 6500 entries and processed 2000 annually. The cost? About 1,000,000 $US (9.6 per cent of UNEP budget). It can be argued that a card base system, which would be printed on a quarterly basis and distributed all over the world, would be as effective as the early INFOTERRA. To make things worse, the UN Annual Review reports that a hard copy was produced and distributed to the national focal points. In comparison, GRID costs during the first 4 years of full operation (1988-1991) were 14,369,862 $US (UNEP, 1994) and it is clear that the costs of maintaining EIS have not decreased but rather increased.

In the discussion about GRID (cited above), data transfer issues are raised and a satellite connection is offered as a possible solution. Even today, we are still sending and receiving environmental information on mass-storage media. It is hard to imagine that the price of satellite communication links was lower in 1985.

To show that this trend is set to continue, the reader is invited to explore recent papers about environmental modelling and GIS. A quick look at Wiesel *et al.* (1996) will reveal a wide use of novel information technology. The paper is talk about visualisation component for EIS, and dedicates 2 (rather short) paragraphs to the content and use of the system while focusing on the technical aspects of connecting different software elements and the delivering the information on the WWW. Reading the paper from a distance of 3 years, one feel sorry that they did not include information about the actual use. Most of the software components that they mentioned are either obsolete (like the early Mosaic web browser) or changed to such extent that the paper is unhelpful to anyone who want to establish similar system.

Shouldn't we appreciate the pioneering efforts of all these people in pushing environmental informatics while using the latest ideas from the field of information technology itself? The answer is probably no. High quality output devices (such as plotters and colour printers) were developed for the AEC (Architecture, Engineering and Construction) market - there were not enough GIS users around. There is enough evidence of projects which lost the balance between content and medium. The development of innovative models or techniques for the environmental sciences is sometimes replaced by innovative use of immature techniques from the IT field. It is as if the E in EIS gone missing or became secondary to the IT.

So, we don't need EISs?

It is quite safe to argue that we do need EISs. All through science it is possible to find stories of dead ends, wasted resources on unproductive directions and the like. EISs help us in finding, analysing, monitoring and learning about environmental problems[9]. We wouldn't know about the hole in the Ozone layer, acid rain or the diminishing area of the rain forest without EISs. We need them, they are powerful and useful - but we must learn how to focus on the important aspects without deviating our efforts. There seem to be a constant need to balance between the technical aspects and the actual purposes for creating EIS.

Scale, Jurisdiction and the environment

The different scales may represent one of the well-known problems with environmental problem solving, as environmental problems tend to ignore the man made juridical boundaries. The different scales of the systems might represent the creation of regional governance without changing the official structure (anon., 1996). Sometimes, the EIS is seen as the solution for the jurisdiction problem:

> "*In parallel with its cooperation with external bodies, participation of third countries in the work of the EEA is clearly important since* ***environmental problems and challenges are not confined by national frontiers****. This has been envisaged from the outset and provisions for their involvement is covered by Article 19 of the Council Regulation setting up the agency. Considerable interest has already been shown by member states of the European Free Trade Association (EFTA) as well as by countries of eastern and central*

[9] I did not write "solving" deliberately - I couldn't find any example that the EIS have "solved" any environmental problems...

> *Europe to participate fully in the EEA's programme.* ***The conclusions of European environment ministers' conferences at Dublin (June 1990), Dobris, (Czechoslovakia) in June 1991 and Lucerne (April 1993), emphasised the importance of integrating environmental information systems throughout Europe***." (From the European Environmental Agency site. *Emphasis added*)

Bearing in mind the obstacles of data sharing within a national framework, the portrayal of EIS as transboundary panacea is false. An illustration for the lack of data sharing between different jurisdictions exists in the GLREIS map. The map on the web side does not depict the boundary between the aforementioned 2 Canadian provinces. It should not come as a surprise that this map was produced in the USA (and it provokes the question about the extent of transboundary collaboration in GLREIS). For your convenience Figure 5 shows the Canadian provinces borders alongside the map from the GLREIS.

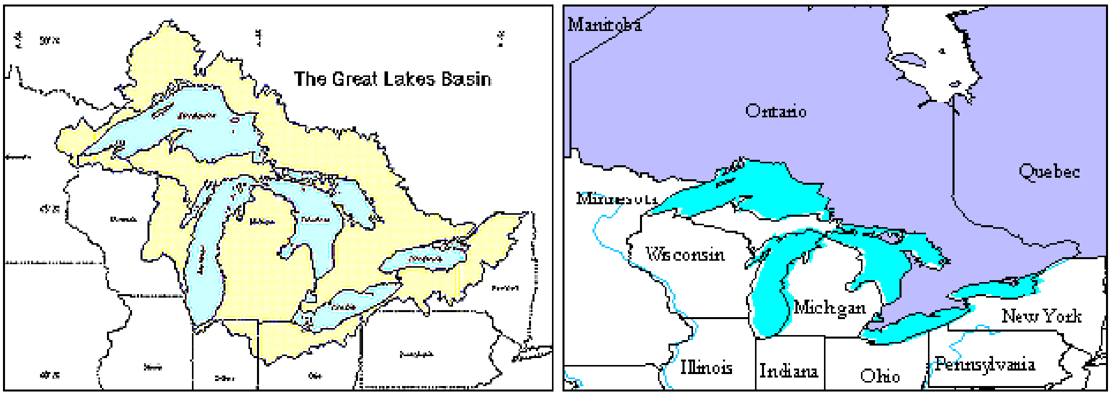

Figure 5 - Great lakes area maps

The problem with EISs

Can we explain why it seems so difficult to create and manage effective EISs?

There are several possible explanations. Like many other aspects of environmental management, EISs are an inherently multidisciplinary project. Again, it's possible to trace this aspect from the early days of GIS, turning again to McHarg:

> "*GIS world: .. you have to work with quite variety of experts in different fields, right?*
> *McHarg: ... The instruction I offered .. was based upon having ... geologists, meteorologists, certainly hydrologists, always a soil scientist, ecologists, limnologists, plus ethnographers, anthropologists and of course computer scientists....*"*(*GIS World, 1995)

In the general case of EIS we should add statisticians (preferably with knowledge in spatial statistics) and cartographers.

The technical and organisational problem mentioned previously just adds to the difficulties. The need for a long-term commitment is also problematic in an ever-changing technological domain. HOLIT serves as a good example for effort that was based on a certain version of technology (the early WWW) and dies out. We can pinpoint the reasons for this - either lack of commitment from the authorities to "pump" information and to maintain the site, or the technological change. Both reasons demonstrate the obstacle with EISs.

We should look at the most vital EISs, while trying to generalise what contributes to their robustness. GRID is a good example. In spite of the early bumpy road, when GRID became operational (the early 90s) the technology that GRID is based upon matured. I would also point to the institutional context within which GRID operates - an international organisation, dedicated to collection and dissemination of environmental information. It seems that the national and regional EISs, where a proper organisation exists - GRLEIS which run by the EPA, or SAST (for the Mississippi region) which is run by the USGS have similar features.

Public access to environmental Information

In recent years, there has been a growing demand to "open up" the environmental information resources and provide access to the general public. Early last year (1998), the member countries of the Economic Commission for Europe have signed the "Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters" (UN/ECE, 1998). The convention declares that:

> "*..improved access to information and public participation in decision-making enhance the quality and the implementation of decisions, contribute to public awareness of environmental issues, give the public opportunity to express its concerns and enable the public authorities to take due account of such concerns* ...."

And in article 5:

> "*Each party shall ensure that environmental information progressively becomes available in electronic databases which are easily accessible to the public through public telecommunications networks*..."

The convention, of course, uses general terminology and does not explain how to provide the information in a "digestible form". As mentioned, EISs rely on multiple expertise from a diverse range of fields. There isn't a single scientist who has knowledge in all the fields that EISs touch.

This situation leaves the EISs developers and maintainers puzzled. They are aware of the level of complexity in the information and data sets that they are using, they probably agree with the concept of public openness and public participation. To show how confused the environmental agencies are in this task, we can look at the following press release by the European Environmental Agency:

> "*The European Environmental Agency (EEA) and it's American counterpart, the Information Office of the United States Environmental Protection Agency (EPA) are progressive in their co-operative program...The main goal is to develop a common approach in the field of environmental information.*
>
> *The EEA is developing a broad information system and make the content available to policy makers as well as to the public. The EPA is reinventing environmental information to create a simple environmental information system in order to facilitate and ease public access.*

This exchange of experiences is providing possibilities for an improved level of information by exposing it and also to improve implementation of legislation by making it public." (EEA Press Release, 5/9/1997, *emphasis added*)

This point must be emphasised. We do not have the knowledge and the tools to make the environmental information public. Putting the information into the public domain is simply not enough. We can expect to see more and more EISs geared toward this mission in the coming years.

9. Conclusion

Like many other aspects of our "information age", EISs have grown and evolved in the last 30 years. This trajectory is closely related to the changing trends in the field of computing. In a book from 1974 about EISs, the authors questions the need to computerise EIS and discusses other methods (Deininger and World Health Organization. Regional Office for Europe., 1974). By 1998, the computer is seen as the only possible container for EIS (Gunter, 1998). This reliance on rapidly changing technology is causing major tension in the creation and maintenance of EIS – the balancing act between the latest technology and the declared aims of the EIS.

Though the term EIS is still widely in use to refer to these systems, they have moved away from being *pure* "information systems". Most of them handle and manipulate data sets. As computing power increases, EIS are used for complex analysis operations and evaluation of possible scenarios. This transforms EIS into exploration tools where the users evaluate and analyse underlying data sets while constricting his (her) knowledge and meaning on the problem at hand. At the same time, there are expectations from EISs to continue with their traditional role. As shown, this tension results in muddled use of data, information and knowledge in the definitions of EIS. As Checkland and Holwell (1998) have shown, the end result of this mix-up might be the construction of inadequate systems.

EISs on their various aspects, types and behaviour are here to stay. Their history shows a continuous trend of creating specialised systems that are meant to be used by experts. They are now facing the difficult mission of sharing the data, information and knowledge that they store with the public. There isn't a simple and easy technical solution for this problem, as this problem is mainly non-technical. A possible solution is to further explore the development of public centred, bottom-up built EIS that will help the public in using the environmental information.

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Annex 1 - World Wide Web sites

The following list is not an exhaustive account of WWW sites that relate to EIS but rather a list of the sites that have been referred in the course of the paper, and several other sites that (the beginning of 1999) are important for understanding Environmental Information Systems. The sites have been verified in the last months of 1998.

World Wide Web Site	**URL**
USA Environmental Protection Agency	http://www.epa.gov/
USA Environmental Protection Agency - the Center for Environmental Information and Statistics (CEIS)	http://www.ceis.epa.gov/ceis_home.html
UNEP INFOTERRA	http://www.cedar.univie.ac.at/unep/infoterra/
UNEP GRID (Arendal)	http://www.grida.no/
GLREIS (Great Lakes Regional EIS)	http://epaserver.ciesin.org/
UNEP Earthwatch	http://www.unep.ch/earthw.html
Berlin UIS	http://www.sensut.berlin.de/sensut/umwelt/uisonline/index_e.html
Central European Environmental Data Request Facility	http://pan.cedar.univie.ac.at/
ISESS home page	http://www.htw.uni-sb.de/eig/isess/isess.html

Annex 2 - Survey methodology

The current survey was based on the use of the term "environmental information system". The main part of the survey was based on the World Wide Web (WWW) as a "knowledge base", and was verified with computerised literature catalogues (such as GEOBASE),.

First, using a dedicated tool for WWW information search (WebFerret from FerretSoft, LLC) all the Uniform Resource Locators (URLs) that relate to the phrase "environmental information system" have been collected. As this tool enables issuing multi-search engines search queries, the results present the combined information from major search engines. This search retrieved about 4500 URLs. The resulting list of URLs was then transferred to a dedicated programme, which fetched each web page and checked for the existence of the string "environmental information system". The filtered list contains 600 URLs. Each page that contained the phrase was marked and was checked manually. By the end of the survey, 56 examples of EISs were found.

A similar method was used to extract the occurrence of the phrases "environment/al information" and "informatics" and their context (3 words before and after). Table B1 summarises the main statistics of the three searches to give the reader an idea about the accuracy of WWW search engines (at least for in-depth searches).

Table B1 - summary of search results

	Environmental Information System	Environment. Information	informatics
Relevant	600 (13.5 %)	552 (4.69 %)	1585 (18.55 %)
Not relevant	3278 (73.76 %)	9941 (84.45 %)	5985 (70.50%)
Server Error	566 (12.74 %)	1278 (10.86 %)	974 (11.40 %)

Relevant pages contain the required phrase, while non-relevant do not. Server error means that the page could not be fetched from the server.