Preliminary Feasibility Study on the Possibility of Implementing GIS within BRIM

This document describes the type (nature, content and structure) of a possible Geographic Information System (GIS) facility for the Biosphere Reserve Integrated Monitoring (BRIM) Programme. In particular, it identifies and analyzes GIS that could be used as a model for the integration (using different information/data layers) of BRIM information and data with socio-economic information/data from other sources, such as CIESIN's (Centre for International Earth Science Information Network) databases. This is a short report on the feasibility of such a facility.

I. GEOGRAPHIC INFORMATION SYSTEMS

General

GIS is a computer system capable of assembling, storing, manipulating, analyzing and displaying geographically referenced information i.e. data identified according to their locations annotated by x, y and z co-ordinates of longitude, latitude and elevation. Any data that can be located spatially x, y (estimated at about 85%) can be fed into a GIS system.

A GIS creates maps from data pulled from databases. Starting with a base map at a chosen scale, different "layers" of spatially defined data (e.g. abiotic, biodiversity data, socio-economic variables) can be overlapped and displayed graphically. Spatial relationships can be visualized and information is linked or integrated combining mapped variables to build and analyze new variables. Data presented in the form of a map as opposed to data tables catalyzes pattern recognition and helps to form connections and to draw conclusions about interacting variables.

GIS graphic display techniques essentially produce maps. With a function known as visualization, a GIS can produce images, drawings, animation and other cartographic products. Changes such as differences in land use can be analyzed over time. It is also possible to create 3-D images and to integrate real time data into the system.

A modern GIS has many analytical tools but essentially two are used: proximity and spatial analysis. The former relies on an algorithm called "buffering" to determine distance between objects. A buffer is a zone of a specified distance around features in a coverage. Buffers can be set at a constant or variable distance based on feature attributes. The resulting buffer zones form polygonal coverage. The spatial analysis can highlight previously undetected spatial relations by integrating data from different layers e.g. soil, vegetation, ownership, etc.

Data capture is the time consuming component of GIS work. The main limiting factor for GIS is the availability of sound data and the compatibility of data format. Since two data sources may not be entirely compatible, a GIS must be able to convert data from one structure to another.

The main data structures of a GIS are raster and vector files. Raster data files consist of rows of uniform cells coded according to data values and are suitable for such variables as land cover classification. Raster files require a lot of computer memory. Vector files are represented as a series of point co-ordinates or shapes bounded by lines and are suitable for such variables as property boundaries. Vector files use less computer memory.

Geographic data and associated tabular data can be constituted internally or acquired from data producers. Before using paper data in a GIS it must be converted into digital form. Modern GIS can use scanners to carry out this task for large projects. Smaller projects can be carried out using digital tables. At the moment a lot of geographic data is already digitized and can be integrated directly into a GIS. A GIS has the necessary tools to harmonize data (scale, level of detail, graphic symbols). Most GIS databases are relational databases whereby data is organized in the form of tables with rows and columns that may be related to each other through columns containing similar data.

A number of general data sources are available:
- basic geographic data as on a typical paper map in raster format
- demography, health indicators, economic data, transports in geographic or tabular form
- environmental data - climate, satellite images, topography
- world data - country borders, populations, incomes, GNP, etc.

In France some of the data suppliers are IGN, Teleatlas, INSEE, Dun & Bradstreet, etc.

A GIS is composed of hardware, software, data, users and methods. Typically, a GIS comprises a client-server architecture. Ideally, the server is dedicated to geographical data and computers are installed with GIS software. The most widely used GIS software in the environmental field is the ESRI (Environmental Systems Research Institute) range of ArcInfo with applications for Internet publishing (ArcIMS) and ArcPad for fieldwork. A GIS can be used on a wide variety of computers from servers to desktop computers connected to a network or stand-alone. GIS software comprises tools and functions for storing, analyzing, and displaying information.

The principal components and functions of GIS software are:
- entry and manipulation of geographical information
- data management system
- tools for requesting, analyzing and visualizing geographic information
- a graphic interface.

ArcInfo is a universal GIS package, which is composed of the following parts:
ArcMap - creates, updates, displays, edits, and analyzes cartographic data
ArcCatalogue - navigates in spatial data, edits metadata
ArcToolbox - with thousands of functions but principally data conversion, spatial analysis and map transformation.

ArcView is desktop GIS software, which allows geographic analysis and cartographic representation in an Office environment.

ArcPad is a portable GIS which permits real time field observations with the help of GPS. It allows geometric measurements, storage and analysis of thematic information and is compatible with all other ESRI products.

GIS on the Internet

ArcIMS is ESRI's software for Internet publication of GIS. It allows the publication of maps and associated information with functions such as zooming, choice of information layers and tabular information requests. It is a system, which is capable of adapting to Internet traffic needs. No software development is necessary to produce a site but there are advanced functions, which allow development of sites with specific interfaces, and sophisticated functions. These supplementary functions require programming capability. As a function of needs, the site can be consulted with a simple browser or via a Java client delivered with ArcIMS. Using a Java client ArcIMS can combine data coming from different sources and with different formats localized in different places including images. It can combine Internet data with local data. ArcIMS is an open multi-platform and multi-source environment. Its interactive functions allow the user to suggest modifications via the browser. Users can modify an element of the database and submit the modifications to the administrator of the site that can decide to integrate it or not. All users can submit a remark in text form on a card and make the information available to all other users of the database.

Costs

Software
ArcInfo costs approximately $20,000
ArcView costs approximately $15,000
ArcIMS costs $12,000

Training needs
ArcInfo -1 week
ArcIMS - 3 days

Links

General sites on GIS
http://www.GIS.com
http://www.usgs.gov/research/gis/title.html
http://www.gis.about.com
http://geo.evenement.com
http://mapserver.gis.umn.edu/
http://www.opengis.org.

Specific site examples of GIS software in use on the web
http://www.geographynetwork.com
http://sacoast.uwc.ac.za
http://www.nationalgeographic.com
http://www.unep.net
http://trinity.wcmc.org.uk/aewa
http://unep-wcmc.org/reception/ims.htm
http://www.naturdetektive.de/2001/dyn/1407.htm

II. THE BRIM PROGRAMME - BIOSPHERE RESERVE INTEGRATED MONITORING

The Biosphere Reserve Integrated Monitoring (BRIM) Programme is being implemented as part of UNESCO's Man and the Biosphere (MAB) Programme.

Among the aims of BRIM are the following:

- to promote the necessity of standardized biological inventory measures as a management and decision making tool
- to survey key scientific research and monitoring potential of biosphere reserves
- to provide means for systematic exchange of scientific information
- to encourage the integration of multiple databases for inter-biosphere reserve co-operation in monitoring global and intra-regional changes in biodiversity
- to provide scientific, administrative and policy making communities with access to all kinds of information available in biosphere reserves
- to specifically take into account socio-economic factors in monitoring and management decisions

The Role of GIS in Integrated Monitoring

There are many projects which are concerned with detecting long-term changes, in particular aspects of the environment (e.g. water quality, acid rain, or ozone), particular groups of organisms (e.g. butterflies, birds, or plants), or particular processes (e.g. crop production or tree health). However, these represent only parts of the environment and ecosystems.

Integrated monitoring is the measurement of related variables in different biotic and abiotic compartments and co-ordinated in space and time to provide a comprehensive picture of the system under study. As argued by Munn (1988), "When based on an interconnected picture of the environment and the biosphere (through the notion of bio-geochemical cycling of trace substances, for example), the monitoring system is much more likely to be responsive to detecting surprises than if it consisted of several disconnected components (an air monitoring network, a water quality network, etc.)" (The UK ECN Internet site).

Considering the definition of integrated monitoring above and the definition of GIS as a computer system capable of integrating spatially defined variables over time, it is evident that GIS is a powerful tool for the implementation of integrated monitoring. Data presented in the form of a map as opposed to data tables catalyzes pattern recognition and helps to form connections and to draw conclusions about interacting variables. Changes such as land use can be analyzed over time through a function known as visualization. Showing where different monitoring activities are taking place could for example indicate where there are gaps in monitoring of different variables over time and space.

GIS in biosphere reserves

In general, relatively few biosphere reserves use a GIS for integrated monitoring and management decisions. However, 54 of the 132 biosphere reserves in the EuroMAB region report using GIS for data acquisition and management (Access 1996). The biosphere reserves that have links with universities and research institutes have in general benefited more from GIS technologies.

Specific Examples of GIS in biosphere reserves

Vosges du Nord-Pfälzerwald Biosphere Reserve, France/Germany. The "Observatoire du Parc" (SIGIS) is a geographic service funded by the EU 'Life' programme using ESRI's ArcInfo GIS system. The French part of the biosphere reserve has a complete and advanced GIS system, which has been used very effectively in integrated monitoring and management decisions. The objectives of the service are:

- to obtain detailed and equally distributed data for all the zones of the biosphere reserve
- to explore diverse subject areas and variables
- to monitor and evaluate multi-institutional projects.

GIS projects are defined in terms of their technical and communication use. Data acquisition and integration into the GIS system is partial and progressive and is project and problem driven. The database consists of basic geographic variables (maps, aerial and satellite photos, boundaries), land use variables (agriculture, forests etc.), natural resource data (biodiversity, protected areas, wetlands etc.), socio-economic data (population, traffic flow, etc.), and a list of the cultural heritage and tourist activities in the biosphere reserve. There is a partnership project called 'Cigogne' that centralizes data in the region for the service of different users.

A small selection of projects where GIS has been used in integrated monitoring and management decisions in the French part of the biosphere reserve follows:

- Land use changes and the maintenance of landscape and ecosystem diversity

Using aerial and satellite information with GIS, land use changes from 1962 to 1995 revealed a marked increase in the covering-over of valley floors due to forest encroachment. The number of cattle, and thus pastures, in the area had declined due to the decline in the number of farmers. A project involving the introduction of the rustic Highland cattle breed for extensive rearing used GIS to determine which valleys were suitable for this type of land use and thus ecosystem diversity was maintained.

- The conservation of traditional orchards

Using GIS to study land use changes and urbanization over time, the threat to traditional orchards and to the biodiversity of traditional varieties of fruit trees was identified. A complete survey of local orchards was carried out using GIS and fieldwork. Land use plans and urbanization trends were combined to produce a map of the risks and threats to orchards which served as a basis for negotiation and the elaboration of management plans with local farmers.

- Reconciling biodiversity conservation and tourism

Using GIS, areas with protected species and paths frequently used by tourists were mapped. The forest authorities can estimate numbers of walkers. Zones of possible conflict of interest were highlighted and certain paths were closed to the public.

Amboseli Biosphere Reserve, Kenya. GIS is used to monitor elephant population dynamics and the occurrence of bush fires in collaboration with the Universities of Oxford and Cambridge. By applying several Remote Sensing techniques and GIS techniques an interactive model (ISM-Interactive Spatial Modeling) has been developed by ITC (International Institute for Aerospace Survey and Earth Sciences) in the Netherlands, to be used by managers, planners and others involved in the management of ecosystems. The model not only considers the 'protected' area itself, but also takes the surrounding areas with human activities into consideration. The result obtained is a spatial presentation (with qualitative and quantitative data) of the expected outcome of a management scenario, which enables managers to evaluate their management options before putting them into practice.

Benin/Burkina Faso/Niger: Parc "W". This Park is intended to become part of a transboundary biosphere reserve (the Région "W" du Niger Biosphere Reserve exists already) in the future. It will benefit from a $4.2 million UNEP-GEF grant, which will finance a GIS system in collaboration with the Centre de Télédétection (Cenetel) in Cotonou, Benin.

In the South-East Asian (SeaBRnet) region, GIS is seen as one of several tools that participating sites should use for research and monitoring purposes and in the East Asian region (EABRN), one of the activities is related to field projects including GIS applications.

Development of a GIS system for the MAB Directory

On the global scale of the World Network of Biosphere Reserves and the MAB Directory, essentially descriptive or metadata are available on the monitoring activities of the individual biosphere reserves. This Access (Microsoft) database of approximately 4 MB is in mdb format. These data could be extracted by ESRI's ArcView software and displayed on an Internet site mapping facility using ArcIMS software. A relatively comprehensive list of abiotic, biotic, socio-economic and integrated monitoring variables exists. These variables are geographically referenced at the scale of the location of the biosphere reserves. Using a GIS system, different layers of monitoring variables could be integrated into a GIS system, which would be accessible through a world map indicating the location of all biosphere reserves.

At first, some key monitoring variables could be selected e.g. climate (abiotic monitoring), presence of alien species (biodiversity monitoring), demography (socio-economic monitoring), GIS (integrated monitoring). By using the zoom facility on a GIS graphic interface the user could draw a rectangle around the area of interest. By choosing the monitoring variables required by means of a drop-down menu, the GIS system could create a map displaying where a certain type of monitoring is being carried out. By using the information function of the GIS by clicking on the biosphere reserve, an information window could give further details on the monitoring variables and eventually the research results and general information on the biosphere reserve. However, the issue of copyright to these data needs to be addressed and clear rules of access defined. Links could give direct access to maps where individual biosphere reserves have GIS systems.

Using the Java client function, the software ArcIMS for web publishing can combine data coming from different sources and with different formats localized in different places as well as local data, images and vector files all with a simple browser.

To date, it seems that no world monitoring programme has a GIS facility for displaying where, when and what type of monitoring is taking place on a global scale. Hence, a BRIM GIS facility could possibly act as a platform for other monitoring programmes to publish their activities. A centralized system could exist which would allow gaps in monitoring to become evident. The WCMC publishes GIS maps on its Internet site for certain monitoring activities. The soon to be published internet mapping service of the Ramsar site (hosted by CIESIN) maps variables such as land use and population density with the localization of Ramsar sites.

Other variables for which data are available at a global level could be integrated into a BRIM GIS system (for example biogeographic regions, land cover, etc.). Socio-economic data available at a global level that could be integrated into a BRIM GIS system are for example:

- human development index
- demographic statistics
- economic wealth
- indicators of sustainable development
- life expectancy and health
- gender equality
- food production
- economic incentives for biodiversity conservation
- level of external debt etc.

Data sources

Apart from the BRIM database itself the following data sources could be used in the development of a GIS for BRIM, in particular for the integration of socio-economic monitoring variables.

Columbia University
Centre for International Earth Sciences Network (CIESIN) and Socio-economic Data and Applications Centre (SEDAC)

Cost free sources:
- world population statistics
- indicators of environmentally sustainable development (World Bank)
- social indicators of development (World Bank dataset containing 125 socio-economic variables for more than 170 economies for the1965-1993 period)
- world resources (World Resources Institute).

UNDP
- human development index

World Bank
- raw data for the World Bank's 'Monitoring Environmental Progress' with variables such as manufacturing activity, external debt, etc.

UNESCO
- world education indicators
- scientific maps

Food and Agricultural Organization of the United Nations
- agriculture
- nutrition
- food
- forestry
- food quality control

Organization for Economic Cooperation and Development (OECD)
- economic incentives for biodiversity conservation, metadata on individual country initiatives
- development indicators for most countries (economic wellbeing, social development, environmental sustainability, and regeneration)
- general indicators (in collaboration with the World Bank)
- transport, health, science, technology, industry and education for OECD countries

Access 1996
EuroMAB's directory of permanent plots, which monitor flora, fauna, climate, hydrology, soil, geology, and the effects of anthropogenic changes in 132 biosphere reserves in 27 countries. Information on permanent plots in biosphere reserves is provided in the form of a metadata base. The Access database is not available as yet on the Internet but in hard copy form (Access 1996). 54 of the 132 biosphere reserves confirm using GIS for data acquisition and management. A BRIM GIS could show where these biosphere reserves are located. Some of the GIS information (monitoring, management scenarios) emanating from these biosphere reserves could be published on the BRIM web site as examples for reserves which do not benefit from GIS systems.

MAB Flora MAB Flora
The Information Center for the Environment (ICE) at the University of California, Davis, in co-operation with US-MAB and the MAB Programme has produced standardized databases containing species inventories of plants and animals reported from biosphere reserves. As the MABFlora/MABFauna databases have grown, both in terms of the numbers of records and in the frequency with which these databases are accessed, personnel from a large number of protected areas that are not part of the World Network of Biosphere Reserves have asked to

contribute data to the effort. This database is comprised of an inventory of species present or absent in biosphere reserves and in other protected areas. With the development of the database it will be possible to define some qualifying factors, for example whether a species is endemic or alien and would thus be likely to effect the management decisions. Data from this data source could be used to map presence or absence in biosphere reserves of some of these species.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The introduction of GIS into the BRIM Programme needs to be addressed in the general context of the MAB Programme. It needs to be determined whether the MAB Programme should provide an integrated information service combining databases, GIS and web technology. Such a service could enhance the role of MAB as an open ‘learning environment’ for Member States, individual specialists, governmental and non-governmental institutions as well as for the MAB Secretariat.

An Internet GIS would also act as a communication and information tool. The production of maps in an interactive manner is a much more direct and powerful communication tool than displays of lists and tables.

The integration of a GIS Internet mapping service into the BRIM Programme would contribute to the achievement of its two main objectives:

- to provide access and encourage exchange of scientific and administrative information between biosphere reserves especially through electronic media
- to promote scientific research and integrated monitoring which incorporates socio-economic variables in biosphere reserves.

The integration of a GIS facility into the MAB Programme in general and into the BRIM Programme in particular would make data management more productive and be a driving force in the pursuit of more precise information. A GIS can respond to commands to identify gaps in the system of protected areas and sustainable land use from a variety of perspectives. It would also make the integration of socio-economic data easier.

By having a visible and interactive international initiative for monitoring activities in the form of a GIS Internet mapping service, the BRIM Programme would use its position as an international programme to create linkages and develop synergies.

It is certain that precise data in many areas are lacking. The use of GIS systems for integrated monitoring and as a decision making tool in natural resource management exists to varying degrees in the World Network of Biosphere Reserves. There is wide scope for development. The implementation of a GIS will force all participants in the programme to make progress in the acquisition of more reliable data on all types of monitoring.

On the scale of the individual biosphere reserves, GIS greatly simplifies the preparation of integrated biodiversity conservation strategies and demonstrates how various management or development options are likely to effect long term ecosystem sustainability. It can make it easier to determine which species and communities are currently protected and to identify alternative conservation strategies, which support sustainable development.

The following recommendations can be made:

- A first step could be the integration of an Internet GIS mapping tool to the BRIM website. At first, selected monitoring variables could be mapped. The provision by BRIM of an internet based mapping tool for monitoring activities in general and integrated monitoring activities in particular on a world scale would position the BRIM project as a truly global platform for monitoring programmes. Data about monitoring programmes in the network of biosphere reserves and other monitoring programmes could be integrated to give a comprehensive picture of environmental monitoring in the world.

- In the short-term individual biosphere reserves with GIS systems could be linked to the BRIM GIS system by a hyperlink but in the long run, with the integration of databases, a global information system could be developed. It could also link databases from other monitoring programmes.

- GIS systems in individual biosphere reserves should continue to be studied and information on GIS systems exchanged between biosphere reserves. An interim step could be the publishing on the BRIM web site of GIS maps from specific biosphere reserves with accompanying explanations constituting a learning tool on the use of GIS in integrated monitoring. The sharing of technology could also be encouraged.