EVOLUTION OF ENVIRONMENTAL INFORMATION SYSTEMS IN AFRICA

C. Paradzayi *, H. Rüther

Department of Geomatics, University of Cape Town, Private Bag, Rondebosch 7701, South Africa
prdcha001@mail.uct.ac.za, heinz.ruther@eng.uct.ac.za

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ABSTRACT:

Man's largely uncontrolled use and exploitation of the natural environment and the ever increasing needs of an – arguably - overpopulated world have lead to a situation in which only scientific assessment, planning and management can provide some measure of sustainability of the use of natural resources. Especially in the developing world with its limited access to technology, funds and expertise, excessive exploitation of natural resources has caused severe environmental degradation and there are communities which appear to be entirely dependent on an exploitative use of natural resources for their survival. Decision-makers and planners require reliable and current environmental information, to arrive at effective, realistic and sustainable management plans. Environmental Information Systems (EIS) provide a technology by which such environmental information can be combined, structured, managed and made available to planners and decision makers. This technology is an expansion of Geographic Information Systems (GIS). The paper will examine EIS in the context of environmental management and outline the role GIS plays in this discipline. The paper will report on the evolution of EIS in Africa in the context of Nolan's four-stage model. Problems such as technical constraints, institutional barriers and limited human resources that have characterised the implementation of EIS will be noted. The paper will outline some benefits of introducing EIS and conclude by looking at the future of EIS as well as suggesting some possible ways of overcoming some of the inhibiting factors.

1. INTRODUCTION

1.1 Environmental Information Systems (EIS) in the Context of Environmental Management

Mankind must attempt to find the delicate balance between its developmental needs on the one hand and the complete preservation of the status quo, or preferably the reversal of environmental damage, on the other. While it is highly unlikely, if not entirely unrealistic to assume, that environmental management models will provide for full sustainability, every effort must be made to minimise negative human impact on the environment. It is well known that increased population and socio-economic developments, such as urbanisation, apply tremendous pressure on agriculture, biodiversity, climate, vegetation, wildlife, and water resources, among others. Man's exploitation of these resources inevitably leads to environmental degradation in the form of soil erosion, deforestation, increased urbanisation and irregular settlements (EIS Uganda, 2002). Sound environmental management strategies, utilising appropriate spatially referenced land information as input, have to be in place to achieve sustainable development. According to WLIP (1991), environmental information includes information relating to topography, soil, geology, minerals, vegetation, land cover, wildlife, land use, land use controls and restrictions, jurisdictional boundaries, historic and prehistoric sites, economic projections, etc. These data have to be spatially referenced through land survey records, geodetic control networks, aerial photographs and remote sensing imagery in a variety of spectral bands and resolutions. Environmental practitioners can use EIS as a management technology to determine, organise and manage and the optimal utilisation of environmental resources. Environmental Information Systems should therefore, include strategies, procedures and institutional frameworks, together with data management tools, that ensure access to environmentally relevant data and allow for their analyses (Prévost and Gilruth, 1999). These systems should contain a wide range of environmental components so that environmental practitioners can develop holistic, cross-media and multi-disciplinary approaches to environmental management. The complexity of an environmental information system depends on the number of environmental components required to serve the defined management objectives. Users of EIS should be able to query these systems and derive information on fauna and flora locations, migration routes, sources of pollution, land ownership, archaeological sites, protected areas, location of endangered species, demographics, etc (NRDC, 2001).

1.2 Role of GIS in Environmental Management

Geographic Information Systems (GIS) are a fundamental component of environmental management because they are capable of recording, storing and processing data with geographical, temporal and thematic content. Effective environmental management entails the gathering and analysis of data from disparate sources and often the modelling of processes. A GIS enables the accurate, efficient and repeated testing of management strategies and classification scenarios to assess their suitability before implementation. A GIS can also be joined directly with an existing environmental model to provide both an efficient source of input data for the model and an effective means of visualising and analysing model output or results.

* Corresponding author.

Unlike paper maps, a GIS is not static and can be updated continuously to provide a more current and useful information system. Importantly, once a GIS database for an area has been developed it can be used to underpin a multitude of projects. This is efficient in that basic datasets to be used by different projects can be shared and has strategic importance in that interdisciplinary co-operation is enhanced and consistency between project results is increased (NRDC, 2001). Interdisciplinary co-operation is particularly important in environmental management where responsibility for the planning and management of an area or a resource is shared between a number of organizations or departments. GIS is therefore, the universal bridge that can provide traditionally sector-based environmental agencies access to holistic management strategies.

Environmental Information Systems are an expansion of GIS synthesizing the often complex body of environmental information to support planning, analysis and decision-making. Due to their capabilities, a large number of environmental information systems are being established worldwide to address different environmental and resource management issues. They serve for the assessment of environmental risk, for the management of areas suffering a conflict in land use activities, or for the efficient and sustainable use and exploitation of natural resources.

2. NOLAN'S MODEL

The establishment of environmental information systems, particularly in African countries, has followed the traditional approach to information technology adoption as predicted by Nolan. Nolan's model outlines the evolution of information systems in four stages: innovation, contagion, control, and integration (Yeates *et al.*, 1994). According to Lyytinen (1991), each stage of EIS development has its own distinct characteristics.

2.1 Innovation

During the initiation stage, computers are used to satisfy basic needs of very few enthusiastic individuals within an organisation. As the use of computing technology gathers momentum, computerisation problems will inevitably arise. These problems are further compounded by the fact that typically minimal planning is done before the establishment of computing facilities. At this stage management is least concerned about these problems since they are not the major focus of the organisation's activities.

2.2 Contagion

Successful implementation of information technology (IT) by few individuals often triggers a rapid increase in the use of computing within the organisation. Management will begin to realise the great potential of this technology while most users' expectations increase. This results in parallel developments of computing applications leading to duplication of computing facilities and the adoption of different specifications for hardware and software.

2.3 Control

At this stage, most organisations establish computing departments to coordinate the various computing initiatives in their bid to plan, control and formalise the growth of the technology. The position of IT management in the organisation is well acknowledged, often leading to controlled standardisation of hardware and software configurations. The information system planning is given high priorities and management controls the costs. Data processing becomes centralised, creating a single information system for the whole organisation.

2.4 Integration

Information systems have the tendency to grow in leaps and bounds, reaching unmanageable proportions within short periods of time. As the system grows, control structures are re-evaluated, sometimes leading to the decentralisation of application development. Use and application development is rationalised and coordinated. Planning is widely accepted and any centralisation or decentralisation of computing resources and applications is controlled through business strategies.

3. STATE OF ENVIRONMENTAL INFORMATION SYSTEMS DEVELOPMENT IN AFRICA

Environmental Information Systems development in Africa is going through the different stages of the Nolan's model with different countries at different stages development. The continent as a whole is at the control stage and efforts are being put towards the establishment of national EIS frameworks with the view of expanding these to regional and eventually continental frameworks.

Technological advances in the field of remote sensing from the early 1970s to the early 1980s, led to the evolution of environmental information management. These developments, such as the launch of remote sensing satellites (LANDSAT, SPOT, etc), provided large amounts of environmental data that could be used for analysis and management. Few enthusiastic individuals championed the establishment of environmental information systems at departmental levels of various institutions concerned with environmental management. The majority of EIS related activities during this decade were exploratory or experimental in nature and confined to specific sectors with few, if any, linkages between sector efforts. Most of the environmental information systems were created to support donor-funded (UNEP, UNDP, FAO, etc) projects such as environment support projects and natural resources management projects and were, as a result, supply-driven and, project as well as data-oriented. Pockets of expertise (information communities) in the fields of GIS, remote sensing and database management systems (DBMS) technology developed in most African countries during this era.

During the 1980s more and more institutions became aware of the need to establish environmental information systems due to increased pressure on natural resources from rising population levels as well as natural disasters such as floods and drought. This period saw a phenomenal growth in the number of actors involved in EIS construction. Duplication of data and resources during this stage was inevitable due to the legacy of sectoral environmental management policies. These policies delegated different government ministries to manage different sectors of

the same environment. In many countries, for example, the departments of forestry and wildlife are separate institutions run by different ministries. The result was a multitude of EIS groups operating as an unruly collection of factions pulling in different directions, each driven by its own valid objectives (Prévost and Gilruth, 1999). In Zimbabwe, for instance, the Integrated Resources Information System (IRIS), Vegetation Resources Information System (VEGRIS) and Agricultural Land Evaluation Information System (ALEIS) initiatives had remote sensing activities but were funded by different donors and were completely uncoordinated. The national institute for remote sensing was not involved in the development of these information systems (EIS-Zimbabwe, 2002). This state of EIS development posed a crisis because the lack of coordination retarded sustainable development and promoted conflict between the different sectors. Discussions on EIS policies to try and control the uncoordinated growth of the environmental information systems were mooted.

Control of the development of EIS initiatives began in the mid-1980s, as a result of the recognition that environmental information was a distinct cross-sectoral issue through the adoption of National Plans to Combat Desertification and National Conservation Strategies. The same realisation came out of the National Environmental Action Plans (NEAP) processes initiated in the late 1980s, which emphasised the need for shared solutions and integrated data products. The 1992 UN Conference on Environment and Development (UNCED) in Rio de Janeiro called for the establishment of information systems that would improve access to information with environmental relevance and make it available as a basis for decision-making. This challenged the environmental information communities to recognise their mutual interest and work towards a greater synergy of their respective efforts. EIS initiatives were propelled from a supply-driven to a demand-driven orientation. The underlying principle is that EIS should serve a clearly specified management need, and that data should not be collected unless an end use is defined (Prévost and Gilruth, 1999). Some African governments have responded to this challenge by formulating holistic environmental management policies. The World Bank has been funding the Environmental Information Systems for Sub-Saharan Africa (EIS-SSA) Program (now EIS-AFRICA) since the early 1990s, to promote the implementation of effective environmental information systems. The Program supports African countries as they assess their priority needs in terms of environment and land information systems, and analyse the technical, institutional, legal and economic issues hampering their possibilities of meeting these needs (EIS-SSA, 2001).

Environmental management is effective if it is integrated into the decision-making process at all levels. The complex nature of the environment makes the distributed model ideal for the establishment of EIS. Here, data sets are constructed and hosted by institutions with the appropriate statutory mandates under the control and supervision of capable data custodians. The recognition and support of data custodians is crucial in controlling the development of EIS. The data custodians are encouraged to develop a culture of data sharing and to have policies that minimise duplication of resources. Countries such as Uganda, Ghana, Zambia, Eritrea and Tanzania have launched initiatives to establish national environmental information networks (EIN) (UNEP, 2002). These frameworks aim at minimising the institutional and technical constraints to EIS development by providing horizontal and vertical structures for sharing data within the environmental information communities. It is relatively easy to coordinate members of the EIN when their disparate data sets are being aggregated to fulfil high-level management objectives such as State of the Environment Reports (SOERs). The Ghana - Country at A Glance (G-CAG) database was created by generalising and synthesising data from several custodians. It is a synoptic, inter-operable, and user-friendly geographical database designed to assist in national-level environmental management and planning. The aim was to construct a versatile and inter-operable geographic database directed towards decision-makers and similar persons who need to have an overview over the country for large area planning purposes. Another aim with the data sets in the Ghana-CAG is to serve as an introduction to the detailed data sets that are available at the custodian organisations (EIS News, 1999). EIS initiatives such as the Peace Parks Program (2002) and Lake Tanganyika Biodiversity Program (2002) have transcended national boundaries and are being used to generate valuable environmental information on shared resources.

4. PROBLEMS ENCOUNTERED DURING EIS EVOLUTION

The development of EIS has been fraught with numerous problems ranging from institutional barriers to technical constraints as well as limited human resources capacities. These inhibiting factors have been well documented in World Bank reports on cases in Best Practices of EIS for countries such as Zimbabwe, Ghana, Mozambique, Uganda and Senegal. These problems are consistent with predictions of Nolan's model for IT adoption during the early stages.

4.1 Technical Constraints

Most African governments operate under stringent financial resources and usually fund projects that have immediate political and socio-economic gains. Funding for projects with long-term gains such as EIS projects, was therefore, not readily available from central governments. In some cases, the huge capital expenditure required for the new technologies was prohibitive. Donor- funded projects in this sector became the norm. This resulted in a number of problems including the proliferation of incompatible hardware and software configurations in implementing agencies. The lack of project coordination resulted in the adoption of different database development standards on different projects. The wide spectrum of data sources resulted in data integration problems caused by different map projections and coordinate systems, different naming conventions, and different accuracy standards. This posed, and still poses, severe data harmonisation difficulties as the dissimilar sources have to be integrated into a single format. As an added complication it became obvious that the electronic communications facilities in most African countries could not meet the demands of the distributed nature of EIS data and facilities.

4.2 Institutional Barriers

Institutional barriers arise from the legacy environmental management frameworks, which were largely sectoral. Most organisations lacked a coordinated participatory approach, which is crucial for the success of EIS implementation. This could be attributed to the resistance to central coordination as some of the environmental practitioners considered this as a threat to their autonomy. In some cases, environmental managers feared the exposure of their incomplete or substandard work. In most countries, there was no clear policy on environmental management. Organisations carried out their functions independent of each other and lacked vertical and horizontal networking to improve data access and sharing. The legal mechanisms for inter-sectoral information exchange are virtually non-existent in most countries. The fact that copyrights to environmental data are not clearly stipulated is of major concern in most organisations in terms of data dissemination.

4.3 Human Resources

During the infancy of EIS implementation, most projects depended on donor-funded expatriates from abroad due to the lack of sufficiently trained local personnel to man them. The expatriates were usually employed on contract basis and most projects were not sustainable as soon as the experts left. Although a number of local personnel were trained as part of capacity building in most projects, these were often offered higher managerial posts and thus removed from the technical aspects of the EIS. This was exacerbated by the failure of African academic institutions to produce enough personnel in the field of environmental management (Ruther, 2001). The training often concentrated on environmental GIS technology rather than on environmental information management.

The ideal EIS is one in which all these constraints are minimised, enabling data integration and migration between sectors of the EIS community. The EIS community needs to continue to develop new applications that encourage several partners (data holders *or data custodians*) to share information for their mutual benefit.

5. BENEFITS OF ENVIRONMENTAL INFORMATION SYSTEMS

The establishment of EIS provides a focal point at which decision-makers and planners can draw authentic and viable information on environmentally related issues. The establishment of EIS initiatives compels organisations to take stock of their data inventories and update them to remove any deficiencies that might be inherent in legacy systems. This is apparent when different environmental components are being integrated into a unified system. EIS encourages inter-disciplinary cooperation and networking, resulting in shared responsibilities and tackling of environmental issues in a holistic manner. This should naturally lead to the minimisation of functional duplication and efficient utilisation of available resources. EIS initiatives are closely linked to capacity building within the implementing organisation. Current technologies, including latest versions of hardware and software, are acquired and staff undergoes further training courses, thus broadening the technology knowledge base in Africa. In the present information era, the implementation of EIS initiatives can induce the growth of allied disciplines such as the electronic communications sector. Information superhighways provide the backbone for the transmission of environmental information to the various users located in different sites. A significant outcome of EIS is that the state of the environment can be assessed at any point in time and this is critical for the sustainable utilization and conservation of natural resources.

6. CONCLUDING REMARKS

It is central to the development of Environmental Information Systems that they are integrated both vertically and horizontally, to overcome some of the existing institutional barriers. WLIP (1991) advocates the development of a decentralised confederation of systems based on common standards, where those with land information responsibilities would continue to collect, maintain and keep custody of that information. The distributed approach promotes greater flexibility and discretion for participating institutions in developing their own environmental information systems. Formal and/or informal data sharing arrangements, encompassing standards and conventions, should be in place to promote integration and interoperability of environmental information. In theory, existing individual data sets need to be converted to comply with the agreed standards and conventions only if they are to be shared. However, common standards should be applied wherever possible and suitable as currently unforeseen needs for integration might arise at a later stage. Uganda is a good example of a country with a decentralised environmental information network. Here, the environmental management policy is enshrined in the country's 1995 Constitution. A National Environmental Action Plan was published in 1994 and is implemented at district and local council levels under the auspices of a coordinating body, the National Environmental Management Authority (EIS-Uganda, 2002).

Environmental information systems should be demand-driven and based on thorough needs and institutional analysis with focus on information requirements. Dependence on specific technologies must be minimised. This should ensure an easier sharing of information among the members of the EIS community. A common data infrastructure is the backbone for the integration of distributed information systems. The development of a common data exchange format and model for the entire spectrum of users needs thorough investigation. Data integration is becoming feasible due to advances in Global Positioning Systems (GPS), information and telecommunications technologies, which are making it easier to share resources and assets.

EIS initiatives should not be undertaken in isolation. They should be closely linked to National Spatial Data infrastructure (NSDI) initiatives so as to harmonise the data architecture and exploit the available resources to the maximum. For example, the South African National Spatial Information Framework is tasked with developing the parameters for that country's spatial data infrastructure. Smith (1999) reckons that GIS organisations and users will make significant cost savings through reduced duplication or recapture of spatial data and the use of metadata to locate the available datasets. In most of the SSA countries, the National Mapping Organisations are responsible for NSDI initiatives and should be consulted by EIS practitioners prior to and during EIS implementation.

The training of EIS practitioners should combine technology training and environmental information management (Ruther, 2001). This should play a significant role in the formalisation of

the development of EIS in Africa. Collaboration between the EIS community and the academic institutions should be encouraged. Universities will be encouraged to undertake research into some of the problem areas such as environmental database design and implementation. Geomatics institutions in countries such as Ghana, Democratic Republic of Congo, Kenya, Nigeria, South Africa, Tanzania, Zambia and Zimbabwe should be encouraged to incorporate EIS into their curricula and to be research partners with implementing agencies and organisations.

EIS initiatives should embrace new technologies such as the World Wide Web (WWW) and Internet so that decision-makers and planners have ready access to environmental data. EIS applications should incorporate multi-media functions so that thorough analysis and clearer assessments of environmental conditions can be carried out.

In conclusion it can be said that the full potential of EIS has not been fully realised in Africa due to the prevailing state of technological, political and economical development in most countries. The ability of these systems to account the state of the environment makes them ideal for raising public awareness on environmental issues, thus empowering the citizenry to make informed decisions on the use available resources for sustainable development.

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