KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS
COLLEGE OF ENVIRONMENT DESIGN
DEPARTMENT OF CITY AND REGIONAL PLANNING

COMPUTER-AIDED PLANNING (CRP- 507)

TERM PAPER (TERM 012)

GIS Technology: Planning for Sustainable Development

BY
YUSUF ADEDOYIN AINA
(STUDENT ID: 210285)

INSTRUCTOR: DR. BAQER RAMADAN

Table of Contents

1.0 Introduction

Sustainable development has become a global concept since 1987 when it was broached by the World Commission on Environment and Development. The concept arose from the need to have a balance consideration of social, economic and environmental factors in our developmental efforts. The principles of sustainable development require that interregional and intergenerational dimensions be incorporated into development goals and practices (Box 1). Governments at international, national and local levels have tried to incorporate the principles of sustainable development in their developmental plans and projects (HABITAT, 1998). However, the gap between sustainable development in principle and in practice still exists with the need for adequate information on the resources to be managed.

1 Environment: The physical 'carrying capacity' of the environment imposes limits to many human activities and means we must reduce our consumption of resources. We must live within these so that we pass the planet on to our descendants with its ability to support human life undamaged;

2 Futurity: We have a moral duty to avoid `compromising the ability of future generations to meet their own needs';

3 Quality of life: Human well-being has social, cultural, moral and spiritual dimensions as well as material;

4 Equity: Wealth, opportunities and responsibilities should be shared fairly between countries, and between different social groups within each country, with special emphasis on the needs and rights of the poor and disadvantaged;

5 Precautionary principle: if we are uncertain about the environmental effects of any actions/developments we should apply this principle and err on the side of caution.

6 Holistic thinking: solving a complex sustainability problem requires that all the factors that contribute to that problem be incorporated in the solution

Box 1. Principles of Sustainable Development

Source: Adapted from (CMRE, 1998)

The issues related to economic, social and environmental principles of sustainable development are very complex and require an integrated approach. Moreover, sustainable development encompasses spatial and temporal dimensions. Sustainable development is temporal, as implied by the term "development" and spatial since all development takes place on the Earth surface (Langaas, 1997). Spatial information affects 80% of all human decision-making and is therefore strategically important to decision makers and for managing sustainable development (FIG, 2001). The European Environmental Agency (1999) noted that the issues connected with sustainability are not complex by being merely complicated, but by their nature of involving deep uncertainties and a plurality of perspectives.

The complexity of the issues involved in sustainable development has implication for policy and decision-making. Planners and decision-makers should have access to unprecedented quantities and types of resource and environmental information to implement the concepts of sustainable development (Ehlers, 1995). The information required for decision-making cut across different sectors, agencies, spatial boundaries and time frames. Datasets are required to be available at a number of levels, i.e. local, national, regional and global (FIG, 2001). Therefore, there is need for a platform that will capture, integrate, manipulate and analyze these datasets and present them as information for supporting sustainable development. Better systems of knowledge creation and application need to be included in the strategies of sustainable development (Clark, 2001).

GIS (Geographic Information Systems) is a computer-based tool that can be used by decision-makers to address complex and multi-dimensional issues that are related to sustainable development. GIS has the capability of storing, displaying, manipulating and analyzing geographically referenced data. It is useful to integrate different components of sustainability assessment for decision-making, planning and management (STOA, 2001). GIS has been utilized in quite a number of programs, projects and researches to address environmental problems. The applications of GIS are in a diverse range of areas, including land-use change analysis (Chen, 2002), impact assessment (Rodriguez-Bachiller, 2000a), monitoring (Preston, 1993), environmental sensitivity mapping (Jensen et al. 1993) and National/Regional GIS and environmental databases (Langaas, 1997, SFRA, 2002). Most of the applications have been limited to specific issues, projects and regions. The challenge of successful application is to integrate all available information on issues of sustainability. There is need for integrated systems bridging the frequently separate domains of research, monitoring, assessment, and support for operational decision-making (Clark, 2001).

The opportunities offered by the improvement in GIS technology has to be harnessed by planners and decision-makers in integrating datasets and information for sustainable development. There are improvements in data capture, translation, transformation and data sharing. Geographic data networks have also been improved through computer networking and standardization. Remote Sensing and Global Positioning Systems are increasingly integrated with GIS in different environmental applications. Above all, the decrease in costs of hardware and software has led to a prominent increase in use of the technology. As planners have a central role in achieving sustainability, GIS technology should be operationalized to be more amenable to planning and decision-making. The role of GIS in planning for sustainable development could be enhanced if it is utilized within expert systems and decision support systems environment. It is therefore imperative to investigate into the ways GIS and other related technologies could be operationalized in planning for sustainable development.

1.1 Aims and Objectives

This main aim of this study is to review recent developments in the field of GIS and other related technologies, and highlight the potential of these tools in planning for sustainable development. The study develops a framework for GIS application in achieving sustainable development.

1.2 Approach

The approach of this study is to review available literature in the field of GIS and sustainable land use planning. The study presents the findings of the review and case studies on the use of GIS in sustainable development.

2.0 Sustainable Development and Spatial Planning

The concept of sustainable development was defined by the Brundtland Commission Report (WCED, 1987) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition is broad and has posed some difficulty in implementation. However, different forms of guidelines have been developed to further improve the implementation of the principles of sustainable development. Agenda 21 was adopted by United Nations Conference on Environment and Development to serve as a global guideline for implementing sustainability. The main areas highlighted by Agenda 21 are: social and economic dimensions, conservation and management of resources for development, strengthening the role of major groups, and means of implementation (UNCED, 1992). The key theme of Agenda 21 concerns human health and well-being and promotion of a balance between the environment and development.

Agenda 21 recognizes the vital role of planning in achieving sustainability as it points out that national strategies, plans, policies and processes are crucial in achieving the goals of sustainable development. Chapter 7 and 40 of Agenda 21 addresses the need for promoting sustainable land-use planning and management and developing better means of data collection, assessment, analysis and co-ordination. Agenda 21 points out the importance of bridging data gaps and improving information availability for planning and decision making at the local, provincial, national, and international levels.

In view of the crucial role that planning can play in achieving sustainability, many writers have tried to suggest the types of planning process and tools that could be amenable to sustainability. Blowers (1993) argued that one of ways in which local authorities can deliver sustainability is through making their land use planning process sustainable. He proposed an integrated planning process that has three dimensions: trans-media, trans-sectoral and trans-boundary. Trans-media refers to the different environmental pathways of air, land and water. Trans-sectoral means the integration of different sectors such as transport and energy in policy making. Trans-boundary refers to vertical integration between different levels of government. Part from making the planning process sustainable, planners also need to acquire better planning skills and tools. Briassoulis (1999) suggests that substantive and procedural groups of skills are needed by planners to foster sustainable planning. Planners must be equipped with reliable forecasting tools. Planners need to find practical and available mechanisms that can improve the basis of planning judgments at both the technical and political level (Gwilliam, 1993).

3.0 GIS and related technologies

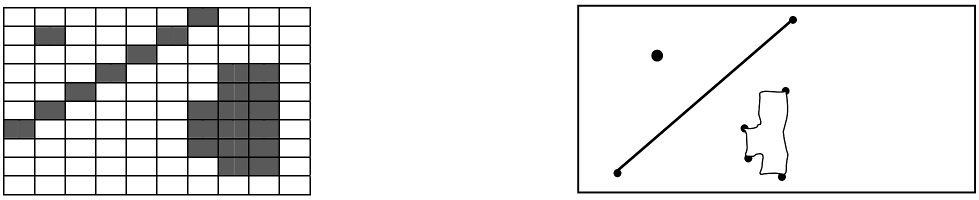
A GIS can be defined as a computer-based system that capture, store, manipulate, analyze, and display georeferenced data. GIS is different from automated cartography and database management systems through its specialized capabilities of generating maps from information and spatial analysis. STOA (2001) suggests three main goals of GIS:

i) acquiring, storing, managing and integrating geographically-referenced data;

ii) providing tools for data analysis, with the help of mathematical models;

iii) representing data and the results of the data analyses mainly through thematic maps, charts and tables.

The power of GIS is the ability to link spatial data with attribute data or a database. GIS represents reality by layers of features called themes. Each theme has homogenous geometric elements. For example, administrative boundaries, road networks, drainage, and vegetation can be displayed as different layers or themes. The layers are linked with their attribute (for example, name of street, width, length, etc. of roadways) through their geographical location. GIS uses two types of data models to store and display objects: vector and raster data models (Figure 1). Geographical features are represented in a vector model by points and lines, which have topology, to form nodes, arcs and polygons. The points are represented by their x and y coordinates; lines are represented by joined coordinate pairs; and polygons are closed lines, with first and last nodes having the same x-y coordinates. In raster model, objects are represented in grid form. A raster grid is a regular matrix or two-dimensional array of cells (or pixels). Each cell is linked with a set of related attributes in the database.



(a) (b)

Figure 1. Data representation models: (a) raster model (b) vector model

Data acquisition is a very important component of GIS. The cost of data input is usually a very high percentage of the total cost of implementing GIS. Data for GIS can be obtained in different ways: digitizing/scanning maps, aerial photographs, field survey, Global Positioning System (GPS), published data and remote sensing. Paper maps and mylars can be digitized (through digitizing table) and scanned to create data layers or spatial dataset. Aerial photographs are photo taken by cameras from aircraft. The photographs can be rectified and input into GIS. Field data that are in digital format can be used to generate mapped features for GIS. The GPS is an important technology that has been used to locate positions without extensive survey. The GPS receiver captures signals from satellites to calculate its position on the earth surface. Elevation and position data from GPS can be input into GIS. As a tool for data collection remote sensing technology provides the means to consistently monitoring the earth. Remote sensing is usually integrated with GIS in environmental management applications.

3.1 Remote sensing technology

The science of remote sensing involves collecting data on earth features by detectors from remote platform. Airplanes and satellites are the main platforms used in remote sensing. The detectors (sensors) collect and record energy emitted, reflected, and transmitted by an object. The recorded value, which is the characteristic (signature) of the object can be processed and interpreted to collect information about the object. Two types of sensors are used in remote sensing: active and passive sensors. The active sensor transmits radio waves (radar) or use low-powered lasers. Passive sensor detects the reflection of sun's energy from the object. The resolution, spectral band, and time of the imagery are important factors to consider in applying remote sensing data. The resolution is the smallest difference that can be distinguished and spectral band is a defined interval in the electromagnetic spectrum. Time is very important especially in environmental monitoring because atmospheric conditions affect the signatures that are recorded by the sensor.

Recently, there have been notable improvements in the field of remote sensing. More satellites are orbiting the earth and more information at higher resolutions and shorter time intervals are being collected. High-resolution images such as the IKONOS images (82cm nadir viewing) provide opportunity to obtain more accurate information about earth features and thereby improving environmental monitoring and management. Apart from technical improvements, the cost of acquiring satellite data is also declining thereby leading to wider application of satellite images. Extracting information from images has been enhanced through the developments in image processing methodologies (Herzog, 2000).

Numerous studies have been carried out by applying information derived from remote sensing data for environmental monitoring and management. The studies range from global to local level. De Sherbinin (2002) catalogues the applications and likely applications of remote sensing technology in monitoring and enforcing international environmental treaties such as the Ramsar Convention on Wetlands, the Kyoto Protocol, Convention to Combat Desertification and Convention on Biological Diversity. A common field of application of remote sensing is land-use/land cover change or change detection studies. Multidate data are compared to analyze changes in land-use or environmental changes (Alwashe and Bokhari, 1993; Chen, 2002; Jensen et al. 1993). Increasing number of studies is conducted by integrating remote sensing data with GIS thereby enhancing the data input aspect of GIS (Chen, 2002; Jensen et al. 1993).

3.2 Current trend in GIS technology

Recent trends show that GIS is becoming increasingly connected with other types of information systems and tools, such as general Database Management Systems (DBMS), programming software, 3D Modeling, Virtual Reality and the Internet. Although the connection of GIS to other tools and systems tends to reduce the functionalities of GIS, it generally improves the capabilities and usefulness of GIS in solving decision-making problems. Programming software allows the customization of GIS for specific uses and development of better GIS capabilities. The advent of the World Wide Web has introduced hitherto unimagined possibilities for operating GIS remotely. Remote access to GIS via the Web has the potential of transforming desktop GIS from one-to-one correspondence between users and desktop databases to many-to-many correspondence between users (Heikkila, 1998). Remote GIS opens more opportunity for citizen participation in decision-making and exchange of databases.

GIS functionality is also being embedded in analytical tools such as Space Syntax, Expert System and Spatial Decision Support System. Space Syntax is a technique of modeling and describing spatial configuration. Amir and Nkwenti (2002) show the usefulness of GIS adaptation and enhancement of syntactic analysis for effective pedestrian and vehicular movement. Syntactic analysis could be applied in assessing the social impact of development. An expert system (ES) is a computer program that tries to encapsulate the way an expert solves particular problems. Such a system is designed by crystallizing the expert's problem solving logic in a "knowledge-base" that a non-expert user can then apply to similar problems in a different situation (Rodriguez-Bachiller, 2000b). Spatial decision support systems (SDSS) are computer-based systems designed to help decision-makers solve complex spatial problems. SDSS provide a framework for integrating analytical modeling capabilities, DBMS, graphical display capabilities, tabular reporting capabilities and expert knowledge. Rodriguez-Bachiller (2000b) highlights that Impact Assessment, GIS, ES and SDSS are complementary and their integration could be useful in environmental management.

4.0 Applications of GIS in Environmental Protection and Planning

Numerous environmental GIS applications have been reported in the literature. The studies include project, local, national, regional and global levels of applications. The most common applications are in baseline studies or environmental inventories and monitoring. Adeniyi et al. (1992) made an inventory and monitor changes in agricultural resources using Landsat data within GIS environment. Jensen et al. (1993) applied Landsat TM data and GIS in environmental sensitivity mapping of oil spills in United Arab Emirates. Chen (2002) employed Landsat TM data within a GIS context to show the impact of natural forces and human activities on land cover changes regional sustainable development in Ansan City, Korea.

GIS has also been applied in impact assessment and promoting the principles of sustainable development. Rodriguez-Bachiller (2000a) highlights the potential of applying GIS in impact assessment by identifying GIS operations that are relevant to impact assessment (Box 2). Langaas (1997) points out that GIS can play a vital role in the spatial analysis of indicators of sustainable development. Parfett (1998) developed a GIS designed to analyze the relationships and subsequent impacts on energy consumption and the greenhouse emissions different urban elements including socio-economic factors, density, municipal zoning and transportation patterns.

Box 2. GIS operations potentially relevant to impact assessment

(i) Storing considerable amounts of information related to a territory
(ii) Displaying rapidly and easily visually appealing maps of such information
(iii) Superimposing maps (map "overlay") to identify and measure overlaps
(iv) Combining several maps, weighted or not, into composite maps ("map-algebra") to calculate the value of a composite variable for different parts of the territory
(v) Measuring the size (number, area, length, perimeter) of map features
(vi) Using distances to construct "buffer" zones around certain features
(vii) Drawing contour maps derived from the point-values of variables
(viii) Building pseudo-3D (or "2.5", as sometimes referred to) models of a terrain, and calculating topographic characteristics (slope, aspect) of its parts
(ix) Identifying "areas of visibility" of certain features on one map from the features of another, using the terrain models mentioned above.

Source: Rodriguez-Bachiller (2000a).

In the regional/global context, the Baltic Sea Region initiated Planning System for Sustainable Development project that has developed a GIS-based computer aided tools to promote sustainable spatial planning and development in the Region (SFRA, 2002). The tool developed is an internet-based interactive database. The European Environmental Agency (EEA) developed a spatial and ecological assessment of the trans-European transport network (TEN) using indicators and GIS methods (EEA, 1998). Tateishi and Kajiwara (1991) used different sets of remotely sensed data to derive global land cover and change information.

5.0 Issues in GIS applications

The application of GIS in planning for sustainable development has some challenges especially in integrating complex data from different sources and levels of decision-making. Nedovic-Budic (2000) highlights some policy implications in the application of geospatial technologies and tools in planning practice: database development, standardization, access to data, tool building and integration, technology transfer, and legal framework. These are also the notable issues in applying GIS in planning for sustainable development. Other issues include institutional framework and cost.

Database development is a very important aspect of GIS especially in applying GIS in sustainability issues. There are only few data that are in digital form, which can be easily input into GIS. There is need to make an assessment of data requirement at all levels of decision-making and to direct effort at collecting relevant data in creating sustainability database. Apart from dearth of digital data, the digital databases that are available are not well integrated. Most of the data are in different format, quality and scales that are not compatible. Efforts are being made by the Open GIS Consortium and Federal Geographic Data Committee (FGDC) to promote interoperability between different types of geoprocessing systems, data sources, vendor brands, and computing platforms. There is need to promote data standardization and the development of National Spatial Data Infrastructure (NSDI).

GIS applications cannot be carried out without adequate and capable manpower. Staffing therefore is a big issue in implementing GIS. There is need to promote educational programs in geospatial technologies and also dissemination of research findings and developments in the GIS application. Researches in developing new techniques and methods of data input, analysis and output should be encouraged. A lot of legal issues pervade the use of GIS. The issues include data access, liability, copyright, data protection and access to information by the citizen. There is need for specific legal structure that relate directly to these issues in the context of digital geographic information.

Good governance at all level of decision-making is needed to support the application of geospatial technologies in planning for sustainable development. Good governance will promote equity, fairness and citizen participation, which is very essential in sustainable development. Most national GIS programs are implemented by the central government in a “top-down” approach. So, there is need for institutional framework that will promote the development of National Spatial Data Infrastructure. There is also need for cooperation between governments at the international level to integrate spatial data.

6.0 Framework for applying GIS technologies

It has been shown that GIS application can only be optimized by integrating it with other systems such as Expert System and Spatial Decision Support System (Rodriguez-Bachiller, 2000b). The framework for integrating GIS with other systems could embed GIS in SDSS. SDSS has a framework that is more robust than that of GIS encompassing analytical modeling, DBMS, graphical user interface (GUI), reporting system and expert systems. GIS normally provide DBMS, GUI and reporting system. So the framework could be built by adding analytical model and expert systems to a GIS (Figure 2).

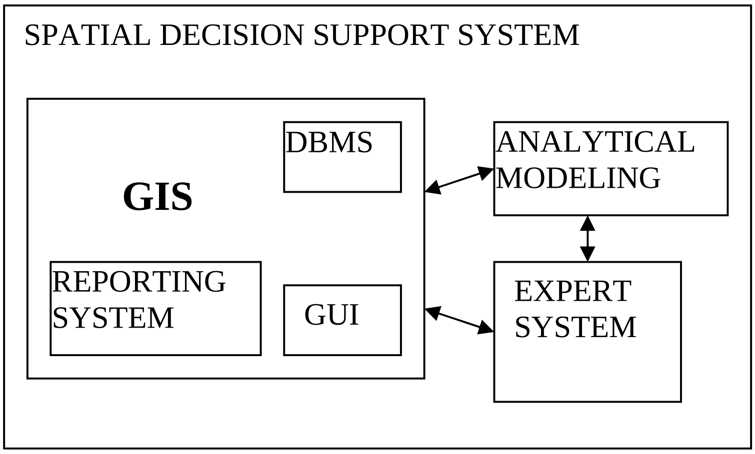


Figure 2. Integration of GIS with other systems.

The above framework is to optimize the capabilities of GIS at any level of application. Since sustainable development is an interregional concept, there is need to integrate spatial data across the globe for effective implementation of the principles of sustainable development. The basic guideline is that there must be integration of data vertically across levels of decision-making and horizontally within these levels (Figure 3). The process of implementing GIS for sustainability should be incremental and "top-down" but there should be channels of feedback from the citizen to promote public participation.

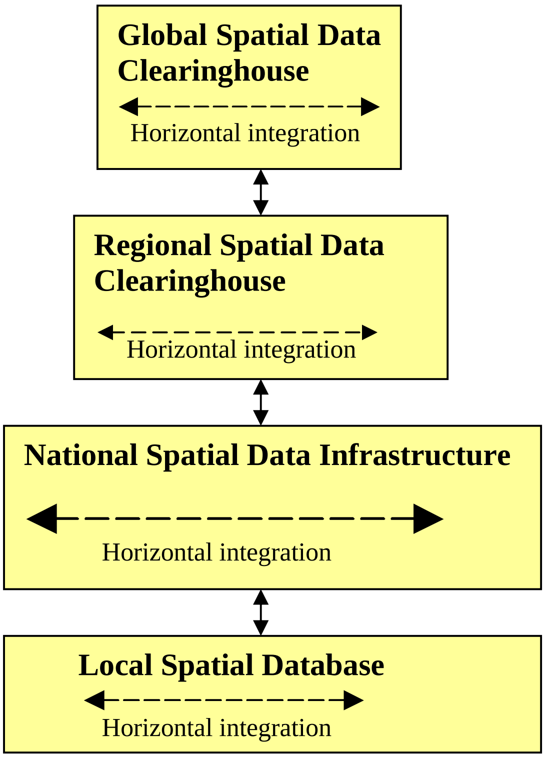


Figure 3. Spatial data integration.

7.0 Conclusion

There have been some improvements in GIS technology since its emergence as a tool for spatial analysis. Due to GIS capabilities of database management and spatial analysis, GIS can be applied in helping decision-makers and planners to foster sustainability. However, there are some challenges especially at the global level, to using GIS as a planning tool for sustainability. The issues of database development, institutional framework, legal framework, data standardization and technology transfer have to be considered. Also, GIS may not be adequate as a stand-alone system for support decision-making. It has to be integrated with other systems such as ES and SDSS for its application to be optimized.

There have been some efforts to address the different challenges facing the application of GIS through the Open GIS initiative and the National Spatial Data Infrastructure. There is need for more efforts towards the coordination and integration of these initiatives at the global level.

References

Adeniyi, P.O., Omojola, A. & Soneye, A.S.O. (1992) Application of remote sensing and GIS in the mapping, evaluation and monitoring of agricultural resources in Northwestern Nigeria. *Proceedings of the Canadian Conference on GIS* '92, Ottawa (Canada), March 24–26, pp. 803–820

Alwashe, M. A. and Bokhari, A. Y. (1993) Monitoring Vegetation Changes in Al Madinah, Saudi Arabia, using Thematic Mapper data. *International Journal of Remote Sensing*, 14 (2), pp. 191-197

Blowers, A. (ed.) (1993) *planning for a sustainable environment*. Earthscan Publications, London

Briassoulis, H. (1999) Who plans whose sustainability? Alternative roles for planners. *Journal of Environmental Planning and Management*, 42 (6), pp. 889

Clark, W. C. (2001) Knowledge systems for sustainable development. *Environment*, 43 (8) pi http://www.britannica.com/magazine/article?query=knowledge&id=2&smode=1

CEMR (Council of European Municipalities and Regions) (1998) *CEMR Local Agenda 21 Basic Guide*. http://www.ccre.org/

Chen, X. W. (2002) Using remote sensing and GIS to analyze land cover change and its impacts on regional sustainable development. *International Journal of Remote Sensing*, 23 (1), pp. 107-124

De Sherbinin, A. (2002) Remote sensing imagery: Making sense of available data. *Environment*, 44 (1) pp. 3-4

European Environment Agency (1998) Spatial and Ecological Assessment of TEN: Demonstration of Indicators and GIS Methods. Environmental issues series no. 11 http://reports.eea.eu.int/index_table

European Environment Agency (1999) Information tools for environmental policy under conditions of complexity. Environmental issues series no. 9 http://reports.eea.eu.int/index_table

Ehlers, M. (1995) Advanced technologies for sustainable development in developing countries: the role of GIS and remote sensing. *Proceedings of Geoinformatics' 95 Hong Kong International Symposiums on Remote Sensing, Geographic Information Systems & Global Positioning Systems in Sustainable Development and Environmental Monitoring.*

FIG (International Federation of Surveyors) (2001) Recommendations from the Nairobi Conference. http://www.fig.net/figtree/news/nairobi/recommendations.htm

Gwilliam, M. (1993) Sustainability in action, in *Planning for a sustainable environment*. (ed. Blowers, A.), Earthscan Publications, London

HABITAT (United Nations Centre for Human Development) (1998) *Sustainable Cities and Local Governance*. HABITAT, Nairobi, Kenya.

Heikkila, E. J. (1998) GIS is dead; long live GIS! Journal of the American Planning Association, 64 (3), pp. 350-360

Herzog, M. T. (2000) GIS Technology and Implementation, in *Urban Planning and Development Applications of GIS* (eds Easa, S. and Chan, Y.), American Society of Civil Engineers, Virginia, USA

Jensen, J. R., Narumalani, S., Weatherbee, O., Murday, M., Sexton, W. J. and Green, C. J. (1993) Coastal Environmental Sensitivity Mapping for Oil Spills in the United Arab Emirates Using Remote Sensing and GIS Technology. *Geocarto International*, 8 (2), pp.5-13

Langaas, S. (1997) The spatial dimension of indicators of sustainable development: The role of Geographic Information Systems (GIS) and cartography, in *Sustainability Indicators: A report on the Project on Indicators of Sustainable Development* (eds Moldan, B., Billharz, B. and Billharz, S.), SCOPE 58, John Wiley & Sons: Chichester. http://www.grida.no/prog/norbal/docs/gisisd/

Langaas, S. (1998) Transboundary European GIS databases: A review of the Baltic region experiences, in *European Geographic Infrastructures: Opportunities and Pitfalls*. (eds Burrough, P. and Masser, I.), GISDATA V, Taylor and Francis Ltd. http://www.grida.no/prog/norbal/docs/gisdata/

Nedovic-Budic, Z. (2000) Geographic Information Science Implications for Urban and Regional Planning. Journal of Urban and Regional Information Systems Association, 12 (6), pp. 709-728

Nkwenti, D. I. And Amir, A. O. (2002) Syntactic Modelling & Analysis: A GIS adaptation and enhancement for effective pedestrian & vehicular systems. *Proceedings of GIS 2002 International Conference and Exhibition*, Manama, Bahrain, March 9-14, pp. 135-150

Parfett, R. (1998) Development of a Geographic Information System for Planning Sustainable Urban Living Environments. *URISA 1998 Annual Conference Proceedings*, Charlotte, North Carolina, July 1998, CD-Rom, 650-662.

Preston, E. B. (1993) Remote Sensing, GIS Technologies Support Sea Ice Motion Monitoring. *GIS World*, 6 (1), pp. 36-39

Rodriguez-Bachiller, A. (2000a) Geographical Information Systems and Expert Systems for Impact Assessment Part I: GIS. *Journal of Environmental Assessment Policy and Management*, 2 (3), pp.369-414
http://www.worldscinet.com/jeapm/02/sample/S14643332000203.html

Rodriguez-Bachiller, A. (2000b) Geographical Information Systems and Expert Systems for Impact Assessment Part II: Expert Systems and Decision Support Systems. Journal of Environmental Assessment Policy and Management, 2 (3), pp.415-448
http://www.worldscinet.com/jeapm/02/sample/S14643332000203.html

SFRA (South Finland Regional Alliance) (2002) *Planning System for Sustainable Development*. Bulletin no. 2, http://www.pssdtoolbox.net/

STOA (Scientific and Technological Options Assessment) (2001) *GIS for Sustainability Assessment*. Briefing Note no 6, European Parliament.
www.europarl.eu.int/stoa/publi/pdf/briefings/06_en.pdf

Tateishi, R. and Kajiwara, K. (1991) Global land cover monitoring by NOAA NDVI data. *Proceedings of the International Workshop of Environmental Monitoring from Space, Taejon, Korea, 15–18 November 1991* (Seoul: Korean Associate of Remote Sensing), pp. 37–48.

UNCED (United Nations Conference on Environment and Development) (1992) *Earth Summit: Agenda 21- The United Nations Programme of Action from Rio.* United Nations, New York. http://www.igc.org/habitat/agenda21/

World Commission on Environment and Development (WCED) (1987) Our Common Future. Oxford University Press, Oxford.