The Indian Geographical Journal

Vol. 76 December 2001 No. 2

GIS for Marginalization or Empowerment in Environmental Management:

A South Indian Example

Martin J. Bunch

Faculty of Environmental Studies, York University, Toronto, Canada

Geographic Information Systems (GIS) exist to transform data into knowledge and present this knowledge in various formats for the purpose of supporting decisions. In doing so, GIS are portrayed as knowledge-based systems that are free from bias. In fact, GIS is a socially constructed technology. The entire process of GIS production, from software development to data creation, analysis, visualization and interpretation of GIS output, is characterized by political, economic and social motivations. This paper presents a model of communication for GIS that illuminates the potential for GIS to both marginalise and empower vulnerable and excluded groups in environmental management and planning situations at each stage of the GIS production process. Inclusive and empowering uses of GIS in recent research in South India are discussed. In particular, GIS was central to a process of conceptual and environmental modelling intended to support rehabilitation and management of the Cooum River in Chennai. This process incorporated the perspectives of citizens and NGOs into expression of system relationships that were represented in a GIS-based Decision Support System and simulation model. The process led to identification of qualitatively different kinds of system interventions than were tried (and failed) in the past to rehabilitate this extremely stressed system.

[Received: September 2002]

Geographic Information Systems (GIS) are "a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes" (7). Thus, GIS exist to transform data into knowledge and present this knowledge in various formats for the express purpose of supporting decisions (Fig. 1). In doing so, GIS are usually portrayed as knowledge-based systems that are free from bias. In fact, GIS is a socially constructed technology (33). The entire process of GIS production from software development to data creation, analysis, visualization and interpretation of GIS output is characterized by political, economic and

Fig. 1

GIS exist to transform data into knowledge in support of decision making

social motivations. Because of 1) the hidden nature of bias in GIS, 2) the level of funds, skill and education required to use the technology, 3) the political economy of information associated with database construction, and 4) the perceived legitimacy of the scientific, expert-oriented epistemology on which the technology is based, the use of GIS can lead to marginalization of groups that do not have the economic, social, or human capital to use GIS to legitimize their perspective in environmental management and planning decisions. Awareness of such issues reduces the potential for marginalization and may lead instead to the use of GIS to empower.

This paper presents a model of communication for GIS that is used to explore the issue of marginalization and empowerment in GIS. First, a model of cartographic communication offered by Robinson and Pechenik (25), and an improved model by Chrisman (8) that considers cultural transmission of information to users of GIS output, are briefly reviewed. I offer a further model of GIS that separately considers the roles of 1) engineers of proprietary GIS software, 2) database developers, 3) GIS analysts, and 4) end users of GIS products in the GIS production process. This model is used to illustrate the potential for marginalization or empowerment in GIS. An example is presented from a recent programme of research in Chennai (formerly "Madras"), India for rehabilitation and management of the Cooum River, in which GIS is used to support a participatory, stakeholder-based process.

Transmission of Information with Maps and GIS

A Cartographic Communication System

Robinson and Pechenik (1976) described the process and product of map-making as a "communication system" (Fig. 2) in which the real world is observed, interpreted and presented by a cartographer. The cartographer selects relevant features and interprets their meaning based on the purpose of the map, the cartographer's training and worldview. These features are stored on the map, that is both database and product of the cartographic process. A user of the map will interpret it according to his/her own purpose. His/her conception will be influenced by his/her training, experience of the world and worldview.

This is a process of reification of certain selected features. What is represented as real

Fig. 2
A cartographic model of communication. After Robinson and Pechenik (1976).

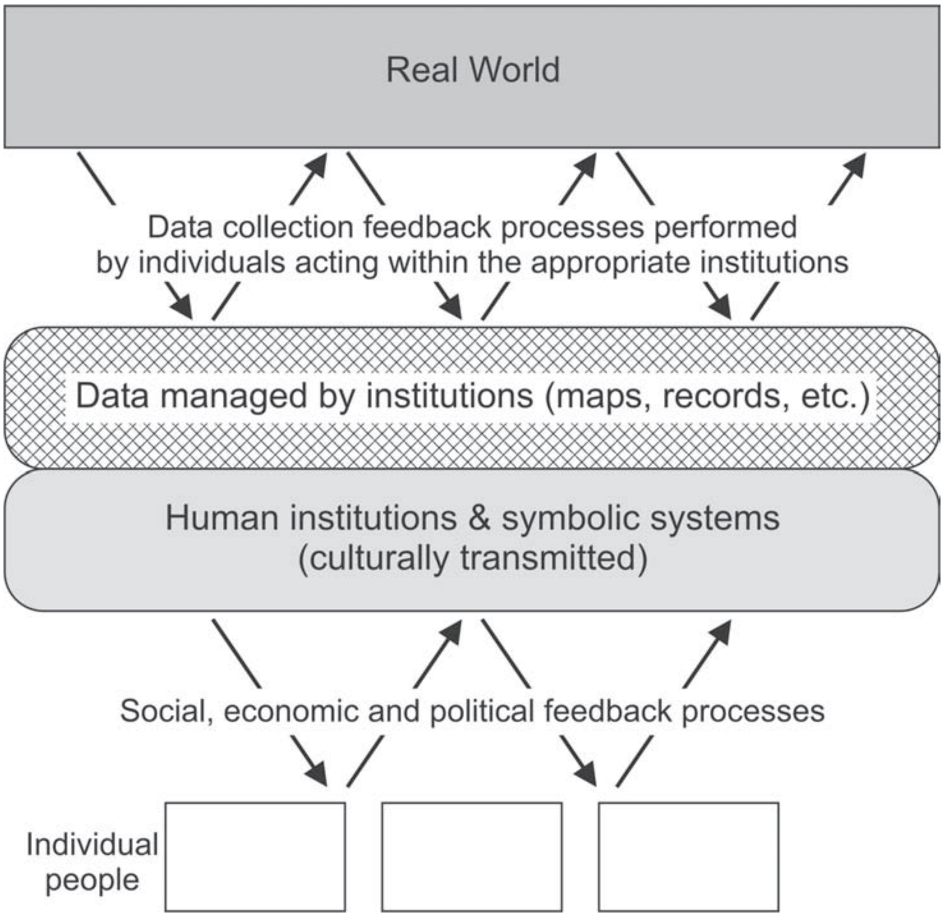

Fig. 3
A model of communication that considers cultural transmission of information. After Chrisman (1987).

(and how it is represented) is determined by the economic, social or political motivations of the mapmaker, and modified by the conception of the map user. In the cartographic model the mapmaker makes a selection of the phenomena for representation on the map. Representation is made with available cartographic techniques, and is restricted by the technology and form of the paper map as to how much, and in what way, that representation may be effected.

Cultural Transmission of Information and GIS

Chrisman (8) improved on this model for GIS (Fig. 3). He described a multidimensional model in which data are collected, stored and manipulated not by individual cartographers, but by human institutions. In Chrisman's model issues such as institutional mandate, procedures and rules, standards and cartographic conventions become important in the cultural transmission of information to the end user of GIS products. Consider that data are transformed into information and communicated to users by human institutions using human symbolic systems. The process is a kind of cultural transmission of perceptions of the real world, through the institutional milieu to the end user. Such things as the mandate of the institutions collecting and transmitting the data will influence, for example, decisions about what spatial and non-spatial entities in the real world are of interest, what kind of data are collected (at what scale, over what time frame) and how they will be manipulated (for example, classification and generalization) and symbolized. Other influences include the disciplinary training and value systems of individuals inside of institutions.

A Model of Communication for GIS

GIS Production and Communication

Chrisman's (8) model is illuminating. As with Robinson and Pechenik (25) his discussion is appropriate to a process of transmission of information that involves selection of relevant spatial entities observed in the real world, about which data are collected, stored, manipulated, analysed and presented. For GIS, these activities are undertaken primarily by individuals within institutions who can be described as database designers and GIS analysts.

However, writers on GIS and society identify issues that imply that there is at least one other group of organizations and individuals that should be separately considered. For example, Obermeyer (23) discussed the "hidden technocracy" in GIS, and Aitken and Michel (1) identified "the insidious default button" that represents methods, techniques and underlying theory built into GIS that are available to (sometimes uncritical) users. Decisions about which pre-packaged methods and techniques are provided to users are not made by database designers and GIS analysts. These decisions are made by the software designers and programmers of private proprietors of GIS software.

Others (9, 26, 27, 28) note that the data that GIS analysts use are conceived within worldviews, collected in ways, and maintained for purposes that do not necessarily correspond to ways of knowing and interests of those who are affected by the decisions being supported. Rundstrom (26) noted, for example, that "the Western or European-derived system for gathering and using geographical information is in numerous ways incompatible with corresponding systems developed by indigenous peoples of the Americas." Sahay (27) noted that in India "assumptions of time and space vary significantly from those inscribed in GIS technology."

Geographic information science is rooted in a western scientific worldview that is characterized by rationality, empiricism and positivism (24). Specific concepts and methods arising from this Western scientific tradition can be identified that are fundamental in the development and use of GIS. Examples are the use of the scientific method, statistical techniques to estimate and describe error, and probabilistic methods for determining membership in a group. More fundamental influences are conceptual systems such as Cartesian space [from Rene Descartes (1596-1650)] that governs the way entities are located in space and measured in GIS, and Boolean logic [from George Boole (1815-1864)] that provides GIS analysts with basic means of combining and selecting data.

Fig. 4 presents a model of communication for GIS. This model is useful as a heuristic device to understand influences on the representation of reality presented using GIS. There are four issues that the model implies: 1) software engineers embed certain ways of representing spatial and non-spatial entities in the GIS software; 2) institutions and individual database designers select phenomena from the real world, and collect and digitize data about such phenomena in the construction of GIS databases; 3) GIS analysts, working within the epistemology allowed by the software and with data constructed by database designers, interpret the needs of end users and produce GIS output; and 4) end users interpret GIS products, and this interpretation is influenced by their own set of purposes, experience of the world and worldview. Though I have listed these issues separately, they will not always manifest apart from one another. For example, the database designer might also be the GIS analyst.

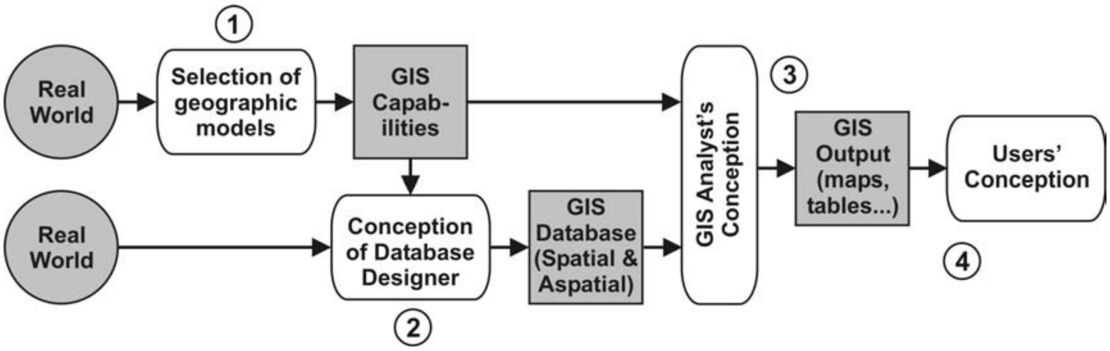

Fig. 4

A model of communication for GIS that highlights the roles of the software engineers, database designers, GIS analysts, and end users of GIS products.

Embedded Ways of Knowing

In the creation of GIS, the developers of GIS software construct a system for representation of the real world ("1" in Fig. 4). This involves selection of geographic models with which to represent reality. Specifically, GIS employ concepts and systems such as Cartesian space, Pythagorean geometry and Boolean logic to represent and manipulate spatial entities (28). Furthermore, based on such fundamental representations are selections of tools and techniques by software designers to supply to GIS analysts. For example, many GIS provide the facility to represent or derive topological relationships (such as connectivity, adjacency, inclusion, exclusion, intersection and co-location) among spatial entities. Another example of methods and techniques that encode particular ways of analysing and understanding geographic phenomena are the provision of standard models in GIS. These are often packaged as GIS tools for analysis of such phenomena and processes as watersheds and soil erosion.

In this way GIS developers encode a particular way of knowing into the GIS, and restrict the tools available to analysts to those the developer considers relevant. They dictate how the real world may be represented and analysed using GIS. This is what Obermeyer (23) refers to as "the hidden GIS technocracy." The situation is alleviated somewhat by the possibility to extend the functionality of many GIS. For example, GIS analysts may develop new modules for modelling and analysis that are not provided by the developers of the core software. Many GIS incorporate or support programming tools for this purpose. Still, this requires facility in programming, and ultimately "there are fundamental limits to the ways in which alternative notions of time and space, or narrative and chronology, can be represented" using GIS technology (9).

Selection and Encoding of Geographic Phenomena

The second row of the model ("2" in Fig. 4) represents the process whereby GIS database developers select phenomena from the real world and encode this in the GIS. In doing so they are constrained to ways of representing phenomena encoded by software developers. Also, selection of relevant features by database developers is informed by the developers' intentions, training, worldview and the constellation of issues, such as institutional mandate and standard procedures, identified by Chrisman (8). The same is true for how such features are measured, generalized and categorized. Thus, developers of GIS databases determine what is represented as real in GIS (1), within the bounds of what can be represented in the GIS.

Whether the resulting representation of reality, that has been created to support a particular decision or decision-making process, corresponds to the perception of reality held by those affected by GIS-supported decisions is a different matter entirely. Consider, for example, a GIS database created by the Tamil Nadu Slum Clearance Board. For this agency slums are a problem to be dealt with by clearance or improvement. A GIS database constructed by such an agency may not incorporate information (or even correspond spatially) to what may be considered important to slum dwellers, for whom slums are a solution to the problem of homelessness and proximity to employment opportunities.

Analysis and Interpretation using GIS

GIS analysts work with the conception of reality created by database designers and software engineers to present a picture of the real world that is also influenced by their own perceptions ("3" in Fig. 4). A number of authors indicate that the use of GIS is often expert-oriented, elitist and can even be anti-democratic (e.g. 1, 10, 20, 23). GIS analysts are highly skilled and trained in a rational-positivist paradigm. Their approach to any particular problem (including their selection of GIS tools and what is considered to be 'good' data) will thus be influenced by a "scientific" worldview. GIS analysts interpret user needs and make decisions about the spatial extent of data to be analysed, the means of analysis and the type of output (such as maps, tables, charts and summary statistics) to provide end users.

End users are presented with the results of a process that is embedded in an epistemology that is scientific, expert-oriented and data driven ("4" in Fig. 4). This is widely regarded as a legitimate perspective. GIS output is typically evaluated by how scientifically rigorous the process of its production has been. In support of a particular decision, end users interpret GIS output (e.g., maps, tables, charts, summary statistics) and arrive at their own conceptions of reality based on the GIS-produced evidence and their own purposes, worldviews and knowledge sets.

The Potential for Marginalization and Participation in GIS

Harris and Weiner (13) identify three ways that the use of geographic information systems can contribute to social and spatial marginalization. They are: 1) data access and the political economy of information; 2) geo-demographics and the surveillant capabilities of GIS; and 3) GIS epistemologies, and the multiple realities of landscape. My concern in environmental management and planning is with the first and last of these categories. For a discussion of geo-demographics and the surveillant capabilities of GIS, the reader is referred to the paper by Goss (11).

The first category (data access and the political economy of information) refers to the fact that GIS and the transmission of geographic information are neither objective nor value-free (13). Rather, GIS is a socially constructed technology (33). Because of the politics and power relationships associated with environmental management and planning, access to both data and GIS technology will not be equal for all groups. Those who produce and control the data may exclude less powerful groups from its use. Furthermore, not all groups will have the funds, skill and education to use GIS even if physical access to hardware, software and data is not an issue. The institutional location of most GIS also erects barriers - leading to bureaucratization of the technology and distortion of knowledge (30 in 13).

The third category (GIS epistemologies, and the multiple realities of landscape) indicates that "GIS technology captures one official version of reality that is heavily biased toward a scientific, agency, and "expert" data-driven representation" (13). Alternative forms of knowledge, that may be represented and transmitted for example, via sketch maps, narratives and oral histories, are generally excluded from GIS. There are, however, "multiple realities of landscape" that are based on multiple perspectives of stakeholders in environmental management and planning situations, and on epistemologies that do not depend on, and may not be compatible with concepts of Cartesian space, Boolean logic and the kind of spatial primitives realized in GIS. It has been found for example that local and traditional knowledge systems exist in parallel to scientific knowledge, and that this can improve understanding of environmental and resource management problems (2, 19).

Awareness and consideration of such issues in GIS, however, leads to the conclusion that applications of GIS in a manner that is informed by, and sensitive to differential access and multiple epistemologies may empower previously excluded groups. Some GIS practitioners have realized this and have proposed or attempted to use GIS for public engagement, equity, empowerment of previously marginalised groups, and representation of traditional knowledge (see for example, 10, 13, 15, 18, 31, 34). Richard Chase Smith (29), for example, used GIS to attempt to empower indigenous communities in the Amazon Basin. His team used transect walks, season calendars and local histories to interpret remote sensing imagery and produce land use and territory maps on which to base long-range resource management plans. Beverly Bird (3) described attempts (through the EAGLE project) to integrate traditional knowledge into scientific methodologies and representations in GIS, and to build GIS capacity in indigenous communities in Ontario, Canada.

Participation and GIS: An Example from Research in South India

Overview of the Cooum River Environmental Management Research Programme

Research undertaken in recent years in Chennai demonstrates that an awareness of the potential of GIS for marginalization can inform a process that stimulates participation. The example is taken from the Cooum River Environmental Management Research Programme (4). This was an independent research programme undertaken in the late 1990s to support rehabilitation and management of the Cooum River, an extremely polluted and prominent urban stream that flows through the centre of the Chennai Metropolitan Area to the Cholamandalam Coast (the Coromandal Coast) on the Bay of Bengal. The problem of the Cooum River is long standing. For decades well-intentioned management by agencies such as the Tamil Nadu Public Works Department, the Corporation of Chennai, the Tamil Nadu Slum Clearance Board and the Chennai Metropolitan Water Supply and Sewerage Board have failed to improve the situation. The Cooum remains a foul-smelling open sewer.

The research programme adopted an 'Ecosystem Approach' (17) that was influenced by Adaptive Management (12, 14, 22, 32). Typical in adaptive management programmes is the collaborative development of simulation models and their use to explore management scenarios. To this end, in the Cooum River research, a GIS was loosely coupled with an environmental model, and a user interface for the construction of exploratory management scenarios was developed. This acted as a decision support system (DSS) that was a key learning tool, and the use of which fostered collaboration among stakeholders.

Two workshops in 1998 and 1999 were organized in which participants from various government agencies and departments, environmental NGOs, representatives of private corporations and the public-at-large worked together to develop a conceptual model of the Cooum River environmental system, generate a framework for the GIS-based DSS, identify key data, develop simple management scenarios, and perform simulations based on those scenarios. The process is described in detail elsewhere (4, 5, 6).

Collaborative Development of a Conceptual Model

The research programme included a set of exercises in the first workshop for the development of a conceptual model of the Cooum River situation. This was intended to inform a framework for a Decision Support System (DSS) and simulation model that would be used to develop and explore management scenarios for the Cooum River environmental system. The first workshop involved forty nine stakeholders (from eight government agencies and departments, eight environmental, heritage and business NGOs, academics from a variety of disciplines, and Chennai citizens) in problem-identification exercises, 'Rich Picture' diagrammatic expression of the problem, modelling of subsystems of human activity, temporal and spatial scoping exercises, generation of objectives for management of the system and linking indicators to management objectives (Fig. 5). This 3-day workshop produced a

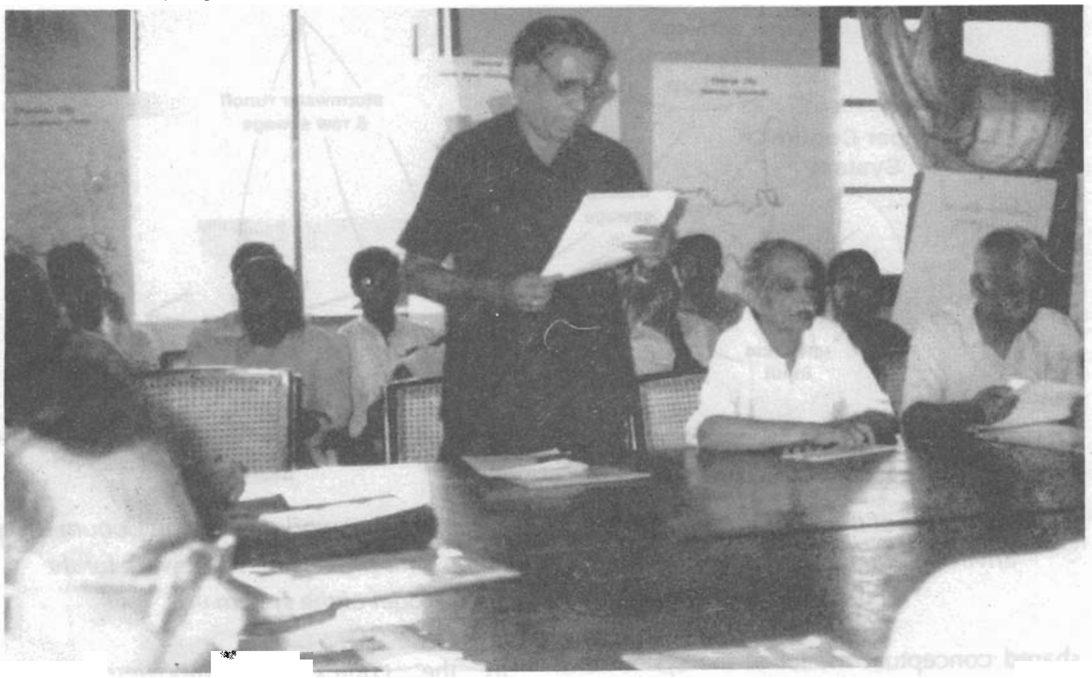

Fig 5

Presentation of breakout session results by participants at one of the Cooum River Environmental Management Research Programme workshops.

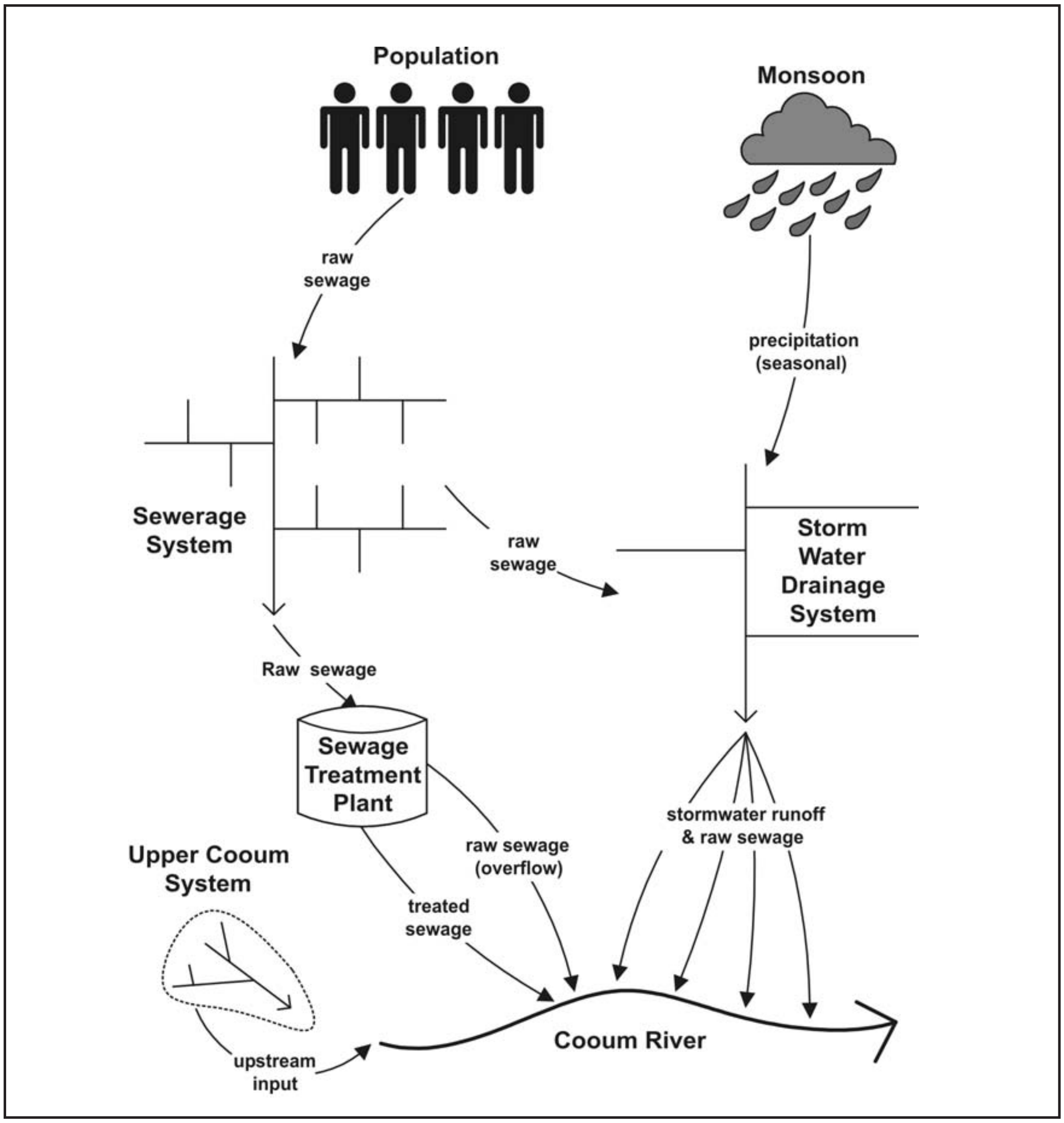

Fig. 6

Core structure of the Cooum system as it emerged from the first workshop of the Cooum River Environmental Management Research Programme. This provided a framework for the construction of a computer simulation model of the system (4).

shared conceptual model of the system that informed a framework for the DSS that is presented in Fig. 6.

In the context ofempowerment and marginalization in GIS, this process was illuminating. The reader should note that the process was undertaken without consideration for the capabilities of any particular GIS, nor for the availability and quality of data. The exercise was multi-stakeholder, so the description of the system that arose from the workshop was not tied to the mandate of any particular agency. Because of this, the process generated a more appropriate (i.e., less disciplinary and less jurisdictional) model for managing the Cooum system than had been used in the past.

The model that arose identified a system that workshop participants variously described as an "urban system" or a "waste disposal system." In contrast, previous management had employed a physical description of the Cooum as a river system. Spatially, participants identified and separated out the lower (urban) Cooum as the system of interest. The upper Cooum, outside of the city, was thought to be characterized by different processes and actors. Once again, this was a change from the standard government agency/department conceptualization of the system that does not distinguish between rural and urban reaches of the river and watershed. Furthermore, the processes identified as most important in the situation were tied to human activity. Subsystems were modelled as human activity systems, and as the research programme progressed, this influenced the type of management interventions explored.

The first workshop generated a shared conceptual model and a framework on which to build a DSS. This information was used to construct the Cooum River Environmental Management Decision Support System (Cooum DSS). This GIS-based DSS had three main modules: the GIS module, the DSS module, and the water quality simulation module.

The Cooum River Environmental Management Decision Support System

The GIS Module

Workshop participants developed an understanding of the system that was characterized by activity of the Chennai population to produce sewage, and route this sewage by way of the storm water drainage system and the sewerage system to rivers and canals in the city. A strong theme that arose in discussing the population was that of slums - pockets of urban poverty, haphazard development and un-serviced communities scattered throughout the city. Accordingly, the four main spatial data layers developed for the GIS database were corporation divisions (wards) in the city (that could be associated with a variety of population attributes such as income distribution, water consumption, and proportion of water consumed that is produced as sewage), slum locations (that modify the proportion of population in a ward that is serviced by the sewerage system), urban stormwater drainage catchments (SWD), and sewerage catchments (that together with the SWD catchments was used to route sewage produced by the population to the waterways, or to a sewage treatment plant).

GRASSLANDS GIS (21), a Windows version of the public domain GIS GRASS (Geographic Resources Analysis Support System) was used to store and manage the database. This was a low-cost and accessible GIS that was extremely extensible since both its underlying (open) source code (in C) and

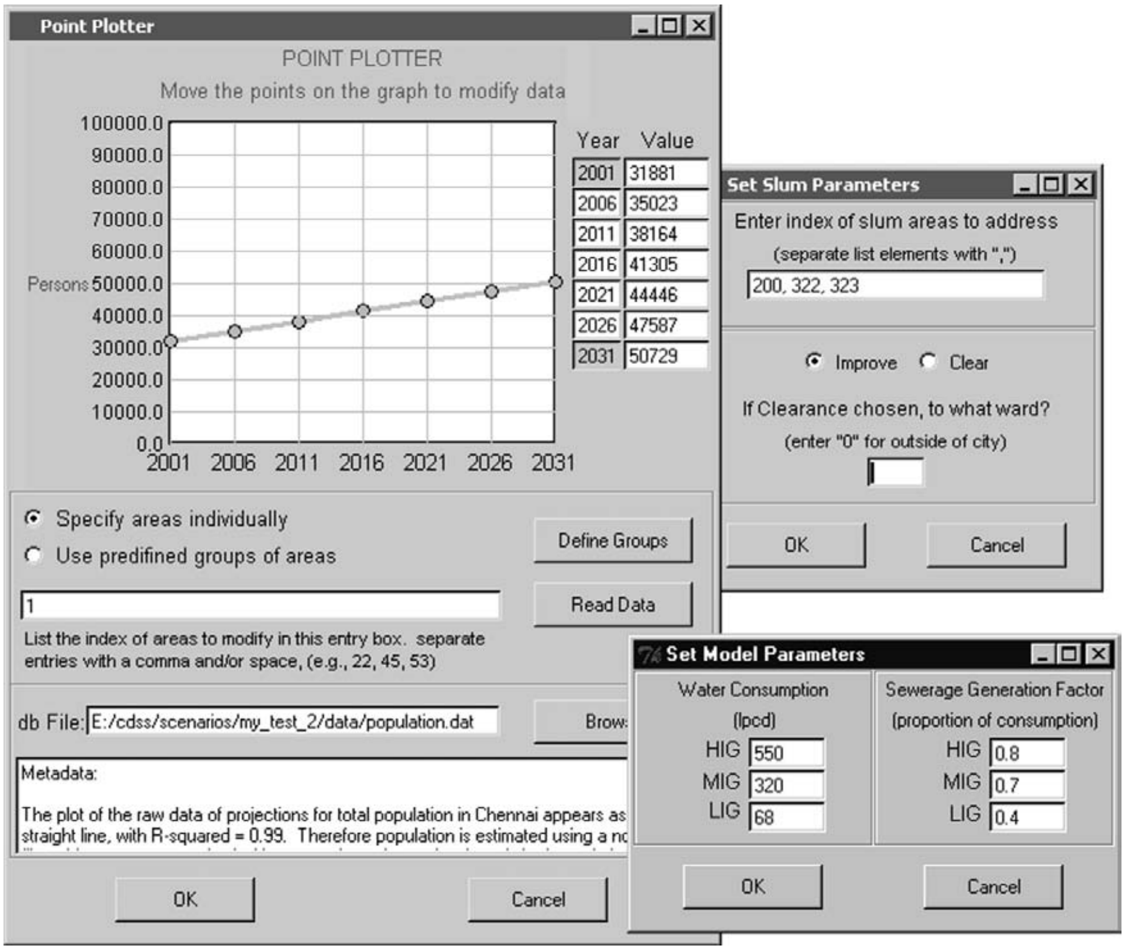

Fig. 7

Three of the tools in the Cooum River Environmental Management Decision Support System (Cooum DSS) that collect management scenario parameters from users.

user interface (in TCL/TK) could be accessed and modified by a knowledgeable user. The open source interpreted programming language TCL/TK is installed with the programme for the development of user interfaces and automation of tasks. As discussed earlier, extensible GIS is one way that decisions about what can be represented in GIS (and how it can be represented) may be moved forward in the GIS production process (Fig. 4). Open source software facilitates this by allowing access to source code of software so that it can be modified to suit the purpose at hand.

Attributes of the data layers were stored in comma delimited text files and linked to GRASS format vector layers via standard Object Database Connectivity (ODBC) tools on the Windows platform. The GIS data layers and associated attributes provided the basic spatial data employed by the DSS module to parametize the water quality simulation model.

The DSS Module

A user interface to the DSS was developed in TCL/TK. This interface presented users with a series of tools to develop management scenarios. The selection of tools was derived from participant discussion in the first workshop having to do with potential management interventions and management objectives. For example, using the DSS, users may undertake "what-if" analysis by changing ward population, population growth rates and income distribution in any or all wards in the city. They could also speculate about the impact of clearing slums (removing the population to serviced areas in other wards or to outside of the city) or improving them (providing slums with sewerage service in situ). Other tools for building management scenarios provided the capability to modify water consumption figures, sewage generation factors (a ratio of sewage production to water consumption), and environmental data such as rainfall and upstream input to the system. Fig. 7 shows some of the DSS tools. The DSS parametization tools called routines programmed in C/C++ that modified the data files and parametized the water quality simulation model.

The Water Quality Simulation Module

Participants in the programme of research considered water quality indicators to be inclicators of the state of the overall Cooum system. Because of this, the DESERT (DEcision Support System for Evaluating River Basin sTrategies) (16) water quality and hydraulic simulation system was coupled to the GIS to simulate 5-day biochemical oxygen demand (BOD5), dissolved oxygen (DO) and ammonia-nitrogen (NH3-N). DESERT is a free and extensible hydrologic modelling system. Hydraulic variables were simulated using the steady state (diffusion wave) method and water quality was simulated with the mass transport (mesh, steady state) method. Output from DESERT could be stored in text or excel files and presented in chart form.

Development of Exploratory Management Scenarios and Simulation Modelling

At the second workshop in 1999 fifty-two participants from government, NGOs, academe and others used the Cooum River DSS to collaboratively develop exploratory management scenarios (Fig. 8). These explored the impact on water quality indicators of simple, single intervention management scenarios. Exploratory management scenarios included baseline scenarios (for monsoon ancl dry seasons), improvement of slums (provision of sewerage service), increased capacity of the Koyembedu sewerage treatment plant (STP), improved treatment technology at the STP, in-migration/natural increase at the city periphery, and increased upstream input from the upper Cooum system. Development of these scenarios generated much debate

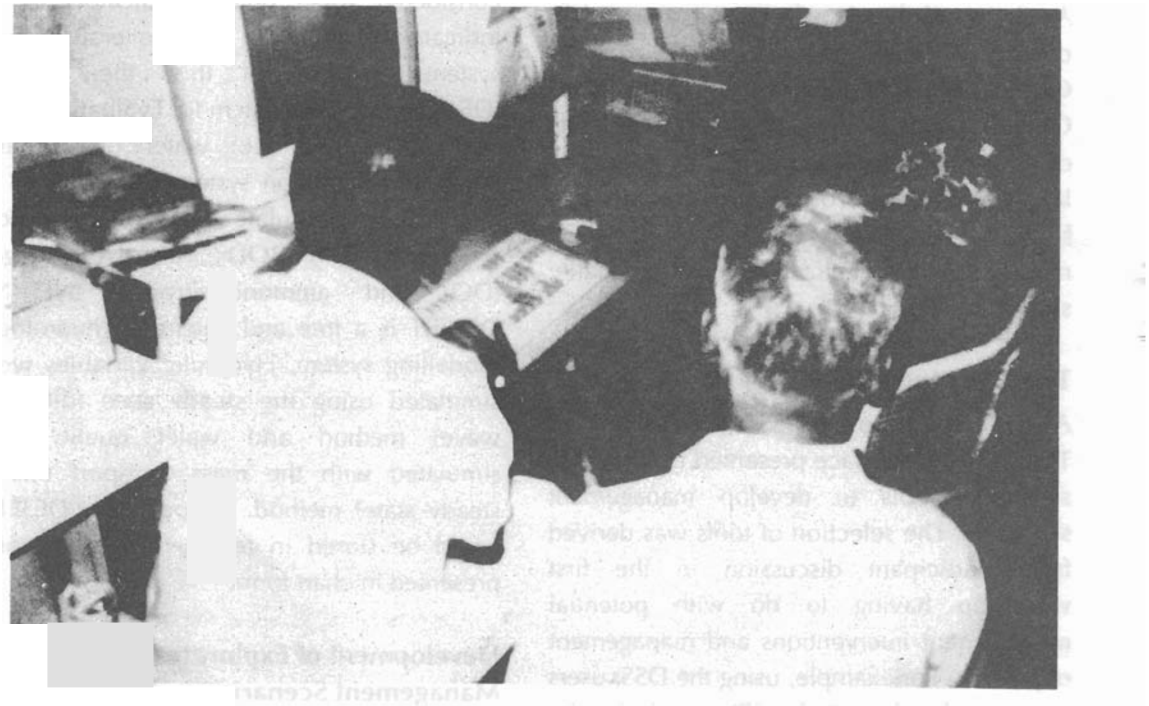

Fig. 8
Collaborative development of exploratory management scenarios in the second workshop of the Cooum River Environmental Management Research Programme

among participants. Because the Cooum DSS made the relationships expressed by participants in the first workshop operational, and because it required specification of parameters such as water consumption of various income groups, treatment capacity at Koyembedu STP and water quality characteristics of sewage, the participants re-examined assumptions made in the first workshop and improved the conceptual model of the Cooum system. For example, they specified a relationship among income, water consumption and water quality characteristics of raw sewage that had not been made in the first workshop.

In this way GIS and environmental modelling were used as adaptive learning tools. Instead of a 'black box' producing forecasts of future system states, the Cooum DSS was open to scrutiny by stakeholders. In fact, because of participants' integral involvement in developing the conceptual model and framework for the DSS, ownership of both the process and of the product (the Cooum DSS and simulation results) was transferred to participants.

Another important characteristic of the process was that provision in the DSS to acquire a wide variety of parameters from the user allowed expression of alternative future visions of the system. This, coupled with a conceptual model that crossed jurisdictional and disciplinary boundaries and the participation of key stakeholders, resulted in a "landscape of reality" represented in the Cooum DSS that was more oriented to the problem of rehabilitation of the Cooum River environmental system than to management of the river within jurisdictional and disciplinary boundaries. This led to important differences in recommendations for intervention from previous management processes. In the past, management has been constrained by jurisdictional fragmentation and lack of communication and collaboration among government agencies and departments. Management of the situation has been restricted to physical and engineering sorts of interventions. These have dealt with pollution at the "end of pipe". In contrast, as the workshops progressed, participants more and more identified management interventions to deal with the pollution at its source. That is, they addressed the activity of the population of Chennai, rather than dealing with remedial action on the river. Such interventions are likely to be more difficult to implement, but are also more likely to lead to long-term improvement of the situation.

Conclusions

Some of the ways that communities may be marginalised in the use of GIS are 1) selective participation in the definition of what is "real" in GIS, 2) control of access to data and GIS technology, and 3) an official, version of reality that is biased toward a scientific, "expert" and data-driven representation. In the Cooum River Environmental Management Research Programme, an awareness of such issues led instead to an expansion of communities involved in defining what is "Real" in GIS from one or two government agencies and departments to a broader range of government, NGOs, academic and citizen representatives. These were involved from the beginning of the programme in such activities as problem definition, system conceptualization, and expression of key relationships. Not all stakeholders were involved, however. This was an educated, English-speaking group. Some stakeholders, such as slum dwellers, were not directly represented. Future research will attempt to correct this problem.

The research also highlighted data access issues. In the Chennai context data is tightly controlled and accessible data is of poor quality. Because the "black box" of environmental models was illuminated in this work, and because users were asked to specify scenario parameters, these issues were brought to the fore. In fact, participants resolved to establish a working group to pursue such issues so that modelling exercises could be improved.

In this work the narrow focus brought about by over-dependence on an engineering-oriented reductionist model was also alleviated. Participants developed a model that was free of jurisdictional and disciplinary constraints. This is a better model for rehabilitation and management of the Cooum, though in a setting where institutional collaboration is difficult, its implementation may be problematic. In addition, participants explored narratives (for example, the behaviour of Chennai citizens and potential tourism systems centred on Chennai waterways) not just scientific models and forecasts. Overall, participants modelled human activity and targeted it for intervention. This focus on the source of the problem, rather than on its symptoms, is ultimately more appropriate and if the institutional environment allows, could be much more effective than merely attempting to clean up the river after the population has acted to pollute it.

Acknowledgements

An earlier version of this paper was presented at the Platinum Jubilee of the Indian Geographical Society, August 23-25, 2002, at the Tamil University, Thanjavur, India. The author wishes to acknowledge the Madras-Waterloo University Linkage Programme and CUC-AIT for logistical and financial support for parts of this research, Dr. D. Dudycha and Dr. B. Hyma for their guidance, Dr. S. Subbiah and his colleagues at the Department of Geography at the University of Madras for hosting field activities related to this work, and participants in the research programme for their individual and collective contributions.

References

1. Aitken S and S. Michel (1995). 'Who Contrives the 'Real' in GIS? Geographic Information, Planning and Critical Theory', *Cartography and Geographic Information Systems,* 22(1), pp.17-29.
2. Berkes F and C. Folke (1998). 'Linking Social and Ecological Systems for Resilience and Sustainability' in Berkes and Folke (eds.) *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience.* Cambridge: Cambridge University Press.
3. Bird B (1995). 'The EAGLE Project: Re-mapping Canada from an Indigenous Perspective', *Cultural Survival Quarterly,* 18(5), pp.23-24.
4. Bunch M.J. (2001). *An Adaptive Ecosystem Approach for Rehabilitation and Management of the Cooum River Environmental System in Chennai, India.* Geography Publication Series No.54. Waterloo, ON: University of Waterloo.
5. Bunch M.J. (2003). 'Soft Systems Methodology and the Ecosystem Approach: A System Study of the Cooum River and Environs in Chennai, India', *Environmental Management,* 31(2), pp.182-197.
6. Bunch M.J. and D.J. Dudycha (2003). 'Linking Conceptual and Simulation Models of the Cooum River: Collaborative Development of a GIS-based DSS for Environmental Management', *Computers, Environment and Urban Systems,* (In Press).
7. Burrough P.A (1986). *Principles of Geographic Information Systems for Land Resources Assessment.* Oxford: Clarendon Press.
8. Chrisman N.R (1987). 'Design of Geographic Information Systems Based on Social and Cultural Goals', *Photogrammetric Engineering and Remote Sensing,* 53(10), pp.1367-1370.
9. Curry M (1994). 'Image, Practice and Hidden Impacts of Geographic Information Systems,' *Progress in Human Geography,* 18(4), pp. 441-459.
10. Ghose R (2001). 'Use of Information Technology for Community Empowerment: Transforming Geographic Information Systems into Community Information Systems,' *Transactions in GIS,* 5 (2), pp.141-163.
11. Goss J. (1995). 'We Know Who You Are and We Know Where You Live': The Instrumental Rationality of Geodemographic Systems, *Economic Geography,* 71(2), pp.171-198.

12. Gunderson L.H, C.S. Holling and S.S. Light (1995). Barriers and Bridges to the Renewal of Ecosystems and Institutions. New York: Columbia University Press.

13. Harris T and D. Weiner (1998). 'Empowerment, Marginalization and 'Community-integrated' GIS', Cartography and Geographic Information Systems, 25(2), pp. 67-76.

14. Holling C.S (1978) Adaptive Environmental Assessment and Management. Toronto: International Institute for Applied Systems Analysis.

15. Hutchinson C.F and J. Toledano (1993). 'Guidelines for Demonstrating Geographical Information Systems Based on Participatory Development', International Journal of Geographical Information Systems, 7(5), pp. 453-461.

16. Ivanov P, I. Maslieu, M. Kularathna C. De Marchi and L. Somlyody (1996). Decision Support System for Evaluating River Basin Strategies (DESERT): Users Manual. Laxenburg, Austria: International Institute for Applied Systems Analysis.

17. Kay J.J, Boyle, H.A. Regier and G. Francis (1999). 'An Ecosystem Approach for Sustainability: Addressing the Challenge of Complexity', Futures, 31 (7), pp.721-742.

18. Kyem P.A.K (1999). 'Examining the Discourse About the Transfer of GIS Technology to Traditionally Non-Western Societies', Social Science Computer Review, 17(1), pp.69-73.

19. Laituri M (2002). 'Ensuring Access to GIS for Marginal Societies' in Community Participation and Geographic Information Systems, W.J. Craig, T.M. Harris and D. Weiner, eds. New York: Taylor and Francis, Inc.

20. Lake R (1993). 'Planning and Applied Geography: Positivism, Ethics and Geographic Information Systems', Progress in Human Geography, 17(3), pp.404-413.

21. L.A.S (1996). GRASSLAND User's Guide for Windows 95 and Windows NT, Version 1.1, Montreal: Logiciels et Applications Scientifiques (L.A.S.) Inc. (now Global Geomatics Inc.).

22. Lee K.N (1993). Compass and Gyroscope: Integrating Science and Politics for the Environment Washington, D.C.: Island Press.

23. Obermeyer N (1995). 'The Hidden GIS Technocracy', Cartography and Geographic Information Systems, 22(1), pp.78-83.

24. Raper J (2000). Multidimensional Geographic Information Science. New York: Taylor and Francis, Inc.

25. Robinson A and B. Petchenik (1976). The Nature of Maps: Essays Towards Understanding Maps and Mapping. Chicago: University of Chicago Press.

26. Rundstrom R (1995). GIS, Indigenous Peoples and Epistemological Diversity', Cartography and Geographic Information Systems, 22(1), pp. 45-57.

27. Sahay S (1998). 'Implementing GIS Technology in India: Some Issues of Time and Space', Accounting, Management and Information Technologies, 8, pp.147-188.

28. Sheppard E (1995). 'GIS and Society: Towards a Research Agenda', Cartography and Geographic Information Systems, 22(1), pp.5-16.

29. Smith R.C (1995). 'GIS and Long Range Economic Planning for Indigenous Territories', Cultural Survival Quarterly, 18(5), pp.43-48.

30. Taylor P.J (1991). 'A Distorted World of Knowledge', Journal of Geography and Higher Education, 15, pp.85-90.

31. Tulloch D.I. and E. Epstein (2002). 'Benefits of Community MPLIS: Efficiency, Effectiveness,

Equity,' Transactions in *GIS* 6(2), pp.195-211.

32. Walters C (1986). Adaptive Management of Renewable Resources. New York: Macmillan Publishing Company.

33. Warren S (1995). 'Teaching GIS as a Socially Constructed Technology', Cartography and Geographic Information Systems, 22(1), pp.70-77.

34. Weiner D, T. Warner, T. Harris and R. Levin (1995). 'Apartheid Representations in a Digital Landscape: CIS, Remote Sensing and Local Knowledge in Kiepersol, South Africa, Cartography *and* Geographic Information Systems, 22(1), pp.45-57.