Using Geographic Information Systems (GIS) For Spatial Planning and Environmental Management in India: Critical Considerations

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Abstract

Geographic Information Systems (GIS) are computer-based tools used to collect, store, manipulate and display spatially-referenced information. They are used to support decision-making in a wide variety of contexts, including spatial planning and environmental management. Because the process of GIS production, from software development to visualization of GIS output, is characterized by political, economic and social motivations, it is important that GIS practitioners are aware of issues such as access to data and the political economy of information, and the nature of GIS epistemologies vis-à-vis multiple coexisting perceptions of reality. Lack of such appreciation can lead to social and spatial marginalization of communities. Use of GIS in a research program for environmental management of the Cooum River in Chennai, and in support of participatory processes for managing environment and health in slums are used to demonstrate appropriate applications of GIS in India. Internet-distributed GIS as a potential avenue to address issues of public access to data is also considered.

Keywords: geographic information systems; GIS; participatory GIS; PGIS; Critical GIS; GIS and society; public participation; Chennai, India; GIS and development

1. Introduction

Geographic Information Systems (GIS) are a powerful set of computer-based tools used to collect, store, manipulate, analyze and display spatially referenced information (Burrough and McDonnell 1998). They transform data into knowledge and present this knowledge in various formats for the purpose of supporting decisions. GIS are usually portrayed as knowledge-based and free from bias, but in fact GIS is a socially constructed technology (Warren 1995). The process of GIS production, from data creation to analysis to visualization and use of GIS output, is characterized by political, economic and social motivations that bias their use.

It is thus important that GIS practitioners are aware of issues such as: access to data and the political economy of information, and multiple coexisting perceptions of reality and epistemologies that dominate or, alternatively, might usefully inform applications of GIS. As Harris and Weiner (1998) pointed out, lack of appreciation of these issues can lead to social and spatial marginalization of communities. Informed by discussion of such issues in the 'GIS and Society' or 'Critical GIS' literature, subfields of Public Participation GIS (PPGIS) and Participatory GIS (PGIS) have arisen.

While this will be a familiar tune to experts in these subfields (who are often based in Universities) many practitioners will have been trained (and practice) without attention to these themes in GIS. We contend that a sensitivity to such matters is important both for GIS 'experts' and technicians and for those non-users who many want to draw upon this exceptionally useful set of tools in multi- and interdisciplinary projects. This is particularly important when projects involve potentially marginalized peoples, as is often found in 'development' contexts in the Global South. Schuurman (2006) pointed out that there is a gap between the abstract conceptual presentation of Critical GIS and the formalization of these concepts to inform the application of the technology. For this reason we present an overview of critical considerations for the use of GIS, representing this using a simple model of GIS communication as a heuristic device intended to illustrate the relevance of these concepts to GIS practitioners. We illustrate this with examples from our own experience working with GIS in India since the early 1990s.

Indians have been enthusiastically and rapidly adopting GIS and remote sensing technology over the past 15 years. In this adoption, technical expertise in the geomatics fields has tended to be concentrated in scientific research centers, and the related initiatives and programs have been top-town and datacentric (Walsham and Sahay 1999; Geogiadou et al. 2005; Singh 2005). Also, because the development and application of GIS technology is largely rooted in a logical positivist (scientific) epistemology that is widely accepted as legitimate, the technology tends to be embraced uncritically.

With specific reference to India, we argue in this paper that the use of GIS that is informed by interpretive and participatory approaches (which we present as complementary to scientific expertise) can help to avoid some of the pitfalls identified in the Critical GIS literature, and can lead to empowering applications of GIS that are appropriate to socially responsible and sustainable development. The ultimate aim is to improve the efficacy of environmental management and spatial planning efforts in development projects and programs that might employ GIS tools, leading to improved outcomes for stakeholders and actors. There is a growing literature to support such a stance (see for example bibliographies at http://ppgis.iapad.org/) but case studies in India are sparse. We first present issues associated with 'GIS and Society' or 'Critical GIS.' We then review two projects in Chennai, India in which we used GIS in a PPGIS or PGIS role: for decision-support in an environmental management research program focused on the Cooum River, and in support of participatory processes to manage environment and health in slum areas. In addition, the use of internet-distributed GIS (web-GIS) is presented as a potential avenue to address issues of public access to data.

2. GIS and the potential for marginalization in spatial planning and environmental management

In the early- to mid-1990s, the literature on GIS began to demonstrate concerns about the use of GIS in regard to its social and political impacts (Sheppard 2005; Schuurman 2006). Part of this concern had to do with the fact that GIS advances an instrumental rationalist approach to decision-making (Elwood 2002). Instrumental rationalism is a western scientific worldview that is characterized by positivism and empiricism. This is not to say that such a perspective is not valid, nor its associated methods useful. However, because GIS is employed in situations where this paradigm is already dominant, it tends to reinforce instrumental rationalist decision-making to the potential exclusion of other valid and important perspectives. Such perspectives may contribute understanding that is complementary to scientific knowledge, and thus, can improve decision-making. For example, Sahay (1998) notes that in India ``assumptions of time and space vary significantly from those inscribed in GIS technology." For instance, because of the scientific mathematical and cartographic underpinnings of GIS, the technology tends to present spatial relationships objectively – as a spatial reality 'out there' that can be controlled and manipulated. Sahay contends that this poses a conceptual problem to the Indian tradition in which notions of time and space are more subjective, and in which "constructions of space are … more strongly associated with notions of 'place,' and to be 'in-here,' as an integral element of social reality." How then can GIS representations be trusted to 'accurately' reflect the local reality?

While this has not been the experience of the Indian authors of this paper (*Names removed for review purposes*) who were reared in Western thinking in the Indian educational system, this could be the case for less advantaged sections of the population. If legitimacy of input to decision-making is restricted to those who share the expert-oriented western scientific approach, then the result of the GIS-supported decision-making process is likely to be based on incomplete understanding of the situation. Local knowledge and traditional knowledge, for example, could easily be excluded.

One implication of this is that decisions and interventions that do not incorporate the worldview and understandings of relevant stakeholders are not likely to be supported by those stakeholders. This could undermine the success of spatial planning and environmental management efforts. Harris and Weiner noted that lack of appreciation of issues of "GIS epistemologies, and the multiple realities of landscape" is one way that the use of GIS can lead to social and spatial marginalization (Harris and Weiner 1998). A related issue that may contribute to marginalization through the use of GIS is that of data access and the political economy of information (Harris and Weiner 1998). For example, access to both GIS data and GIS technology is not equal for all groups: less powerful groups may be excluded from access to data; poor communities or organizations may not have the resources to purchase computers or GIS software, and not all groups will have the skills or education to make use of GIS technology even if GIS tools and appropriate data are available. Furthermore, it has been known for some time that the institutional location of many GIS also creates barriers that lead to the bureaucratization of GIS technology and the distortion of knowledge (Taylor 1991).

The situation in India today demonstrates many of these concerns. Many initiatives arose in the last decade in India to develop and disseminate digital spatial data for use in GIS. For example, Singh (2005) reported on the National (Natural) Resources Information System (NRIS) (Department of Space), the Natural Resources Data Management System (NRDMS) program (Department of Science and Technology), the Geographical Information System initiative of the National Informatics Centre (GISNIC), and other initiatives such as the large-scale mapping project of the National Natural Resource Management System (NNRMS), the space-enabled Village Resources Centre (VRC) initiative, and the emerging National Spatial Data Infrastructure (NSDI). Other large-scale mapping initiatives also exist, such as the Utility Mapping Project of the National Informatics Centre (GOI 2007), as well as many more-focused projects such as inundation mapping spurred by the 2004 tsunami (Kumar et al. 2008).

In India expertise and access to geomatics technology and data tend to reside in departments and institutions among which coordination and communication for spatial data development and project implementation is poor (Walsham and Sahay 1999). Furthermore, in top-down development and management of such programs there is a tendency to foster a (scientific) expert-oriented, data-driven, technological "remote sensing and GIS bias." This is an approach to spatial planning and environmental management that depends on scientists and technologists to parameterize problems, make appropriate measurements to generate data, and apply the technology for the scientific analysis of spatial data. Singh (2005) for example, in his discussion of the National Informatics Centre's (NIC) GIS initiative, notes that the program is intended to support development planning at the district level, but that district offices are still at an early stage of computerization, and applications of GISNIC, housed primarily in scientific research centers "reflected the remote-sensing and GIS bias, and often resulted in other socio-economic considerations not being given adequate emphasis" (Singh 2005:234). Similarly, Georgiadou et al. (2005) noted that in the case of the NSDI, development has been top-down and datacentric showing "little evidence of systematic interaction between its developers (the scientific institutions) and potential end users (for example, district administration) to understand their information needs."

Figure 1 presents a simple model of communication for GIS that aims to illuminate some key locations in the GIS production process (from software development to interpretation and use of GIS output) at which bias may be introduced (Bunch 2001a). This model is informed by the Critical GIS literature and earlier work by Robinson and Petchenik (1976) and Chrisman (1987). Its purpose is to embody some of the understanding in the Critical GIS literature, acting as a heuristic device to help bridge the gap between conceptualization and formalization in Critical GIS identified by Schuurman (2006), so that GIS practice avoids marginalization, and so that its use may instead lead to empowerment of stakeholder groups and communities. We use this model to inform discussion of the case studies presented later in this paper.

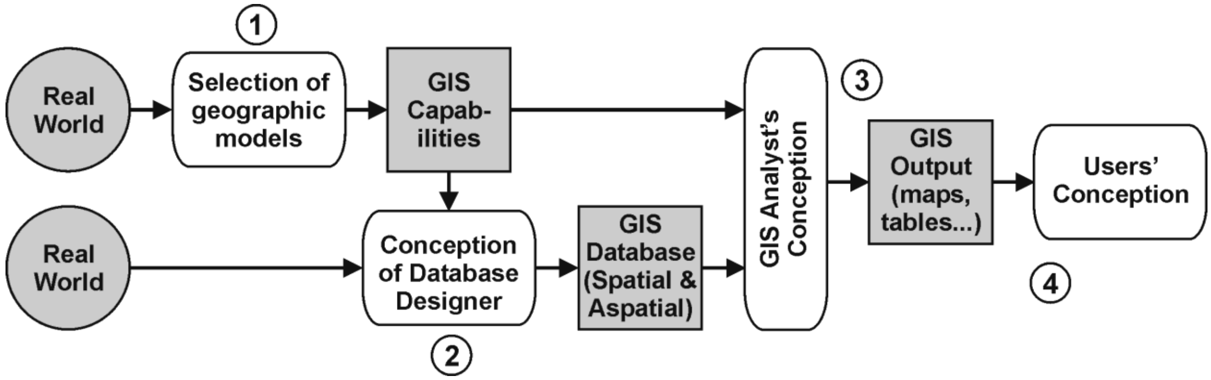


Figure 1: A model of communication for GIS (Bunch, 2001a).

The model describes a process in which the real world is first interpreted by the developers of GIS software ('1' in Figure 1). Developers embed their own understanding of how to encode, manipulate, analyze and represent spatial entities in the technology, for example, the use of Cartesian spatial systems, Pythagorean geometry and Boolean logic (Sheppard 1995). GIS developers also select and create GIS tools and capabilities for data collection, representation, storage, analysis and visualization. Because GIS developers encode their own understandings into GIS software, and also restrict the capabilities of GIS to those they deem useful and relevant to GIS analysts, they dictate how the world is represented in GIS. They are who Nancy Obermeyer refers to as "the hidden GIS technocracy" (Obermeyer 1995).

A second point at which bias enters the GIS production process is at the database design stage ('2' in Figure 1). At this point decisions are made on what aspects of the real world are important to represent in a GIS database, how these aspects should be represented as spatial entities, and the determination of such things as measurement scales, categorization schemes, and frequencies of data collection. This process is informed by database developer's worldview, training, and intentions in developing the database, as well as institutional mandates, procedures and rules (Chrisman 1987). Within the bounds of what can be represented in the GIS, database developers determine what sets of phenomena are represented as real, and how these are represented.

Bias may also be introduced at the point where GIS analysts enter into this stream of cultural communication ('3' in Figure 1). Such individuals are highly trained in the use of the technology to undertake, for example, spatial analysis, cartography and modeling. This will affect their approach to using GIS to manipulate the data that is available to them, such as the selection of GIS tools and their conception of what is acceptable or 'good' data. This has led to concern by some that the use of GIS is often elitist, oriented toward scientific and technological expertise and can even be anti-democratic (Lake 1993; Aitken and Michel 1995; Obermeyer 1995; Ghose 2001).

Finally, end users in the GIS production process ('4' in Figure 1), presented with the results of a process embedded in a scientific, expert-oriented and data driven approach, apply their interpretation (influenced by their own experiences of the world, motivations, values, education, training and worldviews) to such results. The end user may not be aware of the nature of the approach or dominant epistemology, nor of the sets of decisions that have led to the particular representation of the 'real world' that they interpret. However they are likely to view the results of the GIS production process as valid, because the scientific worldview in which GIS technology is embedded is widely viewed as legitimate. The output is evaluated on how scientifically 'rigorous' its production has been – that is, how well positivism and empiricism have been enforced.

The reality of the situation is, of course, more complicated than this simple model. GIS analysts, for example, may be the same individuals as the database developers and/or end users in this model, and the capability for GIS technicians and analysts to extend and customize GIS applications may alleviate some of the concerns about embedded bias (albeit at the cost of very high levels of required skills and education). Nevertheless, the model can usefully serve as a heuristic device to understand some of the issues that may lead to social and spatial marginalization in the use of the technology.

Our intention in presenting this model is not to argue against logical positivism or the scientific perspective in general, but to argue for a *plurality of perspectives* in the process of constructing and communicating knowledge in support of spatial planning and environmental management. This will not lead to the elimination, or even reduction, of bias in the process. However, by incorporating the perspectives (and biases) of relevant actors it will lead to more appropriate representations of reality and to ownership of the process, and its resultant representations, by stakeholders.

3. GIS for Empowerment

From about the mid-1990s the discussion in the GIS literature about the potential for social and political pitfalls in the applications of geographic information systems began to inform the use of GIS (e.g., Elwood 1998; Harris and Weiner 1998; Ghose 2001; Elwood 2002; Laituri 2002; Tulloch and Epstein 2002; Warren 2004). This is particularly evident in the area of Public Participation GIS (PPGIS) and Participatory GIS (PGIS). The literature is still unsettled about the use of these terms, but PPGIS usually refers the use of GIS technologies (primarily in North America) to support public participation in spatial planning and environmental management (particularly at the community level). It is characterized by a grounding in value and ethical frameworks that promote social justice, ecological sustainability, improvement of quality of life, redistributive justice, nurturing of civil society and capacity building. It is best applied in the context of partnerships among stakeholders (for example, government, NGOs, communities, researchers) (Aberley and Sieber 2002). Specific techniques associated with PPGIS can range widely, from implementation of GIS over the internet, to maps drawn with local communities.

'PGIS' is often used to apply to PPGIS types of applications in situations characterized by disadvantaged and marginalized communities, particularly in community development and resource management contexts in developing countries. Rambaldi et al. (2005) indicate that,

> PGIS practice is geared towards community empowerment through measured, demand-driven, user-friendly and integrated applications of geo-spatial technologies. GIS-based maps and spatial analysis become major conduits in the process. A good PGIS practice is embedded into long-lasting spatial decision-making processes, is flexible, adapts to different socio-cultural and bio-physical environments, depends on multidisciplinary facilitation and skills and builds essentially on visual language. The practice integrates several tools and methods whilst often relying on the combination of 'expert' skills with socially differentiated local knowledge. It promotes interactive participation of stakeholders in generating and managing spatial information and it uses information about specific landscapes to facilitate broadly-based decision making processes that support effective communication and community advocacy.

Table 1 summarizes characteristics of PPGIS and PGIS in comparison to traditional applications of GIS technology. The remainder of this paper will briefly present some applications of GIS in southern India which may be considered to fall within the PPGIS and PGIS realm.

Table 1: A comparison between GIS and PPGIS (derived from Kyem 2000 as presented in Sieber 2003). The characteristics of PPGIS shown in this table also apply to PGIS.

GIS	*Dimension*	PPGIS
Technology	*Focus*	People and technology
Facilitate official policy-making	*Goal*	Empower communities
Supply-driven; technological push	*Adoption*	Demand- and need-driven
Rigid, hierarchical and bureaucratic	*Organizational structure*	Flexible and open
Because it is possible	*Why use it?*	Because it is needed
Specified by technologists	*Details*	Specified by users/focus groups
Led by independent specialists	*Application*	Led by facilitators/group leaders
General/multipurpose applications	*Function*	Specific, project-level activities
Top-down	*Approach*	Bottom-up
Capital-intensive	*Cost*	Low-cost

4. The Cooum River Environmental Management Research Program

The Cooum River is an extremely stressed urban stream that flows through the centre of Chennai to the Bay of Bengal. The Cooum is a long standing problem. Its waters consist primarily of household sewage, it has low flow and stagnation related to flat terrain and blockage of the mouth by a sandbar, and it looks and smells foul. It is a threat to public health. Decades of well-intentioned management efforts by agencies having partial jurisdiction over the Cooum and its vicinity (for example, the Corporation of Chennai, the Tamil Nadu Public Works Department (PWD), Madras (now Chennai) Metropolitan Water Supply and Sewerage Board (a.k.a. Metrowater), and the Tamil Nadu Slum Clearance Board (TNSCB)) have failed to improve the situation.

The Cooum River Environmental Management Research Program was an independent research program in the late 1990s that investigated the Cooum River situation. The program drew on Soft Systems Methodology (SSM) and Adaptive Management approaches to operate a multi-stakeholder collaborative process to generate insight into the problem that would lead to innovative ideas for its management (see Bunch 2001b; Bunch 2003; Bunch and Dudycha 2004). Both SSM and Adaptive Management attempt to overcome uncertainty and complexity by mobilizing and representing stakeholder knowledge and perspectives. The development of SSM in particular was an explicit shift away from functionalist systems thinking toward an interpretive systems approach that explicitly represents the worldviews and interests of stakeholders (Checkland 1999; Jackson 2000).

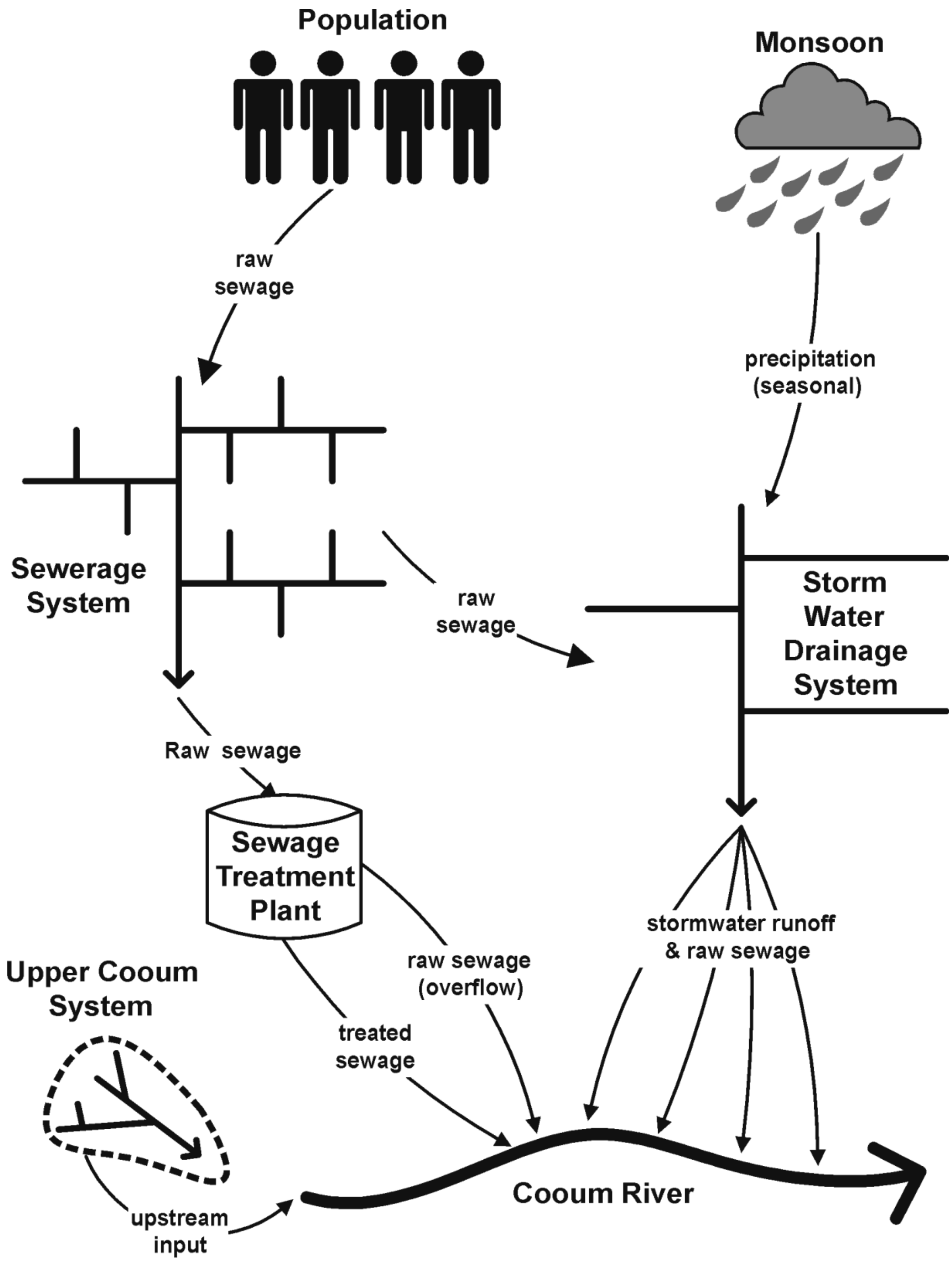
A major component of the program was the operation of a three-day workshop in 1998 and a five-day workshop in 1999 that brought together stakeholders from government agencies (for example, the Madras Metropolitan Development Authority (MMDA), Corporation of Chennai, PWD, TNSCB, Metrowater, the Department of Environment and Forests, and the Directorate of Public Health and Preventative Medicine), NGOs with social and environmental mandates, and academics. These groups were represented (in roughly equal numbers) in a core group of about 30 persons.

The first workshop in March of 1998 was oriented to problem identification and system conceptualization. Over three days, workshop participants worked through a series of exercises that,

- Identified perceived problems associated with the Cooum river situation;
- Identified key actors and components associated with the Cooum problem, and described the relationships among them;
- Drew from this expression of the situation important subsystems (themes), and modeled them conceptually;
- Developed objectives for management of the Cooum situation that were tied to the identified subsystems;
- Developed indicators that could be used to monitor and evaluate progress toward the objectives; and
- Expressed a basic structure of components of the 'Cooum system.'

This last point was the culmination of the first workshop, and served as the framework (Figure 2) for a GIS-based decision support system that was employed in the second workshop. Also of note was the development throughout this workshop of a shared conception of the Cooum system that was rather different from that on which previous management interventions had been based. This understanding of the Cooum environmental system moved beyond the simple bio-physical model of a river system to one that, for example, encompassed the activities of the population of Chennai in consuming water and producing sewage, and of the multiple and various agencies in managing (or not) aspects of the situation. Workshop participants described it not so much as a natural river system, but as an "urban system" and a "waste disposal system."

Figure 2: Basic structure of the Cooum River environmental system (Bunch 2001b).



Between the first and second workshops we developed the Cooum River Environmental Management Decision Support System (DSS) that coupled open source (free) versions of a GIS and a water quality simulation model. The DSS system simulated hydrology and water quality (a key indicator of the overall state of the Cooum system) and was parameterized by spatially referenced data about stormwater drainage, sewerage catchments, the city population, and slum areas, that were stored and managed by the GIS.

Users were able to alter the parameters of the system though an interface developed using a scripting language packaged with the GIS.

At the second workshop (in 1999), participants once again explored a variety of aspects of the Cooum River problem. A significant amount of time at this workshop was spent on use of the GIS-based DSS to undertake scenario analysis of basic management interventions in the Cooum system. Participants constructed scenarios by using the custom DSS interface to change parameters in the system. For example, they could indicate that some or all slums in the city be cleared and relocated outside of the system, speculate on technology or capacity changes at the sewerage treatment plant, or forecast the effect of increased water supply.

Figure 3: Participants working with the GIS-based DSS to construct management scenarios at the second Cooum river workshop in 1999.

Workshop participants worked in groups of 3 to 5 people that were a mix of representatives of government agencies, NGOs and academics. Beyond baseline scenarios that described dry and monsoon seasons, participants developed simple management scenarios to explore:

- the effect on the system of slum improvement,
- population growth,
- increased capacity at the sewage treatment plant,
- improvement of sewage treatment technology,
- artificial increase in flow from the Upper Cooum system, and
- the effect of the storm flush from the first heavy rains of the northeast monsoon

Results of the simulations produced flow rates and values of water quality indicators (5-day Biochemical Oxygen Demand, Dissolved Oxygen and Ammonia-Nitrogen) at 25 metre intervals along the Cooum River.

Understanding of the Cooum River situation was significantly improved, both by the process of developing the GIS-based DSS framework, and by operating it to produce management scenarios. We observed, for example, that participants broadened their perspectives, re-conceiving the situation to incorporate problematic institutional, organizational and even cultural (behavioral) factors. Much debate was also generated about issues of data quality, scarcity of data, and data access.

Actual simulation using the Cooum DSS also produced some interesting and unexpected results, revealing, for example, a severe under-capacity of sewage treatment plants, and evidence that improving slums (providing them with sewerage service) may actually worsen the condition of the Cooum River in certain situations. The scenario analysis highlighted interactions between system components and generated new knowledge about the system that will assist in prioritizing management actions. Informed in part by this work, a World Bank Initiative to restore and manage the Cooum under the Cooum Sub-basin Restoration and Management (CSRM) project is beginning. This initiative is part of the Irrigated Agricultural Modernization and Water Body Restoration and Modernization (IAM WARM) project funded by the World Bank and has the purpose of packaging and phasing potential technical and institutional options based on prioritization and implementability, involving multiple stakeholders.

The Cooum River work as PPGIS: An improved and shared understanding of the Cooum River environmental system was generated through a collaborative multi-stakeholder process in which the GIS was embedded. It is the process that is the key, not the GIS analysis per se (though it does provide a useful representation of the system, database and tools for later work). The process in which GIS was embedded was designed in part to avoid some of the pitfalls demonstrated in the discussion above. The basic system itself was based on a framework that incorporated the understanding of stakeholders in the situation. In this way the model incorporated stakeholders' perceptions of the 'real world.' They determined what components were important to represent (and how) and thus determined what data (and in what form) was required (refer to '2' in Figure 1). For example, breaking from past representations, participants identified the spatial extent of the system of interest to be the urban catchment area (stormwater drainage and sewerage catchments) for the urban reaches of the Cooum River, treating the upper (rural) reaches as a connected but distinct system characterized by different processes and actors.

A focus on the behaviour of actors in the system necessitated collection of data on the city population, such as income classes, and consumption of water by income class. Participants also envisioned changes in the Cooum River environmental system (evolutionary or human-induced) and so informed what capabilities were required to build into the DSS ('1' in Figure 1). For example, the DSS provided the capability to speculate about changes in water consumption patterns of the various income classes, or to modify population numbers and income distribution across the city. Stakeholders themselves undertook the GIS analysis (scenario analysis) ('3' in Figure 1) and were involved in the interpretation of the results ('4' in Figure 1). In fact, this part of the process was usurped by the participants, who found it so elucidating with regard to governance issues and uncertainty in the situation, that they interrupted the workshop to establish a working group to carry on the project and continue improvement of the model. Thus, this process involved stakeholders at all four key locations in the GIS production process identified in Figure 1.

5. An Adaptive Ecosystem Approach to Managing Urban Environments in Slum Settings in Chennai

From the program just described came several recommendations that led to the development of a further program targeted at managing the urban environment in Chennai. One recommendation of participants in the Cooum River research had to do with a consistent theme that arose throughout that work: *slums and slum dwellers*. Slum dwellers were considered to be important stakeholders in the Cooum River problem (as actors within the system who both contributed to, and were impacted by, the problem) but it was not possible to involve them in the program of research. Participants recommended that future research attempt to do so. Furthermore, participants in the Cooum River program believed that many of the themes relevant to management of the Cooum River were also pertinent to other aspects of human-environment interactions throughout the city. They recommended that a research program be designed to broaden the focus of work to the city as a whole.

In 2001 we initiated a new action-research program involving an international and interdisciplinary team of researchers from York University, the University of Madras and McMaster University, with the participation of various Indian NGOs and government agencies. Part of this program, called An Adaptive Ecosystem Approach to Managing Urban Environments for Human Health, is outlined here. We used the relationship between human health and the environment as a cross-cutting theme to broaden the attention of the program to the larger city. Human health can be both an indicator of the overall state of the socio-ecological system, and as a target for management of the system.

One of the initiating activities of this program in Chennai was a multi-stakeholder workshop hosted by the Chennai Metropolitan Development Authority in 2002. This workshop was similar in participant composition and implementation to the first Cooum River workshop. It was oriented toward problem definition and system conceptualization. However, a main difference was that this workshop was also intended to be a vehicle for stakeholders to direct the future orientation of the action-research program. Notably, the workshop participants re-affirmed the concern with slum areas and slum dwellers. They directed a focus on, and collaboration with, slum dwellers. Workshop participants also identified a three-pronged mixed methods model with which to operate the ecosystem approach framework that guided this work. These methods were: Participatory Action Research (PAR), GIS, and the use of socio-economic and health surveys (methods and results of the workshop are described in detail in Bunch et al. (2006)). Parkes and Panelli (2001) note that "PAR involves forms of inquiry where researchers and the researched population form collaborative relations in order to identify and address mutually conceived issues or problems through cycles of action and research."

PAR is typically operated at the community level, often with disadvantaged and marginalized groups. Techniques associated with PAR are similar to those used with Participatory Rural Appraisal (PRA) (such as community mapping and transect walks) but PAR is more consistently oriented to community empowerment and capacity building. Because of the required skill set, access to data, and hardware and software requirements, GIS in this work had to remain in a supporting role "behind the scenes." Nevertheless, the local level work of managing community environments is a collaborative spatial planning process and there were many useful roles for GIS. Some of these roles are briefly reviewed below.

In 2004 two slums were identified as community partners: Anju Kudisai and Pallavan Nagar communities. Anju Kudisai is an inner city slum of about 256 households, located on the banks of the Cooum River (opposite the Central Prison) in Chennai. Pallavan Nagar (consisting of 325 huts) was a fishermen's slum on the beach behind the Fishing Harbour in North Chennai. With the assistance of geographers from the Tamil Nadu Directorate of Census Operations, a basic street layout of these two communities was created using Global Position System (GPS) equipment and GIS software. Our research team further developed this GIS data and used them to support the following activities:

Transect walks and Photovoice techniques: In each community several children, men and women separately led our team members through the communities, describing important attributes and locations within their communities as they went. At locations that the community participants deemed were important in their daily lives, or were of concern due to environmental condition or threat to health, they stopped to take photographs with disposable cameras, and to discuss the site. The route taken for each transect, and each of the photographs, were recorded and stored in a GIS. The information generated by the transect walks, and the photographs were later incorporated into GIS-supported community maps (below).

Socio-economic and health surveys: An exploratory sample survey of household socio-economic and health characteristics was administered to approximately one quarter of households in both communities. These surveys provided some baseline data for the two communities and also served to place researchers in the communities for long periods of time, introducing the action-research program to those community members who had not yet been actively involved. GIS was used to create survey zones so that the survey sample was spatially representative of the community. The maps of zones were used by survey proctors to guide their work.

Community Mapping: A series of community meetings were held in each community to discuss concerns and priorities for action. Areas of importance to the communities, such as spaces used for open air defecation, water tanks, dustbins, loose garbage, and temples, were mapped using GIS. Community maps were produced that integrated this information, as well as information and photographs generated during transect walks, and other details gained from small group and individual interviews. The maps were labeled in English and Tamil script (see Figure 4 for an example).

Once the maps were developed, they were used at community meetings, serving to focus discussion on areas of concern within the community. The maps were very well received in both communities, and it was obvious that community members shared ownership of this representation of their neighborhood. Besides being a vehicle for transfer of ownership of the process, and as a technique to facilitate discussion at community meetings, these maps had several other benefits. For example, youth tended to be drawn into discussions with the adult members of communities because youth were more often literate and could interpret photograph captions and other labels on the map. Also, smaller versions of the maps, when shown to individuals in government departments and NGOs, seemed to reify the existence of the communities to officials, and legitimize the perspective of the slum dwellers. Because the medium was GIS-produced maps, this perspective was presented in the language of the dominant (scientific) paradigm.

Figure 4: A GIS-produced community map of Pallavan Nagar, presented together with photographs taken by community members.

Community Visioning: The GIS-produced maps (not the photographs) were also used in community visioning exercises. The maps served as the core of a diagram that also included iconic representations of issues raised by community members. Relationships among the various components represented on the diagram were labeled and linked with lines. These relationships became the focus for discussion about change – both those that were undesirable, and potential relationships that community members would like to promote. This was a variation of a relationship diagramming technique from SSM that facilitated expression of what the community could be (desirable and feasible futures) as opposed to what it was currently like (as represented on community maps).

The action-research program described here is now in its second phase. Formal partnerships have been developed with a local NGO to sustain the process. Both communities were affected by the Tsunami on 26 December 2004. Pallavan Nagar no longer exists, and its residents have now been relocated / rehabilitated in V.O.C. Nagar and Thilagar Nagar, two post-Tsunami rehabilitation sites, after having resided for almost two years in "semi-permanent" housing in 'Tsunami Nagar', a relief camp north of Chennai. Anju Kudisai now has a new children's toilet and new drainage as a result of community representations to the Corporation of Chennai and new women's bathing rooms have been constructed. Self-help groups are operating in the community, a community based organization (CBO) is forming, solid waste management has improved, and the community has plans for a tuition centre. (See Bunch et al. (2005) for more information about this action-research program and the state of the communities as they were shortly after the 2004 Tsunami).

PGIS and slums: The use of GIS in this work was necessarily limited. Members of the research team used GIS to organize and store information generated in collaboration with community members. These community members do not themselves have access to GIS technology because of issues of literacy, skill and expertise required to use GIS, and cost of access to computer technology (and GIS software and data). In such a case it would be inappropriate even to attempt to build capacity to use tools and information that would remain inaccessible to the community after those bringing expertise and access had moved on. Instead, GIS took a background role, supporting participatory processes. The appropriate use of GIS in such a role depends on the sensitivity of the so-called GIS experts on the team to the potential for GIS to lead to social or spatial marginalization, or alternatively (as in the use of GIS to support participatory processes) to empowerment of marginalized communities.

In this work GIS was used to support the expression of the conception of communities' neighborhoods (contributing to what is represented as "real" in the GIS) ('2' in Figure 1), as well as supporting the action-research program in a logistical role. Thus, community members through their participation in activities such as community meetings and transect walks, helped to determine the aspects of their environment that were important to represent in the GIS (for example, women's and men's defecation areas, areas of drainage problems, locations of temples). Community members also collaborated in the construction of the data, delineating relevant areas within their communities, taking photographs, and contributing narrative descriptions that were all incorporated into the GIS. The maps were employed both as records of community member representations of their communities, and also to facilitate debate about the issues represented on them. Thus, community members were also involved in the analysis ('3' in Figure 1) and interpretation ('4' in Figure 1) of the results of the GIS product.

6. Internet-distributed GIS

Many development problems in the Indian context are characterized by scarcity and poor quality of data, approaches to problems constrained by jurisdictional and disciplinary boundaries, actors in government agencies who are paralyzed by perceived lack of power to share information with other stakeholders, and a public who consistently complain of closed and exclusive management processes. Connectivity and information-sharing based on the internet and the World Wide Web (WWW) are potential vehicles to alleviate such problems. In issues of public participation and empowerment in spatial planning and environmental management situations in developed countries, internet-distributed geographic information systems are starting to be used (see for example Voinov and Costanza 1999; Miller et al. 2004; Bunch and MacLennan 2010).

To implement web-based GIS for public engagement, stakeholders must have access to computers and the internet (this includes physical access as well as computer literacy). Also, web-distributed GIS software and an adequate database must be developed and maintained (either by a stakeholder group or a management agency). The benefit of such an application of this technology is that it has the potential to shift stakeholders from a typical position at the end of the GIS production process ('4' in Figure 1) to the position of analyst (at least in a basic sense) ('3' in Figure 1) by allowing users to choose which data layers to represent, and by providing tools to query, measure and undertake basic spatial analysis (such as buffering) of that data. Some web applications are now providing capability for users to contribute and share data (e.g., see Goodchild 2007; Seiber 2007), and some, notably googlemaps.com, allow users to employ client-side scripts and server-side hooks to expand and customize features of the interface. Thus web-GIS is beginning to provide technological capabilities to allow users to participate in the process of development and communication of GIS-produced knowledge even at early stages of the GIS knowledge production stream (for example, '1' and '2' in Figure 1).

There are signs that the situation in India is ripening for such applications of the technology. Some data is becoming easier to access. Primary census data, for example, is available at http://censusindia.net. There is even a web-GIS implementation at http://www.censusindiamaps.net/ to complement this data. Also, initiatives mentioned earlier in this paper, despite valid criticisms about a continued top-down datacentric approach (for example, Georgiadou et al. 2005; Singh 2005) should make inroads into the accessibility of digital spatial data. In particular, the Government of India (GOI) has developed a Map Policy that is designed to make geo-referenced data easily available for civilian use and the GOI is developing a National Spatial Data Infrastructure that should support district level planning (see http:// nsdiindia.gov.in/). However, current adoption of the internet is still low in India compared to other Asian countries (100 million internet users or 8.5% of the population as of 2010, primarily dial up as opposed to broadband connections (IWS 2011)).

It is important to keep in mind that the application of web-distributed GIS is subject to issues associated with uneven access to technology and data. Even if costs come down, the economically weaker sections of society, those most in need of capacity building and empowerment, would be the very last to have the economic and human capacity to access the technology. If such groups are important stakeholders in the planning or management issue at hand, then the use of web-based GIS for public engagement would be inappropriate. This application of GIS technology for public participation has potential to reach that segment of the population that has literacy, computer literacy, and access to computers and the internet only. If web-GIS is employed, careful thought should be given to what stakeholders may not be included in the process, and other means used to ensure their participation.

7. Conclusions

The model of communication presented in Figure 1 provides a useful heuristic to apply to the cases presented above. The model distills considerations in the Critical GIS literature related to multiple co-existing realities of landscape, unequal access to data and technology, and the necessity for plurality and participation, so as to identify points in the process of GIS-supported production of information and decision-making where stakeholders can be engaged in the production and representation of knowledge. If embedded within participatory and collaborative processes, this engagement can be empowering for communities and might avoid social and spatial marginalization for which traditional applications of GIS technology have sometimes been criticized.

An important point to draw out of this discussion, particularly from the PPGIS and PGIS applications to the Cooum River and Chennai slum community projects, is that necessary scientific and technological expertise needs to be complemented by expertise in collaborative methodology and participatory development. There is a popular saying that “when all you have is a hammer, everything looks like a nail.” The point is not to throw away the “hammer,” but to use it in conjunction with a more full conceptual and methodological toolbag. Methods and tools (such as GIS) should be chosen and applied in a manner responsive to characteristics and contexts of problems, not according to disciplinary or epistemological stances. In most cases this will entail the work of an interdisciplinary team and requires openness to defining problems and discovering an appropriate methodology in collaboration with stakeholders.

In both the Cooum River and Chennai slums projects the use of GIS was informed by an understanding of social and political implications of the use of the technology. GIS was more prominent in the Cooum research, and was kept in the background in work with slum dwellers. However, in both programs it was subsumed in a collaborative process that allowed stakeholders to express their versions of reality, and their visions for a desirable and feasible future. The efficacy of the *process* was important, more so than the scientific rigour of the application of GIS to the problem. We argue that this is an appropriate and useful role for GIS that avoids spatial and social marginalization in spatial planning and environmental management. On the other hand, while the potential in India for application for web-based GIS to support public participation is improving, this would only be appropriate in contexts where all groups have the capabilities and resources to access and use the technology, or when multiple means (beyond GIS) are employed to ensure participation of all relevant stakeholders.

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