

Final Report Year One Activities



Monitoring Beira Using Geographic Urban Indicators

A US Department of Housing and Urban Development Grant
The University Consortium on Geographic Information Science

Department of Geology and Geography
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The Urban Indicators project at West Virginia University, entitled *Monitoring Beira Using Geographic Urban Indicators*, is a collaborative effort between West Virginia University and the Catholic University of Mozambique in Beira. The project is based on the UIP framework of building national and local capacity to collect and use policy-oriented indicators as part of a strategy for the development of sustainable human settlements.

The project was funded with the intention of achieving four broad objectives:

1. **Gain knowledge on the state of urban quality within Beira, Mozambique, which can be used to evaluate existing urban conditions and monitor change.**
2. **Establish a quantitative baseline of spatial data within a geographic information system (GIS), grounded on the UN Urban Indicators Programme, that can be used by a variety of stakeholders to evaluate the effectiveness of policies and programs intended to improve socially and economically distressed communities, increase homeownership, and reduce homelessness.**
3. **Transfer expertise in evaluating urban indicators using spatial analytical techniques and GIS from West Virginia University (WVU) to the Catholic University of Mozambique (UCM). The transfer of knowledge will be through web-based training programs.**

4. **Assist in developing and evaluating policies and programs that are intended to improve the quality of life in Beira.**

Objectives 1-3 have been achieved in year one. Objective four will be one of the foci of this collaboration in year two if funding is continued.

In year one, significant progress was made despite concerns with data availability and reliability. The major achievements in year one can be summarized as follows:

- Deepening of the WVU-UCM partnership and capacity building at UCM
- Development of a workable spatial database for three barrios
- GIS-based urban indicator descriptions for three barrios
- GIS-based modeling for one urban indicator (water)
- Development of a project web-site that includes web-based training modules using ARC-IMS (<http://beira.geo.wvu.edu/>)

If funded in Year Two, we foresee research in three major areas. First, we will complete the web-based modules on remote sensing, implementation of ARC/IMS, and modeling and test their usefulness of all six modules as training. Second, we will continue the mapping of land cover and land use change in the city. We have obtained, and are in the initial stages of, processing the aerial photographs.

Third, we will explore policy and planning applicationsof the work already completed. Finally, we will broaden the spatial scope of the database beyond the three barrios, to include the entire city of Beira. As in Year One, the overall objective of the project will be the building of GIS-based urban indicators.



GIS and Planning

Planning is a future-oriented activity, based ideally on shared information and the active participation and consent of all stakeholders (Nedovic-Budic, 2000). The planning realm encompasses all geographic scales from the national to the local, and combines domains of interest ranging from the natural environment, regional infrastructure, through urban and regional development and economic growth. Planning problems within the urban domain require decision-making and solutions in situations concerning urban growth and change; unemployment, decline and economic revitalization; transportation; environmental degradation; residential neighborhood decline and redevelopment; historic preservation; conservation of land and natural resources; and the provision of open space, parks and recreation facilities (Jones 1997). Alternatively the role of planning agencies may be more routine – focusing on inventory, monitoring, regulation, and enforcement. The tasks confronting planners regularly include the sighting of new industrial areas and the reuse of old ones, the location of hospitals and other essential services, residential developments, recreation and leisure facilities and public open space. They comprise highway building and maintenance, emergency response and hazardous materials planning, zoning, and the ordinary processing of planning applications. In each case the demand for information by the planners and those for whom the plans are made is enormous (Huxhold, 1991, Martin 1996).

Access to information, the ability to process it and the generation of alternative outcomes, frequently in an iterative procedure, are essential in supporting decision-making.

Consequently, GIS is fundamental to planning for its role in maintaining databases of a wide variety of types of spatial on non-spatial data. Information integration on the basis of a shared geographic footprint is seen as one of the major strengths of GIS. Beyond data integration and access facilitation, the power of GIS as a decision support tool stems from its analytical and synthesizing potential. The value of GIS in the planning process increases directly with its ability to portray information at different scales of resolution, generate analytic solutions to planning problems and generate alternative scenarios. The role of “what if?” is nowhere more highly developed and used than within the planning context.

Ideally GIS should offer support to the planning process universally. It is often assumed that the expense of software and hardware is the bottleneck in the increased use of GIS technology in the developing world, but the lack of adequate spatial data remains the most significant constraint (Yeh 2000). In developing countries comprehensive, multi-cadastral, data are scarce. Yeh (2000, 885) comments that in developing countries the most readily available data are from remote sensing sources, leading to an emphasis on land cover rather than land use, and on physical environmental data rather than social and economic.

Socio-economic data are primarily acquired through field surveys, which are expensive, and developing countries are unable to mobilize resources to collect important statistical information. Incomplete, inaccurate, out-of-date data are unfortunately the rule rather than the exception.

Planning for Global Urbanization

The rapid growth of population and its concentration in cities around the world constitute a crucial element affecting the long-term outlook for humanity. Between 1970 and the closure of the 20th century, urban populations increased from 35 to 50 percent of the global total. Indeed, it is estimated that more than 1.5 billion will be added to urban populations across the globe during the next 25 years, when 60 percent of all the world's people will be living in or near cities (Global Outlook, 2001; Kirdar, 1997; Rakodi, 1997). A disturbing aspect of these figures is that 90 percent of urban population growth between 2000 and 2020 will accrue in cities of the developing world. Take Africa for example, long thought of as one of the least urbanized continents, it is expected that over half the population will be urban by the year 2020 (Aryeetey-Attoh, 1997; Rakodi, 1997). This global demographic shift points to the reality that the world's problems are urban problems, the world's future is an urban one, and that cities present the arena where the battle for sustainable human development will be won or lost.

The rapid urbanization of the world's population poses new and special challenges to governments and communities around the world as they confront issues of economic, political, social, and cultural integration and transformation. As we begin the 21st Century, new forms of globalization and technological advancements continue to blur traditional national boundaries.



As such, cities serve simultaneously as international, national and regional engines of economic growth, centers of technological and cultural creativity, homes of the poor and deprived, and the sites and sources of environmental pollution (N'Dow, 1997; Rakodi, 1997). Rakodi (1997:1) remarks, "...our understanding of the dynamics of these cities and the urban systems of which they form part, and our capacity to manage them effectively, are limited".

In this light, it becomes apparent that the development of contemporary societies will depend largely on understanding and managing the growth of cities, and the city will become the test bed for the adequacy of political institutions, for the performance of government agencies, and for the effectiveness of programs to combat social exclusion and to promote economic development.

Information about Cities

Contemporary urban problems include: environmental pollution (Fuchs, 1994; Kirdar, 1997); poverty, homelessness, unemployment, disease, crime, and social inequalities (Global Outlook, 2001; Kirdar, 1997; Knox, 1998; Rakodi, 1997); and poor management, land scarcity, declining resource base, civil strife, and institutional inflexibility (Leitmann, 1999; N'Dow, 1997; Stren and White, 1989; Wekwete, 1994). Too often these problems and phenomena that characterize the process of urbanization continue to be poorly documented and represented, hence depicting a distorted picture of the city. The situation is more critical among cities in the developing world where the divide between urban reality and the ability to comprehend that reality is most significant. In Africa for instance, Rakodi (1997:10) observes, "One of the most significant problems in addressing urbanization issues and in assessing the performance of urban management.... is the dearth of information". The reasons for this lack of data and the unreliability of information are well known: economic difficulties (Stren, 1994); political turmoil (Rakodi, 1997; Stren and White, 1989); war and civil unrest (Kirdar, 1997; N'Dow, 1997); and a combination of over centralization and an emphasis on rural development (Mabogunje, 1992; Obudho, 1994).

The urban information crisis in developing regions severely constrains the ability to develop and analyze effective urban policy. A sustained and systematic appraisal of urban problems, as well as tools for urban policy has been largely inadequate in providing the overall picture of the city

and how it functions. Rarely do these tools provide an indication of the relationships between the performance of individual sectors and broader social and economic development results (Leitmann, 1999). In determining the causes of urban dysfunction and in monitoring progress toward achieving sustainable cities, it is increasingly necessary to rely on effective tools to analyze the performance of cities, within countries, and on a worldwide basis.

There is a problem with reliable and appropriate data at the intra-city scale. Most major economic aggregates, which might measure the health of the urban economy such as city product, investment or trade, etc, are unavailable. Other data, which might measure the condition of the population, infrastructure and the environment, are available in some places and not others, and are seldom collected in a consistent international framework (UNCHS, 2000). Worse still, while enormous data have been generated at very high costs throughout the world, they are often incomplete, inappropriate, inaccurate, or generated for narrow planning applications. There is a global need to build national and local capacity to collect useful information on urban conditions and trends, to convert the information to knowledge through appropriate techniques, and to apply this knowledge in formulating and modifying urban policies and programs (UNCHS, 1999). This will help to resolve the information crises and close the knowledge gaps that blur the vision of city leaders and the hopes and aspirations of urban citizenry.

UN Responses and Global Urban Indicators

The Global Urban Observatory is a UNCHS Habitat's facility for monitoring and evaluating the implementation of the Habitat Agenda and Agenda 21. This body was born of a resolution by the 1996 UNCHS Habitat II Conference in Istanbul, Turkey, that "All partners of the Habitat Agenda, including local authorities, the private sector, and communities should regularly MONITOR and EVALUATE their own performances in the implementation of the Habitat Agenda through comparable human settlement and shelter INDICATORS..." (Paragraph 240 of the Habitat Agenda). The Urban Indicators Program (UIP) and the Best Practice and Local Leadership (BLP) together make up the Global Urban Observatory. This Urban Indicators Program was born of the realization that many cities of the world (particularly the developing world) are faced with an information crisis, which seriously undermine their capacity to develop and analyze urban policy. This decentralized networking and capacity building program responds to one of the most critical needs of urban policy – the need for better information on urban conditions and trends.

The meaning and role of indicators has thus been defined: "...a measure that summarizes information about a particular subject and may point to particular problems ... (and) provides a reasonable response to specific needs and questions..." (UNDP, 2000). Regardless of the definition, literature has demonstrated that various indicators based on easily obtained data can offer useful intelligence for making strategic choices about directing and managing future growth.

Furthermore, while indicators primarily show trends, prioritize and define targets, provide qualitative and quantitative information etc, (Banerjee, 1996; Leitmann, 1999), they can also be more than pieces of information if designed in response to well defined policy objectives (Global Outlook, 2000; Sawicki and Flynn, 1996).

In a special issue of the *Journal of the American Planning Association* devoted to a discussion of indicators, Banerjee (1996:222) summarized the purposes of indicators as:

To measure performance of policies and programs; to examine trends; to monitor the condition of a city or a region; to inform decision-makers; to raise awareness of the public; to define targets; to set planning objectives; to compare localities horizontally (across space) or longitudinally (over time); to raise flags in an early warning system; to guide strategic investment choices; to challenge conventional wisdom; and so forth.

Similar views are shared by Sawicki and Flynn (1996) and Leitmann (1999) who feel that indicators must be capable of affecting citizen action and public policy making, and hence must be formulated through a broad-based partnership approach involving all levels of decision-making and all stakeholders. However, it has been argued that stakeholder participation in this process has always remained questionable as experts dominate the scene (Leitmann, 1999).

In a more detailed fashion, Leitmann (1999) elaborates the need for stakeholder participation in the development of indicators and the problems that beset this phase. Noting that urban indicators must be linked to the

development process, the author emphasizes that a realistic set of urban indicators should be:

“...measurable, based on existing data, affordable, based on a time series, quickly observable, change sensitive, widely accepted, easy to understand, and balanced” (Leitmann, 1999:168). From this discussion, and elsewhere in the literature, it is seemingly apparent that urban indicators involve measurement, and so their validity and meaningfulness in planning is critical and must be within specific contexts — scale, scope, institutional setting, history etc (Banerjee, 1996; Global Outlook, 2001; Leitmann, 1999; UNCHS, 2001). Similarly, the geographic unit of analysis (household, census block, block group, tract, neighborhood, city, county, state, and nation) and the scale at which the data are reported (neighborhoods in one city, all states in a nation etc) must be a central consideration in the creation of such databases (Leitmann, 1999; Sawicki and Flynn, 1996).

It is agreeable that there is no ideal “objective” set of indicators or criteria for developing indicators. Too often, experts in a top-down fashion clearly distanced from the people whose quality of life is being assessed formulate urban indicators. Nevertheless, the United Nations has provided a broad framework from which all nations can base their selection depending on their respective local settings. For instance, in preparation for the HABITAT II conference and the subsequent implementation of the HABITAT agenda, the UNHCS short-listed six key urban indicators as:

- socio-economic development
- infrastructure
- transport
- environmental management
- local government
- housing

From this initial list, an extensive list has been developed under the six categories to comprise of over a hundred and twenty (120) sections (Leitmann, 1999; UNHCS, 1997).



Geographic Information Systems and Urban Indicators

Geographic Information Systems have been commonly used for urban applications such as comprehensive planning, hazard and environmental ‘hot-spot’ identification, zoning, land use inventories, land use and land cover mapping, site suitability assessments, socio-demographic analysis, management of infrastructure, change analysis, as well as other more sophisticated analytical applications (Barnejee, 1996; Leitmann, 1999; Nedovic-Budic, 2000; Maclaren, 1996; Ryznar and Wagner, 2001). GIS has, indeed, become an ideal tool for planners and policy makers (Leitmann, 1999).

The spatial nature of urban phenomena prescribes the use of geospatial technologies in urban management. GIS analysis is mainly used during the informed consultation phase to generate physical and social information, including key correlations, and for monitoring the implementation of plans in cities. Sawicki and Flynn (1996) engaged a thorough conceptual and theoretical examination of the literature where they identify urban environmental indicators as the precursors of neighborhood indicators in the United States. To illustrate the relevance of GIS, it is argued “With many records located in space, the GIS can then aggregate them to any level of geography: city blocks, neighborhoods, census block groups, tracts, municipalities and counties (Sawicki and Flynn, 1996:166).

Furthermore, the analytical capabilities of GIS have made the technology more than just a communicative visual tool

hence most applicable in the development of indicators for evaluating urban policy and the quality of our cities. This way, the use of the technology would fall within the five geographic information science (GIScience) potential areas for planning as identified by Nedovic-Budic (2000:82): database development, integration of geospatial technologies with urban models, building of planning support systems, facilitating discourse and participation, and evaluating planning practice and technological impact.

Applications of GIS have recently disseminated to developing nations in general and Sub-Saharan Africa in particular (Conitz, 2000; Gar-On Yeh, 1991; Hastings and Clark, 1991). It is evident however that the levels of adoption have varied across the continent with richer countries (South Africa for instance) far much ahead of poorer ones (such as Mozambique). Despite the rapid adoption, the use of the technology has tended to reside in externally funded projects or state agencies and rarely is it owned and used by people at the grassroots. Similarly, there has not been a coordinated style of adoption and use in many countries. Although local authorities in different countries in Africa have engaged GIS at different levels, enormous gaps in information and citywide data have become commonplace. In this project, GIS is used for the development of baseline spatial data for the city of Beira, Mozambique, and the analysis of this information for policy formulation and evaluation purposes.

Beira is Mozambique's second city (map 1). Established in 1884 as a Portuguese military base with a port and railway line it was designed to provide connectivity to the interior as well as to handle trade traffic from Malawi, Zambia and Zimbabwe. The city has undergone rapid growth and transformation since the country achieved independence in 1975. From a mere 215,000 inhabitants in 1980, it registered 409,260 in 1997. However, such phenomenal growth has not been without consequences: unemployment, informal settlements, poor service delivery, and environmental decay are common features.

Two challenges lie at the core of Beira's current problems: one is its physical location and the other is its colonial legacy. Built at the confluence of Pungwe and Buzi rivers, the city lies in a swampy floodplain with poor natural drainage. Developable land, therefore, is at premium.

To ensure the functionality of the city colonial authorities constructed a network system of underground and open canals to facilitate drainage. The system worked as long as development controls were in place and there was no pressure to accommodate the African population as part of the urban built environment. Unfortunately post-independence Mozambican cities like their counterparts elsewhere in developing countries suffer from the absence of any systematic, enforced planning.

Without maintenance and development controls the system of controlled drainage has fallen into disrepair and rendered inoperable by the increased squatter formation in low laying areas that are prone to flooding. Equally alarming is the fact that ecologically vulnerable areas account for over 80% of all



The other evil is, of course, the city's legacy of spatial segregation: sound infrastructure and good housing for European enclaves and very little for Africans. In 1975, however the city experienced a dramatic transformation when a massive influx of Africans moved in to reclaim a city hastily abandoned by the departing Portuguese. As densities increased the city found itself ill-prepared and unable to cope with the basic needs of the new population due to lack of both institutional capacity and resources. The existing housing stock and infrastructure simply deteriorated or fell into disrepair. As a result, access to safe drinking water and sanitary sewers in the previously built up city has become a major health issue.

Currently only 43% of the city's residents have access to piped water and of this number only 60% have access to water that meets the World Health Organization minimum standards for safe drinking. Nationally, access to safe water is enjoyed by only 50% of the population while access to sanitation is estimated at 39%. The increased pollution of water supplies associated with a deficient sewerage system or insufficient drainage and overbuilding in flood prone areas where residents use latrines has made both formal and informal residents vulnerable to water-borne diseases. In 1997, for example 11,000 people were treated for diarrhea, while an equally significant number were exposed to cholera resulting in 600 fatalities. Compounding these challenges that the City of Beira would have been expected to address under normal circumstances has been the impact of the civil war that devastated the country for two decades. During and after the civil war, heavy migration from the rural provinces into Beira resulted in a 95% increase in the city's metropolitan population including Dondo.

The current urban population growth rate of 6.4% per annum is one of the highest in Sub-Sahara Africa. A significant proportion of the rural migrants found safe heaven in squatter settlements within and on the urban fringe. As a result, more than 50% of the city's current urban households are squatters without access to basic infrastructure such as portable water, sanitation and waste management and sustainable economic opportunities.

In 1983, the City of Beira attempted to address these challenges by commissioning the Beira Structure Plan. The plan presented ambitious proposals to improve and expand existing urban infrastructure, improve economic opportunity while tackling the serious problem of squatter formation in the ecologically sensitive and poor infrastructures areas of the city. The plan proposals were never adopted or implemented due to the impact of the civil war and insufficient human and financial resources.

Map 1:
Provinces and Main Cities in Mozambique



As relative peace and stability has returned to the country, the city of Beira finds itself faced with multiple problems including the need to: expand employment opportunities for a rapidly growing population and, address challenges of insufficient drainage and sewerage systems, water shortages, power outages, deficient road infrastructure, inadequate shelter, and other failures in city management. Underlying these challenges, however, is the need to develop reliable and useable spatial databases for urban maintenance, management and planning.

There is general agreement that accurate, timely and policy relevant data are a prerequisite for effective planning, management and governance. However, the ability of cities to design and articulate their data needs, obtain relevant data and use it for policy design and monitoring is often inadequate. This scenario is typical of Beira; where both qualitative and quantitative data remain a major constrain to apply to the most pressing problems.

To address this challenge, this project developed a baseline GIS database that uses the infrastructure indicator as a driver to monitor and analyze urban change. The choice of this indicator as a driver is premised on the simple recognition of the close correlation between infrastructure capacity and sustainable urban growth. Besides being essential for urban economic and employment growth both formal and informal access to water and sanitation, the provision of infrastructure is a key determinant for housing provision and a good predictor of housing quality.

Map 2: Urban Indicators Project Study Sites
Beira, Mozambique



According to documentation of the UN Global Urban Observatory (<http://www.urbanobservatory.org/indicators/>) “The purpose of the Urban Indicators Programme is to build national and local capacity to collect and use policy-oriented indicators as part of a strategy for the development of sustainable human settlements... How we anticipate, recognize, measure and interpret urban problems and how we respond to them in policy will determine the overall sustainability of human development.” In addition to broad national and urban indicators, the geographical distribution of urban indicators within human settlements and their immediate environs is an essential component of the measurement and assessment of urban quality and for the evaluation of the effects of policy.

In response to the request for proposals, West Virginia University proposed a project in co-operation with UCGIS and the HUD Office of Policy Development and Research that has the following long-term objectives:

1. Gain knowledge on the state of urban quality within Beira, Mozambique, which can be used to evaluate existing urban conditions and monitor change.
2. Establish a quantitative baseline of spatial data within a geographic information system (GIS), grounded on the UN Urban Indicators Programme, that can be used by a variety of stakeholders to evaluate the effectiveness of policies and programs intended to improve socially and economically distressed communities, increase homeownership, and reduce homelessness.

3. Transfer expertise in evaluating urban indicators using spatial analytical techniques and GIS from West Virginia University (WVU) to the Catholic University of Mozambique (UCM). The transfer of knowledge will be through web-based training programs.
4. Assist in developing and evaluating policies and programs that are intended to improve the quality of life.

The selected study city, Beira (Province of Sofala), is already enrolled in the UN urban indicators project. A GIS has been installed at CIDD-UCM which has the necessary infrastructure, offices, and means of communications, qualified staff and students.

Four primary goals were identified in the original project proposal:

Goal 1: Baseline indicator data are identified and acquired; a database is designed, implemented, and managed.

Goal 2: Methods for estimating disaggregated indicators are designed and evaluated

Goal 3: A long-term, web-based GIS training and education program with disaggregated indicators is developed and implemented for students and professionals.

Goal 4: A business plan is set up to make CIDD-GIS an indicator service center and to disseminate web-based instruction from WVU and UCM.

These goals have been achieved in year one.

Overview of the Data

Good data is essential for good urban indicators. Several key issues arise immediately when dealing with data from developing nations. First, the availability of data can be severely limited. Developing nations lack the information infrastructure necessary to collect, analyze, and interpret large amounts of information. Thus, the analyst is often bound by real constraints on the amount of data with which investigation can be conducted. Second, the quality of data is somewhat suspect. Political considerations, lack of resources, and limited training all interfere with data quality. Additionally, very few developing countries have national data standards, not to mention national *digital* data standards. Finally, accessing available data can be difficult due to language differences and sheer difficulty in transfer. Internet resources are often scarce and poor in quality where available and courier service incurs great expense. Translating digital data is a further difficulty, especially when the data has been collected in a less than optimal method, with meta-data often non-existent or incomplete.

We have attempted in this project to ameliorate some of these issues by working closely with our partners, who both collected and ground referenced much of the data used here. Working with CIDDI at the Catholic University of Mozambique, we obtained GIS coverages on population, land cover and land use, socio-economic

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GIS coverages were obtained from both external sources and were generated internally. Of the images, air photographs were obtained from the state mapping agency, CENECATA and the satellite image was obtained from the Global Environmental Change Program at the University of Virginia.

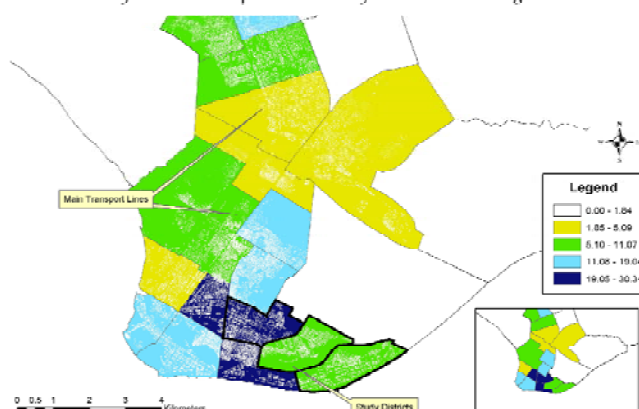
Initial data generation for the entire city of Beira, within the UN framework on urban indicators, presented us with two challenges. First, a fundamental concept regarding the operability of the UN model for urban indicators was problematic, namely the scale of analysis. Intra-urban, or sub-city indicators, are critical in understanding the dynamics of rapidly growing urban areas, especially in the developing world. The UN model lacks sensitivity to scale, thus reducing its overall applicability in a data poor city, such as Beira where internal, as well as external, dynamics drive urban change. Second, we also determined early on in the project that monitoring all of Beira was not feasible due to limited data availability and data quality concerns.

The project database includes five information types:

Population

With population data, we can begin to build predictive models for areas that lack sufficient data. Population data is the most basic form of data used here. Population data was obtained from the Mozambique census for the year 1997. This is a robust data set including population totals, density, and several descriptive variables.

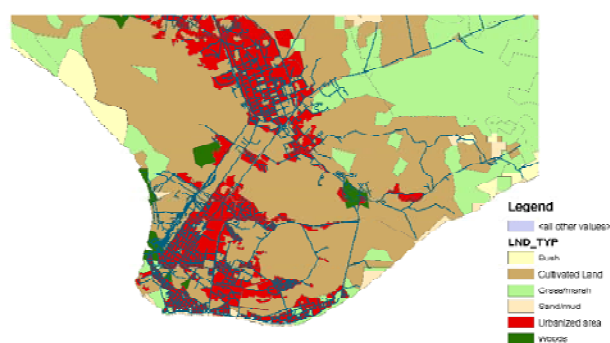
Map 3:
Overlay of Census Population Density Data with Housing Data



Land Cover and Land Use

Land use data includes the city of Beira at selected sample points. The major categories include the urban-built environment, gardening/farming, and open-land. A satellite image was obtained from the Global Environmental Change Program at the University of Virginia from which land cover for the city was digitized. Land use is particularly relevant to this project as the impact of urban agriculture is great in the poorer areas of the city. By identifying these areas of urban agriculture we can make assumptions regarding service provision and livelihood security. Areas with higher concentrations of urban agriculture tend to be those in poorer areas. Urban agriculture also reduces vulnerability of the city's poor.

Map 3A: Land Use Types based on Point Extrapolation



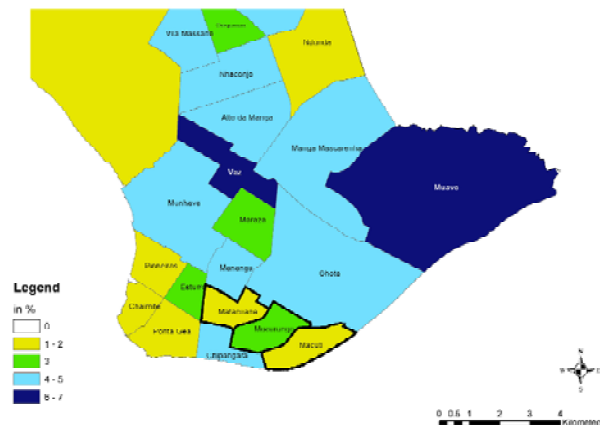
Socio-economic Data

Socio-economic data was collected for the three study barrios, Matacuane, Macurungo, and Maluti by CIDDl and incorporated into the GIS databases. The sample size per barrio was approximately 100. This database includes detailed information on water and sewerage utilization in the three barrios and important demographic data. Variables include gender, age, region of origin, level of education, type of housing, and access to electricity and phone service. Of specific interest to this project are the variables on water connections, particularly access and source of water, water usage and expense, and distance to the nearest water source.

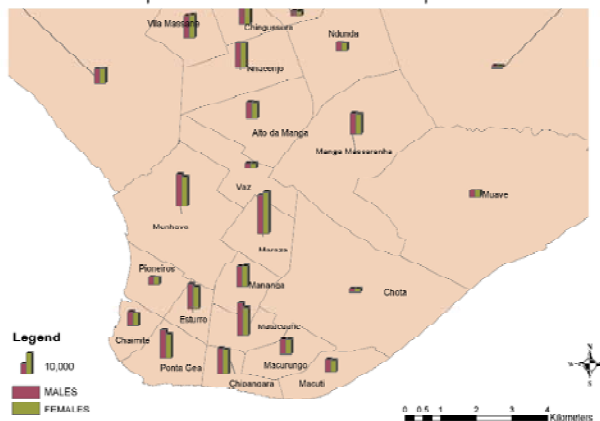
Housing and Buildings

A coverage of buildings was captured and referenced by CIDDl. These buildings include housing and housing type. The density of housing by barrio was plotted and, at the time of writing, is being verified off of recently obtained air photography. This coverage is fundamental in the modeling exercise, as we are concerned with infrastructural connections to houses and differences in connections by housing type.

Map 4: Population Increase in Beira, 1980-1997

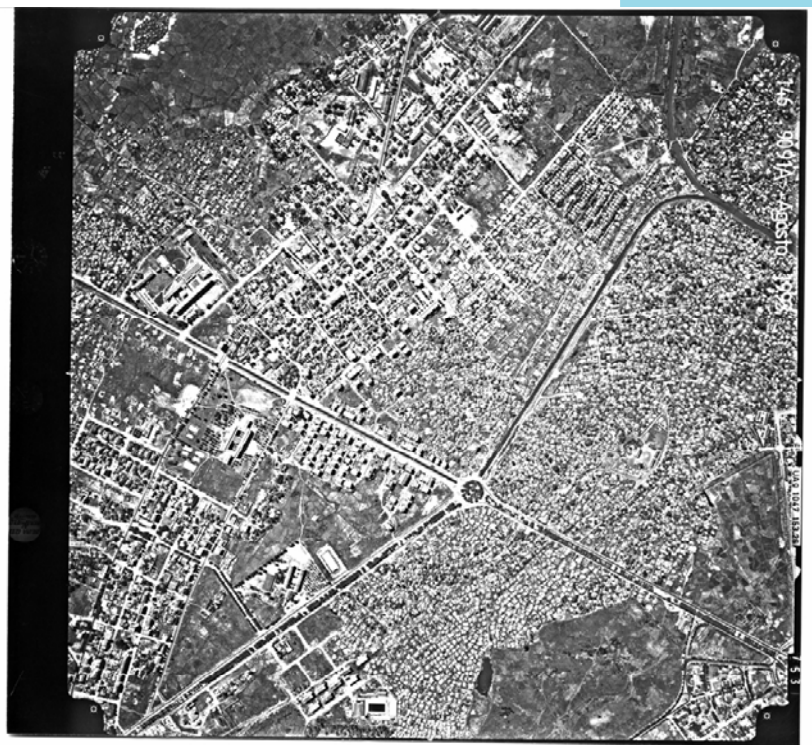


Map 5: Number of Males and Females per Barrio



Air Photography

The aerial photographs obtained from CENECATA, the national mapping agency of Mozambique, are being digitized and will be used to enrich existing data and create new data sets. Coverages were obtained for the years 1982, 1993, and 1996. We anticipate complete digitization of these photographs in the early part of Year Two. Air photography data will be used as an underlay to the digital coverages obtained from CIDD. Specific data layers that will be improved are roads, houses and building stock, and water. As a developing city, Beira exhibits some fundamentally different spatial patterns and methods of service provision from cities in more developed industrialized regions. A network system of underground tunnels and open canals facilitates city drainage (Map 6). In addition to verification of existing data, new layers of information will be obtained from the photography. For instance, the road network on the periphery of the city in the GIS coverage is incomplete. Using the air photos, we have added to the existing data. A second example, land use, provides further clarity in intended data creation. Currently, the land use information for Beira is a point file. Using this coverage and the air photographs we will be able to map land use parcels or polygons.



Methods and Analysis

Methods

For these data to be useful, they all had to be transformed, referenced to the same coordinate system, and checked for errors and cross-compatibility. All files were referenced to the UTM system (WGS 84 Zone 35 South). Errors in projection and referencing were found and corrected for cross-compatibility (do the different coverages match when overlaid?) and graphically enhanced. Once each coverage and image had been corrected, overlay analysis began. Several coverages were overlaid to build the urban indicators. As this project is primarily interested in connectivity, housing and water access were analyzed first. Next, population and housing density were overlaid to determine concentrations in the barrios. Proximity to electrical lines was assessed, although inadequately due to the poor quality of data on such lines.

Land use was overlaid with housing to identify areas of high urban-agricultural activity (garden plots). The satellite image was then overlaid with each GIS coverage for empirical validation. Finally, GIS modeling of the infrastructure data was undertaken. Due to the data quality issues uncovered in year one, we began experimenting with GIS and remote sensing methods to enhance the utility of existing information. If funded, this will be a major focus for year two and will include the creation of a land cover and use change map for the city and region.

Air photographs will be geo-referenced and rectified, enhanced, and digitized. Concurrently the air photography will be overlaid with existing GIS coverages and additional features, e.g. houses, streams, land cover types, will be incorporated into the existing data. Only initial processing of this type has begun.

Map 2: Urban Indicators Project Study Sites
Beira, Mozambique

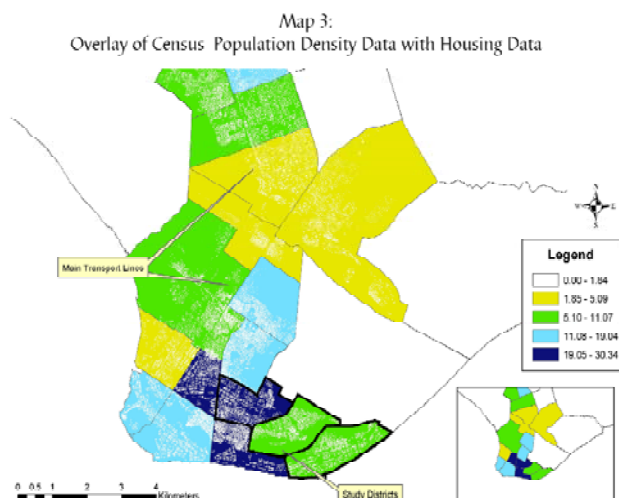


Initial Findings: Descriptive GIS Analysis

Initial findings shown in maps 2-9 are the result of geographic overlay and querying, buffering, and image overlay and querying. Basic mapping will not be included in this section.

a) Landsat Thematic Mapper Image: Map 2 shows the land cover of the city of Beira in 1991. Although generally urban in structure, several parts of the city display large patches of vegetation. To the southwest, large parks and open spaces dominate (shown in red on the false-color image), however, the vegetation in both Macurungo and Macuti are urban gardens, rather than parks or open spaces. Currently, there is no information on the exact use of these gardens. The heaviest concentration of industry is on the west at the rail yards, while the center of the city is marked “CBD”(map 2). The darker green and blue areas to the north of the city are exposed areas (soil, open water, etc.). Streets are manifest as linear, light lines. The white areas along the outer boundaries are beaches. The airport is located in the extreme northeast part of the city, evidenced on the map as a star pattern with the runways in dark blue.

b) Population Density and Infrastructure: High population densities in the city of Beira correlate to the type of housing. Less formal housing areas were identified from the satellite image (and some initial analysis of the air photographs). The less formal housing areas appear to be more densely populated (map 3). However, an inverse relationship was found between service provision and housing density. In short, those areas with the most need for infrastructure are those with less access to it and this helps explain the widespread unsanitary conditions.

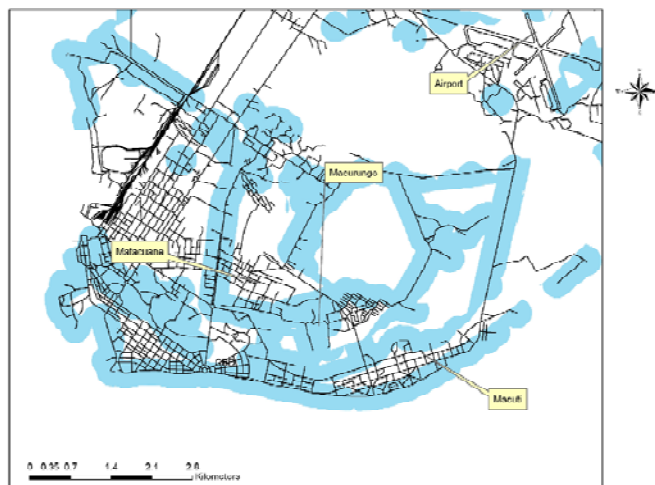


By far, the central and smaller districts have the highest population densities. The concentration of development around the CBD is typical of a developing city.

The periphery of the city is rather close; denoting the poor transportation network. In fact, the city is skewed toward the transportation lines that run to the next city to the northwest, Dondo. Map 3 clearly shows higher densities in the center-west. These districts are rather large in area, but population distribution is not even. There are clear population clusters near the transportation lines.

d) Socio-Economic Data: The most significant analysis of the socio-economic data was in mapping rather than GIS analysis (See Appendix A for data tables). Specifically, density was queried against provision of water service and distance to water source was utilized as a buffer with the GIS coverage of water lines and canals. As map 6 shows, the area of the city within 0.25 km of both water and transportation is rather small. In developing cities, not only is access to water important, but also often getting to the water source point can be a challenge. Most of the areas with easy access to both water and transportation are in the central city area, however, recent water provision to the new settlements in the northeast is also evidenced on this map.

Map 6: Areas within 0.25km of Water and Transportation



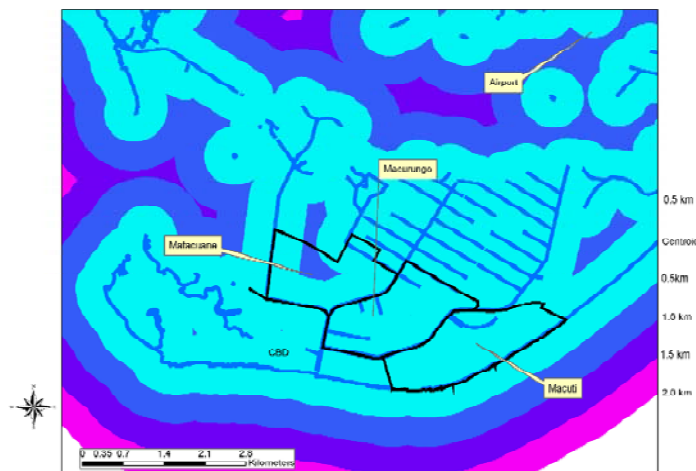
Beira sits on a very swampy, low part of the coastal plain. A major health challenge in a city of this size is drainage of water to prevent water-borne disease. Map 7 shows that the drainage system services a large part of the downtown, with some notable exceptions.

e) Housing and Infrastructure

GIS Modeling

Our goal here was to investigate means of estimating urban indicators at the intra-urban scale using GIS where direct measurement by survey, official record, etc., is unavailable. For example, access to water is one of the 23 key urban indicators defined by UNCHS. The UN Statistics Division defines access to water as having water located within 200 meters of the dwelling; hence the indicator has a specific spatial component.

Map 7: Buffer of Water and Drainage Sources at 0.5 km

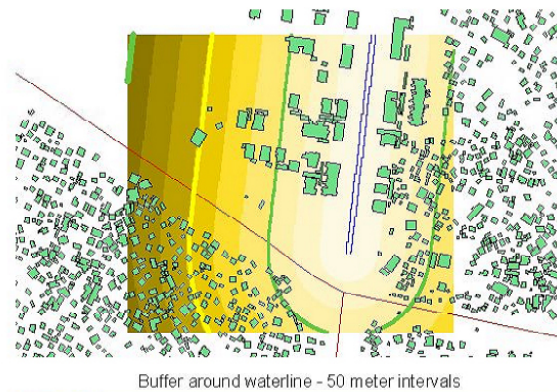


It refers to piped water either within the building or accessible within 200 meters – without extreme effort - to provide for household needs. The indicator is reported as the percentage of households with access to water.

No areal unit is specified, so this statistic may be reported for any geographical zones for which data are available. One method to estimate percentage of households with access to water using a GIS, given the dwelling locations and water pipeline infrastructure is shown (maps 8 and 9).

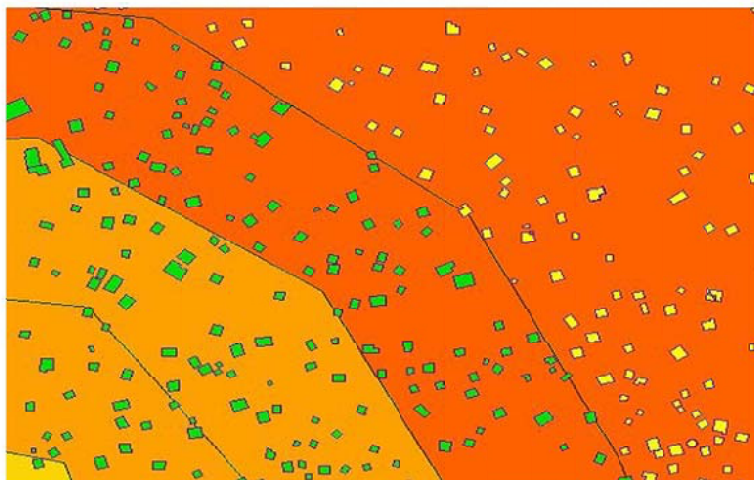
Inputs are a map layer of house footprints (polygons) and a water pipeline layer (arcs). A buffer is created from the water pipelines at convenient distances, for example 50 meters, 100 meters or 200 meters, etc., and this is overlaid on the house layer. Houses within 200 meters of a pipeline are selected as having access to water. A map of administrative zones (census tracts, barrios, neighborhoods) is overlaid on the access to water layer and the proportion of houses in each zone with access to water is calculated. A map showing differential access to water over the entire urban area or of specific dwellings with or without access may be created, for instance, based on map 8.

Map 8 : Use of Buffer Analysis for Access to Water Indicator



Similar methods may be applied for access to sewerage, electricity, gas, and other utilities. The main disadvantage of this approach lies in its reliance on the physical manifestation of the infrastructure. For instance, housing may be mapped from aerial photographs or satellite images, but other types of urban infrastructure such as water mains and sewers are subterranean and therefore cannot be mapped using remotely sensed images. Access to engineering plans or similar data is necessary.

Map 9:
Use of Buffer Analysis for Access to Water Indicator



Houses farther than 200 meters from water main selected (highlighted yellow)

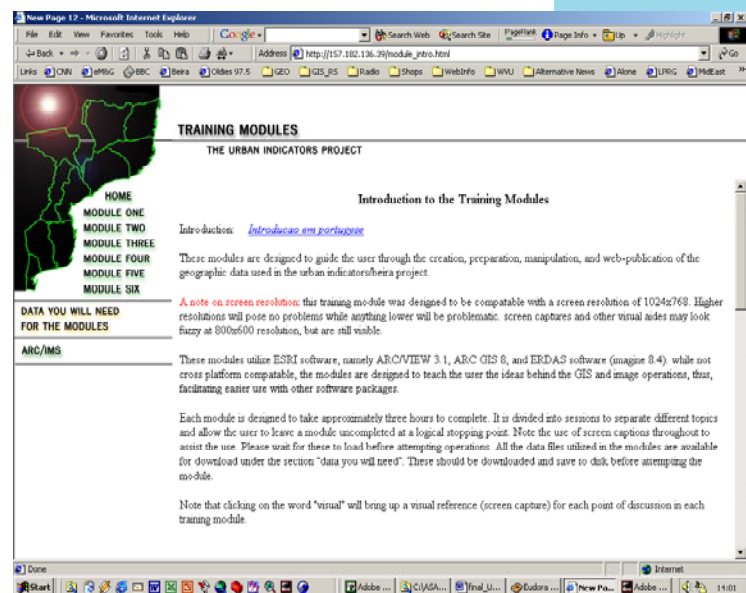
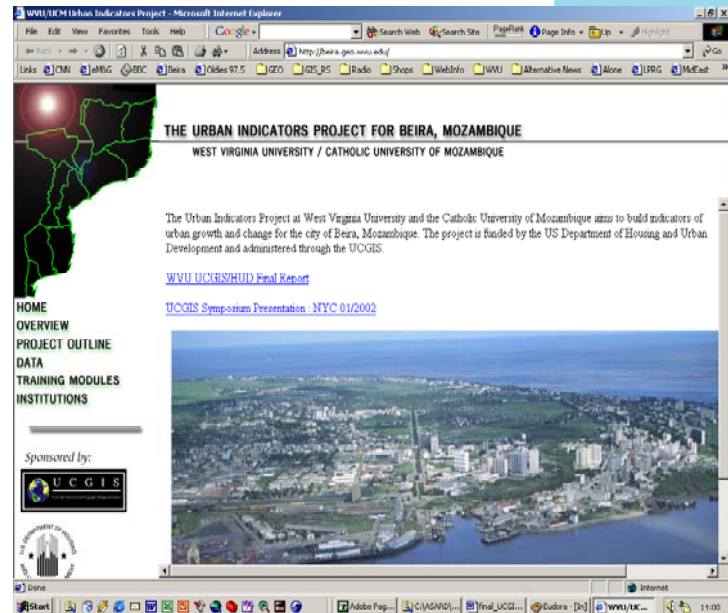
To promote information on this project and to disseminate data and information to the scientific community and our international collaborators, we have established a web-site at <http://beira.geo.wvu.edu/>. This site details the project, including a descriptive overview, a project outline, a data distribution page, the training modules, and institutional profiles. Nested within the site are the training module exercises and the shell of the internet map service (IMS). The site includes several clickable images and downloadable powerpoint presentations of findings as shown in the New York City Symposium in January 2002.

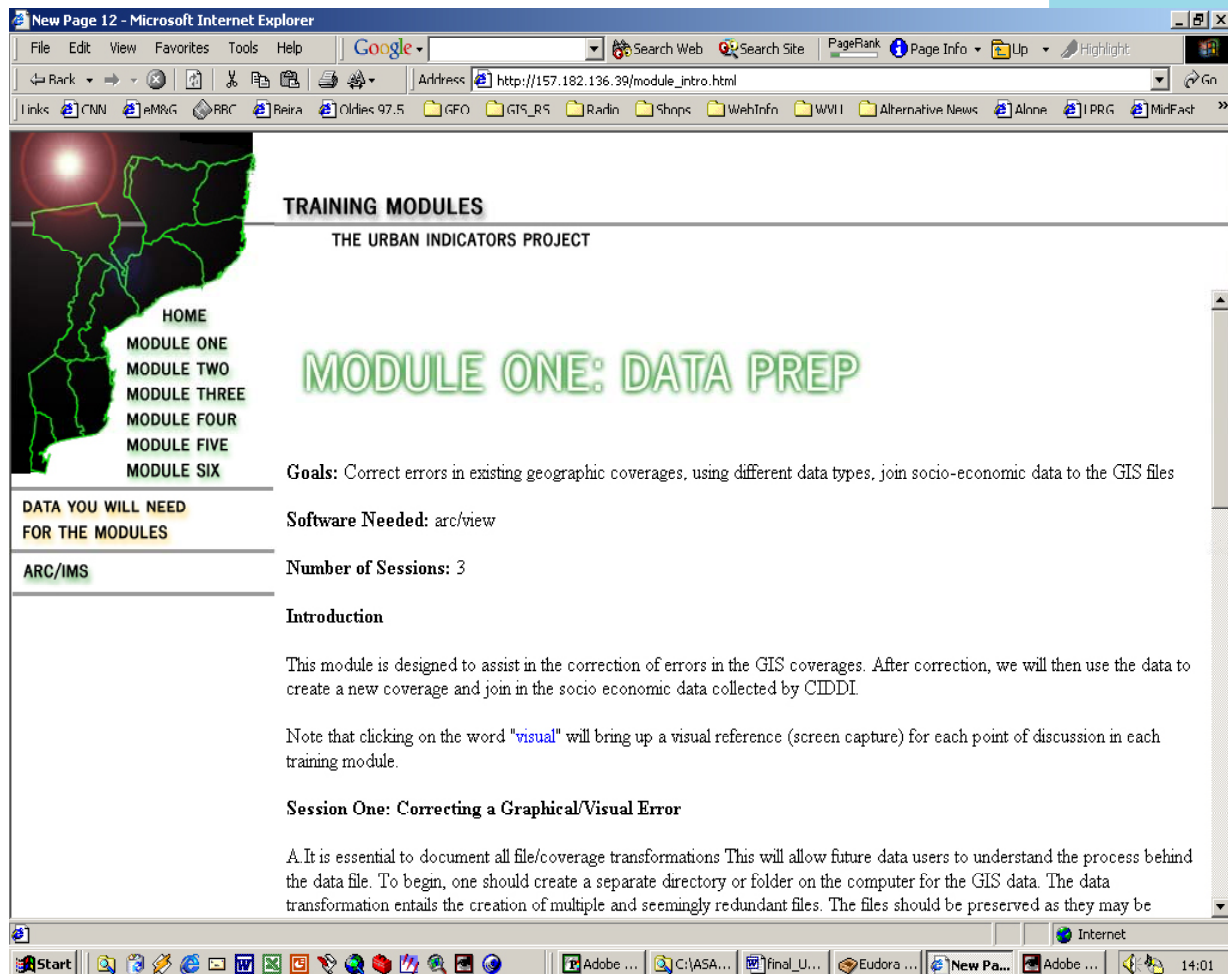
Web Based Training Modules

Web based training with partners in Beira at the Catholic University is a core component of this project. Finding on-site training prohibitively expensive, we set forth to develop web-based training. Each step in data collection, management, and analysis has been developed into training modules (http://beira.geo.wvu.edu/module_intro.html).

There are two stages to the training modules, a basic and introductory stage, and an advanced stage. The introductory stage modules include training sessions on

1. Data management
2. Digital Mapping, and
3. Introduction to GIS





The advanced stage modules include

1. Image Analysis
2. IMS Training, and
3. Analysis and Presentation.

The introductory modules have been completed and the advanced stage modules are being written for web-publication. Problems with the data have slowed progress on the advanced stage modules.

Web-based Training: Internet Map Servers

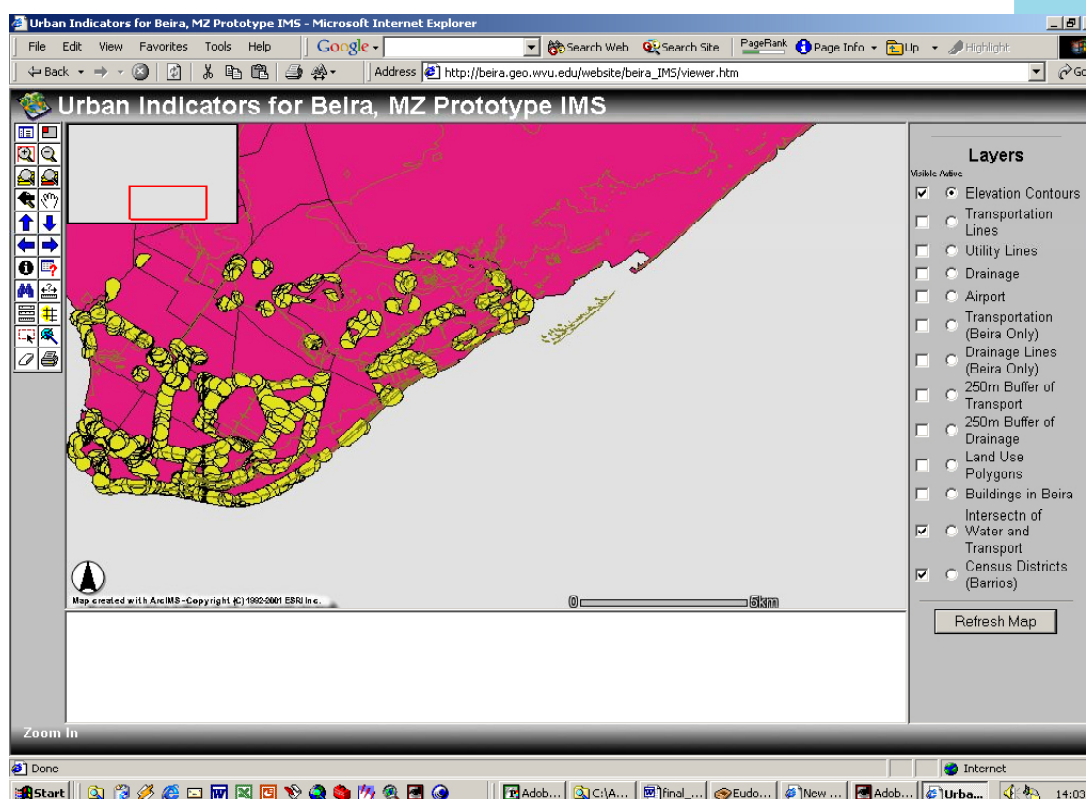
Year One activities included the creation of an Internet map server (Level 0 Prototype at http://beira.geo.wvu.edu/website/beira_IMS/viewer.htm). This server was designed and target toward training of our international partners. The operating software is ARC/IMS, which utilizes the Arc Map component to share maps and data on the Internet. Data obtained in Beira can be corrected and enhanced at WVU and then served back to the Catholic University for further analysis. Advantages of the map server include:

1) ease in transfer of data - Shipping data via CD or printed map is subject to loss or theft in transit;

2) security - ARC/IMS 3.1 allows for various levels of security. An interface may be kept open for the general public while at the same time only authorized users can access sensitive data;

3) more dynamic training – our collaborators in Beira have much more access to the project's daily activities and can be provided with far more opportunities to train. Expensive personnel trips back and forth can be reduced, thus saving limited resources.

Continued development of the IMS will continue, given Year Two finding. We expect to achieve significant improvements to the system with the release of ARC/IMS version 4.0.



GIS for Urban Planning in Developing Countries

The future of GIS for planning in developing countries is dependant on building tools that meet the local needs of planning practices for data manipulation, decision-support, visualization and policy analysis (Brail and Klosterman, 2001). Strategic information resource management and the integration of appropriate technologies for effective planning are, therefore, key to the diffusion of GIS and GIS-based capacity building for planning applications. The availability of both qualitative and quantitative data remains a major constraint to planning efforts in the City of Beira. City planners can overcome some of these problems by using simple techniques such as controlled surveys and extrapolation to build a GIS that will allow them to gain a snap-short of prevailing conditions, identify hotspots, and, to monitor change. A complementary approach would be the use of remotely sensed images of land use types (e.g., housing) in conjunction with existing official records such as city infrastructure layout maps to determine access to facilities such as water, sanitation and electricity, provided the capacity exists to manipulate and interpret such data.

The potential for geographic information systems to assist urban planners in data poor environments that are experiencing rapid change has been demonstrated with this research. For example, valuable spatial information about housing quality, population density, access to critical infrastructure, services, and land use/land cover patterns has been presented. In the case of water, GIS buffering shows poor

access in densely populated neighborhoods and generally poorly serviced squatter communities. There is also a concentration of population growth near the city center and this compounds the strains of urban growth and change. There is also a clustering of population near transportation nodes and networks because of the poor transportation options available to Beira residents. The Beira GIS also indicates significant urban agriculture, and this is consistent with informal housing growth and a steady migration from rural areas. These gardens are an important source of nutrition for residents and planners must recognize this spatial reality and the importance of urban agriculture for peoples' livelihoods.

These examples suggest that GIS technology is appropriate for local planners and planning agencies in Beira. The hardware and software are already available locally and CIDDI-UCM has become a high quality depository for digital spatial information for Beira and all of Central Mozambique. Our conclusion is that GIS is an appropriate technology for city planning in Beira and similar urban areas in developing countries.

Data Issues

Several data issues faced this project, both anticipated and unanticipated. The expectation of many northern institutions that readily available data exists for cities in developing countries cities is inaccurate. The data needs for the list of urban indicators drawn up by the United Nations can be easily met in the developed world, but the case is very different in most developing country situations. This is especially relevant in data-poor African contexts. The following are the most significant data issues faced in this project.

Incomplete meta-data: Directly related to issues of poor data quality are those regarding meta-data. In many cases the data was simply not explained. Where coverages had complete databases, the explanation of the database was absent. Documentation on data creation methods is completely absent and documentation of data quality is being generated, as it also does not exist. The absence of this information, while not proving to be insurmountable, contributes significantly to delay and generation of the information is more time consuming at this later stage than at the time that data are created.

Data quality: Where data exist, they are often of poor quality. A simple satellite underlay showed gaping holes and significant errors in the data. Cross-compatibility is a second data quality issue. Several coverages simply could not be opened together. Projection errors were most commonly the case of poor cross compatibility, but some coverages were captured in different reference systems (about one-fourth of the coverages were captured in the Clarke reference system while half

were captured in a WGS 84 reference system).

A second major data quality issue is that of incomplete data sets. While the GIS features were present in the coverages (line, polygons, points), much of the database relating to these features was un-populated. No data existed for much of the transportation and water coverages. The land use and houses/building coverages had databases only one-fourth to one-half complete. Populating these data sets from the air photography has proven to be time consuming.

Language: Language differences were minimized in that four members of the team at CIDDI spoke English, however a lack of Portuguese speakers on the team at WVU resulted in inevitable bottle-necks as translation from Portuguese to English had to go through the project administrator. Data sets were largely in Portuguese and translation into English was time consuming as each question and variables, in the socio-economic survey for instance, had to be translated. While issues of language will remain, methods should be investigated as to reducing language barriers.

What can we conclude from this exercise?

The initial assumption that these pilot projects could draw/relay on the availability and applicability of UN derived urban indicators to develop a GIS for monitoring and analyzing urban indicators at the sub-city level was too ambitious and unrealistic for two reasons:

1. UN urban indicators, though providing a useful starting point, were intended for country comparisons rather than sub-city level analysis. Since urban problems are contextually based and solutions have to be developed locally, sub-city level analysis of indicators requires the generation of data that is situation specific. This is an important lesson from the Beira experience.
2. Unlike cities in other countries, data on key UN urban indicators were found to be either incomplete or non-existent. This was not surprising given that Mozambique only recently emerged from a long protracted civil war, and therefore faces major challenges on many fronts including reconstituting critical databases for urban policy analysis and institutional capacity building.

The conditions of a poor data environment presented both constraints and opportunities. Specifically, the need to generate new data forced an early decision concerning the choice of indicators and the methods of analysis. In this respect, the training modules developed both reflect the desire and

need to familiarize the user with basic techniques for selecting appropriate indicators, data gathering methods, mapping as well as techniques for integrating disparate data sources to analyze and monitor urban indicators.

Though the methods and spatial techniques applied in this project were dictated by the unique set of circumstances that exist in Beira, they offer useful lessons for other areas characterized by a poor data environment or where local authorities have limited capacity to monitor growth and change. For example, the emerging *colonias* settlements along the US-Mexican border are a case in point. The Office of Housing and Urban Development defines *colonias* as “rural communities and neighborhoods located within 150 miles of the US-Mexican border” (<http://www.hud.gov>). Their conditions mirror those of informal settlements on the urban fringe in developing countries in that they lack adequate infrastructure and other basic facilities or develop spontaneously without jurisdictional sanction and viable livelihood systems.

For regional and local authorities attempting to respond to this growth phenomenon, the various methods used in the Beira context offer possibilities. Remotely sensed data (air photography and satellite imagery), can be used to estimate the pace of *colonias* growth as well as to assess the threat of encroachment to ecologically sensitive areas and farm land. Second, an integration of remotely sensed data and resultant GIS coverages can be used both as a predictive and planning tool for infrastructure improvement, assessing housing conditions, and demand estimation of related basic facilities, for example: water access, electricity, sanitation, schools and recreation.

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Abbot, J., R. Chambers., C. Dunn., T. Harris., E. De Merode., J. Townsend., and D. Weiner. 1998. Participatory GIS: Opportunity or Oxymoron. *PLA Notes* 33: 27-34.

Abbott, J. 2000. The Use of spatial data to support the integration of informal settlements into the formal city. *Presentation at the Urban Research Seminar Series*. ITC, Enchede, The Netherlands.

Abebe, Y. and D. Holdstock. 1993. Applicability of GIS technology for transportation planning and development in developing countries: A case study for Sub-Saharan Africa. Annual Meeting of the Institute of Transportation Engineers (ITE), September 19-22, 1993. Compendium of Technical Papers- pp. 342-346.

Abiodun, O.J. 1997. The challenges of growth and development in metropolitan Lagos. In: C. Rakodi. *The Urban Challenge in Africa: Growth and Management of its Large Cities*. Tokyo: United Nations University Press. Pp. 192-222.

Accordino, J. and R. Rugg. 1999. The Richmond Neighborhood Indicators Project: phase I final report. *Paper Prepared for the Richmond Local Initiatives Support Corporation by the Department of Urban Studies and Planning, Virginia Commonwealth University*. June, 1999.

Aitken, S. and Michel, S.M. 1995. Who contrives the "real" in GIS? *Geographic Information Systems, Planning, and Critical Theory*. *Cartography and Geographic Information Systems* 22(1): 17-29.

Al-Kodmany, K. 2000. Extending geographic information systems (GIS) to meet neighborhood planning needs: Recent developments in the work of the University of Illinois at Chicago. *URISA Journal* 12 (3): 1-17.
 Alspach, A. J. 1999. Integration of Geographic Information Systems (GIS) in regional participatory development projects. *Papers and proceedings of GISOC'99, an international conference on Geographic Information and Society, Minneapolis, MN. June 20-22, 1999*. Url: <http://www.socsci.umn.edu/~bongman/gisoc99/new/alspach.htm>

Anderson, P.S. 2000. Mapping land rights in Mozambique. *Photogrammetric Engineering and Remote Sensing* 66 (6): 769-775.

Angotti, T. (ed.) 1993. *Metropolis 2000: Planning, Poverty and Politics*. New York: Routledge.

Banerjee, T. 1996. Role of indicators in monitoring growing urban regions: The case of planning in India's national capital. *Journal of the American Planning Association* 66 (2): 222-235.

Barndt, Michael., and Will Craig, 1994. Data Providers Empower Community GIS Efforts. *GIS World*, 7 (7), 46-51.

Beavon, K.S.O. 1997. Johannesburg: A city and metropolitan area in transformation. In: C. Rakodi. *The Urban Challenge in Africa: Growth and Management of its Large Cities*. Tokyo: United Nations University Press. Pp. 150-191.

Blackwell Publishers pp. 242-259.

Budic, Z. 1998. The likelihood of becoming a GIS user. *URISA Journal*, 10 pp. 6-21

Budic, Z.D., and D.R. Godschalk. 1994. Implementation and management effectiveness in adoption of GIS technology in local governments. *Computers, Environment, and Urban Systems* 18 (5): 285-304.

Campbell, H, & Masser, I. 1995. *GIS and organizations: How effective are GIS in practice?* London: Taylor and Francis.

Campbell, H. 1996. A social interactionist perspective on computer implementation. *Journal of the American Planning Association* 62 (1): 99-107.

Cavric, Branko I., Horatio G. Ikgopoleng, and Zorica Nedovic-Budic. 2000. Diffusion of Geographical Information System (GIS) Technology in Developing Countries: A Case Study of Botswana. In *Proceedings of Urban and Regional Information Systems Association (URISA) 38th Annual Conference*; Orlando, FL, August 19-23, 2000, pp. 242-251

Clapp, John M., Mauricio Rodriguez, and Grant Thrall (1997). Review essay: How GIS Can Put Urban Economic Analysis on the Map. *Journal of Housing Economics*, 6.

Conitz, M. 2000. GIS applications in Africa: Introduction. *Photogrammetric Engineering and Remote Sensing* (Introduction to Special Issue) pp. 672-673.

Counter, L., D. Stow., B. Kiracofe., C. Langevin., D. Chen., S. Daeschner., D. Service., and J. Kaiser. 1999. Deriving current land use information for metropolitan transportation planning through integration of remotely sensed data and GIS. *Photogrammetric Engineering and Remote Sensing* 65 (11): 1293-1300.

Cowen, D.J., J.R. Jensen., P.J. Bresnahan., G.B. Ehler., D. Graves., X. Huang, C. Wiesner., and H.E. Mackey (Jr.). 1995. The design and implementation of an integrated geographic information system for environmental applications. *Photogrammetric Engineering and Remote Sensing* 61 (11): 1393-1404.

Craig, W., T. Harris., and D. Weiner. 1999. Empowerment, Marginalization, and Public Participation GIS. *A Technical Report of a Specialist Meeting Held under the Auspices Varenus: NCGIA's Project to advance Geographic Information Science* Santa Barbara, CA. October 15-17, 1998.

Crane, R, and A. Danieri. 1996. Measuring access to basic services in global cities: Descriptive and behavioral approaches. *Journal of the American Planning Association* 62 (2): 203-221.

Croswell, P. L. 1991. Facing reality in GIS implementation: Lessons learned and obstacles to be overcome. *URISA Journal*, 3 pp. 43-56

Cuomo, A. 1997. *Mapping Your Community: Using Geographic Information Systems to strengthen community initiatives*. Washington DC, US Department of Housing and Urban Development.

Cutts, F.T., G. Macassa., A.C. Soares., C. Dos Santos., A. Novoa., and P. David. 1996. Child and maternal mortality during a period of conflict in Beira City, Mozambique. *International Journal of Epidemiology* 25 (2) 349-356.

Dueker, K.J., and P. Barton Delacy. 1990. GIS in the land development planning process. Balancing the needs of land use planners and real estate developers. *Journal of the American Planning Association* 56 (4): 483-491.

Elisabetta, P and Chris, B.A. 1996. GIS as a tool for assessing the influence of countryside designations and planning policies on landscape change. *Journal of Environmental Management* 47: 355-367.

- Epstein, E. 1999. GIS and the land management institution. In: *Papers and proceedings of GISOC'99, an international conference on Geographic Information and Society*, Minneapolis, MN. June 20-22, 1999. Url: <http://www.socsci.umn.edu/~bongman/gisoc99/new/epstein.htm>
- Evans, E.H. 1989. National development and rural-urban policy: Past experience and new directions in Kenya. *Urban Studies* 26: 253-266.
- Farvacque-Vitkovic, C and L. Godin. 1998. *The Future of African Cities: Challenges and Priorities for Urban Development*. Washington DC: The World Bank.
- Flax, M. 1978. *Survey of Urban Indicator Data*. Washington, D.C.: The Urban Institute.
- Fuchs, R.J. 1994. Introduction. In: R.J. Fuchs, E. Brennan, J. Chamie, F.C. Lo, and J.I. Uitto (Eds.). *Mega-City Growth and the Future*. Tokyo: United Nations University Press.
- Ghose, R. 1999. Use of Information Technology for community empowerment: Transforming Geographic Information Systems into Community Information Systems. *Papers and proceedings of GISOC'99, an international conference on Geographic Information and Society*, Minneapolis, MN. June 20-22, 1999. Url: <http://www.socsci.umn.edu/~bongman/gisoc99/new/ghose.htm>
- Ghose, R., & Huxhold, W. 2000. Neighborhood strategic planning through GIS-based indicators: The Milwaukee CDBG project. Submitted to *URISA* journal. (under review).
- Goodchild, M. F. 1995. GIS and geographic research. In: Pickles, J. (ed). *Ground Truth: The Social Implications of Geographic Information Systems*. New York: Guilford: Pp. 31-50.
- Goodchild, M.F. 1992. Geographic Information Science. *International Journal of Geographical Information Systems* 1(4): 31-45.
- Goodchild, M.F., M.J. Egenhofer., K.K.Kemp., D.M. Mark., and E. Sheppard. 1999. Introduction to the Varenius Project. *International Journal of Geographic Information Science* 13 (8): 731-745.
- Grimsbo, O. 1981. *Urban Transport in Mozambique: Organization of Taxi operation in Maputo and Beira*. Oslo: Transportoekonomisk Inst.
- Haack, B., and R. English. 1996. National land cover mapping by remote sensing. *World Development* 24: 845-855.
- Hall, P. 2001. Globalization and Urban Economic Prospects. *Global Outlook*, January Edition.
- Handy, S.L. and D.A. Niemeier. 1997. Measuring accessibility: an exploration of issues and alternatives. *Environment and Planning A*, 29 (7): 1175-1194.
- Hanson, S. and M. Schwab. 1987. Accessibility and intraurban travel. *Environment and Planning A*, 19: 735-748.
- Harvey, F., C. Velan., F. Golay., and G. Berthoud. 1999. Approaching networks of GI engineering: Merging quantitative and qualitative research methods. In: *Papers and proceedings of GISOC'99, an international conference on Geographic Information and Society*, Minneapolis, MN. June 20-22, 1999. Url: <http://www.socsci.umn.edu/~bongman/gisoc99/new/harvey.htm>

- Hastings, D.A., and D.M Clark. 1991. GIS in Africa: problems, challenges, and opportunities for cooperation. *International Journal of Geographical Information Systems* 4(1): 29-39.
- Hoeschele, W. 2000. Geographic Information Engineering and social ground truth in Attappadi, Kerela State, India. *Annals of the Association of American Geographers* 90 (2): 293-321.
- Holden, M. 2000. GIS in land use planning: Lessons from critical theory and the gulf islands. *Journal of Planning Education and Research* 19: 287-296.
- HUD, 1997. Mapping your community: Using geographic information to strengthen community initiatives. HUD-1092-CPD, US Department of Housing and Urban Development. Washington DC.
- Huxhold, W, & Levinsohn, A. 1995. *Managing Geographic Information System Projects*. Oxford: Oxford University Press.
- Huxhold, W. 1991. *An introduction to Urban Geographic Information Systems*. New York: Oxford University Press.
- Innes, J.E., and Simpson, D.M. 1993. Implementing GIS for planning: Lessons from the history of technological innovation. *Journal of the American Planning Association*. 59 (2): 230-236.
- Isaacman, A.F. 1987. Mozambique and the regional Conflict in Southern Africa. *Current History* 86: 213-216.
- Jenkins, P. 2001. Strengthening access to land for housing for the poor in Maputo, Mozambique. *International Journal of Urban and Regional Research* 23 (3): 630-648.
- Jordan, G. 1998. A public participation GIS for community based user groups in Nepal: Putting people before the technology. *Proceedings of the Varenus Project: NCGIA PPGIS Specialist Meeting at Santa Barbara, CA. October 14th -17th, 1998.*
- Jordan, G. 1999. The use of participatory GIS in technology poor countries: Case studies from Zambia and Nepal. *Papers and proceedings of GISOC'99, an international conference on Geographic Information and Society, Minneapolis, MN. June 20-22, 1999.* Url: <http://www.socsci.umn.edu/~bongman/gisoc99/new/jordan.htm>
- Kabagambe, D. and C. Moughtin. 1983. Housing the urban poor: A case study of Nairobi. *Third World Planning Review* 5 (3): 227-248.
- Karaska, G.J. 1999. The regional structures of Third World economics: Rural-urban dynamics in Kenya and Madagascar. *Environment and Planning* 31(5): 767-781.
- Kelley, A.C. 1984. *What Drives Third World City Growth? A Dynamic General Equilibrium Approach*. Princeton (NJ): Princeton University Press.
- Kellogg, W.A. 1999. From the field: Observation on using GIS to develop a neighborhood environmental information system for community-based organizations. *URISA Journal* 11 (1): 15-32.
- Kent, R.B., and R.E. Klosterman. 2000. GIS and Mapping: Pitfalls for planners. *Journal of the American Planning Association* 66 (2): 189-198.
- Kingsley, T. 2000. Neighborhood indicators: Taking advantage of the new potential. *Proceedings of the American Planning Association 1999 Conference*. Url: <http://www.asu.edu/proceedings99/KINGSLEY/KINGSLEY.HTM>

- Kironde, J. 1992. Received concepts and theories in African urbanization and management strategies: The struggle continues. *Urban Studies* 29(8): 1277-1292.
- Knox, P.L. 1978. The intraurban ecology of primary medical care: patterns of accessibility and their policy implications. *Environment and Planning A*, 10: 415-435
- Kyem, P.A.K. 1999a. Embedding GIS applications into resource management and planning activities of community groups in Sub-Saharan Africa. *Papers and proceedings of GISOC'99, an international conference on Geographic Information and Society, Minneapolis, MN. June 20-22, 1999*. Url: <http://www.socsci.umn.edu/~bongman/gisoc99/new/kyem.htm>
- Kyem, P.A.K. 1999b. Examining the discourse about transfer of GIS technology to traditionally non-western societies. *Social Science Computer Review* 17 (1): 69-73.
- Leitmann, J. 1999. *Sustaining Cities: Environmental Planning and Management in Urban Design*. New York: McGraw-Hill.
- Leitner, H., S. Elwood., E. Sheppard., S. McMAster., and R. McMAster. 2000. Modes of GIS provision and their appropriateness for neighborhood organizations: Examples from Minneapolis and St. Paul, Minnesota. *URISA Journal* 12 (4): 43-56.
- Levine, J., and Landis, J.D. 1989. Geographic Information Systems for local planning. *Journal of the American Planning Association* 55 (2): 209-220.
- Liverman, D., Moran, E. F., Rindfuss, R. R., and Stern, P. C. 1998. *People and Pixels: Linking Remote Sensing and Social Science*. Washington DC, National Academy Press.
- Longley, P.A., M.F. Goodchild., D.J. Maguire., and D.W Rhind (eds). 1999 (vol. 1 and 2). *Geographic Information Systems: Principles and Technical Issues*. New York: John Wiley and Sons.
- Lupton, M., and C. Mather. 1996. 'The anti-politics machine': GIS and the reconstruction of the Johannesburg local state. *Political Geography* 16 (7): 565-580.
- Mabogunje, A.L. 1992. Perspective on urban land and urban management policies in Sub-Saharan Africa. *World Bank Technical Paper Number 196. African Technical Department Series*, Washington, DC.
- MacDevette, D.R. 1991. Institutional Concerns and opportunities in LIS/GIS: Some experiences from South Africa. *Proceedings of the Third Annual Seminar on LIS/GIS*. Harare, Zimbabwe, 4th -5th, March 1991.
- MacDevette, D.R., G.G. Forsyth, and Y. Jairosi. 1995. The use of personal computer-based GIS for natural resource management. *Paper Presented at the Proceedings of the AfricaGIS 95 Conference, Abidjan, March 5th -10th, 1995*.
- MacDonald, M.L. 1996. Bias issues in the utilization of solid waste indicators. *Journal of the American Planning Association* 62 (2): 236-242.
- Macharia, K. 1997. *Social and Political Dynamics of the Informal Economy in African Cities: Nairobi and Harare*. Lanham (MD): University Press of America.
- Maclaren, V.W. 1996. Urban sustainability reporting. *Journal of the American Planning Association* 66 (2): 184-203.

- McCann, E.J. 1999. "Doctors of space": GIS, political activism, and the restructuring of urban and regional planning. In: *Papers and proceedings of GISOC'99, an international conference on Geographic Information and Society*, Minneapolis, MN. June 20-22, 1999. Url: <http://www.socsci.umn.edu/~bongman/gisoc99/new/mccann.htm>
- McDonald, David. 2000. Municipal Services Project: Comments on the Unicity Commission's . *Discussion Document: Developing the Future City of Cape Town*. Url: <http://www.cosatu.org.za/samwu/mspcritique.htm>
- Meldrum, A. 1991. Railway of refuge. *Africa Report* 36: 63-66.
- Miraftab, F. 1996. *Women's Empowerment: Participation in Shelter Strategies at the Community Level in Urban Informal Settlements*. Nairobi, Kenya: United Nations Center for Human Settlements
- Mitchell, A. 1997. *Zeroing in: Geographic Information Systems at work in the community*. Redlands (CA): ESRI.
- Moneyhan, D.W. 1998. International applications of GIS. In T. Foresman (ed) *The History of Geographic Information Systems: Perspectives from the Pioneers*. Upper Saddle River: Prentice Hall.
- Montagu, A.S. 2000. GIS and natural resource planning in Papua New Guinea: A contextual analysis. *Environment and Planning B: Planning and Design* 27 (2): 183-196.
- Morna, C.L 1987. Doing business in Beira. *Africa Report* 32: 61-63.
- Mozambique: Basic data. 2000. *The Economist Intelligence Unit Limited*. Country Profile 1999-2000.
- Nedovic-Budic, Z. 1999. Evaluating the effects of GIS technology: review of methods. *Journal of Planning Literature* 28 (3): 284-295.
- Nedovic-Budic, Z. 2000. Geographic Information Science implications for urban and regional planning. *URISA Journal* 12 (2): 81-93.
- Nyerges, T., M. Barndt., and K. Brooks. 1997. Public Participation Geographic Information Systems. *ACSM/ ASPRS Annual Convention and Exposition Technical Papers*, pp. 224-233.
- Obemeyer, N. J. (ed) 1998. Public Participation GIS. *Cartography and Geographic Information Systems* (Special Issue - Vol. 25 No. 2).
- Obermeyer, N, and Pinto, J. 1994. *Managing Geographic Information Systems*. London: The Guilford Press
- Ondiege, P.O. 1989. Urban Land and Residential Market Analysis in Kenya. Urban Management Program, Nairobi: UNCHS (Habitat).
- Pandey, S., R. Gunn., K.J. Lim., B. Engel., and J. Harbor. 2000. Developing a web-based tool to assess long-term hydrologic impacts of land use change: Information technology issues and a case study. *URISA Journal* 12 (4):
- Phillips, B. 1995. The view from Beira. *Africa Report*. 40: 20-21.
- President's Council on Sustainable Development, 1999. Towards a sustainable America: Advancing prosperity, opportunity, and a healthy environment for the 21st century. May 1999. Url: <http://www.whitehouse.gov/media/pdf/tsa.pdf>

- Rakodi, C. (ed.) 1997. *The Urban Challenge in Africa: Growth and Management of its Large Cities*. New York: United Nations University Press.
- Ramasubramanian, L. 1995. Building communities: GIS and participatory decision-making. *Journal of Urban Technology*, 3,1, pp. 67 – 79
- Ramasubramanian, L. 1999. GIS implementation in developing countries: Learning from organizational Report to the Institute of transport Economics. Oslo:
- Rondinelli, D. 1983. *Secondary cities in developing countries*. Beverly Hills: Sage Publications.
- Ryavec, Karl. 1999. Integrating participatory mapping of pastoral land use in Tibet with a regional model of population-environment interactions on the Tibetan plateau. *Papers and proceedings of GISOC'99, an international conference on Geographic Information and Society, Minneapolis, MN. June 22-29, 1999*. Url: <http://www.socsci.umn.edu/~bongman/gisoc99/new/.htm>
- Ryznar, R.M and T.W. Wagner. 2001. Using remotely sensed imagery to detect change: Viewing Detroit from space. *Journal of the American Planning Association* 67 (3): 327-337.
- Sanders, R. 1992. Eurocentric bias in the study of African urbanization: A provocative to debate. *Antipode* 24(3): 203-213.
- Sawicki, D. S., and Peterman, D. R. 1998. Understanding the breath and depth of PPGIS supply. *Proceedings of the Varenus Project: NCGIA PPGIS Specialist Meeting at Santa Barbara, CA. October 14th –17th, 1998*.
- Sawicki, D.S and P. Flynn. 1996. Neighborhood indicators: A review of the literature and an assessment of conceptual and methodological issues. *Journal of the American Planning Association* 66 (2): 165-183.
- Schroeder, P.C. 1997. GIS in public participation settings. *Paper presented at the University Consortium for Geographic Information Science Annual Assembly and Summer Retreat, June 15-21, Bar Harbor, ME*.
- Schuurman, N. 1999a. An interview with Michael Goodchild, January 6, 1998, Santa Barbara, California. *Environment and Planning D: Space and Society* 17: 3-15.
- Schuurman, N. 1999b. Lessons in constructing a science: Promises and pitfalls of GIS. *Papers and proceedings of GISOC'99, an international conference on Geographic Information and Society, Minneapolis, MN. June 20-22, 1999*. Url: <http://www.socsci.umn.edu/~bongman/gisoc99/new/schuurman.htm>
- Sheldon, K. 1991. A report on a 'delicate problem' concerning female garment workers in Beira, Mozambique. *Signs: Journal of Women in Culture and Society* 16 (3):575-586.
- Sheppard, E., H. Couclelis., S. Graham., J.W. Herrington., and H. Onsrud. 1999. Geographies of the information society. *International Journal of Geographic Information Science* 13 (8): 797-823.
- Sideway, J. 1993. Urban and regional planning in post-independence Mozambique. *International Journal of Urban and Regional Research* 17 (2): 241-259.
- Siliuzas, R. 1999. Research issues for the adoption of Geographic Information Technology for urban planning and management in developing countries. *International workshop on Concepts and Paradigms of Urban Management in the context of developing countries, Venice. March 11-12, 1999*.
- Singh, R.R. 1999. Sketching the city: A GIS-based approach. *Environment and Planning B: Planning and Design* 26 (3): 455-468.

- Smith, J. 1988. The Beira Corridor Project. *Geography* 73: 258-261.
- Smith, R.C. 1995. GIS and long range economic planning for indigenous territories. *Cultural Survival Quarterly* 18: 43-48.
- Somers, R. 1995. Organizing and staffing a successful GIS: Organizational strategies. *URISA Journal* 7: 49-52
- Stren, 1978. *Housing the Urban Poor in Africa: Policy, Politics, and Bureaucracy in Mombasa*. Berkely: Institute of International Studies.
- Stren, R. (ed) 1994. *Urban Research in Developing World Volume 2: Africa*. Toronto: University of Toronto Press.
- Stren, R., and R. White (eds.) 1989. *African Cities in Crisis: Managing Rapid Urban Growth*. Boulder (CO): Westview Press.
- Sui, D.Z., and J.R. Giardino. 1995. Applications of GIS in environmental equity analysis: A multi-scale and multi-zoning study for the city of Houston, Texas, USA. *Source Journal?* Pp. 950-959.
- Tabor, J.A., and C.F. Hutchinson. 1994. Using indigenous knowledge, remote sensing, and GIS for sustainable development. *Indigenous Knowledge and Development Monitor* 2 (1): 1-4. Url: <http://www.nufficcs.nl/ciran/ikdm/2-1/articles/tabor.html>
- Talen, E. 1999. Constructing neighborhoods from the bottom up: The case from resident-generated GIS. *Environment and Planning B: Planning and Design* 26 (4): 533-554.
- Talen, E. 2000. Bottom-Up GIS: A new tool for individual and group expression in participatory planning. *Journal of the American Planning Association* 66 (3): 279-294.
- Talen, E. 2000. Geographical Access. *International Encyclopedia of the Social and Behavioral Sciences*. Vol. 3.6, Article 7. Neil J. Smelser and Paul B. Baltes, editors. Oxford, UK: Elsevier Science.
- Talen, E. and L. Anselin. 1998. Assessing spatial equity: An evaluation of measures of accessibility to public playgrounds. *Environment and Planning A* 30: 595-613.
- Tarver, D. (ed.) 1994. *Urbanization in Africa: A Handbook*. Greenwood Press, Westport. theory and reflective practice. *Transactions in GIS*, 3, 4, pp. 359 – 380.
- Thurstain-Goodwin, M., and S. Batty. 1998. GIS and town centers: Exploratory environments involving experts and users. *Built Environment* 21 (1): 43-56.
- Treitz, P.M., P.J. Howarth., and P. Gong. 1992. Application of satellite and GIS technologies for land cover and land use mapping at the rural-urban fringe: A case study. *Photogrammetric Engineering and Remote Sensing* 58: 439-48.
- Tulloch, D.L. 1999. Theoretical model of multipurpose land information systems development. *Transactions in Geographic Information Systems* 3 (34): 259-283.
- Tulloch, D.L., D. Barnes., and D. Bartholomew. 1997. The Wisconsin Land Information Program: Supporting community land information system development. *Surveying and Land Information Systems* 57 (4): 241-48.

U.S. Interagency Working Group on Sustainable Development Indicators, 1998. Sustainable development in the United States: An experimental set of indicators. Final report December 1998. Url: <http://www.sdi.gov/>

VanderMeulen, J., and J. Lively. 1994. Information access systems for community planning. *Planning and Zoning News* 13: 11-16.

Ventura, S., Niemann, B., Sutphin, T., and Chenoweth, R. 1998. GIS-enhanced land use planning in Dane County, Wisconsin. *Proceedings of the Varenus Project: NCGIA PPGIS Specialist Meeting at Santa Barbara, CA*. October 14th -17th, 1998. Url: <http://www.ncgia.ucsb.edu/varenus/ppgis/papers/ventura.html>

Ventura, S.J. 1995. The use of Geographic Information Systems in local government. *Public Administrative Review* 55(5): 461-467.

Waldron, J.D., and D.Z. Sui. 1999. Integrating indigenous knowledge and GIS in land use suitability analysis. In: *Papers and proceedings of GISOC'99, an international conference on Geographic Information and Society*, Minneapolis, MN. June 20-22, 1999. Url: <http://www.socsci.umn.edu/~bongman/gisoc99/new/waldron.htm>

Weiner, D., and T.M. Harris. 1999. Community Integrated GIS for land reform in Mpumalanga province, South Africa. *West Virginia University Regional Research Institute (Morgantown)*. Research Paper No. 9907. Url: <http://www.rri.wvu.edu/pdf/files/gisweiner.pdf>

Weiner, D., T. Warner, T. M. Harris, and R. M Levin. 1995. Apartheid representations in a digital landscape: GIS remote sensing and local knowledge in Kiepersol, South Africa. *Cartography and Geographic Information Systems* 22(1): 30-44.

Wekwete, K.H., and C.O. Rambanapasi. (eds.) 1994. *Planning Urban Economies in Eastern and Southern Africa*. Avebury: Aldershot.

Williams, K.G., T.S. Shalaby., and P. Whitehouse. 1994. Spatial analysis and GIS for planning in developing countries; case studies from Africa: Kenya and Mauritius. *EGIS Foundation Position Paper* pp. 1-8.

Wright, D.J., M.F. Goodchild; and J.D. Proctor. 1997a. Demystifying the persistent ambiguity of GIS as "Tool" versus "Science". *Annals of the Association of American Geographers* 87: 346-362.

Wright, D.J., M.F. Goodchild; and J.D. Proctor. 1997b. Reply: Still hoping to turn that theoretical corner. *Annals of the Association of American Geographers* 87 (2): 373.

Yeh, A. G., 1991. The development and applications of geographic information systems for urban and regional planning in the developing countries. *International Journal of Geographic Information Systems* 5(1): 5-27.