LOW-TECHNOLOGY ALTERNATIVES FOR GIS SUPPORT OF WATER RESOURCES PLANNING IN THE A.C.F. BASIN

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Abstract. The purpose of this paper is to provide a pragmatic discussion about the role that low-technology GIS can and will play in support of newly emerging water management structures in the Apalachicola-Chattahoochee-Flint (ACF) region. As with the water resources planning process itself, states and localities in the ACF basin are at differing stages in GIS decision-support. An important concern arises from this scenario: How can planning institutions just beginning to develop GIS best plan for their future decision support needs?

One model for developing GIS capabilities in emerging planning settings is to begin by operationalizing low-technology GIS as one among many tools useful for database management and analysis. Geographers and resource economists at Auburn University have developed a PC-based desktop mapping system to analyze the impacts and adjustments to drought in the Apalachicola-Chattahoochee-Flint (ACF) River Basin during the 1980-1990 period. This experience provides one example to consider in identifying both the strengths and the limitations of low technology approaches to GIS development.

BACKGROUND

Auburn University's ongoing study of agricultural drought adjustments in the ACF Basin has included these research elements: 1) an analysis of how farmers in southeast Alabama responded to climate changes in order to mitigate negative drought and flood impacts; 2) an examination of the relationship between agricultural water use and water resources policy in the ACF region; 3) a comparison of the Alabama, Florida, and Georgia experiences in drought adjustments, especially related to agriculture; and 4) an understanding of how to anticipate for widely varying water use scenarios in the development and implementation of policy. Methods for assessing drought adjustments have included: 1) surveying farmers and interviewing key water management sectors in the ACF region, such as navigational users, industrial users, and environmental users; 2) water management policy analysis, following developments in the ACF comprehensive study and within state management practices through attending open meetings and interviewing policy makers and managers in state government; and 3) development of a model GIS for low technology planning and research settings that permits analysis of data and probing issues of appropriate technology in planning.

The development of a GIS component for Auburn's analysis of drought adjustments in the ACF has been guided by the following objectives: 1) to learn what level of analysis, data transfer, and mapping can be accomplished in the desktop environment with easy to use software and easy to access data bases; 2) to analyze drought adjustments data from survey responses, interviews, and secondary data sources; and 3) to model an appropriate GIS implementation strategy for low resource planning settings. These objectives anticipate that GIS will be developed more intensively than in the past as a part of an overall planning adjustment to drought in the state.

One key element in Auburn's GIS approach for drought adjustments analyses has been to assess the significance of human resources development as a component in the overall functionality of low-technology systems. Human resource constraints have been important to resolving the practical problems of using personal computers as GIS platforms, ranging from operationalizing inexpensive software and shareware to utilizing existing government databases and the analytical capabilities of low-end GIS software.

Understanding the significance of human resources in GIS development is necessary for any planning setting, but critical for resource poor planning settings, where relatively small cost adjustments can impact the entire functionality of even a modest role for GIS decision making support. In the context of hyper-rapid technological developments, the use of low technology can be an important component in achieving technology transfer objectives in planning. However, the Auburn experience in developing low-technology GIS alternatives underscores the urgency for water resource planners in the region to address the human-technology gap with a well projected schedule for database development and decision support.

Anticipating Changes in G.I.S. Support for Water Resources Planning in Alabama

Existing GIS development for water resources planning in Alabama is comprised of the regional contribution within the national public sector agency-based database management and long term archiving activities (for example, soil mapping at local level United States Soil Conservation Service offices). Alabama's state-wide settings for water management, Alabama Department of Environmental Management (ADEM) and Alabama Department of Economic and Community Affairs (ADECA), are developing GIS by building on databases already established within these federal agency settings located in the state and through linkages with state-wide industries (such as Alabama Power). (Warnecke 1992) This reliance on cooperative arrangements with federal agencies or local industries for advancing the state's GIS needs is due to the fact that state funded institutions are not positioned well for obtaining resources related to GIS development and database management.

While technology and data sharing are common elements of well structured GIS development plans, it is still important to articulate GIS needs from within the state's own data requirements. The challenge to the state is to identify how to build on this knowledge and database record but integrate it with newly emerging objectives and newly conceived of and constructed databases that are mandated along with the recent creation of the Office of Water Resources, a division of ADECA. (Office of Water Resources 1994) Developing multiple GIS strategies for appropriate planning settings can produce two potential benefits: 1) integration and coordination of data collected at different geographic scales, and 2) integration and coordination for different water use constituencies within the state.

DESIGN ELEMENTS FOR LOW TECHNOLOGY G.I.S. DEVELOPMENT

Because geographic coordination for water resources management is just beginning in Alabama, GIS development in state planning is occurring simultaneously with the development of planning institutions and database construction. This scenario presents interesting challenges to planners in Alabama: How can we learn from experiences but develop appropriately to our needs as we are just beginning to formalize how we express and document our needs? What shall be an appropriate implementation and integration schedule and process for including new information and uses into the system? How will GIS implementation processes, or planning for GIS and the use of GIS be related to decision making by Alabama's water resource managers? These are questions pertinent to other water resource managers as well. A new subfield of GIS management is beginning to document successful implementation strategies in a variety of GIS settings through case studies. (Campbell 1991, Worrall 1991) Auburn University's experience in developing a low technology GIS approach for analysis of drought adjustments in the ACF, described further below, adds to this literature by focussing specifically on GIS strategies for low resource planning settings.

System Design Criteria

Auburn's approach to GIS development directly contrasts with state-wide GIS development in Alabama in two ways. First it employs a usability constraint on system design, and second it presupposes a geographically integrated water resources planning approach for developing databases and integrating systems. Features of this system are described and assessed here to raise awareness of both the strengths and limitations of low-technology approaches for GIS development.

Database. The database needs of the project included: USDA agricultural statistics for the counties in the study region, rainfall and temperature records by weather station for all weather stations with data in the region, irrigation by county for Alabama, demographic information by county, farm survey results for 65 farms, and stream patterns by county. These databases were chosen because of their accessibility and because they could be used in a desktop GIS environment.

Design Features. The design criteria for this GIS system were to maximize the following in a system: ease of use and maintenance of equipment, low cost, ease of use of software, ease of data entry, and quality output. The system develops databases that can be manipulated on both Macintosh and PC based software for the purpose of spatial analysis and mapping. Because of this, most time in system development has been to work out the mechanics of file translations and database management between the two systems. Of greatest importance is that the system be interactive; that is that databases can be updated and integrated with other databases. As such, this can be a true desktop operation, one in which decision makers and researchers have easy access to tools and mapping capabilities, depending on their current needs.

Human Resources. Human resources are the most important key to this system in that knowledge of the operating systems, database structures, networking, use of peripheral devices, and analytical tools are what drive system development. While it is unrealistic to assume that in a planning setting one individual might have all of these skills, these can be divided among several individuals, and this has been the approach of developing Auburn's system as well. In general, most of the computer trouble shooting has been accomplished by graduate student research assistants, with faculty input driving decisions about databases and analysis. In a planning setting, one staff member could easily absorb most of these activities, an important advantage of a low technology GIS approach. However, it is important for planning settings to understand the ongoing personnel cost of a similar system with regard to system management and in keeping pace with technological advances.

These considerations should be accounted for in the overall planning for GIS implementation - even in the desktop environment. In general, one problem with operationalizing GIS in low resource planning settings is that over-purchasing systems contributes to human resource management problems instead of resolving them. One key to assessing appropriate levels and plans for implementing technological support for water management is to learn from models of other systems. Perhaps system design costs can even be included as an element in assessing overall costs of implementation. Often this is an activity done in partnership with consultants. However, in low resource environments, these additional costs can be preempt effective planning for GIS development.

Measuring System Benefits. One important factor in assessing and justifying GIS costs is to link those to the larger aims of the project and to analytical needs. GIS assessment has become an issue of importance to planners because of concerns in the adjustments of planning activities that occur with GIS adoption. Cost-benefit analysis has been identified as a potentially useful tool for sorting out system design decisions. (Leipnik et al. 1993, Dale 1991) However, little research has documented the effectiveness and appropriateness of using tools such as cost-benefit analysis for assessing and planning GIS development.

As understanding of the far reaching consequences on institutional planning structures improves, assessment techniques will be more openly developed and debated as an essential element in the overall development of GIS. (Obermeyer and Pinto 1994) For low-resource planning settings, this will necessitate scaling what is meant by low and high cost systems against the context of other available systems and in terms of future resource needs. Accurate projections for the likely impact of GIS development on budgets and human resources, even utilizing low technology approaches, will improve the capacity to adapt this technology for specific purposes.

GIS Assessment

In an effort to begin assessing how well the Auburn GIS approach has accomplished stated objectives, system deliverables can be compared against cost structure. The Auburn system, including three dedicated PCs, personnel costs and software costs is comprised of approximately $30,000 invested in building, maintaining and continuing to develop water resources planning related databases and analysis. This investment was carefully planned to support potential upgrades in equipment and to provide for database integration, especially to build on capabilities of other systems. Additional assessment elements include determining how operational the system is overall as well as determining what specific types of products and analysis are outputs. Finally, identifying the operational problems of the system has provided a basis for future GIS development. System deliverables include:

- Choropleth mapping and spatial analysis
- Location and database querying
- Isoline mapping and modelling
- Image processing and overlay analysis
- Interactiveness of the system:
  - AGIS to Idrisi
  - Atlas Pro to Idrisi, Atlas GIS to Idrisi
  - Reliance on internet shareware for conversions such as GIF Converter, Image Alchemy, and internet resources
  - Use of Macintosh for automated mapping
  - Use of scanner for data input, use of secondary compiled data for data input
  - Idrisi-Atlas Pro-Excel-Flostat-Cricket for analysis and data base management
  - Integrating Tiger files with databases
- Databases:
  - Agricultural statistics by county
  - Farmer survey results by point and county
  - Employment and industrial activity by county
  - Irrigation data by county
  - Climate data, by point and county, temperature, rainfall, and deviations from the 30 year norm

System Limitations. Among the limitations that need to be included in an assessment of low technology GIS approaches is time, both for implementing system and maintaining currency with technology and for analysis of existing data. Training is another limitation: focus on the detail of tasks can prevent understanding of the overall development of the system and application of spatial analysis tools. The difficulty of training students who possess other needed technical skills in the use of analytical tools lies in the time-cost constraint. For planners the use of a team approach can offset the problems presented by one or two individuals knowing the technology but not knowing how to apply it to specific planning problems.

Costs are another limitation: at virtually every stage of system development, costs became a constraint, even in a low cost environment. While essential for minimizing excessive costs, data sharing, networking, use of internet resources, and shareware all require time to access, utilize, and integrate with other system elements. Time constraints can also be measured as financial costs in terms of student wages, minor equipment upgrades, and efficiency. For Auburn's project, the tradeoff was to develop as much integration as possible at the expense of analysis, keeping in mind that working out these system bugs were essential to an ability to have continuous system output in the long run. Moreover, these are not new problems in the operationalization of GIS. Rather it is important not to trivialize their importance even in the low-technology environment. This raises important questions about how newly developing GIS operations should begin in their long term efforts to efficiently utilize GIS in resource management.

CONCLUSIONS: TOWARDS A HUMAN-DEVELOPMENT MODEL OPERATIONALIZING G.I.S.

As Alabama is developing GIS and water planning institutions simultaneously, there is an opportunity to design interactive systems and to identify human resource needs from the basis of emerging research in using GIS in resource poor settings. For example, by knowing more about how to operationalize GIS, Alabama can avoid mistakes and develop the use of GIS in a more human-development oriented model. As individuals learn more about GIS, they are better able to assess their own needs. Expecting them to identify needs from the basis of no or little hands on knowledge is unrealistic, leading to under- empowerment in selecting and designing systems and over- reliance on technical support.

Alabama already heavily relies on secondary data sources to comprise its own water management database. GIS development should incorporate these sources. But solving the barriers to this problem can lead to the unaddressed problem of developing its own databases. Alabama's database problem is deeply embedded in its institutional planning history, which is being modified as a part of its need to better manage shared water resources with Georgia and Florida. That there is only beginning to be a statewide water consumption patterns database means that data collection will proceed concurrently with GIS development. This provides an opportunity to develop planning decision making with GIS support as an integrated effort. However, integrating the two processes will require more open planning procedures, as participant water management groups assist in identifying types of data important for specific management tasks.

In fact, within GIS adoption, a whole new category of planner is implied - that of the GIS/Planner coordinator - whose role is to facilitate system design that is compatible with supporting projected decision making functions of the agency from the basis of developing and managing related databases. A critical element to this coordination role is to develop a data reporting and managing system at the local level that is easy to use and to integrate with those at other decision making scales. The level of technology and software use should be easy to develop and should establish a foundation for further adaptation. While most states wish to utilize the most sophisticated systems, in a state such as Alabama where resources in many areas are scarce, a realistic beginning place may have the double advantage of preventing costly mistakes and concurrently developing the collective computer expertise of the staff such that the next level of technology is more efficiently adopted.

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