Global Livestock CRSP

Spatial Decision Support System : An Integrated Approach to Assessing and Managing Natural Resources

Tracy Baldyga, University of Wyoming
Sustainable Management of Rural Watersheds (SUMAWA) Project

Research Brief 08-05-SUMAWA November 2008

Increased awareness of the complex interactions among humans, their environment, and potential land management decisions has created a demand for integrated multidisciplinary decision support tools within a spatial framework. A prototype of a spatial decision support system (SDSS) that incorporates biophysical and economic models into a single user interface, known as the Spatial Environment and Agricultural Decision Support tool (SEADS), has been implemented within the River Njoro watershed. Spatial and nonspatial data are integrated into a spatially and temporally distributed modeling structure, where complex interactions can be studied through scenario building at watershed and subwatershed scales. Using SEADS, the Sustainable Management of Rural Watersheds (SUMAWA) project has successfully examined how land management decisions can be compared across multiple stakeholder groups with competing interests. From the user's perspective, SEADS provides an environment where policy makers and stakeholders can gain greater understanding of the complexities involved in land management decision making. Through increased knowledge of the system, policy makers and stakeholders are able to make more informed and, ultimately, more appropriate long-term land management decisions.

Background

Encompassing the River Njoro watershed, the Lake Nakuru region geo-ecosystem demonstrates a series of complex interactions where a long-established human interface strongly influences environmental processes. The goal of sustainable development is to meet the current needs of society without compromising the ability of future generations to also meet their needs, and it encompasses interlinked economic, ecological and community imperatives. To further this goal, a spatial decision support system (SDSS) was proposed as part of the Sustainable Management of Rural Watersheds (SUMAWA) project. The SUMAWA prototype SDSS, known as the Spatial Environment and Agricultural Decision Support tool (SEADS), not only allows researchers to develop land and water use scenarios but will also encourage and facilitate stakeholder participation for setting criteria and selecting acceptable management scenarios.

The application of the SDSS is illustrated as follows. Within one of the four River Njoro watershed Water Resources User groups, a plan may emerge to set aside areas for communal grazing while simultaneously closing off other areas. After interactively selecting the area for land use change on a map of the watershed, models and tools that are part of SEADS (the Soil and Water Assessment Tool (SWAT), the Modified Universal Soil Loss Equation (MSLE), and economic indicators) are parameterized and run using information related to the new land use map. Examples of criteria generated by these models and used in the SDSS are water quality and quantity, land cover, fertilizer and pesticide applications, and crop types. These new model outputs can then be compared for feasibility and appropriateness with ranked criteria identified through participatory methods. This new proposed land use can be compared to the current land use, as well as any number of additional alternatives proposed by stakeholder groups. Project researchers are presently working to implement the system in a single ArcGIS interface that will generate several output formats (maps, graphs, charts, and reports) that are meaningful for the various stakeholders involved (Figure 1).

Preliminary Findings

For testing the prototype, simulated stakeholder groups were developed that represent the multiple land management interests SUMAWA researchers have identified over the past several years. These groups represent interests in agriculture, conservation and industry. Various land cover scenarios have been developed for research at symposia (Baldyga et al., 2008; Baldyga et al., 2007a; Baldyga et al., 2007b).

SUMAWA researchers developed land use scenarios involving various types of soil conservation and cropping systems that are appropriate for the area from both biophysical and social perspectives. Within SEADS, criteria are converted to a dimensionless index that allows direct comparison among seemingly disparate

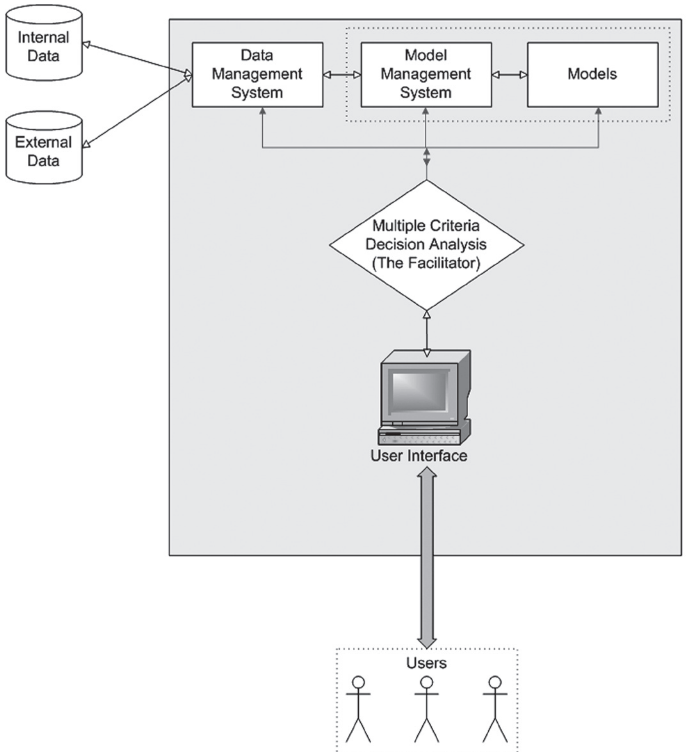

Figure 1. SDSS proposed for use on the SUMAWA project. Source: Baldyga et al., 2008.

criteria. This is accomplished using four simple scoring functions (Figure 2). SEADS does not require stakeholders to assign weights to the criteria. Instead, the criteria ranking assigned by stakeholders is used to calculate the maximum and minimum score for each alternative as constrained by stakeholder ranking, thus removing difficulties a decision maker may face when asked to assign a quantitative importance weight to each criterion. After stakeholder ranking, land use scenarios are ranked from best to worst for each set of identified preferences. This allows land managers to see where groups may be overlapping in preferences and also to examine the differences that can guide further land use scenario development. Ultimately, there is potential for SEADS to convene various stakeholders and facilitate more equitable land management decision-making.

Practical Implications

During fall of 2008, the SDSS was showcased in several venues throughout Africa: the East Africa ESRI User Group Annual Meeting (Kampala, Uganda), AfricaGIS 2007 (Ouagadougou, Burkina Faso) and many government and non-government settings in Kenya (Egerton University faculty and students, World Wildlife Fund for Nature, Kenya Wildlife Service, the Rift Valley Water Resources Management Authority, and local Water Resources User Groups in the River Njoro). The practical application of SEADS was immediately perceived by all the groups. Individual groups suggested applications of the tool for their respective purposes, and these suggestions are being used to further guide SEADS development. SUMAWA expects the final SDSS to be implemented in an ArcGIS interface by the fall of 2008.

The merits of simple GIS and participatory mapping efforts have been widely heralded as the next step in development practices, yet there is a noted lack of GIS applications – such as SDSS – that have the true potential to be stakeholder driven. Development of the SDSS puts the SUMAWA team at the forefront of natural resource management science.

Several DSS and SDSS have been designed and implemented with varying degrees of success in African countries. An SDSS was recently implemented in Niger for the Inner Niger Delta that successfully incorporated economics, ecology and water management but was based solely on policy without stakeholder input (Zwarts et al., 2006). In Kenya, at least two Spatial Decision Support System projects were developed in recent years. In 2003, researchers at the Regional Centre for Mapping of Resources for Development (RCMRD)

Figure 2. Four basic shapes of scoring functions to be used in the proposed SDSS. Each criterion in the SDSS is defined based on one of these four basic functions.

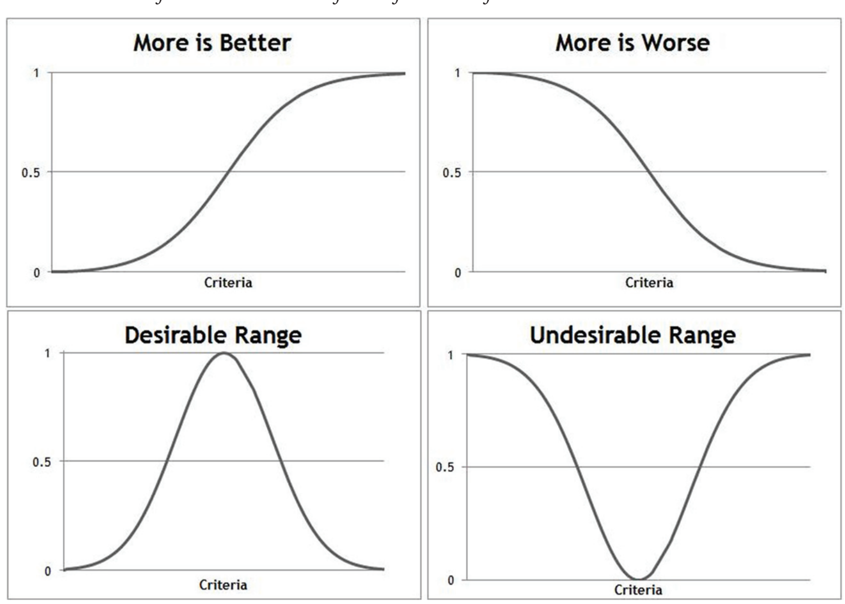

Table 1a-f. Land use alternative scenarios for the upper River Njoro watershed and the watershed location within Kenya. Scenarios were designed to broadly assess impacts of large-scale land management decisions, not actual management decisions. Source: Baldyga et al., 2008.

Table 1a. Current Scenario	
Land Cover Land Use	*Area (Ha)*
Grass	1483.47
Dense Vegetation	5806.89
Plantation Forest	1583.82
Urban	1.17
Degraded	181.71
Small-Grain Crops	706.32
Maize	740.7
Maize-Bean Intercropping	1126.08

Table 1b. Forest Incursions	
Land Cover Land Use	*Area (Ha)*
Grass	2083.41
Dense Vegetation	4487.13
Plantation Forest	135
Urban	1.17
Degraded	181.71
Small-Grain Crops	706.32
Maize	1285.2
Maize-Bean Intercropping	2750.22

Table 1c. All small-scale agriculture as maize	
Land Cover Land Use	*Area (Ha)*
Grass	1483.47
Dense Vegetation	5806.89
Plantation Forest	1583.82
Urban	1.17
Degraded	181.71
Small-Grain Crops	706.32
Maize	1866.78

Table 1d. Contour cropping	
Land Cover Land Use	*Area (Ha)*
Grass	1483.47
Dense Vegetation	5806.89
Plantation Forest	1583.82
Urban	1.17
Degraded	181.71
Contoured Small-Grain Crops	706.32
Contoured Maize	740.7
Contoured Maize-Bean Intercropping	1126.08

Table 1e. Forests converted to small-scale mixed agriculture	
Land Cover Land Use	*Area (Ha)*
Grass	1717.83
Urban	1.17
Degraded	181.71
Small-Grain Crops	706.32
Maize	3601.8
Maize-Bean Intercropping	5421.33

Table 1f. Forests converted to maize	
Land Cover Land Use	*Area (Ha)*
Grass	1717.83
Dense Vegetation	5615.46
Plantation Forest	1540.89
Urban	1.17
Degraded	181.71
Small-Grain Crops	706.32
Maize	740.7
Maize-Bean Intercropping	1126.08

put together what they identified as an SDSS in the Njoro watershed, but it lacked any analysis methods and relied only on standard GIS functionality (Agatsiva and Oroda, 2003). A second and highly successful SDSS was designed and implemented in the Kusa and Koru areas in Kenya (Ochola and Kerkides, 2004). Their spatial decision support system was integrative and interactive in scope and focused on land quality assessments for agricultural purposes specifically.

SUMAWA, on the other hand, is developing an SDSS that is watershed management-based and has the potential to facilitate land use planning efforts throughout East Africa from a stakeholder driven perspective. SUMAWA is making a significant contribution to SDSS research by developing improved methods for integrating and analyzing unstructured data, such as stakeholders' views of natural resources, with structured data from biophysical and economic models.

Issues such as tropical deforestation and overgrazing are receiving a great deal of attention in the public forum as significant factors in decreased ecological function and biodiversity, soil losses, and negatively impacted rural livelihoods. At the same time, there is a call to include more stakeholder input from the village to the national level in making land use planning decisions (World Commission on Dams, 2000). As computer hardware and spatial datasets are becoming more available and accessible, SDSS tools are more commonplace in natural resources management. Globally, there is a strong push to develop these integrated tools for natural resource management, a movement reinforced by the enthusiastic reception of SEADS within U.S. venues and government agencies. SUMAWA's SDSS will enable communities and policy makers to make more informed decisions to work toward a more sustainable future.

Further Reading

Agatsiva, J. and A. Oroda. 2003. "Remote sensing and GIS in the development of a decision support system for sustainable management of the drylands of eastern Africa: A case of the Kenyan drylands." *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences* 34 (6/W6): 42-49.

Baldyga, T. and F. Holley. 2008. "Introduction to SEADS: SUMAWA's Spatial Environment and Agricultural Decision Support Tool." *Research Brief 08-03-SUMAWA*. Global Livestock Collaborative Research Support Program (GL-CRSP), University of California, Davis.

Baldyga, T.J., S.N. Miller, W.A. Shivoga, and L.W. Chiuri. 2008. "Development and use of a multiple objective spatial decision support system in East African rural watershed management." *Proceedings of the American Water Resources Association Spring Specialty Conference*, San Mateo, CA, March 17-19, 2008.

Baldyga, T.J. S.N. Miller, W.A. Shivoga, F. Lelo, G. Paige, and S. Mooney. 2007a. "Development of a participatory spatial decision support system for East African rural planning." Paper and presentation at AfricaGIS 2007, Ouagadougou, Burkina Faso, September 17-21, 2007.

Baldyga, T.J., S.N. Miller, W.A. Shivoga, F. Lelo, G. Paige, and S. Mooney. 2007b. "Rural planning in East Africa using a participatory spatial decision support system." Paper and presentation planned for The East Africa ESRI User Group Conference, Kampala, Uganda, September 13-14, 2007.

Ochola, W.O. and P. Kerkides, 2004. "An integrated indicator-based spatial decision support system for land quality assessment in Kenya." *Computers and Electronics in Agriculture* 45 (1-3): 3 – 26.

World Commission on Dams, 2000. "Report of the World Commission on Dams, 16 November 2000." http://www.dams.org//docs/report/wcdreport.pdf.

Zwarts, L., P. van Beukerling, B. Koné, E. Wymenga, and D. Taylor, 2006. "The economic and ecological effects of water management choices in Upper Niger River: Development of decision support methods." *Water Resources Development* 22(1):135 – 156.

About the Author: Formerly Tracy Baldyga, Tracy Baker is a PhD candidate at the University of Wyoming in the Department of Renewable Resources. She also holds a post-doctoral position at IWMI, the International Water Management Institute. Tracy began working with the SUMAWA project in 2003 as part of the hydrology component, and from 2003-2004, she was a GL-CRSP Jim Ellis Mentorship Program for Graduate Students Fellow. Email: tbaldyga@uwyo.edu or t.baker@cgiar.org.

The GL-CRSP Sustainable Management of Rural Watersheds (SUMAWA) project was established in 2003 and is a multidisciplinary research effort focusing on biophysical and human-related factors governing health in the River Njoro watershed in Kenya.

The Global Livestock CRSP is comprised of multidisciplinary, collaborative projects focused on human nutrition, economic growth, environment and policy related to animal agriculture and linked by a global theme of risk in a changing environment. The program is active in East and West Africa, Central Asia and Latin America.

This publication was made possible through support provided by the Office of Agriculture, Bureau of Economic Growth, Agriculture and Trade, under Grant No. PCE-G-00-98-00036-00 to University of California, Davis. The opinions expressed herein are those of the authors and do not necessarily reflect the views of USAID.

Edited by Franklin Holley & Susan L. Johnson