

**An Alternative Futures Analysis for the Little Kanawha River
Watershed in West Virginia**

By

Vishakha Maskey¹,

Michael P. Strager²,

Charles B. Yuill³

RESEARCH PAPER 2008-5

Paper presented at the

Western Regional Science Association Annual Meetings

Big Island of Hawaii, February 17-20, 2008

Support for this analysis was provided by the Regional Research Institute, West Virginia University. This research project is funded as a Seed Grant titled “West Virginia/ Central Appalachian Land Use Status and Trends Project”.

¹ Post Doctoral Fellow, Regional Research Institute, West Virginia University

² Assistant Professor, Natural Resource Economics, West Virginia University

³ Associate Professor, Landscape Architecture, West Virginia University

An Alternative Futures Analysis for the Little Kanawha River Watershed in West Virginia

Abstract

The Little Kanawha River watershed in West Virginia has been identified to be one of fifteen watersheds in the United States that is projected to have the greatest amount of land conversion during the period from 2002 to 2030 (Steinitz et al., 2005). The contributing factors for land conversion in the region are resource extraction and a disproportional population growth due to suburban sprawl. The outcome of land use change has an impact on water quality, terrestrial and aquatic habitat, and biodiversity. To measure and analyze this change, an alternative futures analysis was used in this study to model scenarios with Geographic Information Systems (GIS) and help guide future policies that are sustainable by balancing the environment and development in the Little Kanawha River Watershed. The major objective of this analysis was to map the likely dispersion or future growth patterns and the impact on water quality and biodiversity. The results indicate that water quality (total suspended solids) is impacted from current development patterns as is the biodiversity (bird community index) and will continue to degrade unless an integrated planning approach which considers preservation of large intact forested lands is implemented.

Keywords: alternative futures analysis, sustainability, geographic information systems, Little Kanawha River, biodiversity, hydrology

1. Introduction

Human land use practices have influenced natural resources at local, regional and global scales (Turner, 1990). Landscapes in West Virginia have been subject to a wide range of land uses, including resource extraction. Various regions in the state are facing land use change and development pressure, such as the Little Kanawha watershed, the Eastern Panhandle, and the North Branch Watershed of the Potomac River. Communities are facing concerns regarding surface and ground water quality from animal waste, surface mines, and stream sedimentation from mining, development, and forestry practices. In addition, sub-urban sprawl from new residential and second home development are also issues related to land use change. These land use activities are contributing to environmental problems.

The evaluation of land use and cover is an extremely important activity for current land management (Kepner et al., 2004). Assessing different land use scenarios using sensitivity analysis provides a foundation for informed decision-making. This study applies such a methodology for the Little Kanawha River watershed in West Virginia. The watershed is projected to be one of fifteen in the entire United States that will have the greatest amount of land conversion from 2002 to 2030 with over 225,000 acres of land projected to be modified (Steinitz et al., 2005). An alternative futures analysis framework was applied to evaluate the different land use predictions and outcomes on water quality and biodiversity. Alternative futures analysis balances environmental and economic aspects in planning and is extremely applicable to changing regions such as the Little Kanawha River Watershed. As part of the approach several policy choices can be considered using sensitivity analysis. The goal of this study is to

develop future land use growth predictions utilizing past and expected future population and growth projections for the Little Kanawha watershed.

The analysis is divided into three scenarios of 1) environmental resource protection scenario, 2) unregulated growth scenario and 3) balanced environmental protection and growth scenario. We used historical spatial and temporal data models for future land use changes for the future with a land use change GIS model. The outcomes are evaluated with hydrology and biodiversity measurements.

2. Literature Review

Examples of scenario based alternative futures analysis include those conducted in Monroe county, Pennsylvania; the region of Camp Pendleton, California; the Willamette River Basin in Western Oregon; the Southern Rocky Mountains in Alberta; the California Mojave Desert; and the Iowa Corn Belt (Steinitz et al., 2003).

Additionally, Blackberry creek Watershed in Kane County and Chico Watershed in Kitsap County, Illinois are a few case studies that use alternative futures analysis for community-based decision making in environmental planning.

The Blackberry Creek watershed resource planning committee with the assistance of numerous municipal, county, regional, state, and federal agencies, as well as private consultants, developed the Blackberry Creek Watershed Management Plan (Environmental Law Institute, 2004). Conservation and conventional versions of the template were developed on a hypothetical 40 acre parcel for a range of land uses including commercial, residential, and agriculture, as well as wetlands and streams. A conservation template was created based on preserving natural hydrologic mechanisms, minimizing changes in hydrology and water quality caused by land development. A

conventional template was based on the current practice for site design and stormwater management, that collects, conveys and detains storm water rather than distributes, infiltrates and retains. The plan was adopted by most of the municipalities mostly because flooding was the major problem that impacted most of the areas in the watershed. The focus of the project was to protect the streams and wetlands from direct modifications, and to prevent degradation of watershed hydrology, and water quality of streams and wetlands.

The Willamette River Basin is a region facing population growth creating land use and water use concerns, habitat loss, and loss of forest land (USEPA, 2002). Their alternative futures analysis had three scenarios of conservation, plan trend and development. Conservation trend placed emphasis on ecosystem protection and restoration. Planned trend represented future landscapes if current policies are implemented and recent trends continues. Development trend loosens current policies to allow free market forces across all components of the landscape. A basic assumption was made that population increases were to grow in a similar ratio that was linear to the year 2050. The three alternative scenarios were compared to present day, historical landscapes and future endpoints in terms of terrestrial wildlife, water availability, small streams and the Willamette River. The results from the analysis were discussed by stake holder groups in developing visions for the area's future and restoration strategy. In addition, the results influenced future decisions of resource use.

Kepner et al. (2004) used Automated Geospatial Watershed Assessment (AGWA) for the San Pedro River Basin alternative futures analysis. A base time was year 2000 projected to 2020. Three scenarios of constrained, planned, and open were evaluated. In

addition, the Soil Water Assessment Tool (SWAT) was used for simulation of the large watershed. The results showed significant alteration on hydrologic responses in the watershed due to urbanization and land use practices. The increase in amount of run-off, sediment discharge and loss of surface water access to the ground water table were predicted from the simulation.

The Chico Watershed alternative futures analysis was used to guide community planning and natural resource protection (Parametrix Inc., 2003). The Chico Creek Watershed was utilized as a pilot project for alternative futures planning due to its healthy salmon runs, large tracts of forestland, two large lakes, and the increasing demands of development within its boundaries. Four different scenarios analyzed the effect on water quality, water quantity and fish and wildlife habitat. The analysis also assessed the potential benefits and impacts of those future land use scenarios. The result was a developed watershed plan based on natural resource protection with citizen's involvement.

Alternative futures with three scenarios of production, water quality and biodiversity were utilized in the Iowa Corn Belt, in response to environmental degradation resulting from agricultural practices (Santelman et al., 2004). Their spatial model evaluated the farmland management policies and the results evaluated impacts of land use change on water quality, social and economic goals, and native biodiversity.

The Soil Water Assessment Tool (SWAT) was used in alternative futures scenarios for two watersheds (Buck and Walnut Creek) in Iowa (Vaché et al., 2002). The model focused on water discharge, annual sediment loads, and nitrate in watersheds based on different agricultural management practices. Three scenarios were developed,

namely, current trends in agricultural practices scenario, water quality concerned scenario, and biodiversity protection and restoration.

The Ecosystem Landscape Modeling System (ELMS) was used for evaluating the potential ecological and economic impacts of future landscape changes in areas of the Rocky Mountain that is facing rapid growth (Prato, 2005). ELMS consists of an economic, land use change, ecological assessment, and policy models. The economic model used IMPLAN and various assumptions to estimate changes in employment and output for alternative future growth rates for sectors in the study area. Future changes in employment and output were translated into land use requirements for residential housing and commercial establishments. The ecological assessment model evaluated impacts of land use changes on potential and realized habitat for selected species. The policy model specified alternative residential and commercial development, infrastructure expansion, and natural resource conservation policies that were incorporated in the economic and land use change models (Prato, 2005). The result evaluated tradeoffs between alternative scenarios associated with future growth and development.

3. Study Area: Little Kanawha River Watershed

The Little Kanawha River watershed is located in central West Virginia with an approximate area of 2,307 square miles (USEPA, 2000) (Figure 1). Forested lands and agriculture constitutes 77% and 16% of the land cover within the watershed. The rest of the watershed is comprised of water, urban built-up land, and transportation usage (USEPA, 2000).

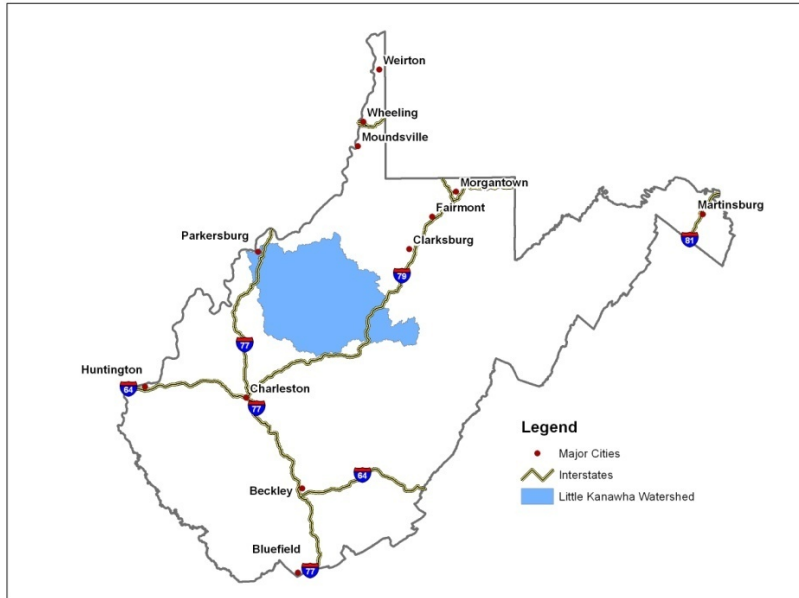


Figure 1. Location of the Little Kanawha River Basin, West Virginia.

The watershed intersects sixteen West Virginia counties and there are four reported watershed protection groups involved in Little Kanawha River. Gilmer watershed coalition is involved in water quantity problems (Flood control, flood warning system), water quality testing, trash and debris removal, restoration work and working with agencies. Friends of the Little Kanawha, Cedarville Community Association and Huges Creek watershed associations serve as alliance and council for watershed adoption (EPA, 2007).

Substantial land use changes have occurred and continue to occur in the Little Kanawha. There has been significant change in agriculture, forestry, mining, accessibility and infrastructure and settlement patterns during the past fifty years (Figure 2). Major land use conversion due to a decrease of agriculture, reforestation, development of a chemical industry and suburban sprawl are the driving factors of land use change.

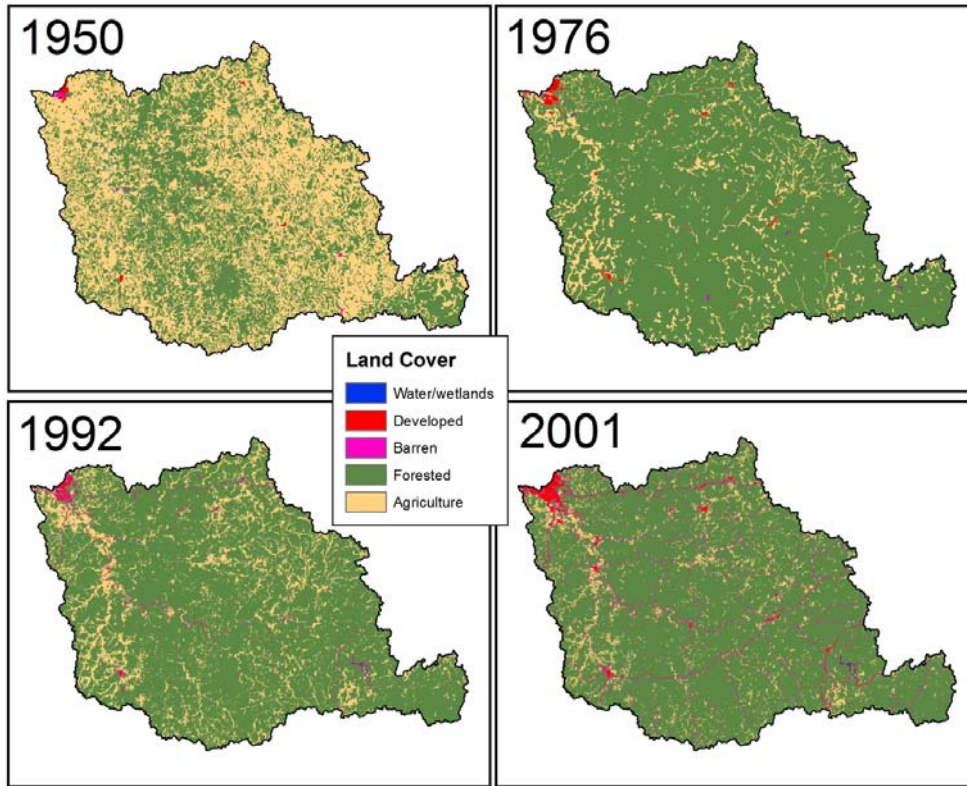


Figure 2. Historical Land use and cover change in the Little Kanawha River Basin, West Virginia.

Due to many contiguous forested areas, the Little Kanawha River watershed is high in species richness (Strager and Yuill, 2002, Figure 3) in many of the headwater locations. Maintaining biodiversity is a significant aspect of the watershed. Land conversion and forest fragmentation due to human activities pose a threat to habitat and biodiversity (Collinge, 1996). Concerns regarding biodiversity protection and habitat restoration are important to this region.

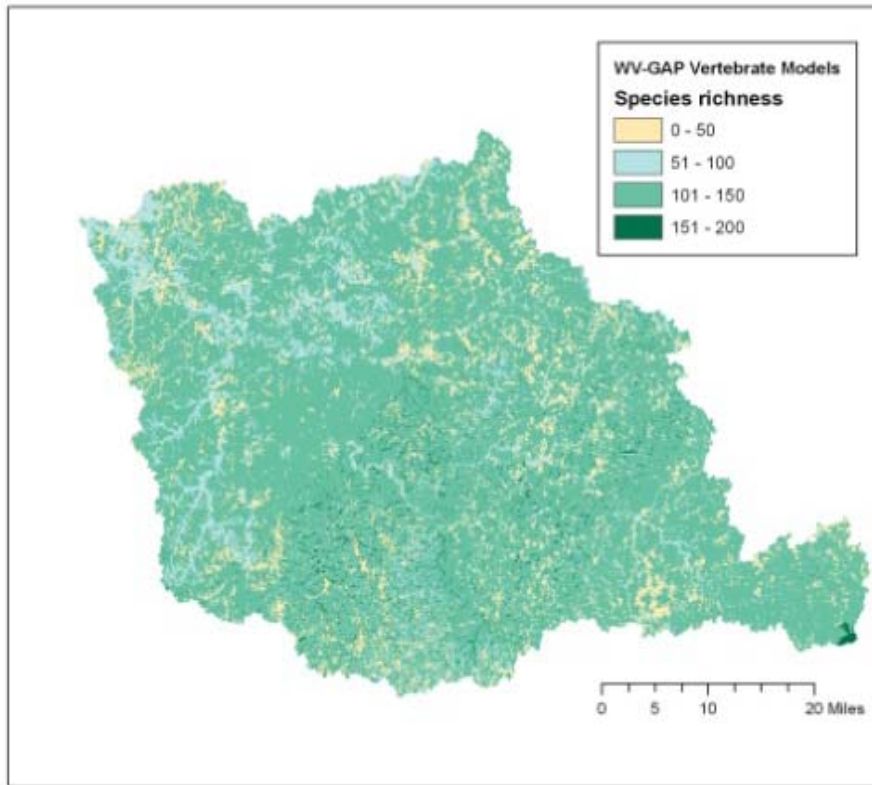


Figure 3. Species distribution in the Little Kanawha River Basin, West Virginia.

In addition to biodiversity, water quality and flooding are additional concerns in the watershed. Flooding was one of the major problems in Little Kanawha River around 1970-1989 (Smith 2008) and continues mainly due to the impact of altering natural vegetation on steep slopes. The alterations also impact water quality as many of the streams are listed as impaired or not meeting their designated uses as shown in Figure 4. The streams tend to be located in both the headwater and mainstem of the river channel indicating diverse issues with point and nonpoint source pollution. According to the USEPA 303 (d) list of impaired waters, there are 47 river miles of the Little Kanawha River from the Burnsville Dam to its convergence with the Ohio River that are not meeting their designated uses of either cold or warm water fisheries, or water contact recreation.

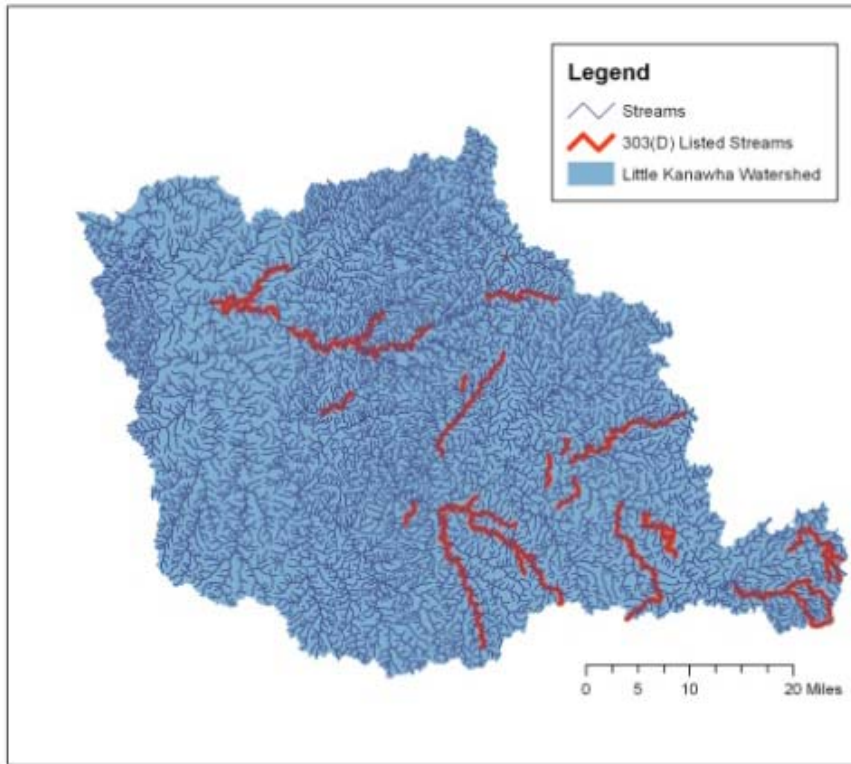


Figure 4. EPA listing of impaired streams for the Little Kanawha River Watershed

Daniels (1993) defines rural sprawl as low-density residential development scattered outside of suburbs and cities, and as commercial strip development along roads outside cities. Rural sprawl with rural residential development at exurban densities according to Theobald (2003) is defined as areas typically 1.7 to 20 acres per housing unit for exurban sprawl. In some states, exurban areas are defined as having between 1.7 and 40 acres per housing unit, depending on state land use laws. Rural areas have >20 acres per housing unit (or >40 acres). Issues faced in the Little Kanawha watershed are an increase in developed land from 0.8% to 6%, also a decrease in agricultural land from 12% to 7% within 1992-2001. More specifically, there is a disproportional amount of development which has impacts on watershed ecology, as well as biodiversity. In

addition, a decrease is projected in forest land due to increased exurban sprawl (Steinitz et al., 2005).

Sustainable development entails maintaining development and conservation, which includes protecting water quality, habitat, biodiversity, and floodplain areas within the context of human habitation and continued sprawl (Theobald, 2003).

4. Data and Methods

Following the approach in the Willamette River by USEPA (2002), we examined policies for future land use and cover scenarios consisting of an environmental resource protection scenario, unregulated growth scenario, and a balanced environmental protection and growth scenario. A general conceptual framework for the alternative futures analysis process is shown in Figure 5. The environmental resource protection scenario (environment) limited development to slopes less than 5%, protected riparian areas that were within 100 meters of streams, avoided development on hydric soils or existing mapped wetlands, and maintained forested areas that had at least 200 acres of core area. The unregulated growth scenario (unconstrained) did not have any of these constraints, and the balanced environmental and growth scenario (balanced) allowed development to occur on any slopes and to fragment forests but did protect riparian areas, and wetlands.

One of the limitations of this study was an accurate measurement of economic impacts from these different scenarios on residential and commercial development that was constrained from these policies. Our initial approach was to examine property sales prices but we did not have digital parcels for this watershed.

The future land use change grids were created with these three policies in mind (environment, unconstrained, and balanced) as input in the Land Use Change Modeler ArcGIS 9.2 extension (Clark Labs, 2007). Output grids from the different scenarios were the major inputs into the Watershed Characterization and Modeling System (WCMS, 2004), and the Bird Community Index (Jones et al., 1997). The WCMS is an ArcGIS extension that was designed to compare and illustrate loadings from nitrogen, phosphorous and total suspended solids on receiving water bodies as a result of land use and cover changes. It has a stream flow model which accounts for average annual conditions that are calibrated to USGS gauges. The Bird Community Index was developed by researchers at Penn State and EPA to determine habitat requirements at the landscape level for neotropical and migratory species birds. It is an overall index of landscape condition in which a higher score for neotropical species is more unique and acknowledged as better for overall landscape quality.

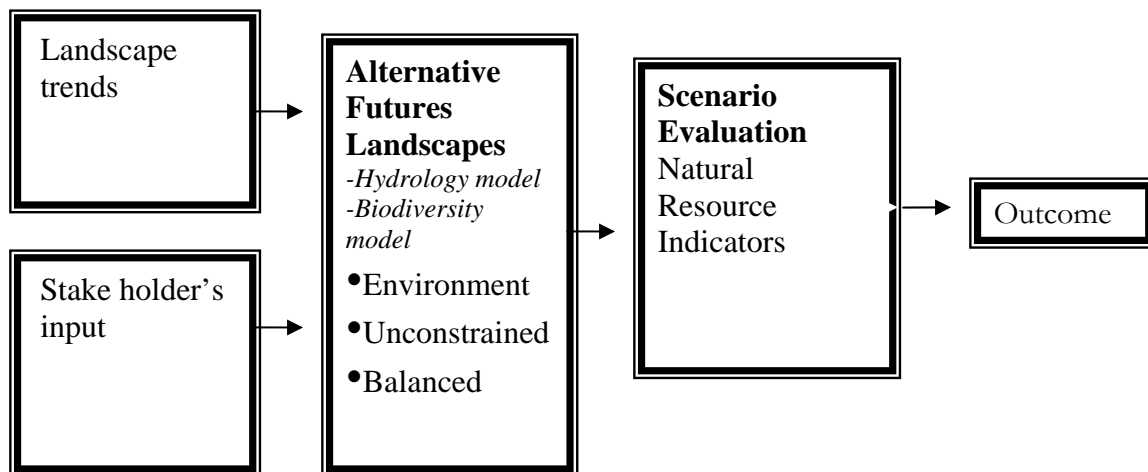


Figure 5. Alternative futures process applied in the Little Kanawha River Basin, West Virginia.

5. Results

The results of the land use and cover modeling gave insights into expected conversion of land under the different environment, unconstrained and balanced conditions. The modeling was primarily driven by existing infrastructure such as roads and already developed areas. Some of the rural areas were difficult to model since many of the traditional drivers which may spur development did not exist in the rural areas (i.e areas that may have favorable property values or parcel sizes for development). Despite this limitation, the model output was run in both the WCMS water quality model and the Bird Community Index as proxies for natural resource indicators. The results are presented as output in table 1. It should be noted that these evaluations are done for the entire watershed boundary and extent which may hide or detract from local effects.

Table 1. Results for Total Suspended Solids and Bird Community Index

Scenario	Total Suspended Solids (cumulative mainstem tributary loadings to the Little Kanawha)	Bird Community Index (measured in total landscape area of neotropical versus migratory species)
Environment	46% less in Kg/Yr compared to current base levels	34% area improvement compared to current levels
Unconstrained	14% more in Kg/Yr compared to current base levels	4% area improvement compared to current levels
Balanced	9% more in Kg/Yr compared to current base levels	18% area improvement compared to current levels

6. Discussion

It was interesting to note that the water quality difference from choosing an environmental development scenario greatly benefits water quality over the other options. This is believed to be a result of the terrain being constrained to the riparian area because of steep and rugged slopes. While we did not have a flood potential indicator, we feel that it would have also shown significant improvement with the environmental scenario based on this reason. The improvements to the bird community index were also noted with the environmental scenario which resulted in an increase of the area of neotropical of 34%. One of the main drivers of this result could be attributed to the environment scenario protected large intact forest areas from disturbances such as clear cut forest management and surface mining. Areas with a low index contain more non forest land uses due to mining, agriculture, mining, timbering, urban/residential development. These areas are fine for generalist species such as European Starlings, American Crows, and Blue Jays. Areas with a high index are primary forested and provide habitat for many neotropical birds including Cerulean Warbler, Scarlet Tanager, and Louisiana Waterthrush.

The unconstrained option resulted in a much lower area for neotropical birds as part of the bird community index and an increase in total suspended solids of 14% compared to base levels. It seems as if the development patterns at the landscape level clearly are due to resource extraction and conversion from forests to other more barren classes. One of the policy recommendations could be to focus any conservation area acquisition on the large intact forested areas since the Jones et al. (1997) reported this as a major area for conservation goals as well.

The balanced scenario was somewhat centered between the extremes of the previous mentioned results however this is difficult to compare since we did not yet have economic development benefits to include in the analysis. For example, much of the economic gains and tax base generated from development was not accounted for in this approach. Future work will attempt to identify more economic benefits as indicators across these landscape and policy options.

Even though our results are limited at this time, we plan to continue development of additional indicators that relate more to human use and economic benefits. We feel at that time our results can begin to assist managers and planners in making informed decisions related to future land use practices that can be used by local policy makers, development planners, stakeholders, and communities in choosing sustainable land use management plans. The projections could provide a technical statement for future valuation projects.

7. Reference

- Clark Labs. 2007. The Land Change Modeler for ArcGIS. Software Extension. Clark Labs, Clark University, Worcester, MA.
- Collinge, S. K. 1996. Ecological consequences of habitat fragmentation: implications for landscape architecture and planning, *Landscape and Urban Planning*, Vol. 36 (1): 59-77.
- Danielson, B.J., R.C. Corry, M.E. Clark, S. Polasky, R.M. Cruse, J. Sifneos, H. Rustigian, C. Coiner, J.Wu and D. Debinski. 2004. Assessing alternative futures for agriculture in Iowa, U.S.A. *Landscape Ecology* 19: 357–374.
- Environmental Law Institute. 2004. Alternative Futures Analysis-Blackberry Creek Watershed, Illinois. Watershed Resource Consultants and the Conservation Foundation. Kane County Department of Environmental Management.
- Hulse, D., J. Eilers, K. Freemark, C. Hummon, and D. White, 2000. Planning Alternative Future Landscapes in Oregon: Evaluating Effects on Water Quality and Biodiversity. *Landscape Journal* 19 (2):1-19.
- Jones, B.K, K.H. Ritters, J. D. Wickham, R.D. Tankersley, R.V. O'Neill, D.J. Chaloud, E. R. Smith, and A.C. Neale. 1997 An Ecological Assessment of United States Mid-Atlantic Region: A Landscape Atlas.
- Kepner, W.G., D.J. Semmens, S.D. Bassett, D.A. Mouat, and D.C. Goodrich. 2004. "Scenario Analysis for the San Pedro River, Analyzing Hydrological Consequences of a Future Environment." *Journal of Environmental Monitoring and Assessment*, 94: 115-127. Kluwer Academic Publishers (http://www.epa.gov/nerlesd1/land-sci/pdf/scenario_spedro.pdf).

- Parametrix Inc. 2003. Kitnap County Chico Watershed Alternative Analysis, Process and Recommendations. Department of Community Development, Kitnap County.
- Prato, T. 2005. Modeling ecological impacts of landscape change. *Environmental Modelling & Software*, Vol. 20 (10): 1359-1363.
- Santelmann, M.V., D. White, K. Freemark, J.I. Nassauer, J.M. Eilers, K.B. Vaché, Shearer, A. W., D. A. Mouat, S. D. Bassett, M. W. Binford, C. W. Johnson and J. A. Saarinen. 2006. Examining development-related uncertainties for environmental management: Strategic planning scenarios in Southern California. *Landscape and Urban Planning*, Vol. 77 (4): 359-381.
- Steinitz, C., Arias, H., Bassett, S., Flaxman, M., Goode, T., Maddock T. III, Mouat, D., Peiser, R. and Shearer, A.: 2003, *Alternative Futures for Changing Landscapes. The Upper San Pedro River Basin in Arizona and Sonora*, Island Press, Washington, DC, USA.
- Strager, J. M. and C. B. Yuill. 2002. WV Gap Analysis Project – Final Report. Natural Resource Analysis Center, West Virginia University, Morgantown, WV. Available online at www.nrac.wvu.edu
- Smith, Deana. 2008. Friends of Little Kanawha. Telephone Communication on March 13.
- Theobald, D. M. 2003. Defining and mapping rural sprawl. Examples from the Northwest U.S. Natural Resource Ecology Lab and Dept. of Recreation & Tourism Colorado State University, Fort Collins, CO 80523.
- Turner, B.L. (ed.): 1990. *The Earth as Transformed by Human Action*, Cambridge University Press with Clark University, Cambridge, MA, USA.

- USEPA. 2002. Willamette Basin Alternative Futures Analysis, Office of Research and Development.
- USEPA. 2000. Metals TMDL for Little Kanawha River Watershed, West Virginia. Final Report, US Environmental Protection Agency, Region 3, 1650 Arch Street, Philadelphia, PA
- USGS. 2005. Summary of Significant Floods in the United States, Puerto Rico, and the Virgin Islands, 1970 through 1989, Water-Supply Paper 2502. U. S. Department of Interior, U.S. Geological Survey.
- Vaché, K. B., J. M. Eilers, and M. V. Santelmann. 2002. Water Quality Modeling of Alternative Agricultural Scenarios in the U.S. Corn Belt. *Journal of the American Water Resources Association*, Vol. 38, No. 3 pp 773-787.
- WCMS. 2004. The Watershed Characterization and Modeling System. Version 9.2. Natural Resource Analysis Center, Morgantown, WV. Available online at www.nrac.wvu.edu.