Maryland's Strategic Forest Lands Assessment—Using Indicators and Models for Decision Support

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Abstract—*Sustaining healthy, ecologically functional, and economically viable forests is an increasing challenge in Maryland due to relentless urban development. Forests that once occupied more than 90 percent of Maryland's landscape today cover only 41 percent of the land. As forests become more fragmented and parcelized they begin to lose their ability to provide important ecological, social, and economic benefits. This paper excerpts the publication "Maryland's Strategic Forest Lands Assessment" which highlights the use of indicators to analyze forest sustainability and multi-variate GIS-based computer models to rank the ecological and economic importance of forestlands at the state level. It also addresses the methodology behind the models and showcases ways of enhancing them for making finer scale land management decisions.*

At the core of the assessment are four computer based thematic models that have used aggregated data sets to determine the Ecological Ranking of Forest Lands, the Economic Ranking of Forest Lands, the Vulnerability Ranking of Forest Lands, and the Riparian Restoration Potential of more than 1000 sub-watersheds. These GIS-based computer models were initially created as indicators and benchmarks at the state scale. More recently the tools have been further honed to help managers make decisions at a number of different scales.

The ecological ranking has been used to assess ecological importance at the state level, but it has also been adapted for use at the parcel scale to evaluate the ecological ranking of lands being considered for fee simple or easement purchase. Similar adaptations were made to watershed models to create a restoration model that could pick out individual stream segments that were of particular interest for forest buffer restoration. Much work still remains to be done, but the availability of finer scale data makes the use of these tools even more relevant for decision support.

Introduction

Maryland faces many challenges in sustaining healthy, ecologically functional and economically viable forests in the face of rapid urban development. Once, more than 90 percent of Maryland was forested. Today only 41 percent of Maryland's land is covered by forest. Maryland is the nation's fifth most densely populated state, with more than 5.3 million people. The rapidly growing population has more than doubled since 1950, threatening an already stressed forest.

Maryland's Strategic Forest Lands Assessment (SFLA) grows from the recognition that the state faces significant loss of the ecological, social, and economic benefits of forests without significant changes to the current pattern of land development. This pattern causes forests to be fragmented from large, contiguous blocks of forest into many smaller, isolated patches. Smaller patches are less effective in preserving ecological function and wildlife habitat. They are more difficult to manage to protect soil, air and water quality. They are also less likely to support the forestry and wood products industry, the fifth largest industry in the State. Maryland's wood products industry is already under significant stresses, but it is not clearly understood how any losses in this sector might impact the state's forests in the future.

Sustainable use of our forest resources, for the multiple benefits they provide, requires careful planning and management to meet the needs of today and tomorrow. This is particularly important in Maryland where pressures on the forest are acute. Maryland's Strategic Forest Lands Assessment provides a baseline of information about where we are now, and suggests criteria and indicators that can be used to measure change, as a first step in working toward sustainability for Maryland's forests.

Ecological Ranking of Forest Lands

To determine forest areas of high ecological value, the Maryland Department of Natural Resource's (DNR) developed a Geographic Information System (GIS)-based computer model that considers both the regional and local ecological significance of the forest. The regional evaluation looks at the ecological importance of large forest patches relative to other forest patches within the same physiographic region. Variables relevant at local scales help to identify conservation values at or in close proximity to a specific parcel.

The data that have been assembled for the ecological model were selected based on their utility in measuring ecological values important to land conservation programs. Specifically, principles of landscape ecology and conservation biology have been interpreted and represented by GIS data layers. Each data set was scored and weighted to represent the importance of that factor in assigning an overall ecological score.

The ecological model gives priority or greater weight to large forest blocks, particularly:

- forest patches with a greater proportion of "interior" conditions
- intact forest blocks (as opposed to patches containing substantial non-forest "gaps")
- patches with a diversity of habitat types
- patches that provide stream or erodible soils protection
- patches that are in close proximity to other forest blocks (as opposed to isolated patches with substantial inter-patch distance)

The ecological model also favors forested corridors that:

- are short as opposed to long
- are wide as opposed to narrow
- contain or have the potential to contain interior forest conditions are intact as opposed to fragmented
- link forest blocks ranking high as opposed to those that rank low
- link similar as opposed to dissimilar ecotypes
- have few or no road crossings
- protect and link riparian systems, and
- connect with large forest blocks

This ecological model was originally developed for use at the state scale, but has been widely used at the county and watershed scale for broad assessments and planning. More recently however the model has been enhanced to assist decision makers and resource managers in making land use decisions. Specifically, an algorhythm was written that allowed resource managers to evaluate and rank the conservation value of individual parcels that were being considered for protection or fee simple purchase through Maryland's Program Open Space. This process allowed staff to justify to the Governor, an acquisition of 58,000 acres, now called the Chesapeake Forest, located in five counties and spread over 200 separate parcels, by showing the protection of ecological function through a network of hubs and corridors connecting to other state and private conservation lands.

Today, every parcel considered for purchase through Maryland's Program Open Space, Maryland Agricultural Land Preservation Foundation, Maryland Environmental Trust or Maryland's Rural Legacy Program are evaluated using this ecological model (DNR 2001, Maryland's Green Infrastructure Methodology). Land conservation partners like The Nature Conservancy, The Conservation Fund, local governments, and local land trusts frequently ask for this analysis to be run on lands they are considering for protection in Maryland. This is an impressive and effective extrapolation of a tool that primarily uses 30-meter satellite data and was originally designed for use at the state or watershed scale.

Methods Used to Develop the Ecological Ranking of Forest Lands

The Ecological Ranking of Forest Lands used the Green Infrastructure methodology, where both hubs and corridors were evaluated and ranked within their physiographic regions. Physiographic regions have a characteristic geology and climate, which shape the ecosystems and biological communities within them. Methods were developed to ensure that ecosystems adapted to these different climates and substrates were represented in the top ranking hubs, so that the best examples in each region might be protected. Another reason for grouping hubs by region is that natural conditions and communities vary greatly between the Coastal Plain and the Appalachian mountains. For example, cypress swamp communities are not found outside the Coastal Plain, and high gradient streams are not found inside this region. A single ecological ranking of all hubs would compare "apples to oranges" and might not succeed in protecting the broad biological and geological diversity of the state.

Twenty-seven parameters were selected and given an importance weighting according to feedback from biologists and natural resource managers; literature reviews; minimization of redundancy, area dependence, and spatial overlap; balancing different ecotypes; data reliability; and examination of output from different combinations. None of the parameters were highly correlated (>80 percent). The highest correlation was between area of upland forest and interior forest streams (75 percent).

To derive a composite ecological ranking, the percentiles for the 27 ecological parameters were multiplied by an importance weighting and added together for each hub. The importance weightings were a function of the parameter's utility and data reliability. Although all hubs are ecologically significant, the ranking system can help prioritize initial conservation efforts. For additional detail on the hub ecological ranking parameters and methods, see the Summary of Methods to Identify and Evaluate Maryland's Green Infrastructure (DNR 2001).

Economic Ranking of Forest Lands

If managed properly, forests can continue to provide ecological services, water quality protection, and habitat, as well as a variety of forest products. The Economic Model for the Strategic Forest Lands Assessment uses GIS to help identify economically important forestlands, particularly those with the greatest potential to yield economic benefits associated with timber management activities. The model includes factors that relate not only to the short term potential economic return on a forest harvest operation, but also the long-term economic sustainability of forest land, considering local and regional influences. At a local or site level, the economic model considers biophysical factors that influence what tree species can be grown in a given area. Also included are data layers that aim to approximate constraints on management of the forest resource.

Site-specific factors incorporated into the model include:

- tree species composition
- soil productivity
- slope
- microclimate
- riparian and wetland features
- presence of sensitive species habitats

At regional or landscape scales, the economic model incorporates factors that affect the ability of the forest to support resource-based economies, including the importance of the timber management and wood products industry to local economies. Also included are data layers that attempt to capture the effects of State and local policy on forestland protection.

Regional or landscape scale socioeconomic and policy factors include:

- population density
- parcelization
- proximity of the forest resource to mills
- role of the forest products industry in the local economy
- existing or planned water and sewer service or other designations for urban growth existing working landscape protection initiatives (for example, Rural Legacy and Forest Legacy Areas)
- existing public and private forest land protection

Methods Used to Develop the Economic Ranking of Forest Lands

Like the ecological assessment the economic assessment uses a Geographic Information Systems (GIS) analysis to overlay multiple layers of spatially referenced data. These data layers, which reflect potential economic benefits or considerations, are used to identify the relative economic value of Maryland's forestlands. All GIS data were converted to grids with a uniform cell size of 30 meters x 30 meters. Elements in each data layer were scored according to potential economic impacts and relationships. Elements known to encourage timber management practices, or create higher potential economic value, were scored higher than elements which may impose management constraints or have lower potential economic value.

One of the parameters that has significant influence on the economic efficiencies of timber management is patch size. Economies of scale are more favorable when larger, although fewer, patches of forest are managed for timber rather than many smaller sized patches. There are also many socioeconomic issues that influence or create constraints for timber management, particularly in urban or urbanizing areas. Social tolerance, local economic importance, landowner objectives and industry infrastructure, will all have an influence on the likelihood of forestland remaining economically sustainable.

Population density is used to predict the social tolerance to and sustainability of commercial timber management activities. As population density increases, the likelihood of sustainable timber management decreases because of land use conversion to development and increasing intolerance to the noise, visual, and safety impacts associated with forest harvest operations. Land parcelization and contiguity of ownership were used as indicators for sustainable forest management. Large parcels of forestland have the benefits associated with economies of scale. Landowners owning larger blocks of forest are more likely to have management objectives that include timber management as compared to the objectives of small lot landowners.

Within the economic assessment we also tried to develop measures to evaluate the local importance of the forest products industry. The importance of the forest products industry to the local economy is evaluated at a county level by comparing the total industry output from the forestry and wood products sectors to the total industry output for all industry sectors (via IMPLAN). Two sector groupings were evaluated separately due to different proximity relationships to the forest resource base.

Maryland Department of Natural Resources (DNR) is currently working with local county officials to evaluate impacts of zoning regulations and incentives on forest ownership and forest industry viability. Baltimore County Maryland has begun an elaborate analysis of forests, ownership, and development patterns using the SFLA methods in an attempt to retain forests that are functioning for both their ecological and economic benefits. The enhanced models may be used to influence policy, direct county programs and to develop effective incentives to retain forestland.

Vulnerability Ranking of Forest Lands

Threats to forestlands arise from multiple potential stressors. The most obvious threat is the conversion of forestland into some form of urban use, such as residential, commercial, industrial, or institutional uses, with the consequent loss of most of its natural resource values. Maryland's forest resources are also threatened by other forces, including biological pests (for example, exotic species, overabundant deer, etc.) as well as abiotic factors (for example, fire, acid deposition).

For purposes of the Strategic Forest Lands Assessment, the vulnerability model that has been developed focuses on the threat of conversion of forestland to development. It only indirectly incorporates other biotic and abiotic stressors. The model looks at regional and site specific factors that contribute to the vulnerability of a given acre of forest to development, as well as factors that make its conversion less likely.

Examples of site-specific data layers used to determine an area's vulnerability include:

- the current level of protection arising from public ownership, conservation or agricultural easements
- constraints on development as a result of physical limitations or regulations associated with environmentally sensitive features, including wetlands and riparian areas, steep slopes, and sensitive habitats

The vulnerability of forestland to development is heavily influenced by the greater geographic setting. Market forces can drive the long-term sustainability of forests as a preferred land use. The vulnerability model approximates these effects by including data layers to assess:

- proximity to population centers
- road access and density
- proximity to existing protected open space
- real estate values

Finally, public policy and investment can also be used to direct growth and, correspondingly, the conservation of forest resources. The model addresses these factors by including data layers for:

- existing water and sewer service areas
- Priority Funding Areas for Smart Growth
- local zoning
- Maryland's Chesapeake Bay Critical Area (separate zoning categories within 1,000 feet mean high tide of the Chesapeake Bay and its tributaries)

Methods Used to Develop the Vulnerability Ranking of Forest Lands

Population growth or loss 1990 through 2000 was a major component of the vulnerability model. Rapidly growing areas were identified by looking at the last decade of population growth in Maryland. Year 2000 human population density within Maryland census blocks (from 2000 TIGER data) was compared to 1990 human population density within Maryland census blocks (from 1990 TIGER data).

Mean Parcel Size was also a major component of the model. The number of forest landowners in the U.S. has been steadily increasing since the early 1900's, and thus the average parcel size has been decreasing (Mehmood and Zhang 2001). In Maryland, the number of forest owners more than tripled between 1978 and 1994, increasing from 42,200 to 130,600 (Birch 1996). Total private forestland ownership increased only slightly, and the average parcel size decreased from 45 acres to only 17 acres. Parcelization often leads to forest fragmentation. As the number of landowners increases, their attitudes and objectives become more diverse, and many choose to convert their land to other uses, especially residential (Birch 1996, Mehmood and Zhang 2001). Parcel centroids were obtained from Maryland Property View. To make the dataset manageable, only parcels at least 1 acre or greater in size could be used in the analysis. Parcels smaller than 1 acre were generally considered to be already intensely developed.

Commute time to major town centers was also thought to be a significant factor in evaluating the vulnerability of forestland. Bockstael (1996), Geoghegan and others (1997), and Bockstael and Bell (1998) found that distance to urban centers such as Washington DC affects land value and the probability of housing construction on private parcels. Wickham and others (2000) found a strong correlation between forest fragmentation and a geographic gradient of urbanization pressure in central Virginia. Land demand pressure was interpolated as a ratio of urban center population, taken from the 1990 Census of Population for each Census Designated Place, over the distance along major roads from these urban centers (Wickham and others, 2000).

Wickham and others (2000) was used to evaluate land demand based on proximity to Washington DC and Baltimore. Land demand pressure was interpolated as a ratio of urban center population, taken from the 1990 Census of Population for each Census Designated Place, over the distance along major roads from these urban centers (Wickham and others, 2000). Extra weighting was given for proximity to DC and Baltimore, which have by far the largest concentration of commuters in the state. Other cities were addressed in the previous metric, commuting time to urban centers. Land demand was calculated from DC and Baltimore as the number of potential commuters divided by the commuting time to these areas.

Market land value was another parameter evaluated to determine vulnerability. Bockstael (1996) and Bockstael and Bell (1998) found that the higher the land value of a parcel, the higher the probability of its conversion to residential use or other development. Maryland's Property View database, which contains market land value, was interpolated to create a continuous cost surface. The distance from major roads make a particular area more prone to development, because of decreased construction costs and increased access to existing infrastructure. These primary and secondary roads improve general accessibility (Bockstael, 1996). Access to major roads is especially important to businesses; most major general access roads are lined with commercial and industrial enterprises. The distance of each grid cell from all interstate, primary state, and secondary state roads was calculated.

In Maryland the area of waterfront property also had to be considered to evaluate vulnerability. Waterfront property is generally more desirable to developers (Bockstael, 1996). Waterfront property was defined as cells adjacent to (i.e., within 166 feet of) river, lake, or bay shorelines, and generally excluding wetlands. Similarly, proximity to preserved open space increased parcel value, and thus its probability of conversion to residential use (Bockstael, 1996). To evaluate this, the distance of each forested cell to all protected lands such as public land, private conservation land, conservation easements, or agricultural easements were calculated.

Riparian Restoration Potential of Sensitive Lands

Still being modified and enhanced, is the GIS-based model to help rank the Riparian Restoration Potential of Sensitive Lands. This model is primarily aimed at prioritizing areas for riparian forest restoration and conservation as part of the Chesapeake Bay restoration efforts through Maryland's Stream ReLeaf Program. Restoration of stream buffers return the highest cost/benefit ratio of any best management practice used to reduce non-point source nutrient loadings to streams within the Chesapeake Bay watershed. Many ecological benefits are also associated with maintaining forest along streams (riparian forest). These include taking up nutrients in ground and surface water flow, as a buffer between streams and adjacent land uses; stabilizing stream banks; shading the water and maintaining its temperature; and providing food as substrate for aquatic and terrestrial animals alike.

The relative percentage of unforested riparian areas within a watershed can be an indicator of aquatic and terrestrial system stress. A Geographic Information System (GIS) was used to calculate the amount of forested and unforested riparian buffer in each watershed. First a 100-foot stream corridor (buffer) was identified around free-flowing streams mapped by the Maryland Office of Planning (OP). This information was combined with OP 1994 land use data showing forested land and with DNR's Forest Resource Inventory (DNR FRI, 1991). To calculate the indicator, the combined area of forested and unforested corridor was summed for each eight-digit watershed. The unforested portion was then divided by the total corridor area to create the percent of unforested riparian buffer.

In Maryland, which would naturally be 95 percent forested, almost all native organisms would have evolved under the influence of forested conditions. Therefore in a natural state, the percentage of unforested riparian buffer in free flowing stream systems should be close to zero. Head-water streams that are further up in a given watershed, create a higher benefit for restoration or protection than river shoreline or estuarine areas lower in a watershed.

In Maryland's Unified Watershed Assessment, completed as part of the Clean Water Action Plan (1998), watersheds with more than 49 percent of stream lengths unforested were considered to be in need of restoration. Watersheds having high percentages of unforested land in the riparian area bordering streams are potential targets for riparian reforestation. Where unforested riparian buffer areas represent smaller percentages of stream mileage, other restoration measures may be more appropriate to achieving water quality and habitat improvement.

This watershed targeting system has assisted DNR and partner agencies in restoring more than 70,000 acres of sensitive agricultural land through USDA's Conservation Reserve Enhancement Program (CREP), including the establishment of more than 1,200 miles of forest riparian buffers in Maryland. Watershed evaluations were done for each of the 127 separate eight-digit watersheds to determine rank. This information was shared with program partners and personnel resources were modified to assist program delivery. The Riparian Restoration Model will be further enhanced as part of the next phase of restoration efforts tied to the Chesapeake 2000 Agreement.

Conclusions

"Maryland's Strategic Forest Lands Assessment" highlights the use of indicators to analyze forest sustainability and the effectiveness of using GIS-based computer models to rank the ecological and economic importance of forestlands. These four GIS-based computer models; the Ecological Ranking of Forest Lands, the Economic Ranking of Forest Lands, the Vulnerability Ranking of Forest Lands, and the Riparian Restoration Potential Model, have been shown to be very effective at assessing forest sustainability at the state, county and watershed scale.

The methodology behind the models when enhanced has been shown to be a very effective decision support tool for making finer scale land management decisions. Much work still remains to be done, but the availability of finer scale data makes the use of these tools even more relevant for future decision support. The promise of these models is their ability to evaluate forest sustainability, land use patterns, and program delivery, simultaneously at the landscape and site level. The challenge will be to use this information to develop land use policy and incentives that will encourage forest sustainability in a rapidly changing environment.

References

American Farmland Trust. 1998. Farms for the future: a strategic approach to saving Maryland's farmland and rural resources. American Farmland Trust, Northampton, MA. 117 pp.

Birch, T. W. 1996. Private forest-land owners of the United States, 1994. USDA Forest Service, Delaware, OH. 183 pp.

Bockstael, N. E. 1996. Modeling economics and ecology: the importance of a spatial perspective. American Journal of Agricultural Economics. 78: 1168-1180.

Bockstael, N. E., and K. Bell. 1998. Land use patterns and water quality: the effect of differential land management controls. pp. 169-191 in R. Just and S. Netanyahu, eds., Conflict and cooperation on trans-boundary water resources. Kluwer Academic Publishers, Norwell, MA.

Forman, R. T. T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press, Cambridge, England. 632pp.

Geoghegan, J., L. A. Wainger, and N. E. Bockstael. 1997. Spatial landscape indices in a hedonic framework: an ecological economics analysis using GIS. Ecological Economics 23:251-264.

Maryland Clean Water Action Plan. 1998. Unified Watershed Assessment. Annapolis, MD

Maryland Department of Natural Resources. 1991. Forest Resource Inventory (FRI).

Maryland Department of Natural Resources. 2003. Maryland's Strategic Forest Lands Assessment (SFLA). Available online at www.dnr.state.md.us/forests/planning/sfla.

Maryland Department of Natural Resources. 2004. Maryland's Strategic Forest Lands Assessment – Summary of Methods – Ecological, Economic and Vulnerability Models.

Maryland Department of Natural Resources. 2001.Summary of Methods to Identify and Evaluate Maryland's Green Infrastructure. Available online at http://dnrweb.dnr.state.md.us/download/grantsandloans/gpevaluation.pdf.

Maryland Department of State Planning. 1973. Natural soils groups technical report. Maryland Department of State Planning (now Maryland Dept. of Planning), Baltimore, MD. 153 pp.

Maryland Office of Planning. 1998. Atlas of agricultural land preservation in Maryland: location, protection, threat, and opportunities for the future. Maryland Department of Planning, Baltimore, MD.

McCann, J., Maryland Department of Natural Resources. 1999. Personal comm.

McGarigal, K., and B. J. Marks. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. Gen. Tech. Rep. PNW-GTR-351. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. 122pp.

Mehmood, S. R., and D. Zhang. 2001. Forest parcelization in the United States: a study of contributing factors. Journal of Forestry 99(4): 30-34.

Miller, K. M. 1997. Sensitive Species Project Review Areas (SSPRA) Metadata. Maryland Department of Natural

Resources, Geographic Information Services Division. Annapolis, MD.
National Gap Analysis Program. 1994. A handbook for gap analysis. National Gap Analysis Program, Moscow, ID.
Pennsylvania Department of Conservation and Natural Resources. 1998. WRCF - Delmarva fox squirrel [Online]. Available at http://www.dcnr.state.pa.us/wrcf/delmarva.htm
Pennsylvania Game Commission. 2001. Delmarva fox squirrel (Sciurus niger cinereus) [Online]. Available at http://sites.state.pa.us/PA_Exec/PGC/squirrel/profile.htm.
Robinson, S. K., F. R. Thompson III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.
Scott, J.M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T.C. Edwards, Jr., J. Ulliman, and R.G. Wright. 1993. Gap Analysis: A geographic approach to protection of biological diversity. Wildlife Monographs 123:1-41.
Wickham, J. D., R. V. O'Neill, and K. B. Jones. 2000. Forest fragmentation as an economic indicator. Landscape ecology 15:171-179.