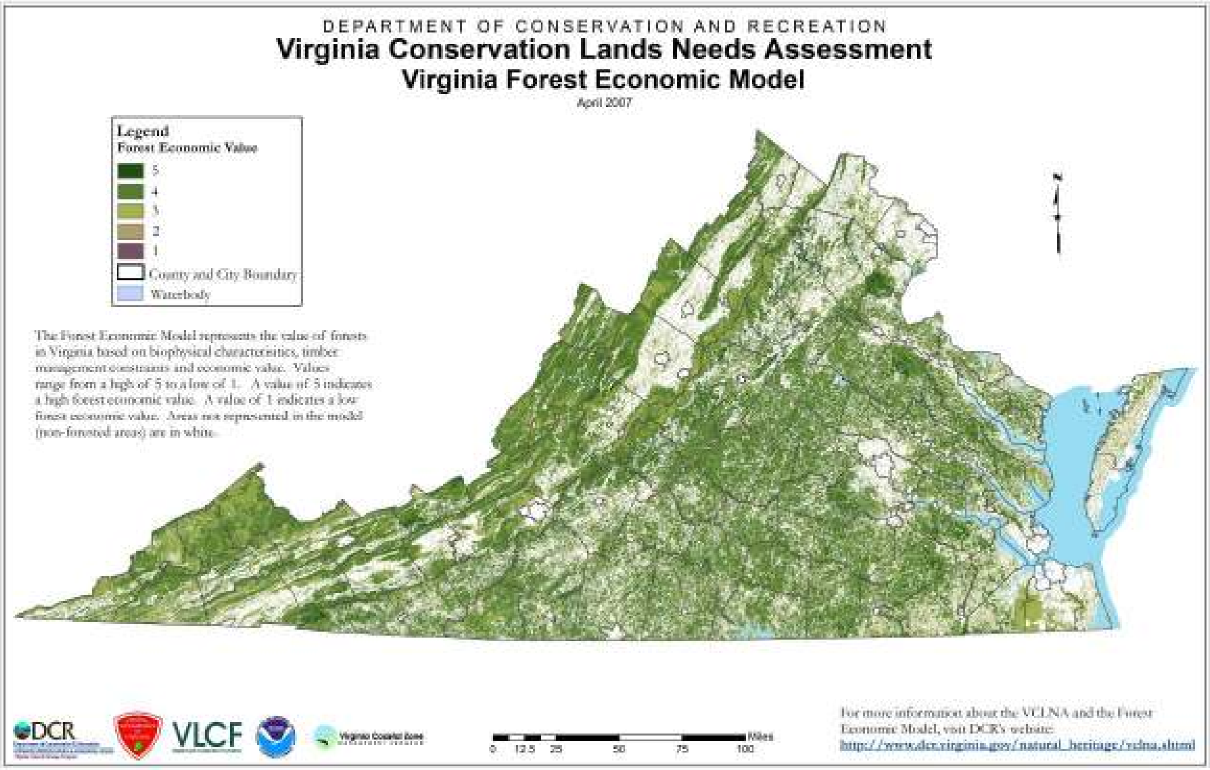
Virginia Conservation Lands Needs Assessment
Virginia Forest Economic Model



Virginia Department of Conservation and Recreation Division of Natural Heritage
Virginia Department of Forestry
Virginia DEQ Coastal Zone Management Program

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INTRODUCTION

The Virginia Forest Economics Model was developed in an effort to map viable forest lands with economic value. Forests play an important role in the ecological and economic health of Virginia. Ecologically, forests in Virginia provide important services which include:

- "Protection of water quality
- Protection of air quality
- Aesthetic quality
- Moderation of climate, including the offsetting of carbon emissions contributing to global warming
- Provision of habitat for many plants and animal species"

(VADOF 2006)

Economically, Virginia forests benefit our citizens as the forests contribute to the economy, individual forest landowners, jobs in the forest product industries and through recreational opportunities. Virginia forests and the forest industry have been estimated to contribute $29.44 billion in benefits (VADOF 2006a).

As development pressure continues across the state, remaining resources are being irretrievably lost to development. "From 2001 to 2004, urban growth and development resulted in an average net loss of 26,100 acres of forest land" (VADOF 2006b). "If the trend continues, Virginia would lose more than 1 million acres of forest land in the next 25 years" (VADOF 2006b).

The development of a GIS model to delineate where valuable forest land exists may serve as a guide to local government, consultants, and developers as to the location of valuable forest land in Virginia. The model also serves as part of a larger green infrastructure plan, which aims to model where Virginia's conservation priorities are located to facilitate an integrated approach to planning and development. For information on the Virginia Conservation Lands Needs Assessment and the Green Infrastructure Modeling effort, please visit the VCLNA website at http://www.dcr.virginia.gov/natural_heritage/vclna.shtml.

The Virginia Department of Conservation and Recreation Division of Natural Heritage (DCR –DNH) collaborated with the Virginia Department of Forestry (DOF) in the development of the Forest Economics Model. "The Virginia Department of Forestry's mission is:

- to protect 15.8 million acres of forest land from fire, insects and disease.
- to manage 17 State Forests and other state lands totaling 47,899 acres for timber, recreation, water, research, wildlife and biodiversity.
- to assist non-industrial private forest landowners through professional forestry advice and technical management programs.

More than 300,000 forest landowners in Virginia control 77% of forest land, which:

- Enhances the quality of life in the Commonwealth of Virginia.
- Supports the forest industry, a significant contributor to the state's economy."

http://www.dof.virginia.gov/info/index.shtml

DOF was used as the expert source for the model development.

Application of the Forest Economics Model

Some general categories of uses to which the forest economics model can be applied include:

- Targeting – to identify targets for protection activities.
- Prioritizing – to provide primary or additional justification for key conservation land purchases and other protection activities.
- Local planning – guidance for comprehensive planning and local ordinance and zoning development.
- Assessment – to review proposed projects for potential impacts to valuable forest land.
- Land Management – to guide property owners and public and private land managers in making land management decisions that enhance local values and the economy.
- Public Education – to inform the citizenry about the value of their community, helping retain the unique sense of place associated with these communities.

Deliverables

Maps will be produced for each Planning District Commissions and included as part of the final report. The report will be available online and on CD by request and include:

- Forest Economic Model maps
- A report detailing the methodology
- Metadata
- Personal geodatabase and shapefiles with forest economic classes attributed with appropriate rank/forest economic value (not a socioeconomic value but an overall ranking value).

METHODOLOGY

The Chesapeake Bay Resource Lands Assessment was used as a template for the Virginia Forest Economic Model. During collaboration with the Virginia Department of Forestry, the methodology for the Virginia Forest Economic Model was altered to reflect a more accurate assessment of Virginia resources. See Figure 1 for an overview of the Forest Economic Model methodology.

Base Data

Biophysical datasets:

- Soil productivity: Soil productivity derived from the Virginia Department of Forestry (see below for methods). Data used to derive layer included NRCS STATSGO and SSURGO data.
- Forest Land Fragmentation: Global Forest Fragmentation, Area Density, and Connectivity. Data obtained from Kurt Riitters, U.S. Forest Service, Southern Research Station, Research Triangle Park, NC <http://www.ecologyandsociety.org/vol4/iss2/art3/>. Data used to represent forest land fragmentation.

Management Constraints:

- Wetland features: National Wetland Inventory wetland information.
- Riparian features: National hydrography dataset.
- Natural heritage resource data: Polygon layer containing conservation sites, general locations and karst features and stream conservation units.
- Slope: Derived from the national elevation dataset.

Socioeconomic datasets:

- Wildland-Urban Interface (WUI): Data obtained from SILVIS Lab, Department of Forest Ecology and Management, University of Wisconsin-Madison <http://www.silvis.forest.wisc.edu/Library/WUILibrary.asp>.
- Forest land use taxation: Socioeconomic layer derived by the Virginia Department of Forestry.
- Preserved areas: A layer created to mask out the preserved areas from the forest land use taxation layer. These preserved areas cannot be harvested.

Mask:

- 2006 Virginia Forest Cover Map: Grid showing forested, non-forested and water areas in Virginia derived by the VA Department of Forestry.

Methodological Steps

Biophysical datasets:

Soil Productivity

Forest soil productivity was estimated from soil data available from the Natural Resources Conservation Service (NRCS), United States Department of Agriculture (USDA). Two datasets were used, STATSGO and SSURGO.

STATSGO

The Virginia State Soil Geographic (STATSGO) database (1994) was downloaded from the NRCS website. The mapping scale for Virginia STASGO is 1:250,000.

The following relevant use constraints are extracted from the metadata for Virginia STATSGO:

> *The level of mapping is designed to be used for broad planning and management uses covering state, regional, and multi-state areas. The approximate minimum area delineated is 625 hectares (1,544 acres), which is represented on a 1:250,000-scale map by an area approximately 1 cm by 1 cm (0.4 inch by 0.4 inch). . . . Delineations depict the dominant soils making up the landscape. Other dissimilar soils, too small to be delineated, are present within delineation.*

Using the Virginia STATSGO For each map unit:

1. Computed weighted mean forest soil productivity for each map unit component using the component percentage composition, and the maximum woodland productivity for any species listed for a component, and using only components with non-null forest soil productivity.

$$MeanPROD = \frac{\sum comppct \times woodprod_{\max}}{\sum comppct}$$

   Where,

   comppct is the representative component percentage composition for the map unit component

   $woodprod_{max}$ is the maximum woodland productivity of all species listed for the soil component.

   MEANPROD values were computed with SQL queries in Microsoft Access and stored in a table object called MEANPROD_SPP. The queries were filtered to include productivity values only for those map units which had non-null productivity values for at least 50% of their composition. The symbol for the species which had the maximum woodland productivity values was recorded in the *PLANTSYM* field of the MEANPROD_SPP table.

2. The MEANPROD_SPP table was joined (1-1) to the STATSGO map unit feature class.
3. Statistics were computed for STATSGO *MeanPRODm* with the following results:

Range	2.97 – 12.00	$m^3ha^{-1}yr^{-1}$
Mean	7.57	$m^3ha^{-1}yr^{-1}$
Standard Deviation	2.03	$m^3ha^{-1}yr^{-1}$

SSURGO

All available (68) SSURGO soil survey area data layers were downloaded from the NRCS Soil Data Mart website merged in a single layer, re-projected to the Virginia Lambert Conformal Conic (NAD83) projection, and topologically edited to remove gaps and overlaps between adjacent soil surveys.

For each map unit:

1. Computed weighted mean forest soil productivity for each map unit component using the representative component percentage composition, and the maximum forest productivity for any species listed for a component, and using only components with non-null forest soil productivity.

$$MeanPROD = \frac{\sum comppct\_r \times fprod\_r_{\max}}{\sum comppct\_r}$$

   where,

   comppct_r is the representative component percentage composition for the map unit component

   $fprod\_r_{max}$ is the maximum forest productivity of all species listed for the soil component.

   MeanPROD values were computed with SQL queries in Microsoft Access and stored in a table object called MU_PROD. The queries were filtered to include productivity values only for those map units which had non-null productivity values for at least 50% of their composition. The symbol for the species which had the maximum forest productivity values was recorded in the *FirstofSYM* field of the MU_PROD table.

2. The *MeanPROD* values ($ft^3ac^{-1}yr^{-1}$) were converted to metric units ($m^3ha^{-1}yr^{-1}$) using the conversion constant of 14.29 ft^3m^{-3} and stored in the field *MeanPRODm* in the table object MU_PROD.
3. The MU_PROD table was joined (1-1) to the SSURGO map unit feature class.
4. Statistics were computed for SSURGO *MeanPRODm* with the following results:

Range	2.02 – 13.72	$m^3ha^{-1}yr^{-1}$
Mean	7.98	$m^3ha^{-1}yr^{-1}$
Standard Deviation	1.83	$m^3ha^{-1}yr^{-1}$

Reclassification

Both the STATSGO and SSURGO productivity values were converted to a 10-point score according to the following table. A score of zero was assigned to areas which had no forest productivity estimates. The areas assigned a zero value included large water bodies and a few soil map units which had no forest productivity estimates (or estimates only for less than 50% of the map unit).

Productivity ($m^3 ha^{-1} yr^{-1}$)	Score
< 4.00	1
4.00 – 4.99	2
5.00 – 5.99	3
6.00 – 6.99	4
7.00 – 7.99	5
8.00 – 8.99	6
9.00 – 9.99	7
10.00 – 10.99	8
11.00 – 11.99	9
> 12.00	10

The productivity scores were calculated and stored in attribute table fields: *GridValue* for SSSURGO in the MU_PROD table, and *GRIDCODE* for STATSGO in the MEANPROD_SPP table.

Combining STATSGO and SSURGO

1. The STATSGO polygon feature data layer was converted to a 15-m cell raster with the same extent as the Virginia Forest Cover Map (VFCM) raster dataset, and assigned a raster cell value of the productivity score from the *GRIDCODE* field.
2. The SSURGO polygon feature data layer was converted to a 15-m cell raster with the same extent as the Virginia Forest Cover Map (VFCM) raster dataset, and assigned a raster cell value of the productivity score from the *GridValue* field.
3. Both the STATSGO and SSURGO rasters were reclassified to convert NoData values to zero.
4. In order to use the higher resolution SSURGO data were available and fill in with the STATGO data where SSURGO data is not available, the following map algebra function was used to combine the two rasters into a raster called **ForPro**: con (SSURGO > 0, SSURGO, STATSGO)
5. Set ranks:

SoilProductivityScore	Reclass Rank
1	1
2	1
3	2
4	2
5	3
6	3
7	4
8	4

9	5
10	5

Forest Land Fragmentation

A forest land fragmentation grid was used to rank forest lands based on fragmentation index. The Global Forest Fragmentation, Area Density, and Connectivity grid is available from the U.S. Forest Service at http://www.ecologyandsociety.org/vol4/iss2/art3/. The Forest fragmentation index was downloaded in BSQ format and converted to a 30 meter grid in Arc.

The forest fragmentation grid was recoded in ArcGRID to reflect the following ranking:

CLASS	VALUE	RECODED RANK
Interior	4	5
Perforated	3	4
Edge	1	3
Transitional	6	2
Patch	5	1
Undetermined	2	0
Unlabeled	7	0

Management Constraint Datasets:

Wetland and Riparian Features

The National Wetlands Inventory (NWI) was used to represent wetlands and the National Hydrography Dataset (NHD) was used for riparian feature representation. NWI data was obtained from U.S. Fish & Wildlife Service, National Wetlands Inventory (<http://www.fws.gov/nwi/>). Data was obtained in shapefile format.

NHD was obtained from the USGS (<http://nhd.usgs.gov/index.html>). NHD data was downloaded from the USGS site, both high resolution and medium resolution data were used as high resolution data is not available for Virginia statewide. The NHD was downloaded as a geodatabase.

NHD and NWI were buffered at 100 feet based on the Chesapeake Bay Preservation Ordinance Resource Protection Area buffer size. Data were attributed with a value of 1 and converted to a 30 meter grid with Spatial Analyst. The grid was coded with a value of 5 for area outside of the buffer in GRID.

Natural Heritage Resource Data

Natural Heritage Resource data were obtained from the Virginia Department of Conservation and Recreation Division of Natural Heritage in shapefile format. The shapefile contained polygon coverage of conservation sites, general location sites (threatened and endangered species and habitat information), karst features and stream conservation units. The stream conservation units were buffered at 100 feet and a simplify was run in ArcGIS with a 0.5 meter tolerance. Data was coded with a value of 1 and converted to a 30 meter grid with Spatial Analyst. The grid was coded with a value of 5 for area outside of the buffer in GRID.

Slope

Slope was derived from the National Elevation Dataset with Spatial Analyst. Processing done on NED included running a fill.

Slope was recoded to set ranks as:

Slope Value	Slope Rank
0 - 10	5
11 - 20	4
21 - 30	3
31 - 40	2
> 40	1

Socioeconomic Datasets:

Wildland-Urban Interface (WUI)

"The Wildland-Urban Interface is where houses meet or intermingle with wildland vegetation. The WUI is where wildfire poses the biggest risk to human lives and structures. It is also an area of widespread habitat fragmentation, introduction of invasive species and biodiversity loss. (http://silvis.forest.wisc.edu/projects/WUI_Main.asp)"

The WUI was converted from an ArcINFO export file (.e00) to coverage and built in ArcINFO. The coverage was converted to a grid in Arc using WUICODE00 as the value item. The WUI was recoded in ArcGRID to set ranks as (called WUI):

WUICODE00	WUIHDEN00	RANK
23	low density interface	0
24	medium density interface	0
25	high density interface	0
33	low density intermix	3
34	medium density intermix	2
35	high density intermix	1
41	uninhabited no vegetation	0
42	very low density no vegetation	0
43	low density no vegetation	0
44	medium density no vegetation	0
45	high density no vegetation	0
51	uninhabited vegetation	5
52	very low density vegetation	4
90	water	0

Forest Land Use Taxation

The economic value is based upon the economic return possible from pine or hardwood timber stands. These values are estimated by DOF for each county with forestland use taxation. As input to the method we gathered estimates of average stumpage values (prices paid for standing timber) on a county by county basis. These stumpage values were used in the forest economics layer analysis along with woodland productivity ratings for general soils types in the STATSGO dataset.

The Forest Land Use Taxation layer was derived by John Scrivani from the Virginia Department of Forestry, Division of Resource Management. The forest land use taxation layer was derived with:

1. County estimates of stumpage values were interpolated for pine & hardwood species.
2. Forest productivity rasters were generated based upon STATSGO estimates.
3. For 30m cells of pine: forest value = pine stumpage x soil productivity
4. For 30m cells of hardwood: forest value = hdwd stumpage x soil productivity

The Forest Land Use Taxation layer was reclassified in ArcMap to set ranks based on an Equal Intervals as (called foreco):

FOREST ECO EQUAL INTERVAL VALUE	RANK
39.0868 - 48.5167	5
29.6567 - 39.0867	4
20.2267 - 29.6566	3
10.7967 - 20.2266	2
1.366 - 10.7966	1

Masks:

Preserved Areas

Preserved areas were derived from the VA Department of Conservation and Recreation Division of Natural Heritage Conservation Lands database (http://www.dcr.virginia.gov/natural_heritage/conslandmap.shtml). Preserved areas were selected from Conservation Lands in ArcMap where Manage Area Type was equal to:

MATYPE = NF Wilderness Area

NPS Easement
NPS Holding
NPS National Memorial Hospital
NPS Scenic Easement
NPS Wilderness Area
National Park
State Park

The select set was exported to a shapefile called preserved_forests.shp. The preserved forests were attributed with a value of 0, then converted to a 30 meter grid with Spatial Analyst (called preserved).

Forest Mask

A forest cover image was derived by Jim Pugh from the Virginia Department of Forestry, Division of Resource Management.

“The Virginia Forest Cover Map (VFCM) was developed to identify forest in Virginia as defined by the United States Forest Service (USFS) Forest Inventory and Analysis (FIA) Program.

VFCM was developed to provide an estimation of forest area in the state, to provide baseline data for forest health, disturbance and harvest monitoring, and for examination of forest fragmentation” (Pugh 2007).

The image was recoded as:

FOREST COVER DESCRIPTION	IMAGE VALUE	RECLASSIFIED VALUE
NODATA	0	0
WATER	1	0
NON-FORESTED	2	0
FOREST	3	1

Combination of Biophysical, Management Constraint and Socioeconomic Datasets

1. The Forest Land Use Taxation layer was multiplied by the preserved forest grid in ArcGRID to mask out all preserved forest areas. The output was called foresteco.
2. All grid nodata values were set to 0 in ArcGRID.
3. All grids were summed in ArcGRID:
   Grid: |> final = sum(foreco, forfrag, heritage, nhd, nwi, slope, soilprod, wui) <
4. Final grid was multiplied by the forest mask to remove all non-forested areas:
   Grid: |> foresteco_f = final * for_mask
5. The final forest economic layer was converted to an integer grid:
   Grid: |> forecn_int = int(foreco_f + .5) <|
6. The forecn integer grid was recoded in ArcGRID to set ranks as:

FORECO FINAL VALUE	FORECO RECLASSIFICATION
30 - 36	5
24 - 30	4
18 - 24	3
12 - 18	2
6 - 12	1

7. The final grid was renamed to forest_f.
8. Forest_f was converted to a shapefile with Spatial Analyst. Called forest_economics.shp. The attribute table field name ForEconVal is the forest economic rank for the particular polygon entity.

Model Validation

The Forest Economic Model was quality controlled/assured through a visual assessment process. The USGS 3 ¼ minute quarter quadrangle was overlaid on top of the grid and original input data feature classes. The USGS grids were systematically assessed in ArcMap to visually check for the absence of data in all model input grids in relation to presence of an original polygon in the original input feature classes.

Final validation on the compiled model included a review by the Virginia Department of Forestry.

RESULTS

Maps were produced for each Planning District Commission, statewide and Coastal Zone and are included as part of the final report. The report will be available online and on CD by request and include:

- Forest economic model maps for each PDC, the Coastal Zone and the state.
- Metadata
- Personal geodatabase, shapefile or ESRI grid format.

DISCUSSION

The Forest Economic Model may serve as a guide to state and local government, consultants, and developers as to the location of important forest resources. The model can be used alone or integrated with other datasets, such as the VCLNA Vulnerability Model (growth prediction model) or Ecological Model, to identify which resources are most at risk to growth pressures or would serve to contribute to an ecological core area. "In terms of vulnerability, forests with low economic and ecological value are projected to experience the highest risk for development" in Maryland (Jantz et al. 2004).

The model may also be used to help guide local land use planners in the development of their comprehensive plans. It is important to look at the landscape as a whole and assess how growth may impact important resources, such as the environment, what remaining farmland or timberland is available or how water quality will be affected, before more development is introduced.

The models serve as part of a larger green infrastructure plan, which aims to model where Virginia's conservation priorities are located to facilitate an integrated approach to planning and development. For information on the Virginia Conservation Lands Needs Assessment and the Green Infrastructure Modeling effort, please visit the VCLNA website at http://www.dcr.virginia.gov/dnh/vclna.htm.

FUTURE APPLICATIONS

Additional Data Incorporation

Development of a statewide model constrains the model to statewide available datasets. In the future, particular areas can be appended to with additional information specific to that area.

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Figure 1. Forest Economics Methodology Overview.

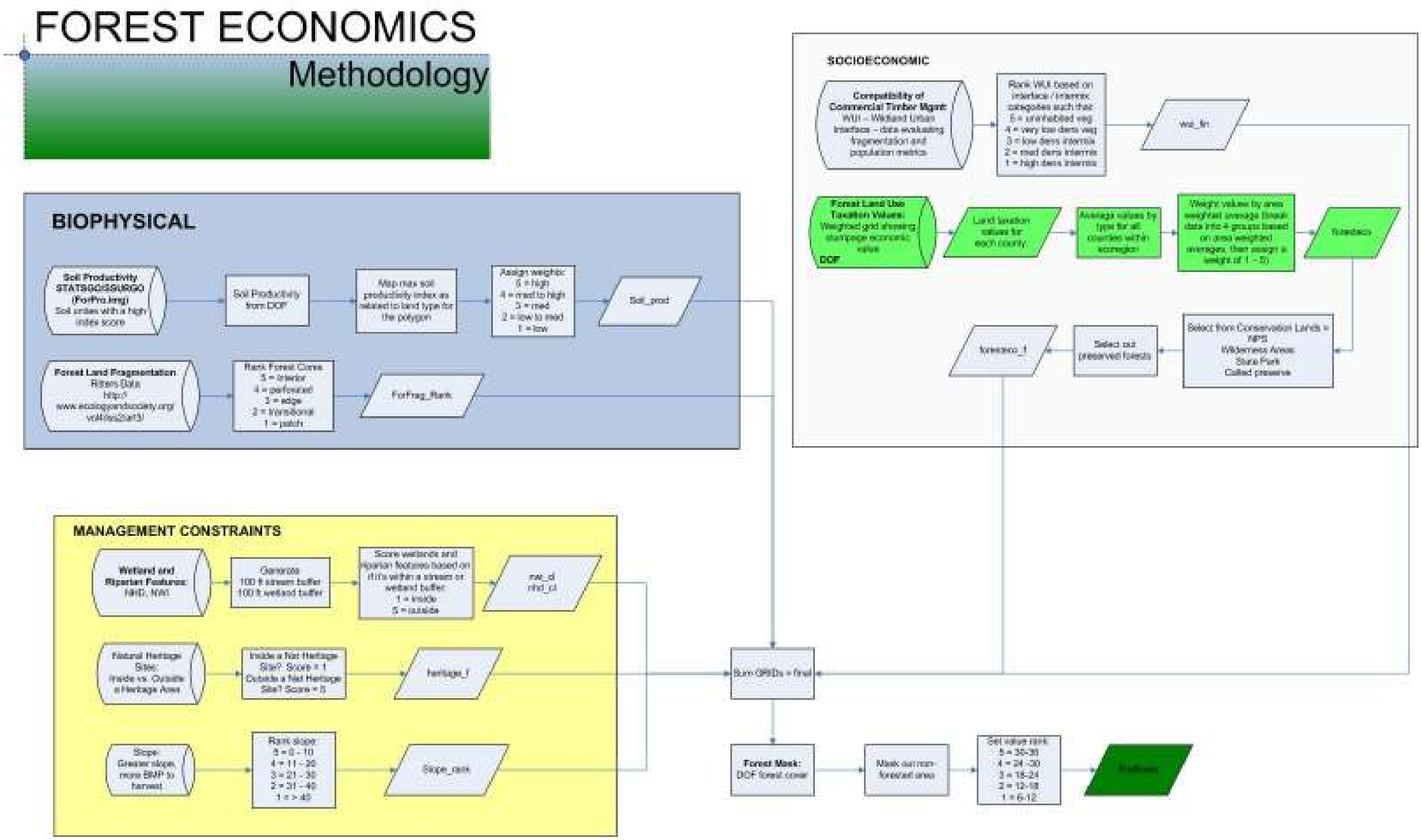

Figure 2. PDC 1 LENOWISCO Forest Economics Model.

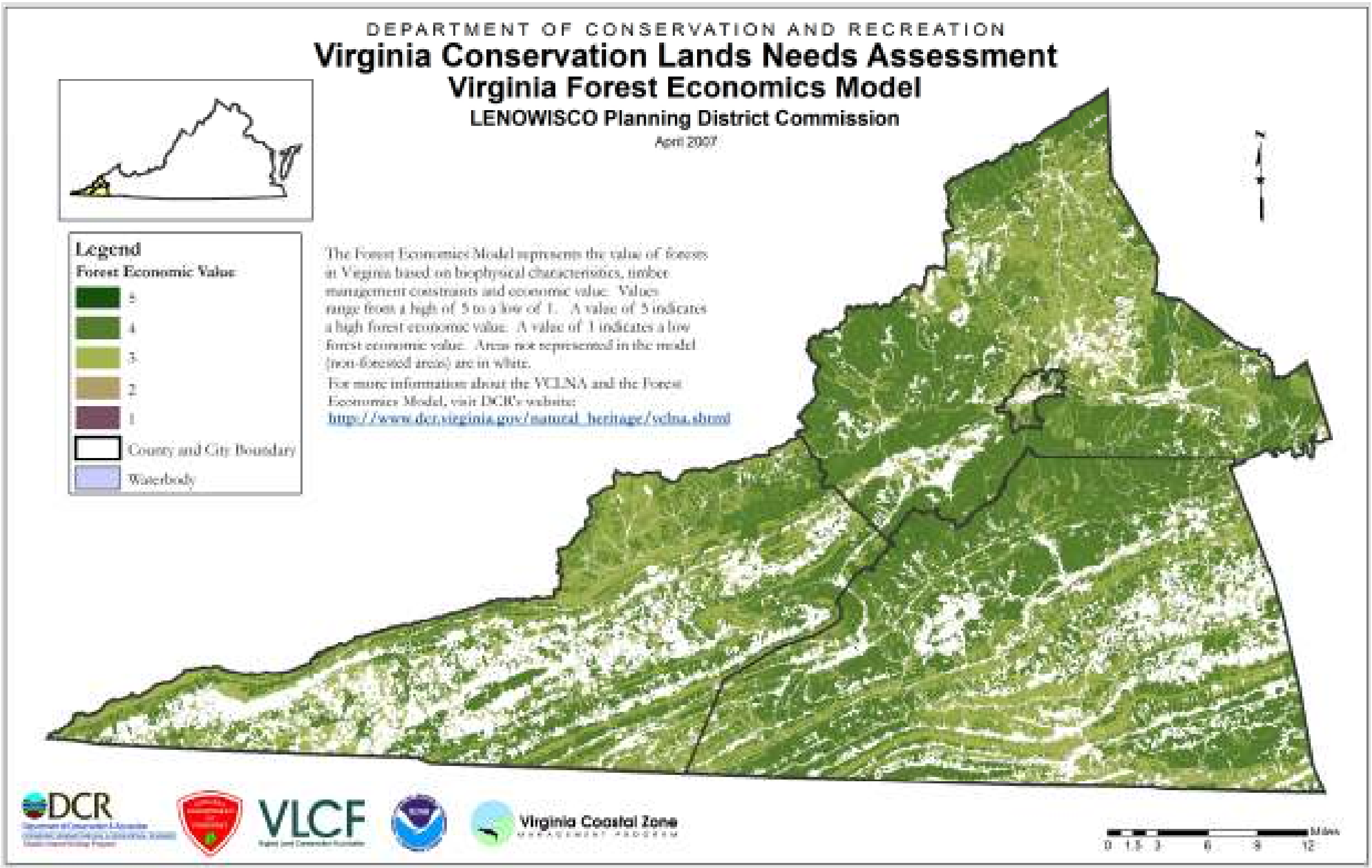

Figure 3 PDC 2 Cumberland Plateau Forest Economics Model.

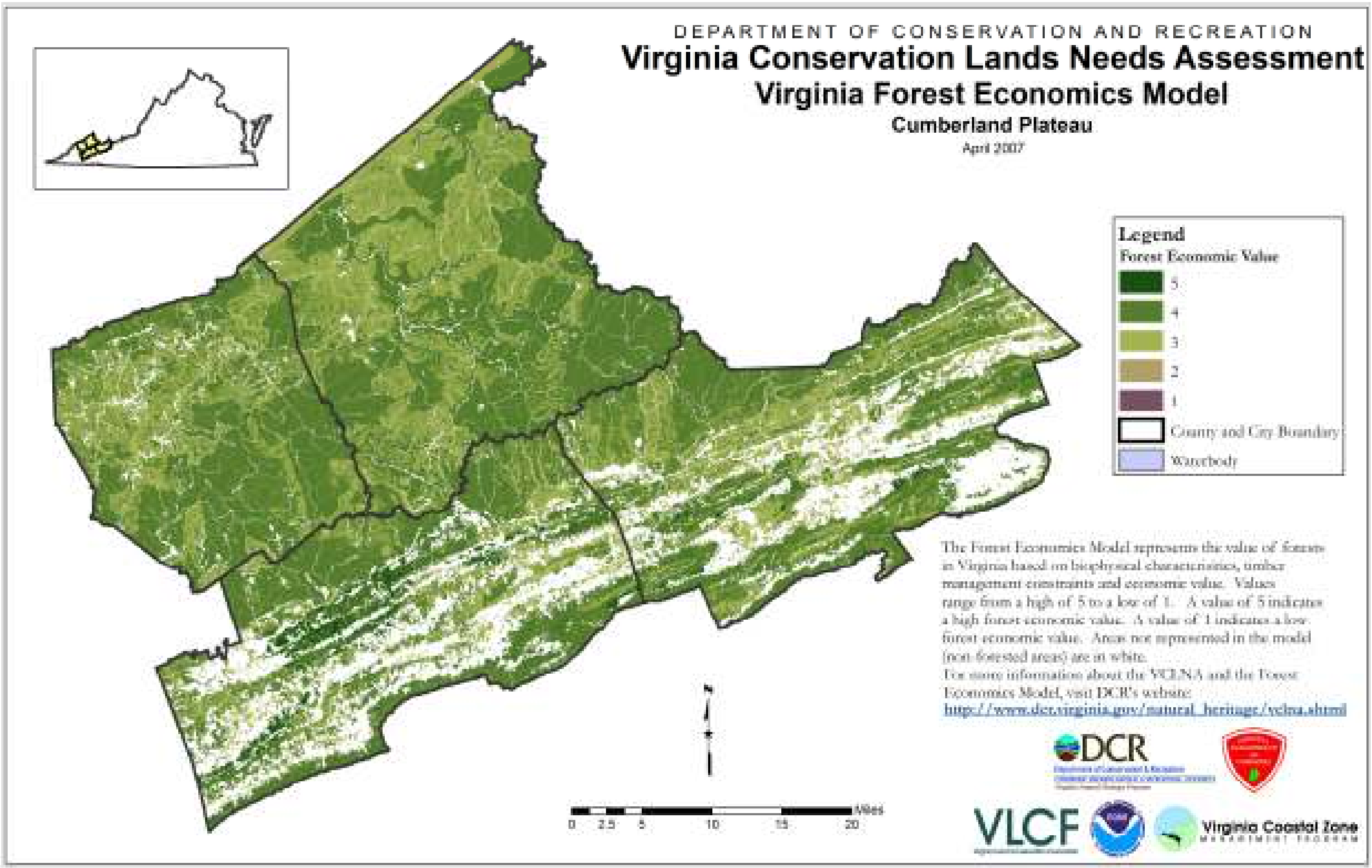

Figure 4. PDC 3 Mount Rogers Planning District Commission Forest Economics Model

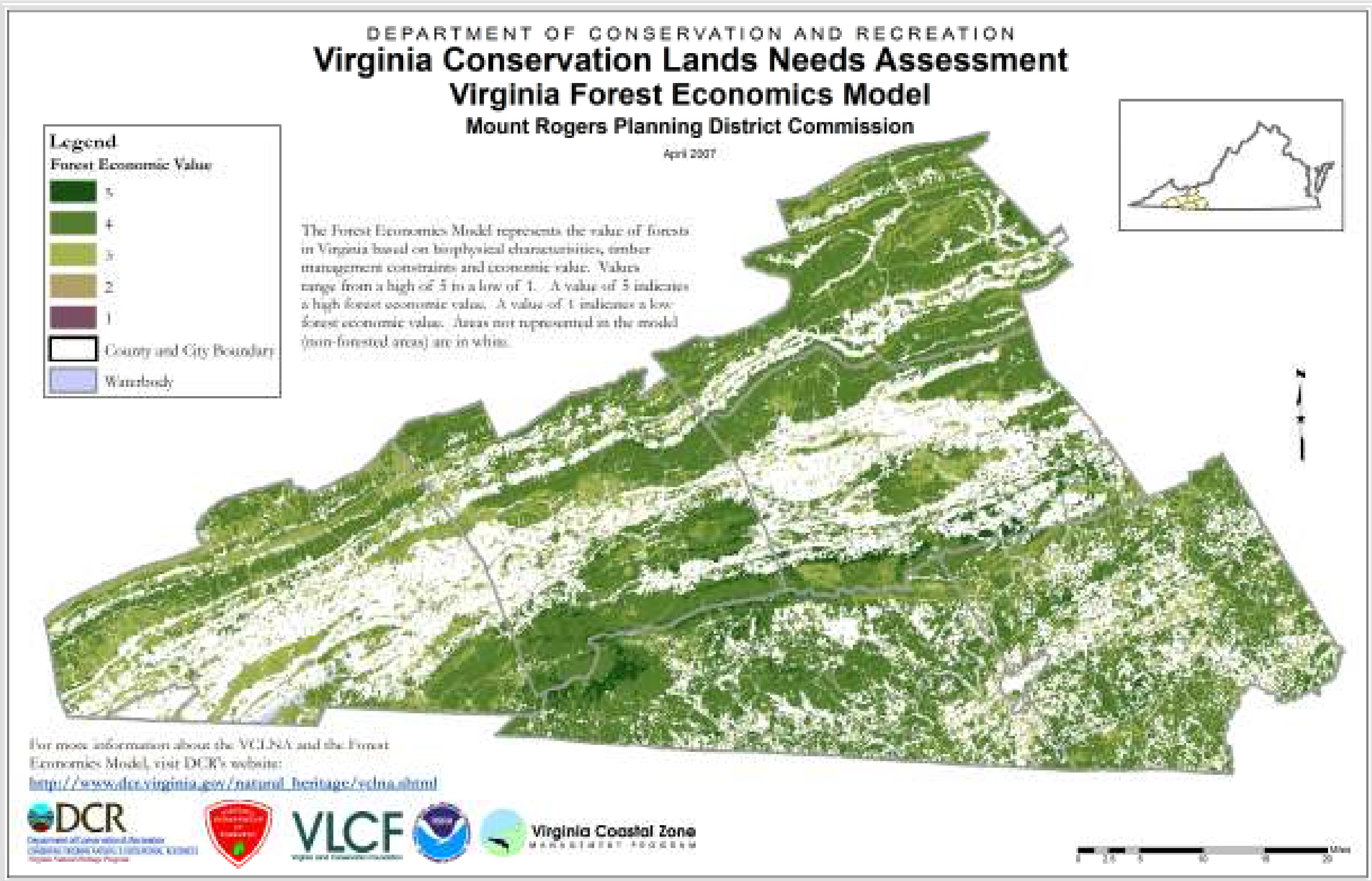

Figure 5. PDC 4 New River Valley Planning District Commission Forest Economics Model.

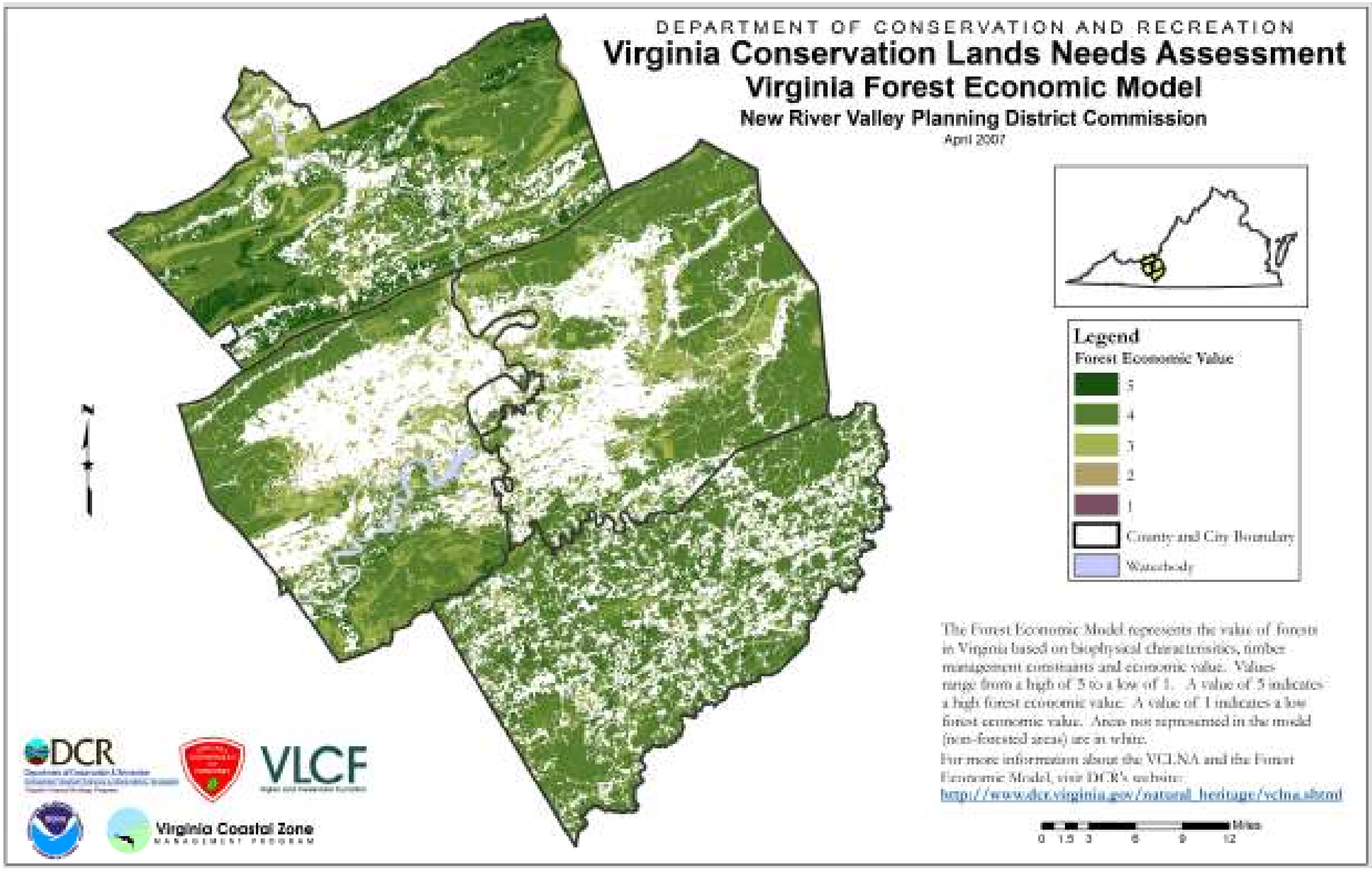

Figure 6. PDC 5 Roanoke Valley-Alleghany Regional Commission Forest Economics Model.

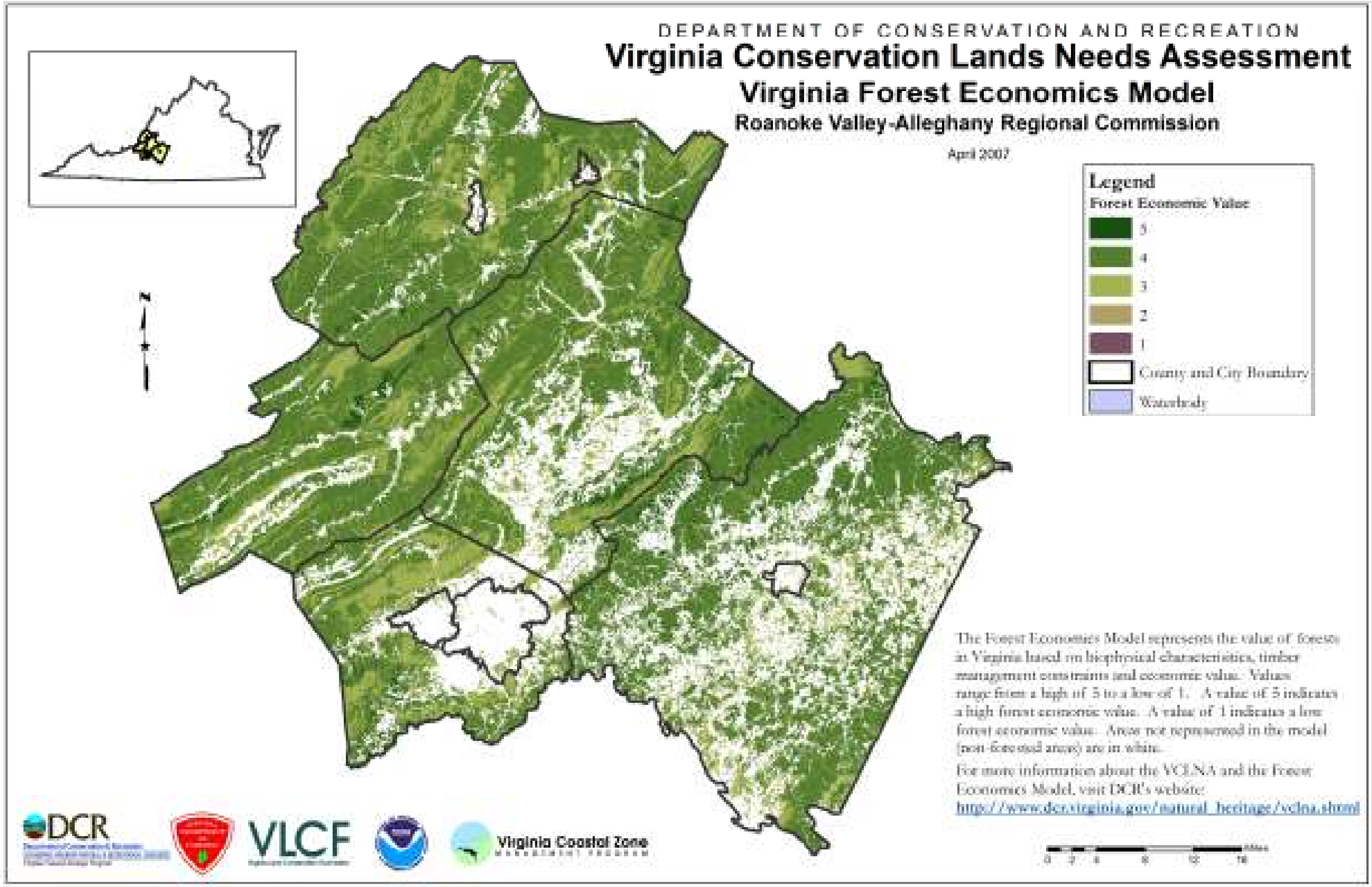

Figure 7. PDC 6 Central Shenandoah Forest Economics Model

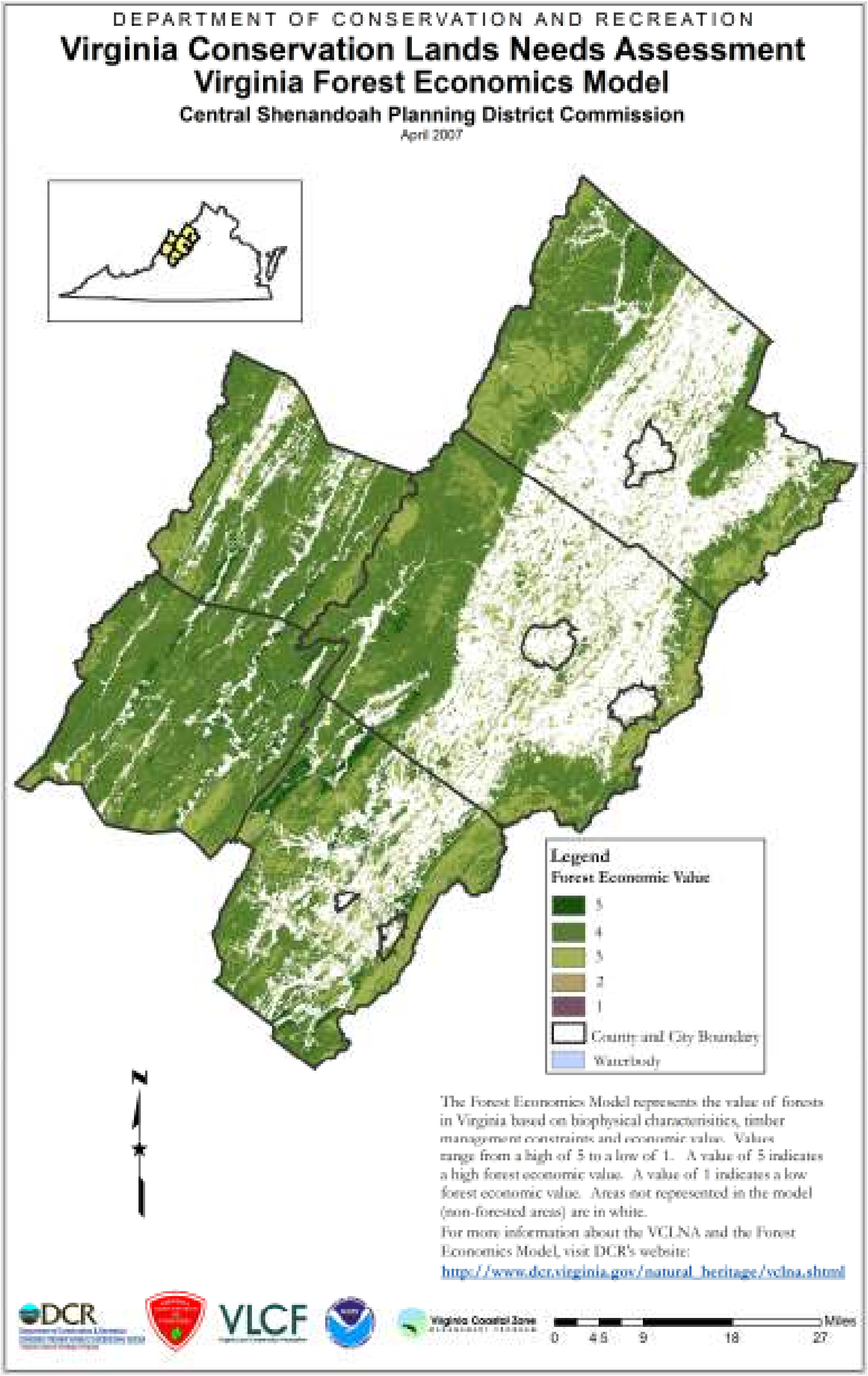

Figure 8. PDC 7 Northern Shenandoah Valley Regional Commission Forest Economics Model.

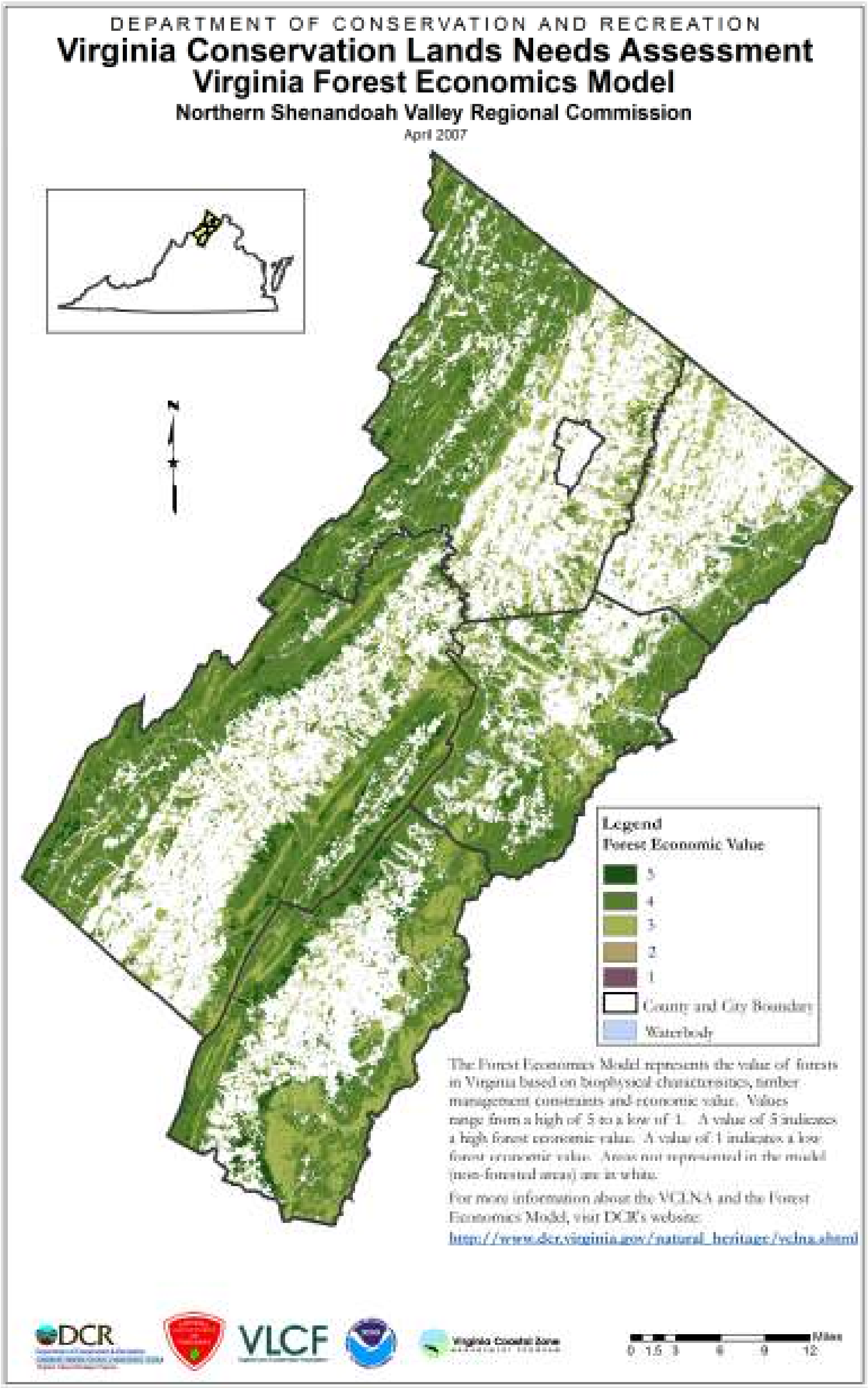

Figure 9. PDC 8 Northern Virginia Regional Commission Forest Economic Model.

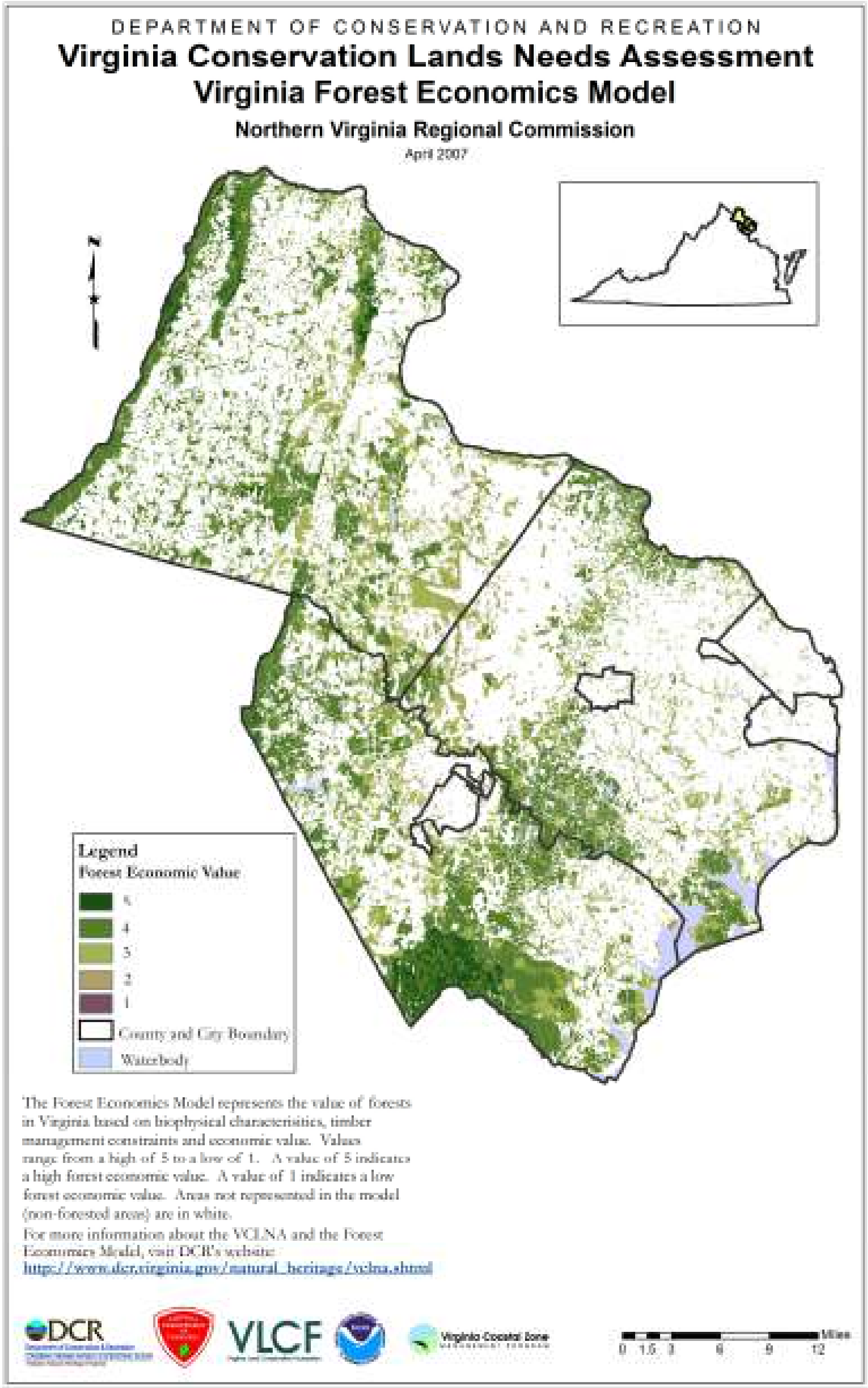

Figure 10. PDC 9 Rappahannock-Rapidan Regional Commission Forest Economics Model.

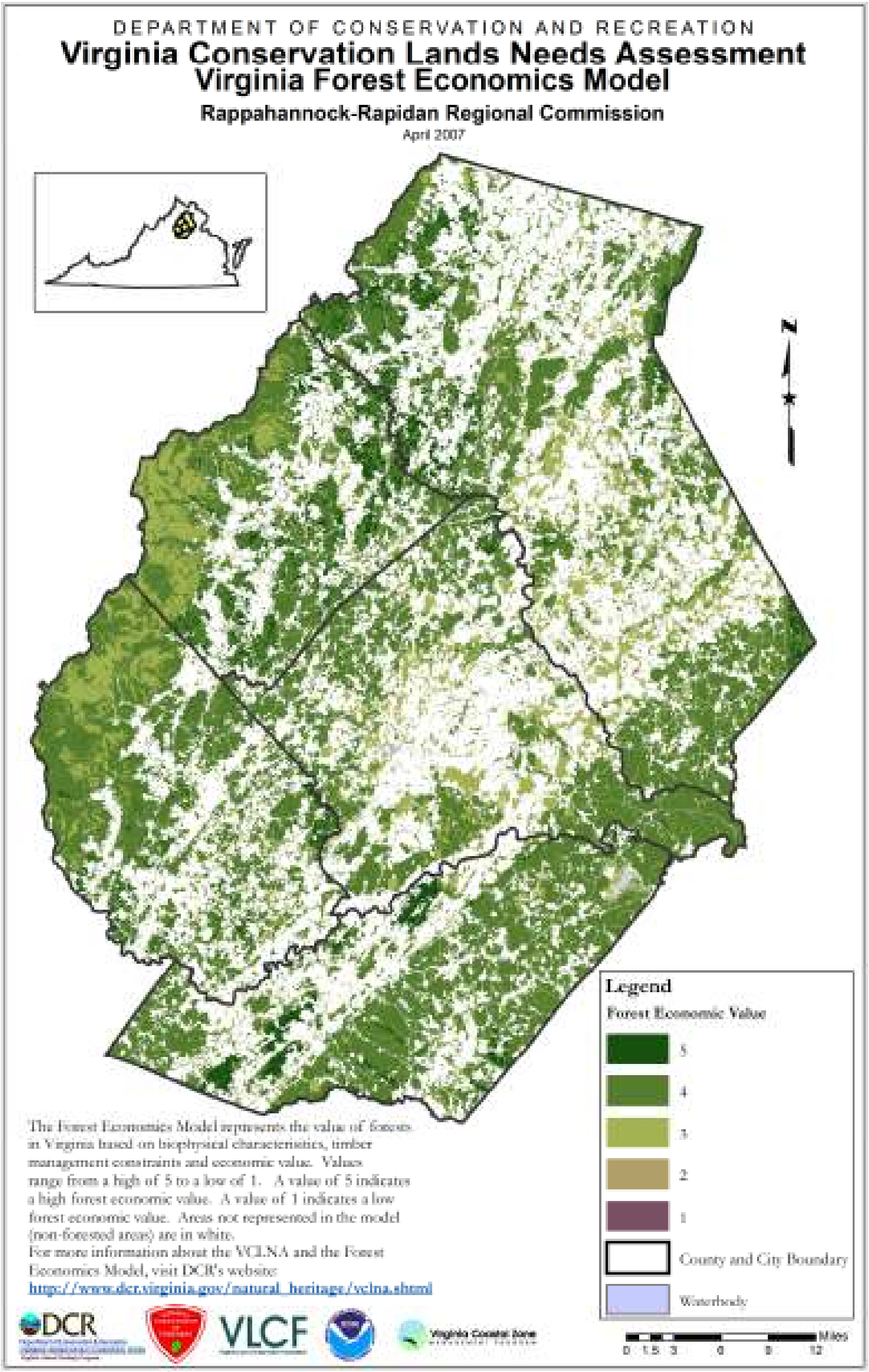

Figure 11. PDC 10 Thomas Jefferson Planning District Commission Forest Economics Model.

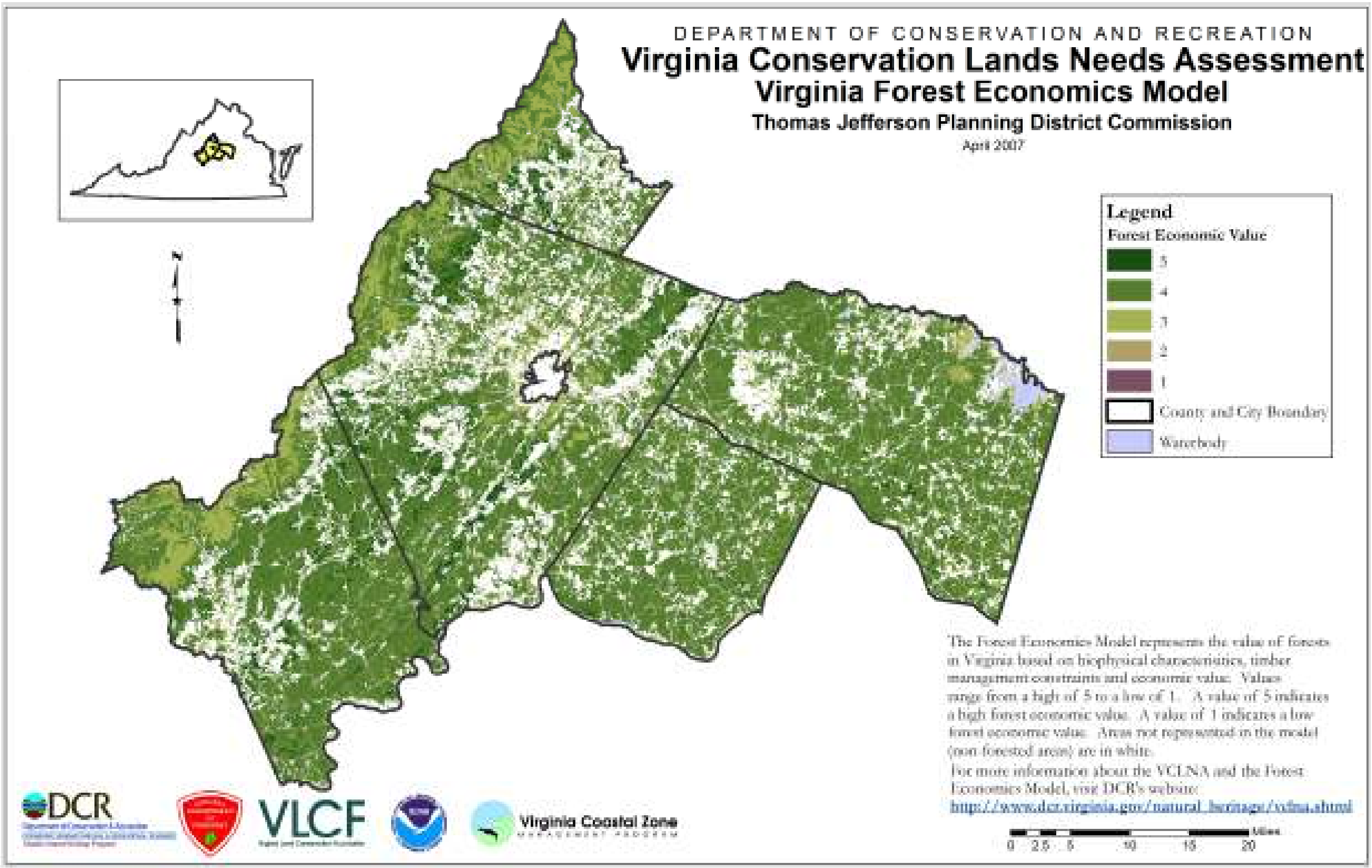

Figure 12. PDC 11 Region 2000 Local Government Council Forest Economics Model.

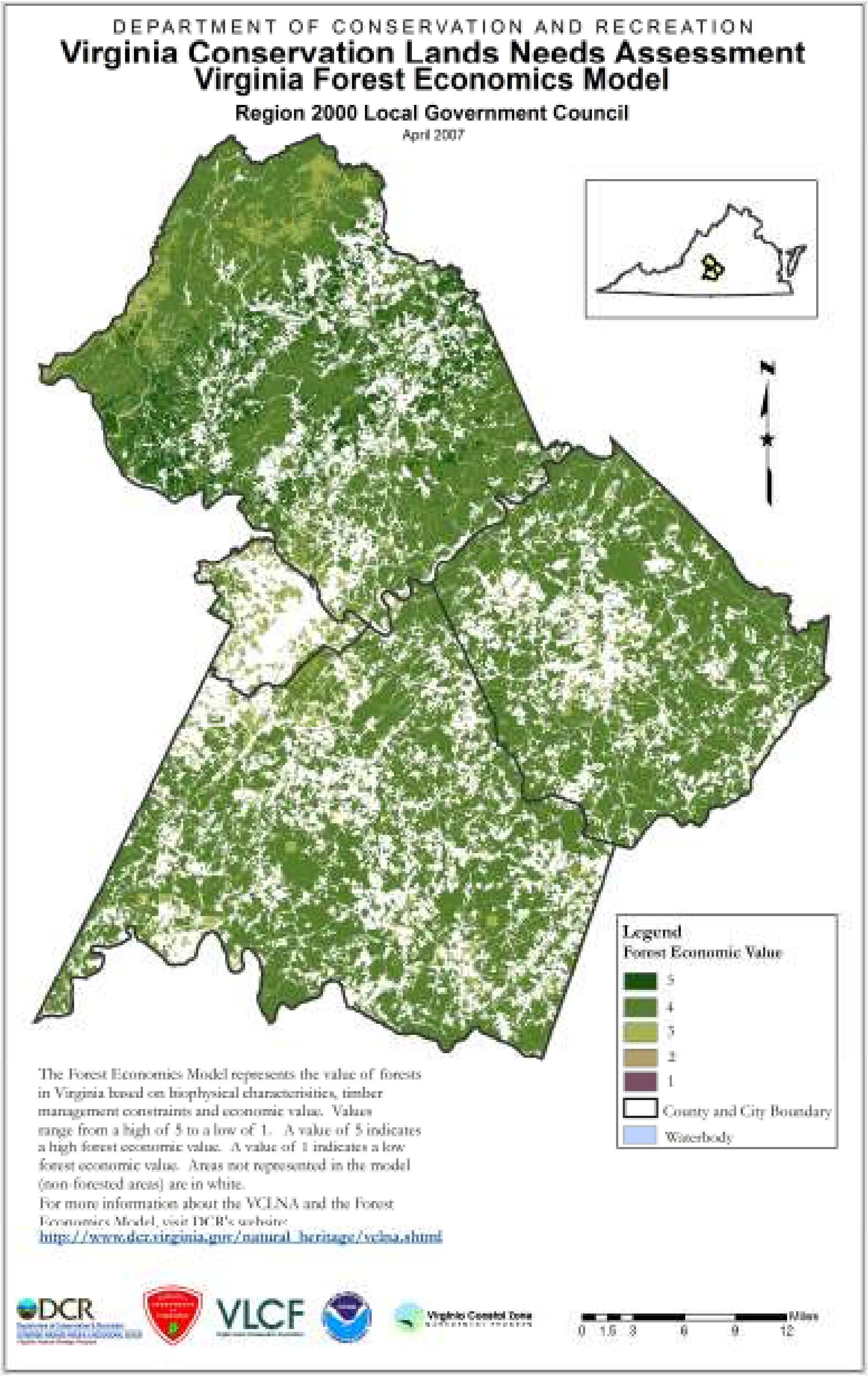

Figure 13. PDC 12 West Piedmont Planning District Commission.

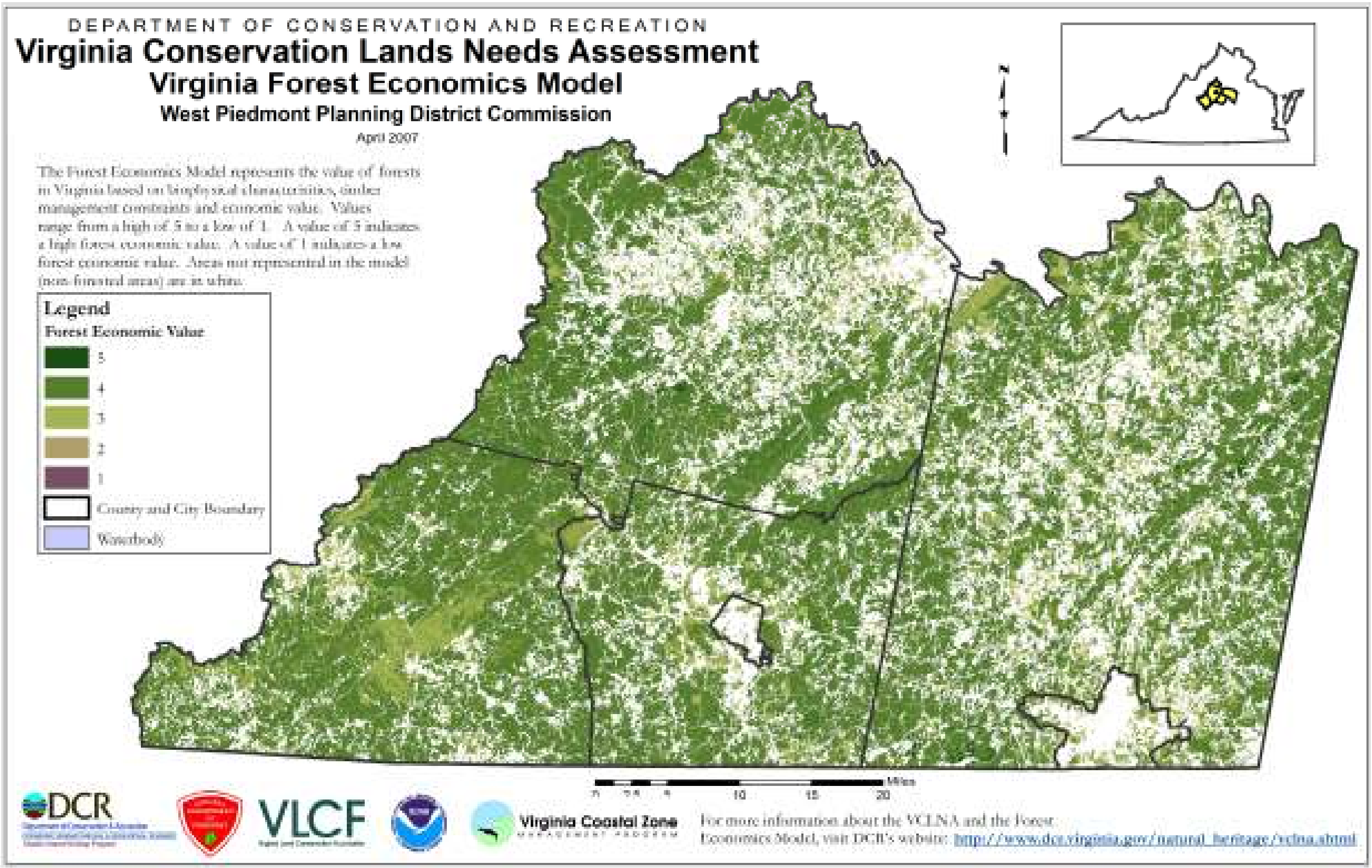

Figure 14. PDC 13 Southside Planning District Commission Forest Economics Model.

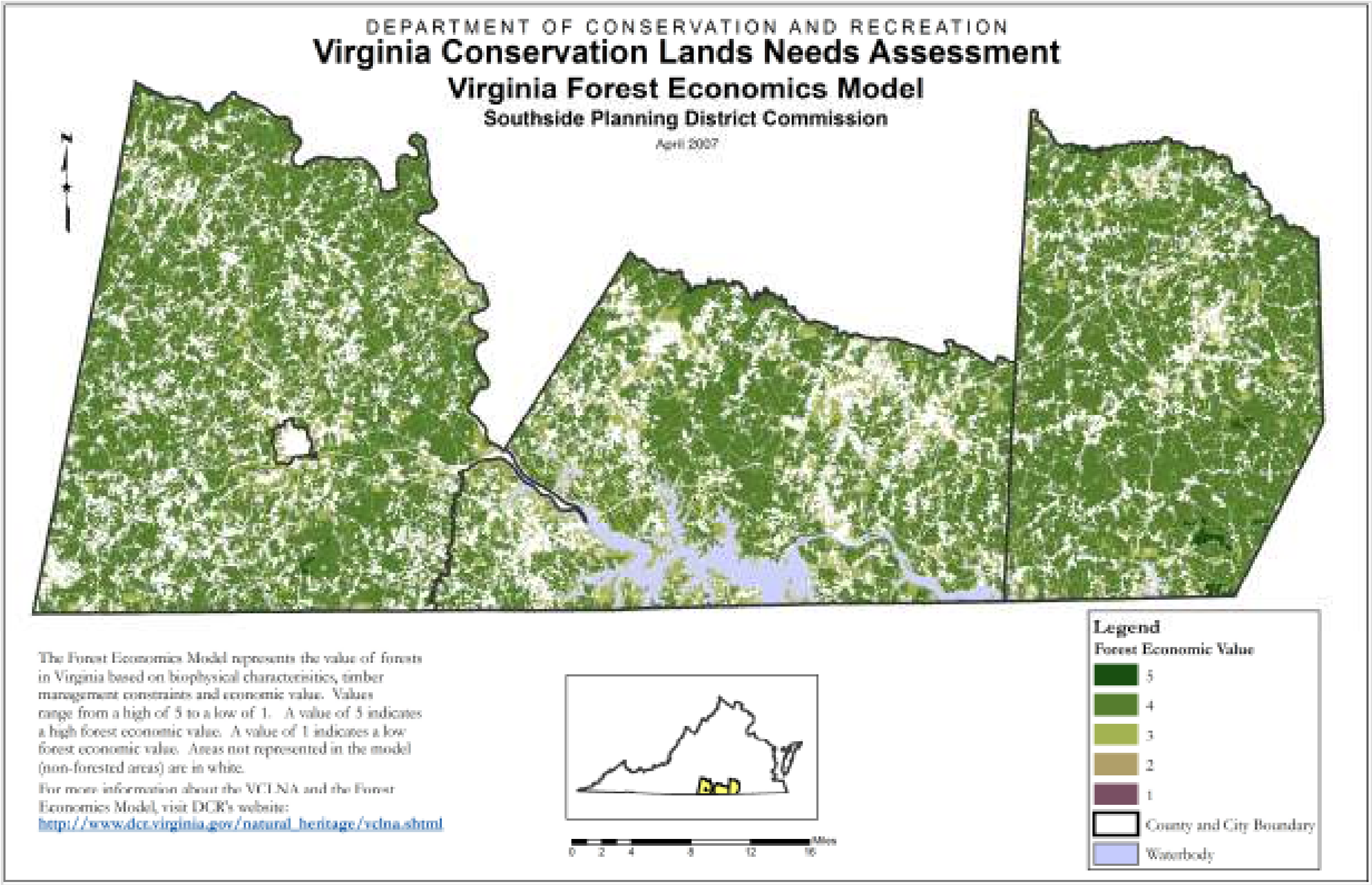

Figure 15. PDC 14 Commonwealth Regional Council Forest Economics Model.

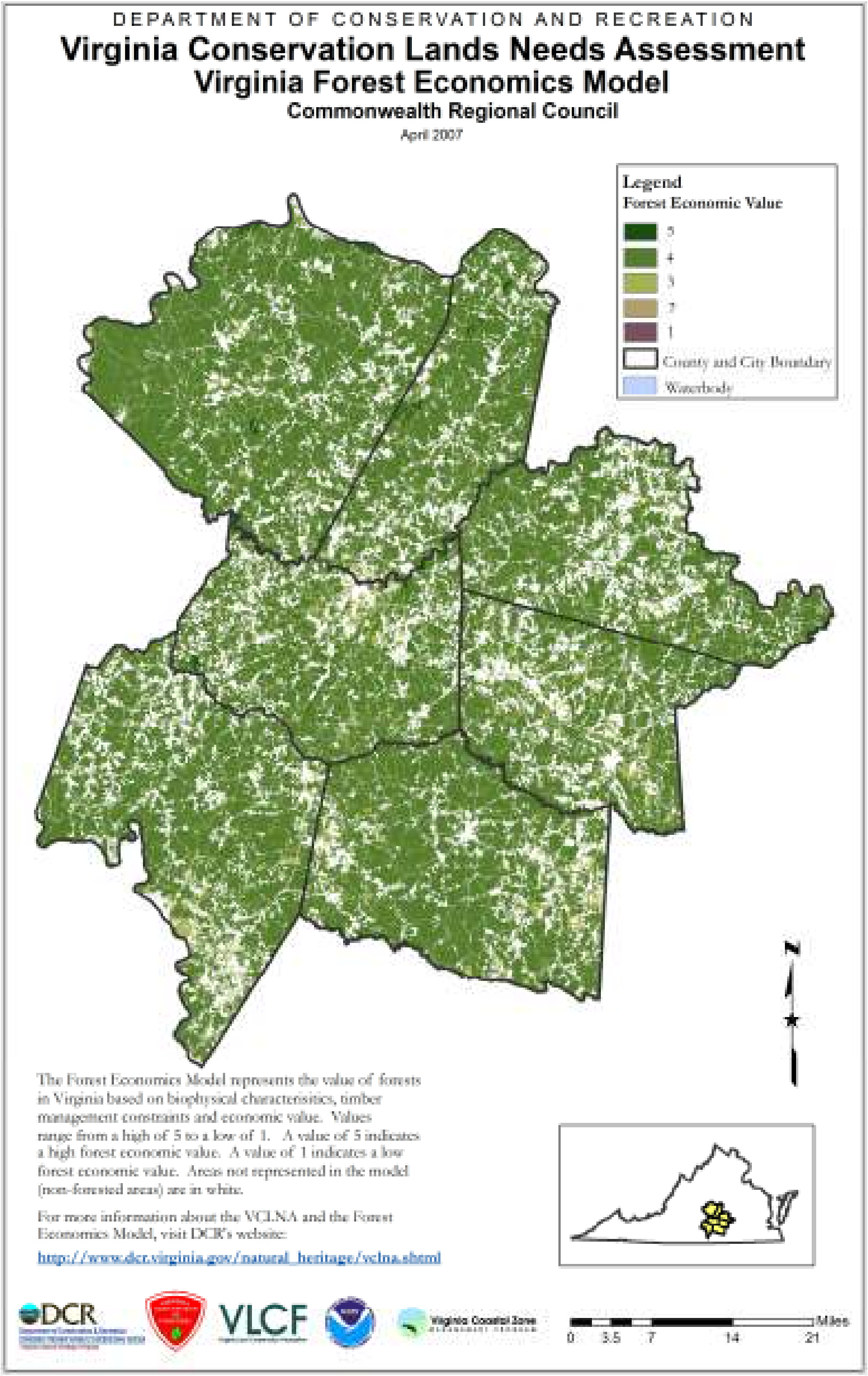

Figure 16. PDC 15 Richmond Regional Planning District Commission Forest Economics Model.

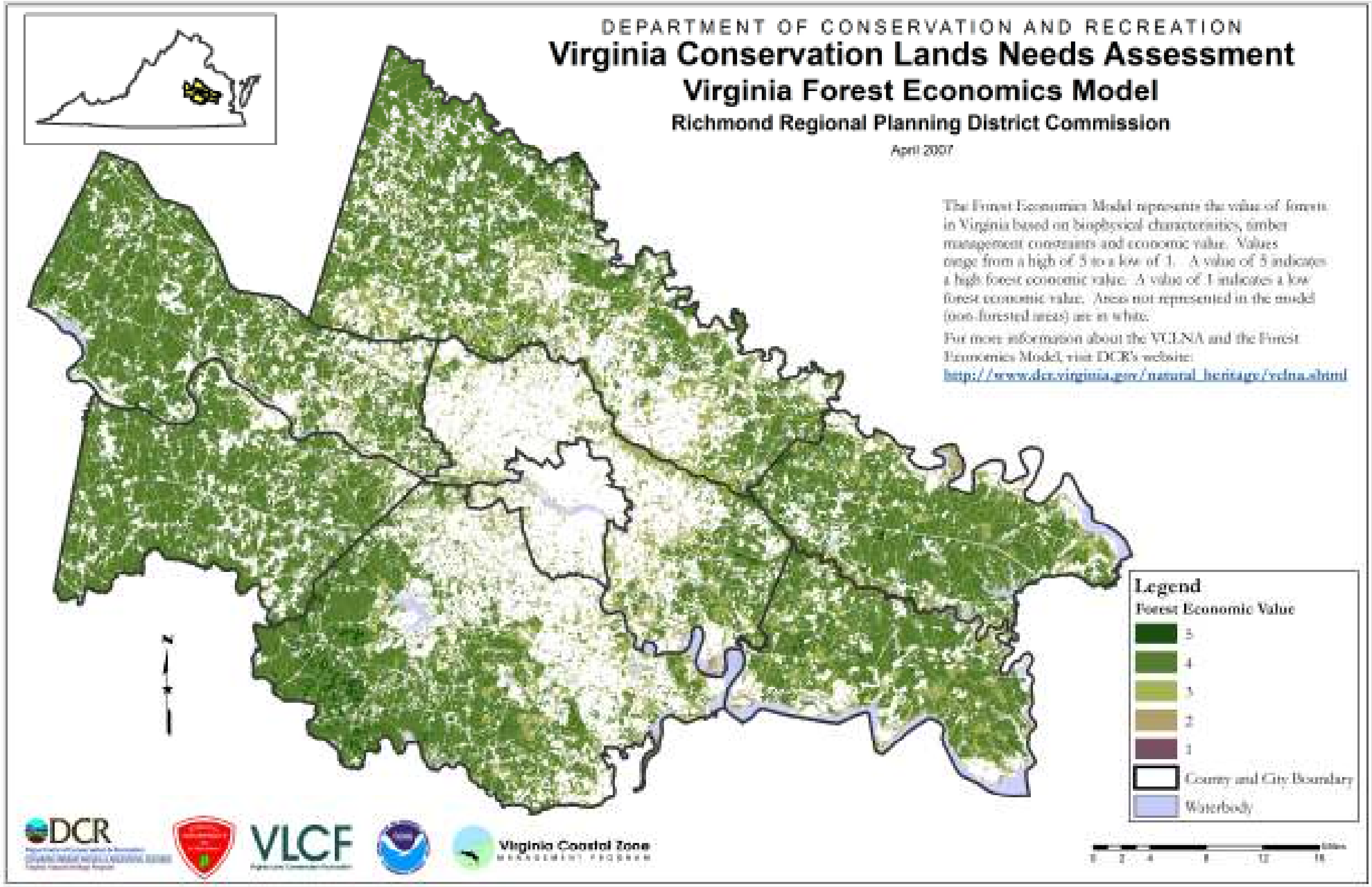

Figure 17. PDC 16 George Washington Regional Commission Forest Economics Model.

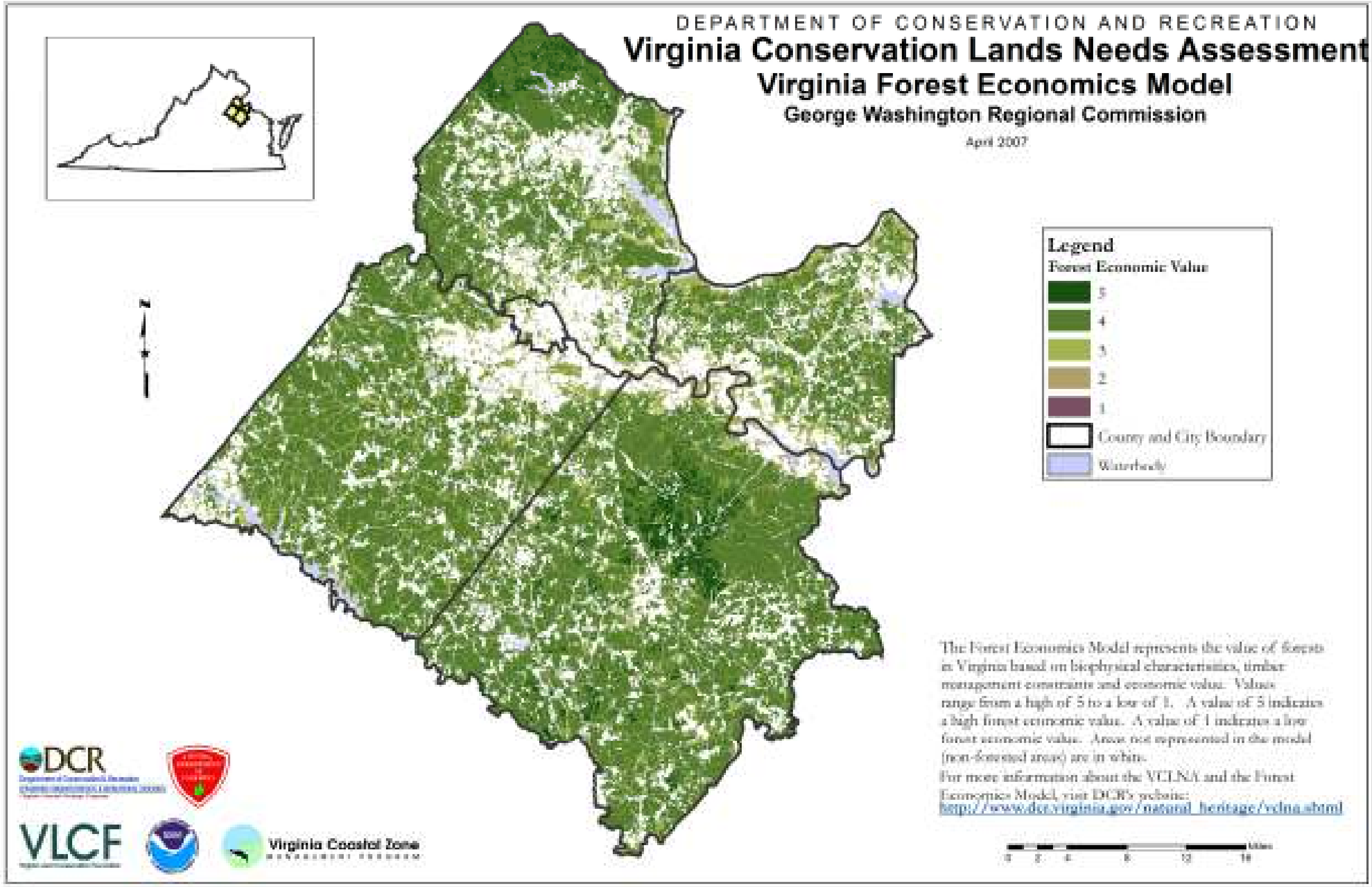

Figure 18. PDC 17 Northern Neck Planning District Commission Forest Economics Model.

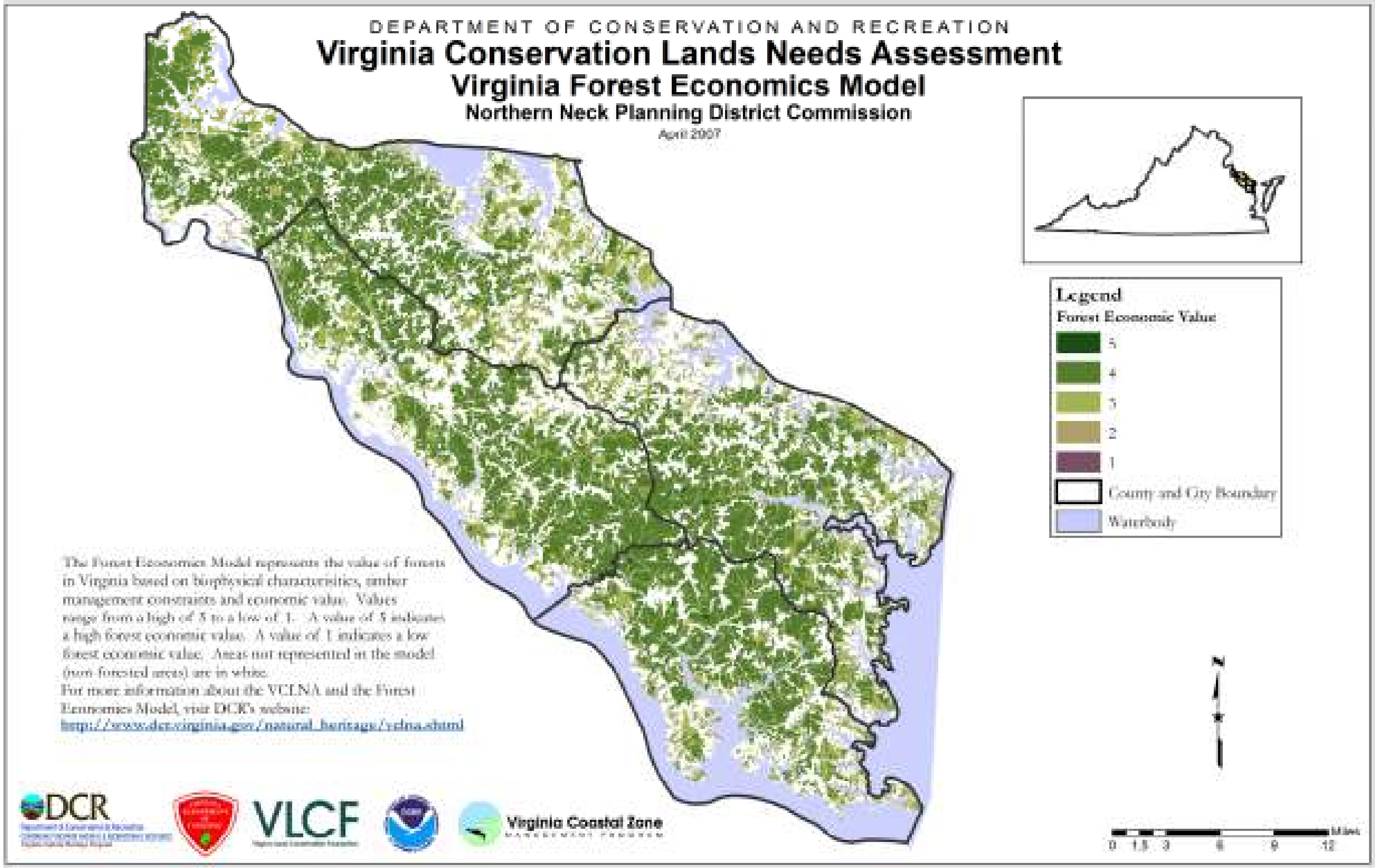

Figure 19. PDC 18 Middle Peninsula Planning District Commission Forest Economics Model.

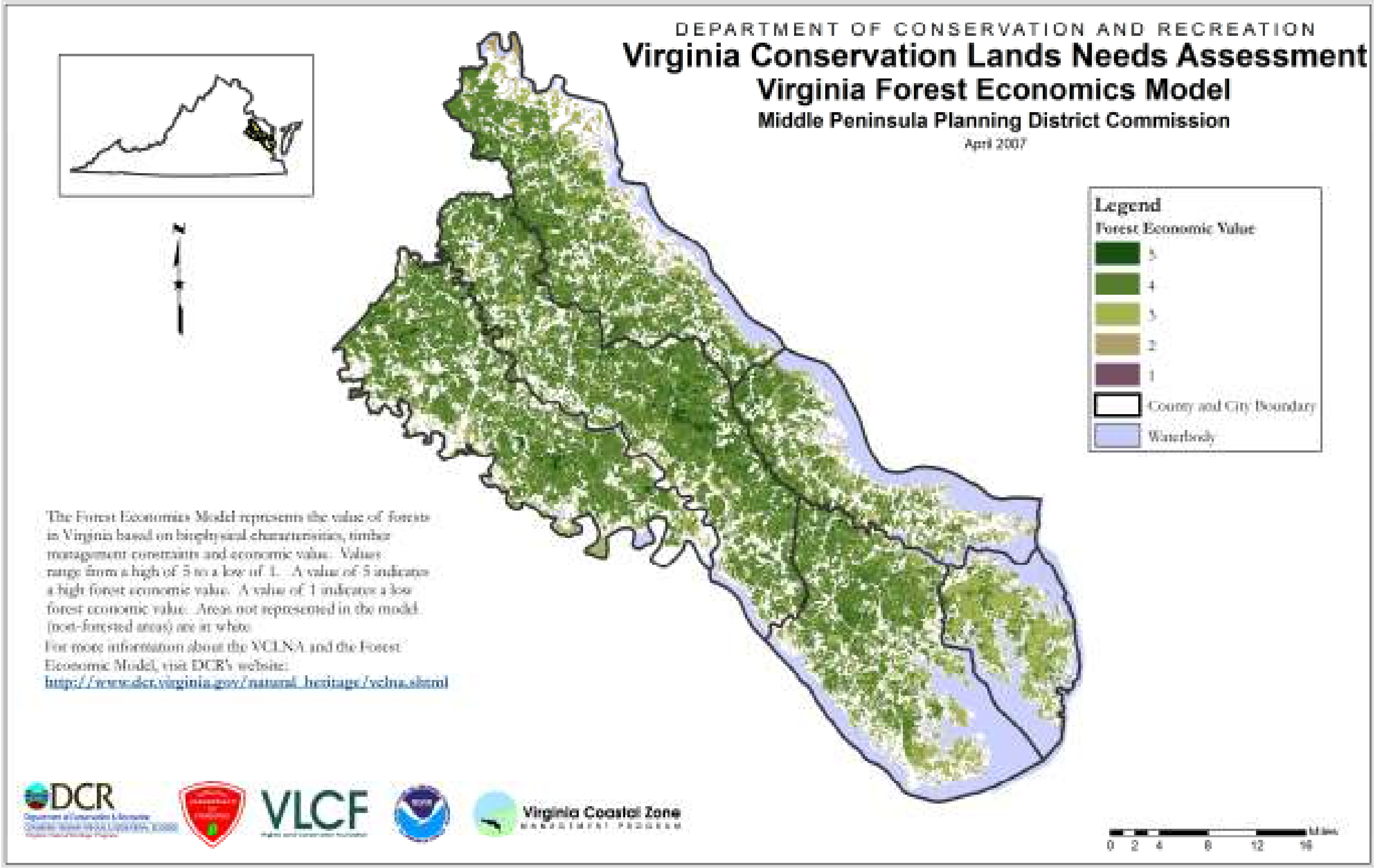

Figure 20. PDC 19 Crater Planning District Commission Forest Economics Model.

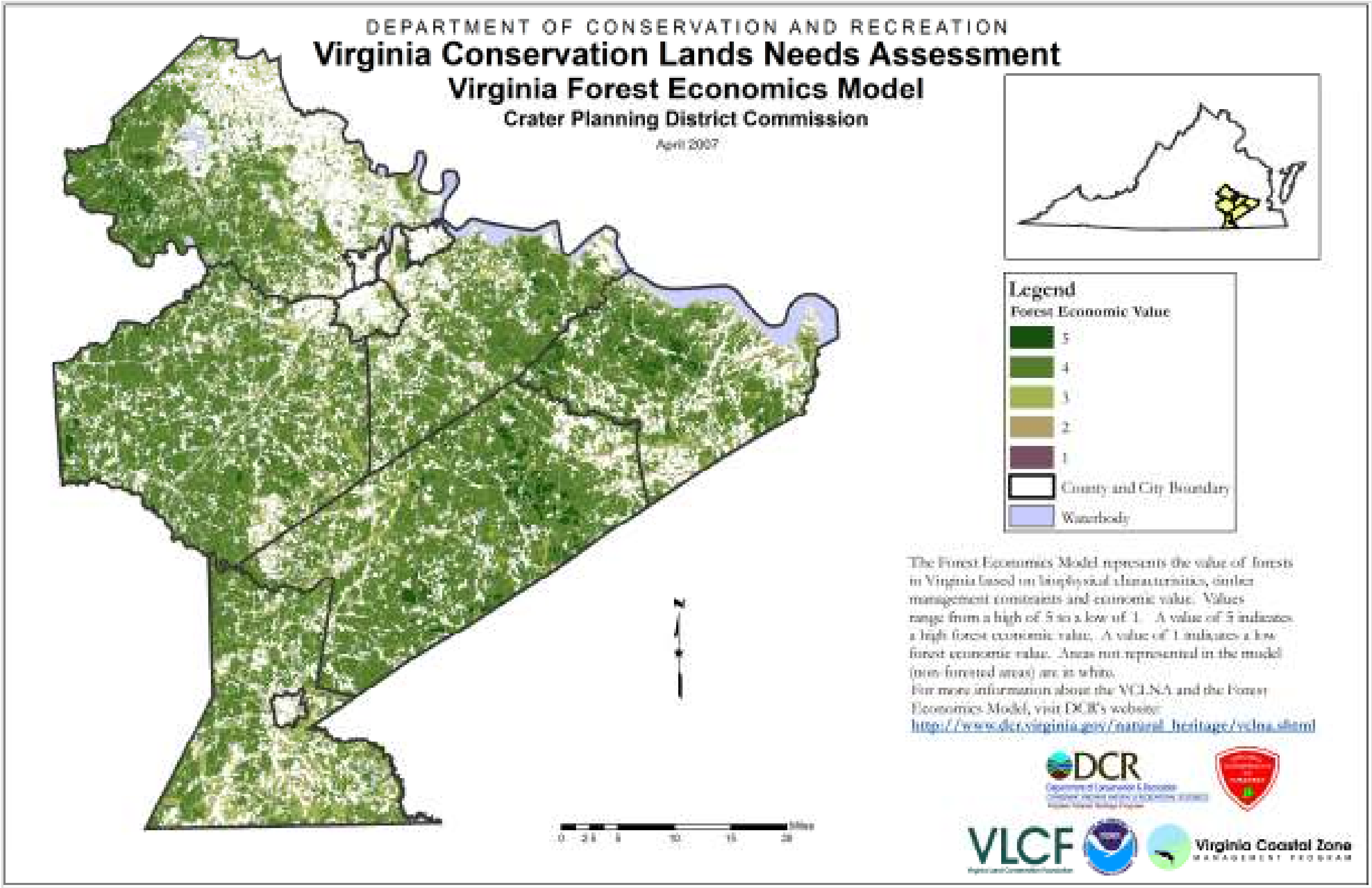

Figure 21. PDC 22 Accomack-Northampton Planning District Commission Forest Economics Model.

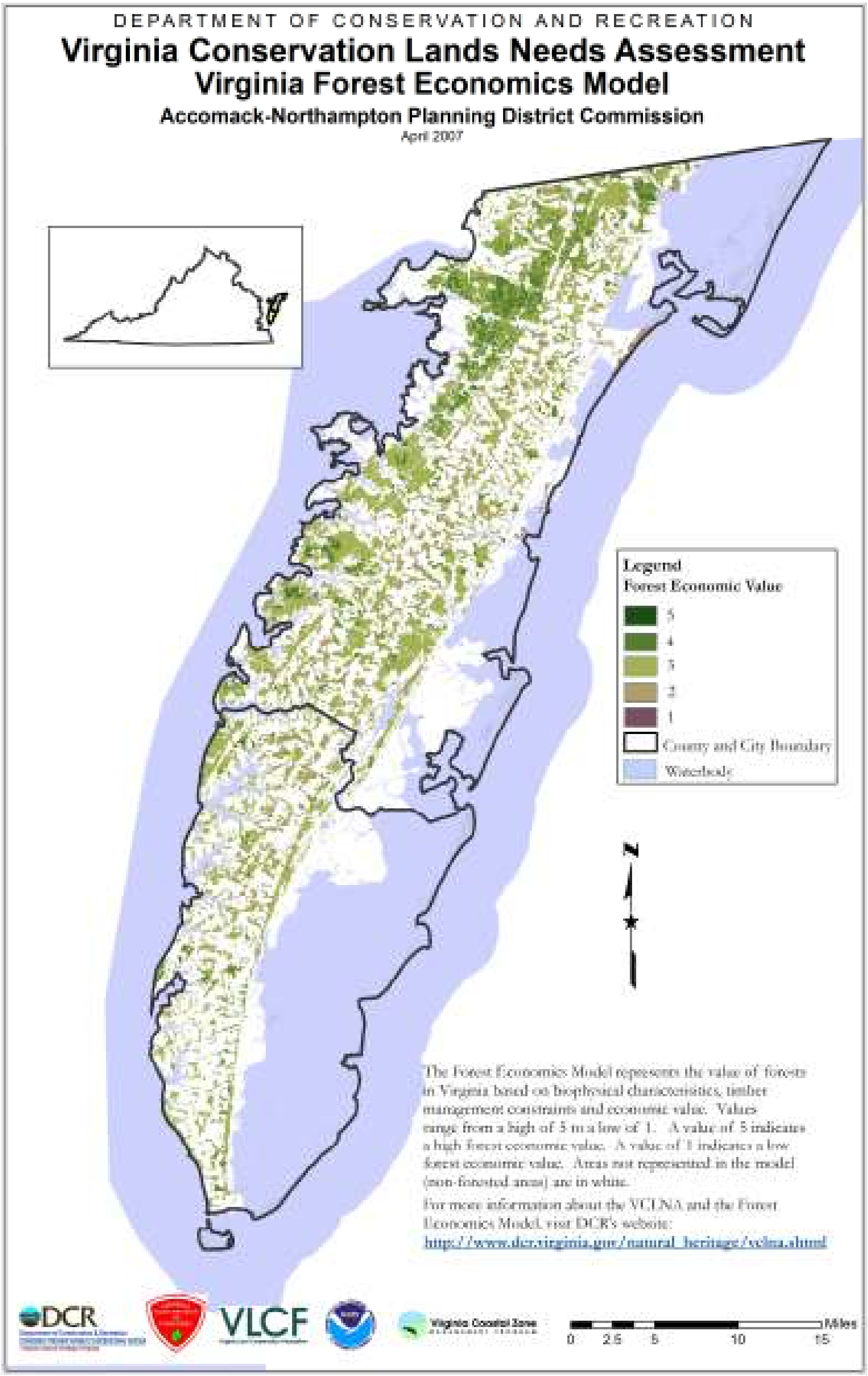

Figure 22. PDC 23 Hampton Roads Planning District Commission Forest Economics Model.

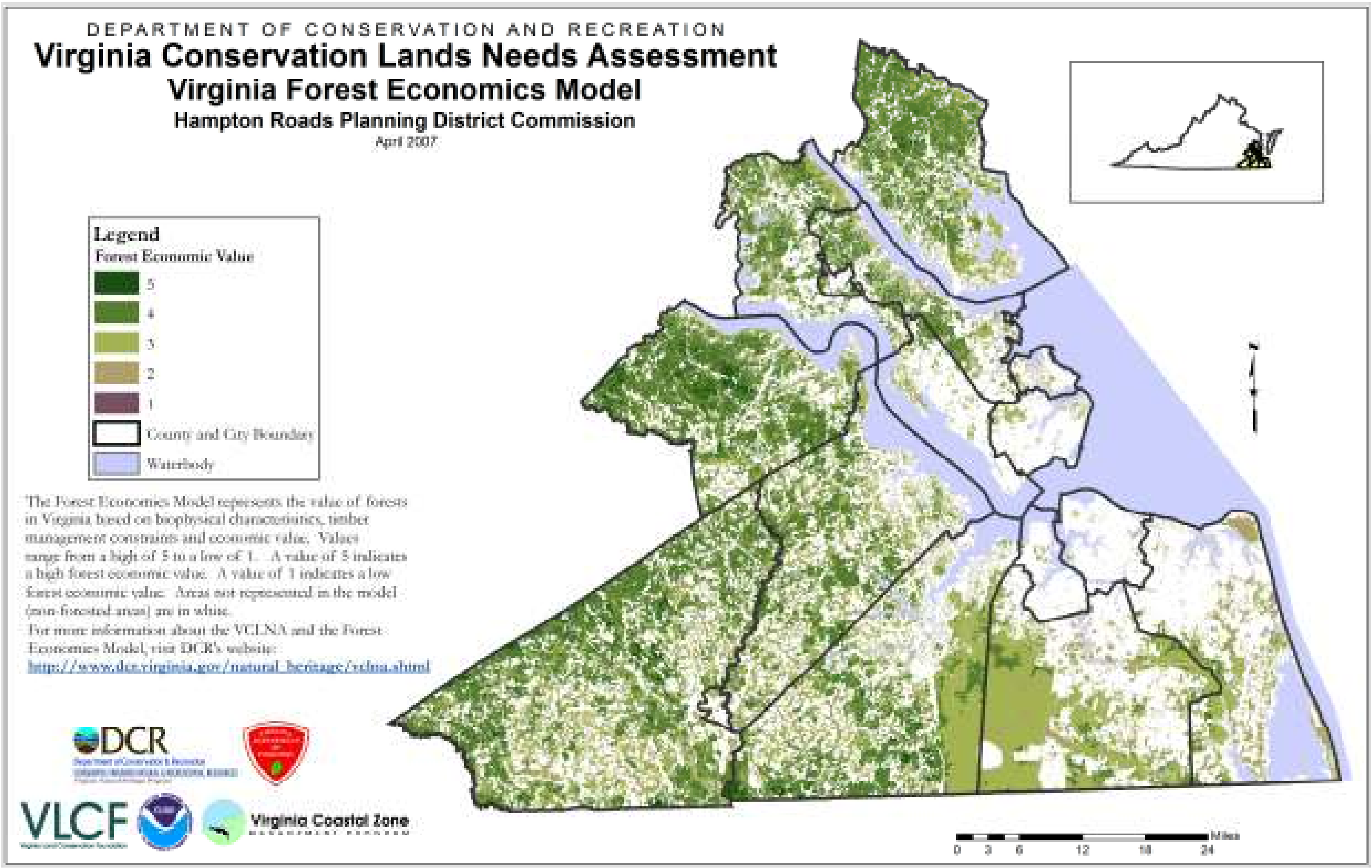

Figure 23. Coastal Zone Forest Economics Model.

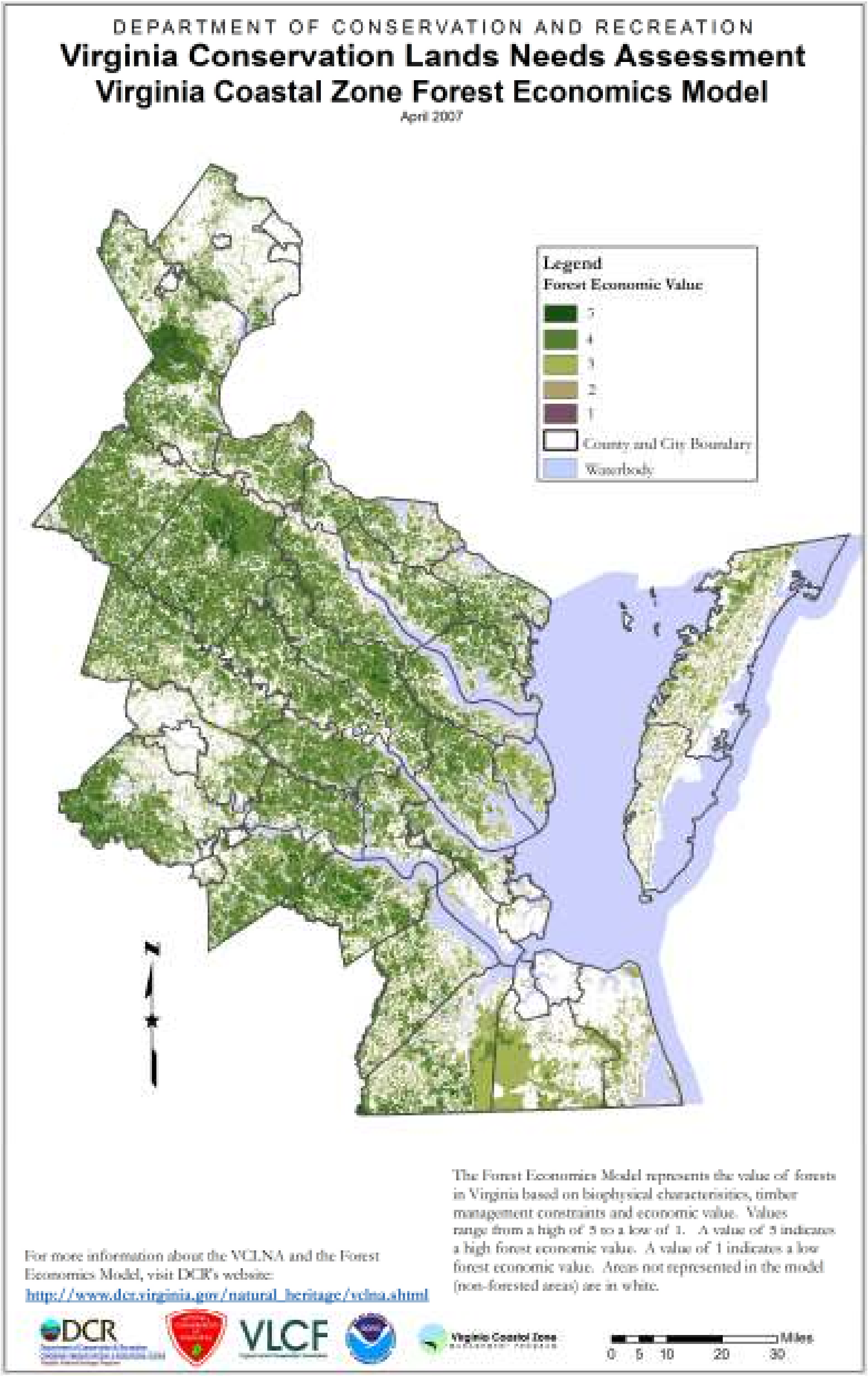

Figure 24. Statewide Forest Economics Model