Geospatial approach to Nitrate-leaching index for Virginia

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Abstract

Excess nitrate-N leaching into ground and surface waters from agricultural regions has been an increasing concern throughout the U.S. Currently, the nitrate-leaching index (LI) in Virginia is assigned by county based on tables that were “quasi-interpolated” from N-leaching isolines derived from the soil hydrologic groups and precipitation data. The availability of high-resolution GIS data allows for analysis which include raster based precipitation and evapotranspiration data and SSURGO digital soils data, making differential within-county assessments possible. The existing method used in Virginia, the New York state model, and a unique N-leaching model, which includes evapotranspiration, were analyzed using ArcGIS. While the results of the three LI methods do not vary significantly for most counties in Eastern Virginia, counties in the Shenandoah Valley have an average of 35,000 acres which would have an N-leaching index in the high and very high ranges if the NY-based or evapotranspiration models were applied.

Introduction

In Virginia, the current LI values are assigned by county from a set of tables generated with the assistance (as we understand it) of Drs. Tom Simpson and George Hawkins of Virginia Tech. The values in these tables were “quasi-interpolated” from a set of LI statewide isoline maps that were generated for each hydrologic grouping (A, B, C and D). It is clear from inspection of these maps and the resultant assigned LI values by county that only a limited set of interpolated estimates was allowed. For example, where a county fell between the LI 15 and LI 20 isolines, it was assigned a “17” regardless of location or distance along the apparent gradient. According to the NRCS 590 Standard, areas that have LI >10 need to have a management plan in place.

In spring 2004, the District of Columbia Water and Sewer Authority in conjunction with the Metropolitan Council of Governments asked us to assess the current application of the NRCS N-leaching Index (LI) method to the assignment of winter N-leaching risk in Virginia. In particular, we were asked to estimate the percentage of agricultural land available for biosolids application which currently falls within an LI range of >10 or >15 (high and very high risk categories). As part of this process, we also felt it necessary and important to examine the underlying procedures used to assign LI values by county in Virginia.

Initial study: King George and Stafford Counties

Two counties located in northern Virginia were analyzed using USDA-NRCS SSURGO soils data and the soil hydrologic group was used to query and apply the existing LI values. This vector data was converted into a 30m grid.

County	A	B	C	D
King George	17	13	6	6
Stafford	17	9	6	3

Table 1. Existing LI values for two counties in initial study.

The U.S. Geological Survey National Land Cover Data (NLCD) was chosen to identify agricultural lands. The dataset has two agriculture categories; row crops and pasture/hay was reclassified to show only the two agricultural categories (row crops and pasture/hay) and this 30m grid was combined with the existing LI index grid. Acreage was calculated in each of the LI risk categories over the two types of agricultural land. The results are below and indicate a significant difference in area put into high and very high risk categories between the two neighboring counties.

King George Co.

N index risk	N index	NLCD Landuse	Area (acres)	% of county	% Ag land with N-index >=10	% Ag land with N-index >=15
very high	17	row crops	1,410	1.2		
very high	17	pasture	958	0.8		
high	13	row crops	7,107	5.9	59.7	8.9
high	13	pasture	6,448	5.4		
high	10	row crops	20	0.0		
high	10	pasture	26	0.0		
moderate	6	row crops	5,518	4.6		
moderate	6	pasture	5,266	4.4		
		Total	26,755			
		County total	119,987			

Stafford Co.

N index risk	N index	NLCD Landuse	Area (acres)	% of county	% Ag land with N-index >=10	% Ag land with N-index >=15
very high	17	row crops	12	0.0		
very high	17	pasture	31	0.0		
moderate	9	row crops	1,673	0.9	0.1	0.1
moderate	9	pasture	8,312	4.6		
moderate	8	pasture	19	0.0		
moderate	6	row crops	2,892	1.6		
moderate	6	pasture	12,838	7.2		
moderate	3	row crops	534	0.3		
moderate	3	pasture	2,157	1.2		
		Total	28,469			
		County total	179,049			

Table 2. Results of the initial study; existing N-leaching index applied in agricultural lands.

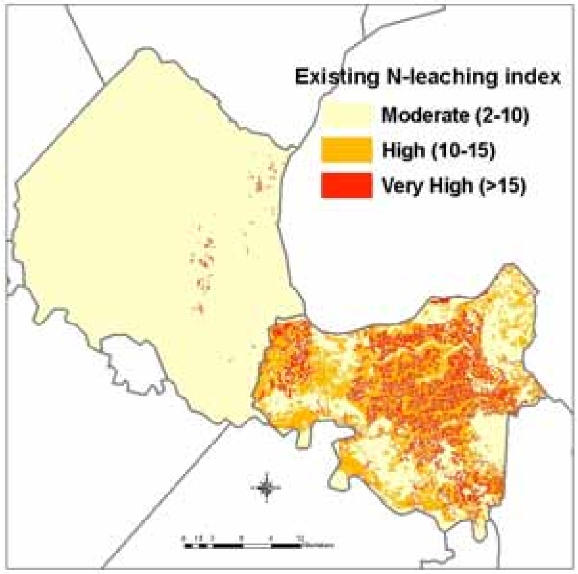


Figure 1. Existing N-leaching index for King George and Stafford counties, VA.

The discrepancy in N-leaching index between two counties is due primarily to two factors. First, the existing LI applied to King George County's hydrologic group B (nearly 45,000 acres) put it in <u>high</u> risk whereas Stafford's hydrologic group B soils placed in <u>moderate</u> risk category. Secondly, King George has nearly 22,000 acres more mapped as hydrologic group A than Stafford County.

We began applying existing LI index to various counties in agricultural areas of eastern Virginia to determine if other inconsistencies across county boundaries exist and to estimate acreage of agricultural lands in Virginia that have high or very high nitrate-leaching risk.

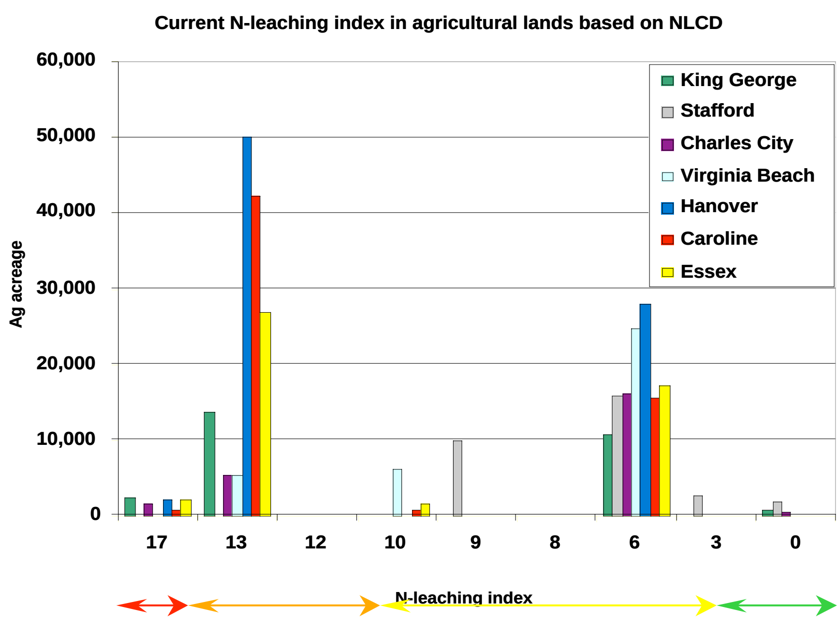


Figure 2. Graph of agricultural area (acres) by existing LI assignment within several eastern Virginia counties. The arrow below indicates very high (red), high (orange), moderate (yellow) and low (green) risk categories.

Precipitation

In all nitrate-leaching models, precipitation plays an important role in determining risk for a specific area. By using a GIS model and precipitation raster data, the LI index can be assigned differently within a county. This is particularly important in counties in the Shenandoah Valley and northern Blue Ridge where significant variation in precipitation can mean over- or under-estimation of LI risk.

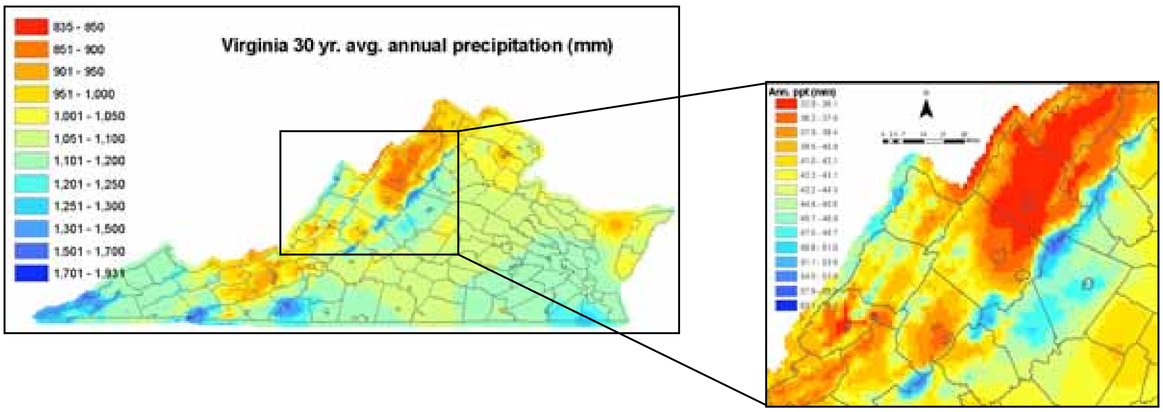
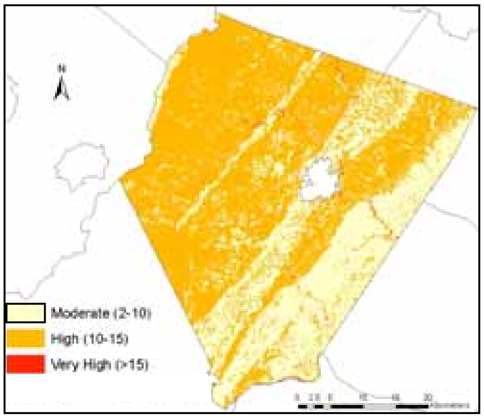
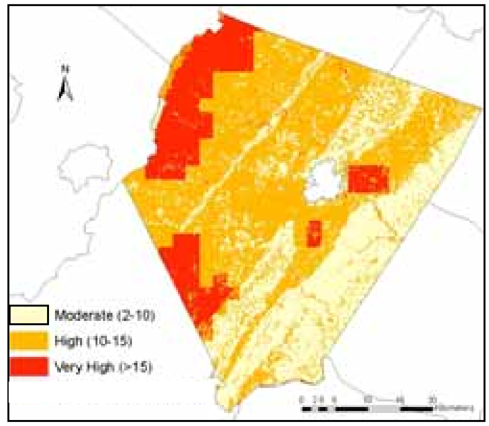


Figure 3. Gridded Parameter-Elevation Regressions on Independent Slopes Model (PRISM) climate data was used for the statewide precipitation information. Although the horizontal resolution fairly crude, (4km, filtered to 2km), the product is commonly used in statewide and regional GIS analyses. The blow up section of the Shenandoah Valley and northern Blue Ridge shows the variability in precipitation within several counties.

New York N-leaching Model

The state of New York has adopted a nitrate-leaching index based on soil hydrologic group and township-based precipitation data (Czymmek et al., 2003). The New York nitrate leaching index is the product of the percolation index and the seasonal index (Williams and Kissel, 1991). We applied the NY model to several Virginia counties based on the soil hydrologic group reported by NRCS SSURGO soil polygons and 30 year average PRISM annual and winter (October-March) precipitation data. We compared acreages between the LI risk categories using the existing Virginia and the NY models/approaches. In most counties in eastern Virginia, very similar LI values were calculated using Virginia's existing LI and the NY LI but counties where precipitation varied significantly within the county, large differences occurred.





Existing model		
N-risk	**Acres**	**% in risk cateogory**
Moderate	169,053	36.8
High	289,339	63.0
Very High	1,191	0.3

NY approach		
N-risk	**Acres**	**% in risk cateogory**
Moderate	154,408.9	33.6
High	233,000.7	50.7
Very High	72,145.5	15.7

Figure 4. The existing Virginia LI (left) and the NY model LI (right) for Albemarle County, VA. Most of the variability within the two models can be accounted for by within-county precipitation differences although the large pixel size of the PRISM data is evident in the models.

Evapotranspiration

A comprehensive nitrate-leaching model for Virginia and other southern states must account for winter evapotranspiration (ET). In summer, ET exceeds precipitation such that no leaching occurs where fields have vegetative cover. From October through March, precipitation exceeds ET and leaching occurs but in warmer climates, late fall and early spring ET is more significant and should be removed from the winter precipitation so leaching is not overestimated (Figure 5).

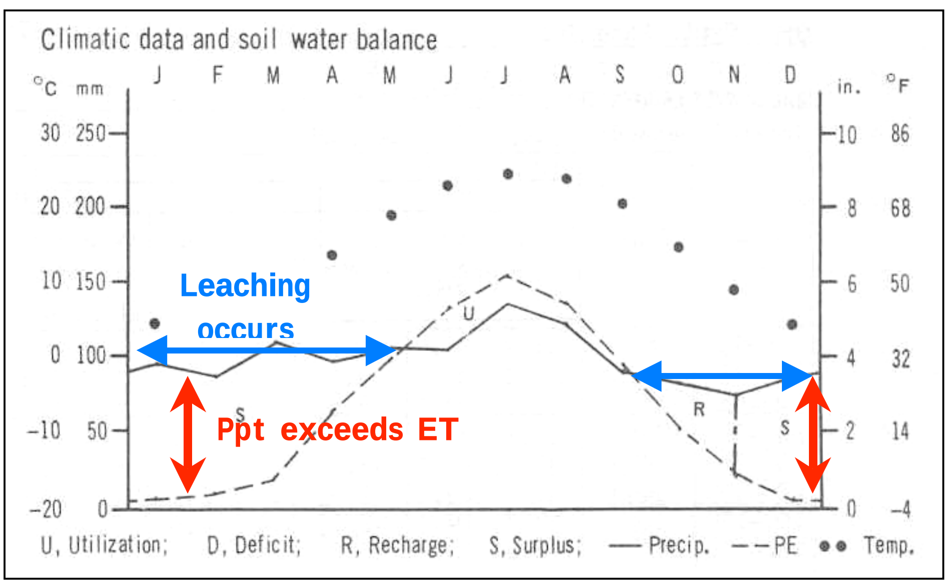


Figure 5. Water balance figure for Carroll County, Virginia. Our model removes ET from the winter (Oct-Mar) precipitation, which is not insignificant in warmer climates.

The Thornwaite method was used to create 30 year average ET model using the PRISM data (Sforza, 2004). The October through March ET raster was subtracted from the winter precipitation to produce a corrected winter precipitation grid and the NY LI model was applied (Figure 6).

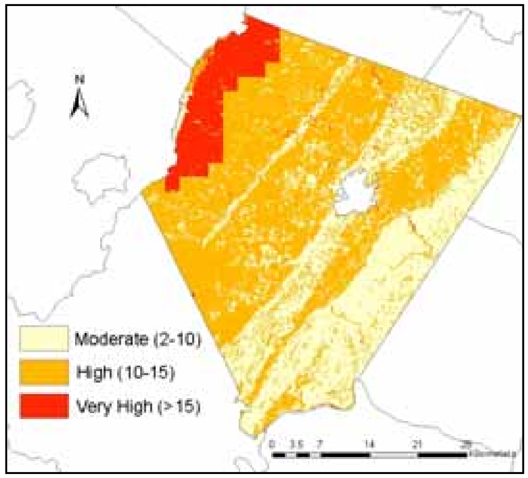
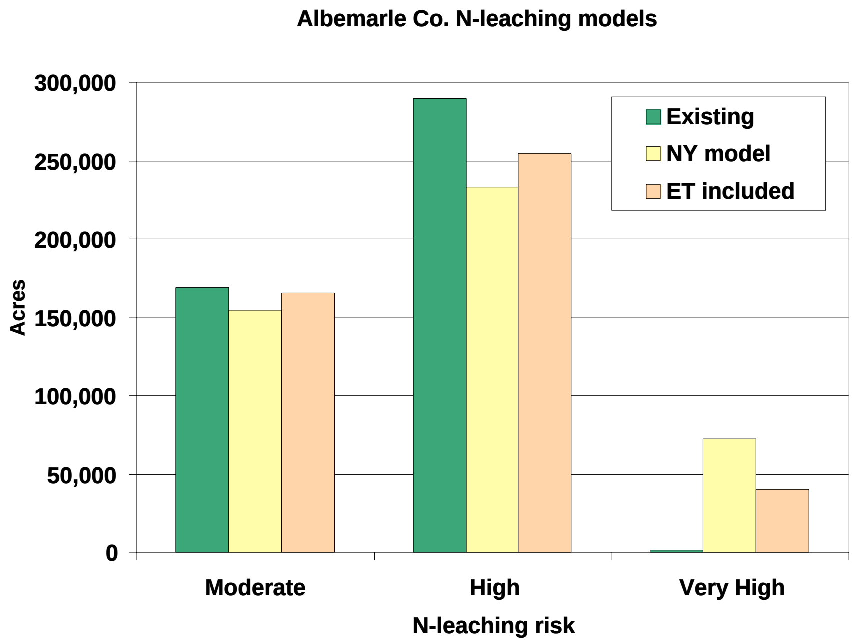


Figure 6. Nitrate-leaching index for Albemarle County with ET removed from winter precipitation before applying NY-model equations.

Discussion

Comparisons of area within each nitrate-leaching risk category (moderate, high and very high) for the three models tested were completed for several counties in Virginia. Some of the biggest differences in area between the models occur in the Shenandoah Valley and in counties along the trend of the Blue Ridge Mountains. Precipitation differences within individual counties in this area cause large differences in nitrate-leaching index assignment in the NY and our model. Figure 7 shows the results for Albemarle and Warren County, both located partially within the Blue Ridge province. In Albemarle County, while the acreage in high and very high risk categories were similar between all three models, the existing model has very minimal acreage in the very high risk category. This redistribution of risk between high and very high leaching risk is not insignificant as it would have implications to farm management plans as specified in the US Dept. of Agriculture-Natural Resources Conservation Service Nutrient Management plan (590). In Warren County, the existing nitrate-leaching model has less than 600 acres in high risk category and none in the very high risk category. Contrast this with the NY leaching model and our ET model which have 35,000 acres and 25,000 acres in high and very high risk categories, respectively.



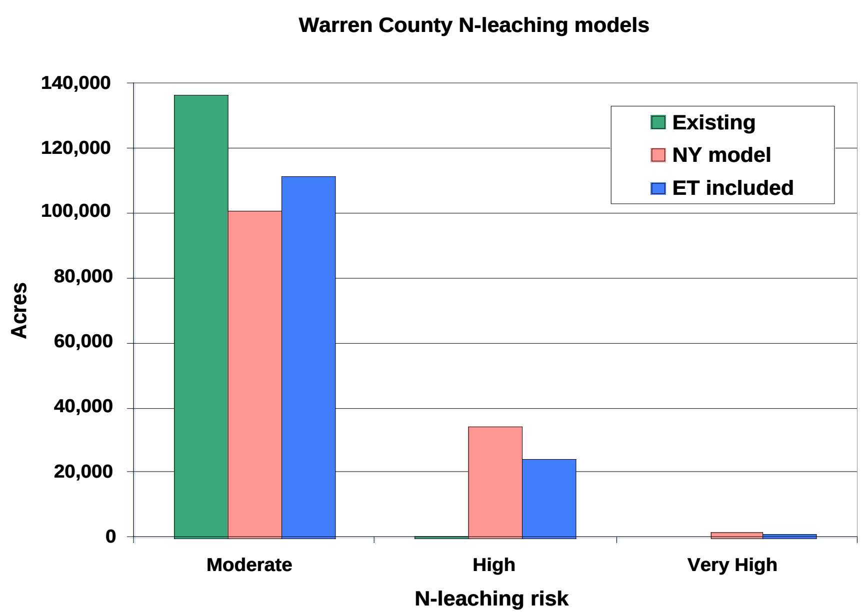


Figure 7.Comparison of the three models for Albemarle County, VA (above) and Warren County, VA (below) based on acreage in each LI risk category.

Conclusions

Correct assessment of nitrate-leaching risk is an important environmental concern for the state of Virginia. Although the current LI guidelines for the state incorporate two critical factors (soil hydrologic group and annual precipitation) it does not factor in winter precipitation or evapotranspiration. Additionally, the current assessment does not account for precipitation variability within a county. By using high resolution GIS soils, precipitation and evapotranspiration data, differential within-county assessments are possible which is significant especially within Virginia counties along the spine of the Blue Ridge Mountains where precipitation is highly variable. The large agricultural acreage in Virginia warrants attention in leaching index assessment and integration of best management practices at the local level.

References

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