Chapter 4: Comparative Assessment of Mid–Atlantic Watershed Conditions

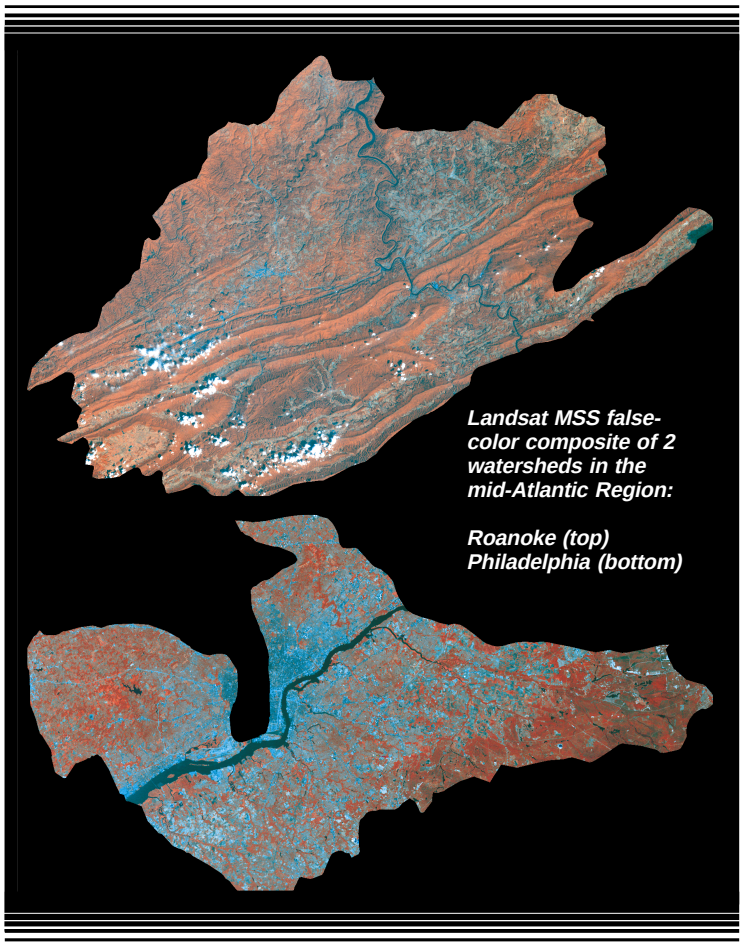
This chapter summarizes the indicators presented in Chapter 3, in order to identify changing environmental conditions across the region. A simple way to do this can be adapted from the magazine, *Consumer Reports*. When rating products, *Consumer Reports* provides relative scores on performance or features to help the consumer decide which brand to purchase. As applied here, each indicator from Chapter 3 could be considered as a guide to relative watershed "performance" for an indicator, and that could help in determining which watershed to "buy."

The watershed ranks for each indicator are presented in a *Consumer Reports* format in Table 4.1 (see discussion on Data Interpretation, inset on next page). It is possible to get an idea of the relative condition of a watershed by reading across a row and counting the number of boxes of a particular color. Watersheds dominated by green and khaki colors are in better relative condition (more desirable) than those dominated by red and orange (less desirable). Table 4.1 can be used by readers to identify conditions of watersheds relative to a particular question or interest. For example, the reader may want to know how their individual watershed rates relative to other watersheds in the region with regard to a set of forest habitat indicators. The table provides a way for readers to explore different combinations of indicators for the watershed they live in, and to compare their area to neighboring watersheds. Because watershed ranks are shown, each column contains an equal number of the different colors (recall that there is an equal number of watersheds in each of the 5 groups).

Of course, an atlas is about maps. Maps show the spatial distributions that cannot be seen in tables. A simple summary of the data in Table 4.1 is shown on the maps in Figure 4.1. The map at the upper left shows the number of indicators for which a given watershed was ranked in the top 20% (most desirable) of all watersheds. The map at the bottom right shows the number of indicators for which a given watershed was ranked in the lowest 20% (least desirable) of all watersheds.

Comparisons of the maps suggests some general conclusions. Relative to all other watersheds in the mid–Atlantic region, the watersheds in southeastern Pennsylvania and the northern end of the Chesapeake Bay have consistently lower values for all of the landscape indicators. Conversely, there are a few watersheds in southwestern and north–central portions of the region that have consistently higher scores across all the indicators.

Although the maps are valuable for their simplicity and ability to show watersheds that have consistently higher or lower scores, a more sophisticated technique is needed to group all of the watersheds into categories of environmental quality. Cluster analysis is a statistical technique that is often used to find groups based on the similarity of data values. One familiar example of the clustering technique is the assignment of new hospital patients to groups of similar risk, based on factors such as age, medical history, and other factors.



A cluster analysis was done using nine of the 32 indicators from Chapter 3 (see inset below). These nine indicators were selected because they represent a broad range of environmental condition measurements and were not highly correlated with each other overall. The procedure identified nine groups of watersheds (Figure 4.2). The mean indicator scores for each cluster (Table 4.2) can be inspected to see how the groups are different.

Cluster Analysis

Some additional details might be helpful for readers with a statistical background. A minimum-distance-to-mean routine was used for the cluster analysis, and the results were checked using canonical discriminant analysis. Canonical discriminant analysis is useful for finding combinations of variables that explain the variability in the clusters. It is possible to determine if there is good separation between clusters by using bivariate plots of canonical scores. If the clusters identified were not distinct in bivariate canonical space, then it is likely that there is no real difference between the clusters.

Several iterations of the cluster analysis were undertaken using different combinations of variables and transformations. The iteration that produced the most distinct separation of clusters in canonical space was taken as the solution.

Nine indicators were used in the cluster analysis because it is better to use indicators that are not strongly correlated. The nine indicators used were:1) 1990 population density, 2) population change, 3) road density, 4) proportion of streamlength with roads within 30 meters, 5) proportion of watershed with agriculture on slopes greater than three percent, 6) proportion of watershed streamlength with adjacent forest cover, 7) proportion of watershed supporting forest interior habitat at three scales, 8) average atmospheric sulfate wet deposition, and 9) number of water impoundments per 1,000 stream kilometers. Pair-wise correlations were less than ± 0.5 in all but two cases. Population and road density are naturally correlated. Both were kept to emphasize population impacts because many of the landscape indicators used (e.g., forest interior habitat) are naturally low when population pressures are high. Agriculture on steep slopes (> 3%) and streamlength with adjacent forest were moderately inversely correlated. Both were kept because they measure different aspects of the environment. The former is an indicator of erosion potential and the latter is an indicator of water quality and habitat. Because of the strong correlation between population and road density, only roads were included in assigning relative cumulative impact scores (see Table 4.2).

Because cluster analysis is sensitive to large differences in data values, all indicators were transformed using either logit, log (base e), or square root transformations. After transformation, all variables ranged between -10 and 10. The cluster means shown in Table 4.2 have been back-transformed to their original values for presentation.

Plots of the first and second canonical scores showed that clusters 1, 2, 3, 8, and 9 formed distinct groups, and that clusters 5 and 6 were well separated from clusters 4 and 7. Distinct separation of clusters 5 and 6 and clusters 4 and 7 were evident on plots of the 1st and 3rd and 1st and 4th canonical scores, respectively. These results suggest that the clusters are probably different from each other. Examination of individual indicator values by watershed groups (clusters) supports this conclusion.

Note: Some of the watersheds on the regional boundary were not included in the statistical analysis because most of their area is outside the mid-Atlantic Region. These “edge” watersheds often had unrealistic, extreme values for one or more indicators, and extreme values have undesireable consequences on cluster analysis. The watershed encompassing Philadelphia(code 2040202 in Figure 3.6) was also excluded because of its extreme values; most of the watershed, however, does lie within the regional boundary. Based on its indicator values, the Philadelphia watershed probably belongs in cluster 6.

Cluster means were used to rank the groups according to relative cumulative impact. The ranking was done by reading down the columns and marking (red in Table 4.2) the three cluster means with the most extreme values. The three highest values were marked for population density, population change, road density, roads by streams, agriculture on steep slopes, atmospheric sulfate deposition and impoundment density; higher values for these indicators suggest potential negative impact. The three lowest values were marked for forests by streams and proportion of the watershed supporting interior forest habitat at three scales; lower values for these indicators suggest potential negative impact.

After identifying the three values in each column, the number of red values for each cluster was counted in each row. This count is interpreted as a measure of relative cumulative environmental impact for that group of watersheds. The score was then used to rank the watershed groups. Higher scores suggest greater adverse impact than lower scores. These numbers were used to interpret watershed conditions as follows.

Data Interpretation

The following information should help explain how to interpret Table 4.1. Boxes shaded in gray indicate that no data was available for that indicator. This problem was confined to the vegetation change indicators for about 40 watersheds. Also, for most of the indicators in Chapter 3, a relatively high or low value has a clear meaning relative to landscape condition. For example, high values of soil loss suggest greater erosion problems. But the interpretation is less clear for other indicators, such as forest edge, the vegetation increase indicators, and impoundment density. A high proportion of forest edge suggests more clearing of forests, which many people would consider to be a negative impact. Increasing edge habitat, however, can increase the abundance of some wildlife game species, which many people would see as a positive impact.

In addition, many of the indicators shown in Chapter 3 are correlated with each other. If indicators are positively correlated, then they tend to increase or decrease together. If they are negatively correlated, then one tends to decrease as the other increases. In both cases, the value of one indicator can be predicted from the value of the other, and so there is no “new” information to be gained from the second one. For example, where forest density is high, the amount of forest edge is necessarily low, and where atmospheric nitrate wet deposition is high, atmospheric sulfate wet deposition also tends to be high. The reason for presenting correlated indicators in Chapters 3 and 4 is to provide information in different terms. If only a small set of uncorrelated measures were presented, then much of the real–world meaning of landscape patterns would be lost — it would be up to the reader to know which indicators that did not appear were correlated with the ones that were presented. For example, farmers may be more interested in nitrate deposition, instead of its correlate sulfate deposition, because nitrogen is a component of fertilizer. Likewise, deer hunters may be more interested in the location of edge habitat, not in an inversely correlated measure of high forest density. By studying maps of all the indicators for all watersheds, the reader is able to compare and see which are correlated, and choose which ones to consider, based on his or her own perspectives. Finally, the fact that some of the indicators are correlated should be viewed as an opportunity and not a problem; by restoring values for a given indicator it is likely that other indicators will also change.

	POPDENS	POPCHG	RDDENS	UINDEX	STRD	NO3DEP	SO4DEP	OZAVG	DAMS	CROPSL	AGSL	FOR%	RIPFOR	RIPAG	STNL	STPL	PSOIL	INT7	INT65	INT600	INTALL	FORPAT	EDGE7	EDGE65	EDGE600	FORFRAG	NDVIDEC	NDVIINC	NDVITOT	NDVI3%	1STDEC	1STINC	1STTOT	Total Green	Total Red
3010102	■	□	■	□	■	■	■	■	□	□	■	□	■	■	□	□	□	□	■	■	■	□	■	■	■	□	□	■	□	■	■	■	■	5	2
3010104	■	■	■	■	■	■	■	■	■	□	□	■	■	■	□	□	□	□	■	■	■	■	■	■	■	■	■	□	□	■	■	□	□	5	1
3010105	■	■	□	□	■	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	■	□	□	□	■	■	9	2
3010106	■	■	■	□	■	■	■	■	□	□	□	□	■	■	□	□	■	■	■	■	■	□	□	■	■	■	□	■	□	■	■	■	■	7	1
3010201	■	■	■	■	■	■	■	□	■	■	■	■	■	■	□	□	□	□	□	□	□	■	■	■	■	■	■	■	■	■	■	□	■	10	6
3010204	■	■	□	□	■	■	■	□	□	■	■	□	■	■	□	□	□	□	□	□	□	■	■	■	■	□	□	□	■	■	■	■	■	7	2
2050202	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	24	5
2050203	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	23	4
2050205	□	□	■	■	□	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	18	2
5050005	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	19	3
5050006	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	13	3
5050007	□	■	■	■	■	□	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■	■	■	■	18	4
5050009	■	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	14	4
5070101	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	18	4
5070102	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	□	11	2
5070201	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	16	4
5070202	■	■	□	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	15	4
5090102	■	■	■	■	■	■	■	□	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	12	4
2050201	□	■	□	■	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■	■	■	□	□	□	4	3
2050204	□	■	■	□	■	■	■	■	■	■	■	□	■	■	□	□	□	■	■	■	■	□	□	■	■	■	■	□	□	■	■	□	■	4	4
2050206	□	□	□	□	■	■	■	■	■	■	■	□	■	■	■	■	□	■	■	■	■	■	■	■	■	■	□	□	■	□	□	□	□	2	2
2050304	■	■	■	□	■	■	■	■	■	■	■	□	■	■	□	□	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	□	3	3
2070001	■	■	■	■	□	□	□	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	7	1
2070002	■	■	■	■	□	■	■	■	■	■	□	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	□	□	■	■	□	□	□	2	1
2070003	■	□	■	■	□	□	□	■	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■	□	■	□	■	■	14	4
2070005	■	■	■	■	□	■	□	■	□	■	■	■	■	■	□	□	■	□	■	■	■	■	■	■	■	■	□	■	■	■	□	□	□	0	8
2070006	■	■	■	■	□	■	■	■	■	■	■	■	■	■	□	□	■	□	■	■	■	□	■	■	■	■	■	■	■	■	■	■	□	2	7
2080201	■	■	■	■	■	■	■	■	■	□	□	■	■	□	■	■	■	■	■	■	■	□	■	■	■	■	■	■	□	■	■	■	■	16	2
2080202	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	7	2
2080203	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	7	1
3010103	■	□	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	8	4
5010001	□	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	12	5
5010003	□	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	13	5
5010005	■	■	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	15	4
5020001	■	□	■	■	□	■	■	□	■	□	□	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	4	0
5020004	■	□	■	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	17	4
5030201	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	12	1
5030203	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	11	3
5050002	■	■	■	■	■	■	■	■	□	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	□	■	□	□	□	□	□	□	□	4	1
5050003	■	□	■	■	■	■	□	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	□	□	■	■	■	□	■	■	■	■	9	1
5050004	□	□	□	■	□	■	■	■	□	■	□	■	■	■	■	■	■	■	■	■	■	■	■	□	□	■	□	□	□	□	□	□	□	14	2
6010101	■	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	□	■	■	■	■	□	□	□	■	■	□	□	□	□	□	□	□	4	5
6010205	■	□	■	■	■	■	■	□	■	■	■	■	■	■	■	■	□	■	■	■	■	□	□	□	□	■	□	□	□	□	□	□	□	2	3
2070011	■	■	□	□	■	■	□	■	□	■	■	■	□	■	□	□	□	■	■	■	■	■	□	□	□	■	□	■	■	■	□	■	■	2	4
2080102	■	■	□	■	■	■	■	□	■	■	■	□	■	■	■	■	□	□	□	□	□	■	■	■	■	□	□	□	□	□	□	□	□	4	1
2080104	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	4	4
2080105	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	□	□	□	■	■	■	■	■	7	5
2080106	■	■	■	□	■	■	■	■	■	■	■	■	□	■	■	□	□	■	□	■	■	■	■	□	□	□	□	■	■	■	■	■	■	6	3
2080107	■	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	■	□	■	■	■	■	■	□	■	6	3
2080109	■	□	□	■	■	■	■	□	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	4	9
2080206	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	6	6
2080207	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	■	■	■	■	■	■	■	■	■	■	□	■	6	2
3010202	■	□	■	■	■	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■	■	■	■	■	■	■	6	5
3010205	■	■	■	■	■	■	■	■	□	■	■	□	□	□	■	■	■	■	□	□	□	■	■	■	■	■	□	□	□	□	□	□	□	3	4
2040207	■	■	□	■	■	□	□	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	7	12
2060002	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■	■	■	□	■	5	15
2060004	■	■	■	□	■	■	■	■	■	■	■	■	■	■	□	□	■	□	■	■	■	■	■	■	■	■	□	□	■	■	■	■	□	1	8

Table 4.1
Summary of watershed rankings by indicator. The color scheme of green, khaki, yellow, orange, and red represents the first– through fifth–ranked groups of watersheds, respectively. This table includes all watersheds used in the cluster analysis.

	POPDENS	POPCHG	RDDENS	UINDEX	STRD	NO3DEP	SO4DEP	OZAVG	DAMS	CROPSL	AGSL	FOR%	RIPFOR	RIPAG	STNL	STPL	PSOIL	INT7	INT65	INT600	INTALL	FORPAT	EDGE7	EDGE65	EDGE600	FORFRAG	NDVIDEC	NDVIINC	NDVITOT	NDVI3%	1STDEC	1STINC	1STTOT	Total Green	Total Red
2060005	■	▒	□	■	▒	□	□	▒	▒	▒	▒	■	■	■	■	■	■	▒	▒	▒	■	■	▒	▒	▒	■	□	□	□	□	□	□	□	6	13
2060007	□	▒	▒	▒	▒	□	□	□	▒	▒	▒	■	▒	▒	■	■	▒	■	■	■	■	■	▒	▒	▒	▒	□	□	□	□	□	□	□	5	8
2060008	▒	■	□	■	▒	□	□	▒	▒	▒	▒	■	▒	▒	■	■	■	■	■	■	■	■	▒	▒	▒	▒	□	□	□	□	□	□	□	3	11
2060009	□	■	▒	▒	▒	□	□	□	▒	▒	▒	▒	□	□	■	■	▒	▒	▒	▒	▒	□	▒	▒	□	▒	□	□	□	□	□	□	□	4	3
2060010	□	■	□	■	▒	□	□	□	▒	▒	▒	■	□	□	■	■	■	■	■	■	■	■	▒	▒	▒	■	□	□	□	□	□	□	□	6	12
2080110	▒	▒	▒	▒	▒	▒	▒	□	□	▒	▒	■	▒	□	■	■	■	■	■	■	■	■	▒	▒	▒	■	□	□	□	□	□	□	□	7	10
2040101	▒	■	■	▒	□	□	▒	▒	■	□	□	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	■	■	■	▒	▒	▒	□	□	▒	□	□	7	6
2040103	▒	▒	□	▒	□	□	▒	▒	■	□	□	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	■	□	▒	▒	▒	□	▒	■	▒	5	3
2040104	□	■	■	▒	□	□	▒	▒	■	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	■	■	▒	▒	□	□	□	□	□	□	□	15	5
2040105	■	▒	■	■	■	□	□	□	■	■	▒	▒	▒	▒	■	■	■	▒	▒	▒	▒	□	▒	▒	▒	■	■	■	■	▒	■	■	■	3	16
2040106	■	□	■	□	▒	▒	□	▒	■	▒	▒	□	□	■	▒	▒	□	□	▒	■	■	□	■	▒	▒	▒	▒	■	■	■	■	■	■	3	9
2040203	■	■	■	■	■	▒	▒	▒	■	▒	■	■	■	▒	■	■	■	■	▒	▒	▒	■	▒	▒	▒	■	■	■	■	▒	■	■	■	3	20
2050101	□	▒	▒	▒	▒	□	▒	▒	■	▒	▒	▒	□	□	▒	▒	▒	▒	▒	□	□	▒	▒	■	■	□	□	▒	□	▒	□	▒	▒	6	3
2050107	▒	▒	▒	□	▒	▒	□	▒	■	■	▒	□	□	□	□	□	▒	□	□	□	□	□	▒	▒	▒	▒	□	▒	▒	■	□	▒	▒	1	3
2080204	□	■	□	▒	▒	▒	▒	■	■	▒	□	▒	▒	□	□	□	□	□	□	□	□	▒	▒	▒	□	▒	□	□	□	□	□	□	□	0	3
2080205	▒	▒	□	▒	▒	▒	▒	▒	■	▒	▒	▒	▒	▒	▒	▒	▒	▒	□	□	□	▒	□	□	□	▒	□	▒	▒	▒	□	▒	□	6	1
5020003	▒	▒	▒	▒	■	▒	▒	▒	■	□	□	▒	▒	▒	▒	▒	▒	□	□	□	□	□	▒	▒	□	□	▒	□	▒	□	▒	▒	▒	2	2
2050104	▒	▒	■	▒	▒	■	▒	▒	▒	■	■	▒	■	■	▒	▒	▒	□	□	□	□	■	▒	▒	□	▒	▒	▒	□	▒	▒	▒	▒	5	7
2050106	□	▒	▒	▒	□	▒	□	▒	▒	■	■	□	▒	▒	▒	▒	▒	▒	▒	□	□	□	▒	□	□	▒	□	▒	□	▒	□	▒	▒	1	2
2050301	▒	□	▒	▒	▒	■	■	▒	□	■	■	▒	■	■	▒	▒	▒	□	□	□	□	▒	▒	▒	▒	▒	▒	■	■	□	▒	■	▒	3	9
2050302	▒	▒	▒	□	▒	▒	▒	▒	▒	■	□	□	■	■	▒	▒	□	▒	▒	▒	▒	■	▒	▒	▒	▒	▒	▒	□	□	▒	▒	▒	1	4
2050303	▒	□	□	▒	□	▒	▒	□	▒	▒	▒	□	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	□	▒	▒	▒	▒	▒	□	■	▒	▒	▒	2	6
2050305	■	▒	▒	■	▒	■	■	▒	□	▒	□	■	■	■	■	■	■	▒	▒	□	□	▒	▒	▒	▒	▒	▒	■	■	□	▒	■	■	3	14
2070004	□	▒	□	■	□	▒	▒	▒	□	■	■	▒	■	■	▒	▒	■	▒	▒	□	□	▒	▒	▒	▒	▒	■	▒	▒	■	▒	■	□	3	8
2070007	▒	■	▒	■	▒	▒	□	■	▒	▒	□	■	■	■	■	■	■	▒	▒	□	□	▒	▒	▒	▒	▒	□	□	□	□	□	□	□	3	9
2080103	▒	■	▒	▒	▒	▒	▒	■	▒	▒	▒	▒	▒	■	▒	▒	■	□	□	□	□	□	▒	▒	□	□	▒	■	▒	▒	▒	■	▒	2	6
3010101	□	▒	□	▒	□	▒	▒	■	□	▒	□	□	□	□	□	□	□	□	□	□	□	▒	□	□	▒	□	□	▒	□	□	▒	▒	▒	5	1
5010006	□	□	▒	□	▒	■	■	▒	□	■	■	□	▒	□	□	□	□	□	□	▒	▒	▒	□	▒	▒	□	▒	□	▒	■	□	▒	▒	0	5
5010007	▒	▒	▒	□	□	▒	■	▒	▒	■	▒	▒	▒	▒	□	□	▒	▒	□	□	□	□	□	□	□	□	□	▒	▒	▒	□	□	□	2	2
5010008	■	▒	▒	□	▒	■	■	▒	▒	■	▒	□	□	□	□	□	□	□	□	□	□	■	□	□	□	□	▒	□	□	▒	□	□	□	1	7
5020002	□	▒	□	□	■	□	▒	▒	▒	□	□	▒	■	■	▒	□	□	□	▒	▒	▒	▒	□	▒	▒	□	▒	▒	▒	□	▒	■	□	3	4
5020006	■	▒	▒	□	□	■	■	▒	□	■	■	□	□	□	□	□	▒	□	□	▒	□	▒	□	□	□	□	▒	□	▒	▒	□	▒	□	1	5
5030106	□	▒	■	□	■	▒	▒	▒	▒	□	▒	□	□	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	□	□	□	□	□	□	□	2	2
5030202	□	▒	■	□	▒	□	□	▒	▒	□	▒	□	■	■	□	▒	▒	□	□	▒	▒	▒	□	□	□	□	□	□	□	□	□	□	□	0	3
5050001	▒	■	□	▒	▒	▒	▒	■	▒	■	■	▒	■	■	▒	▒	▒	▒	□	□	□	□	□	□	▒	□	▒	▒	▒	■	▒	▒	□	5	7
5050008	▒	▒	▒	▒	■	□	□	▒	□	□	□	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	□	□	▒	□	□	□	□	□	□	□	1	1
6010102	▒	□	■	▒	■	▒	▒	▒	▒	■	■	▒	■	■	▒	▒	■	▒	□	□	▒	■	▒	▒	▒	▒	□	□	□	□	□	□	□	3	8
6010206	▒	□	□	▒	□	▒	▒	▒	▒	■	■	▒	□	□	▒	□	□	▒	▒	▒	▒	▒	□	□	■	▒	□	□	□	□	□	□	□	2	4
2050306	▒	▒	▒	■	▒	■	■	▒	□	■	■	■	■	■	■	■	■	■	■	■	■	▒	▒	▒	▒	■	■	□	■	■	■	□	■	3	21
2060003	■	□	■	■	▒	■	■	□	▒	■	■	■	■	□	■	■	■	■	■	■	■	■	▒	▒	▒	■	■	■	■	■	■	□	□	4	23
2060006	■	■	▒	■	▒	▒	□	■	▒	□	□	■	□	□	■	■	□	■	■	■	■	■	▒	▒	▒	■	▒	■	■	□	□	■	■	4	17
2070008	■	■	▒	■	▒	□	□	■	▒	■	■	■	■	■	■	■	■	■	■	■	□	■	▒	▒	▒	■	▒	■	■	□	□	■	■	3	21
2070009	▒	■	▒	■	□	■	■	■	▒	■	■	■	■	■	■	■	■	■	■	■	□	▒	▒	▒	▒	■	■	▒	■	■	■	□	■	4	21
4120101	▒	□	■	■	▒	■	□	▒	▒	□	□	▒	□	▒	▒	▒	■	■	■	■	■	▒	■	▒	▒	■	□	□	□	□	□	□	□	1	9
5010004	▒	□	□	▒	▒	■	□	□	▒	▒	■	▒	□	▒	▒	▒	■	▒	□	■	■	▒	□	□	■	▒	□	□	□	□	□	□	□	0	6
5030102	▒	▒	▒	■	▒	▒	▒	▒	□	□	▒	■	■	■	▒	▒	■	■	■	■	■	▒	▒	▒	▒	■	□	□	□	□	□	□	□	2	13
5030105	■	▒	▒	▒	□	■	■	▒	▒	▒	■	▒	□	□	▒	▒	▒	■	■	■	■	□	■	□	▒	▒	▒	■	▒	□	▒	▒	□	1	9
2040202	■	▒	■	■	▒	▒	▒	▒	■	□	□	■	▒	□	■	■	▒	■	■	■	■	▒	▒	▒	▒	■	■	■	■	▒	■	▒	■	3	17
2040201	■	▒	■	■	■	▒	▒	▒	■	▒	▒	■	■	▒	■	■	▒	■	■	■	■	▒	▒	▒	▒	■	■	▒	▒	□	■	■	□	4	16
2040205	■	□	■	■	▒	▒	■	▒	▒	□	□	■	▒	▒	■	■	■	■	■	■	■	■	▒	▒	▒	■	■	▒	■	■	■	□	■	3	19
2070010	■	▒	■	■	□	□	□	■	▒	□	□	■	■	▒	▒	▒	□	■	■	■	■	■	▒	▒	▒	■	▒	■	■	□	▒	■	■	3	16
2080108	■	▒	■	■	▒	▒	▒	▒	■	▒	▒	■	■	▒	■	■	▒	■	■	■	■	■	▒	▒	▒	■	▒	□	□	□	□	□	□	5	14
2080208	■	▒	■	■	■	▒	▒	▒	■	▒	▒	■	□	▒	■	■	▒	■	■	■	■	▒	▒	▒	▒	■	□	□	□	□	□	□	□	5	12
5010009	■	▒	■	▒	▒	■	■	▒	▒	▒	▒	▒	▒	□	□	□	□	▒	▒	▒	▒	■	▒	▒	▒	▒	▒	□	□	□	□	□	▒	2	6
5020005	■	▒	■	▒	■	▒	▒	▒	▒	■	■	▒	■	■	▒	▒	▒	▒	▒	▒	▒	▒	■	□	▒	▒	■	▒	□	□	■	■	▒	3	7
5030101	■	▒	■	▒	▒	▒	▒	▒	▒	□	▒	▒	▒	□	□	□	□	▒	▒	▒	▒	□	■	▒	▒	▒	□	□	□	□	□	□	□	2	2
5030104	■	▒	■	▒	▒	▒	▒	▒	□	▒	▒	▒	□	▒	□	□	□	▒	■	■	■	▒	■	□	▒	■	□	□	□	□	□	□	□	2	6

Table 4.1 continued

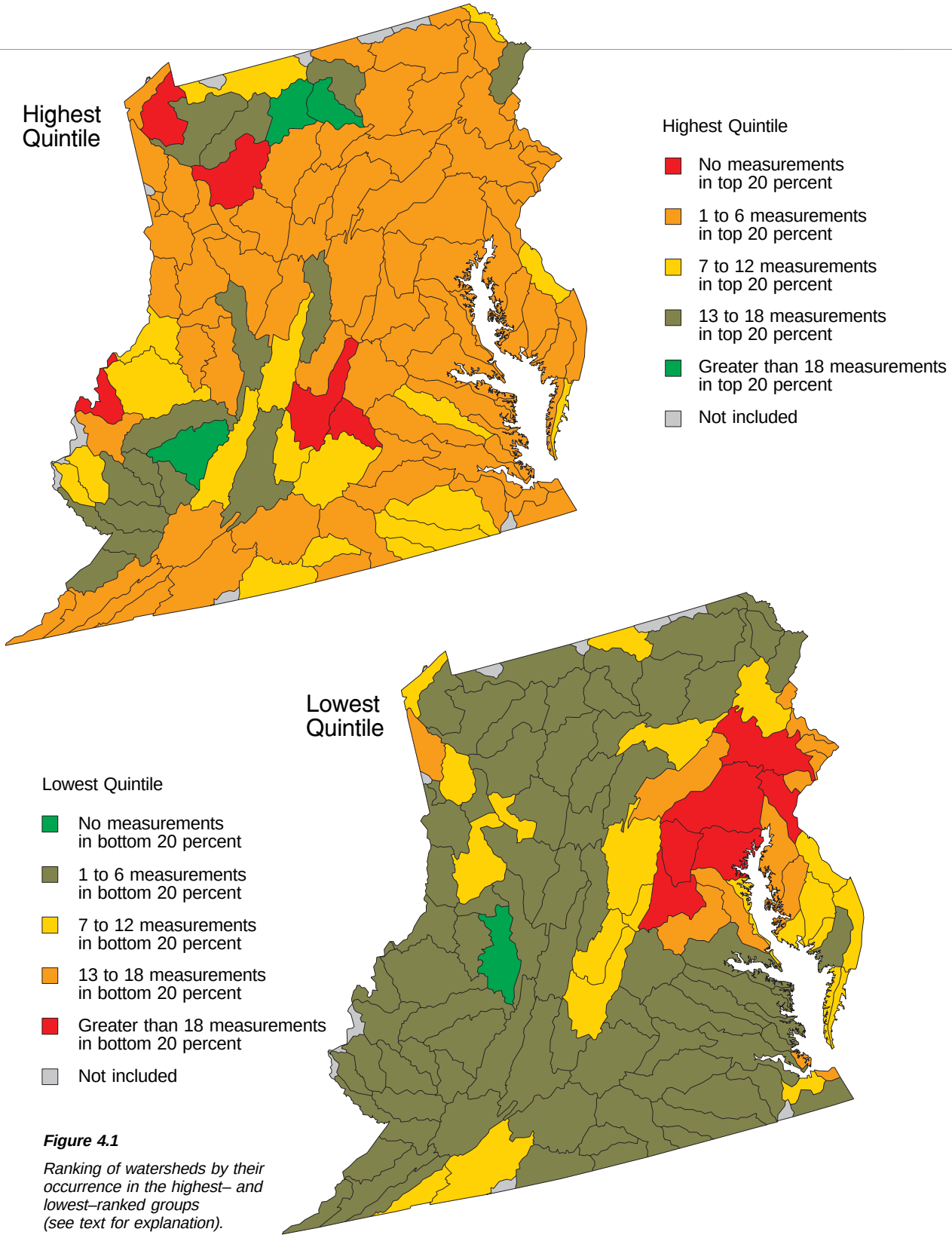


Figure 4.1

Ranking of watersheds by their occurrence in the highest– and lowest–ranked groups (see text for explanation).

Figure 4.2.

Results of the cluster analysis and ranking of watersheds based on indicator values. The ranking is based on the column of relative cumulative impact scores that is shown in Table 4.2.

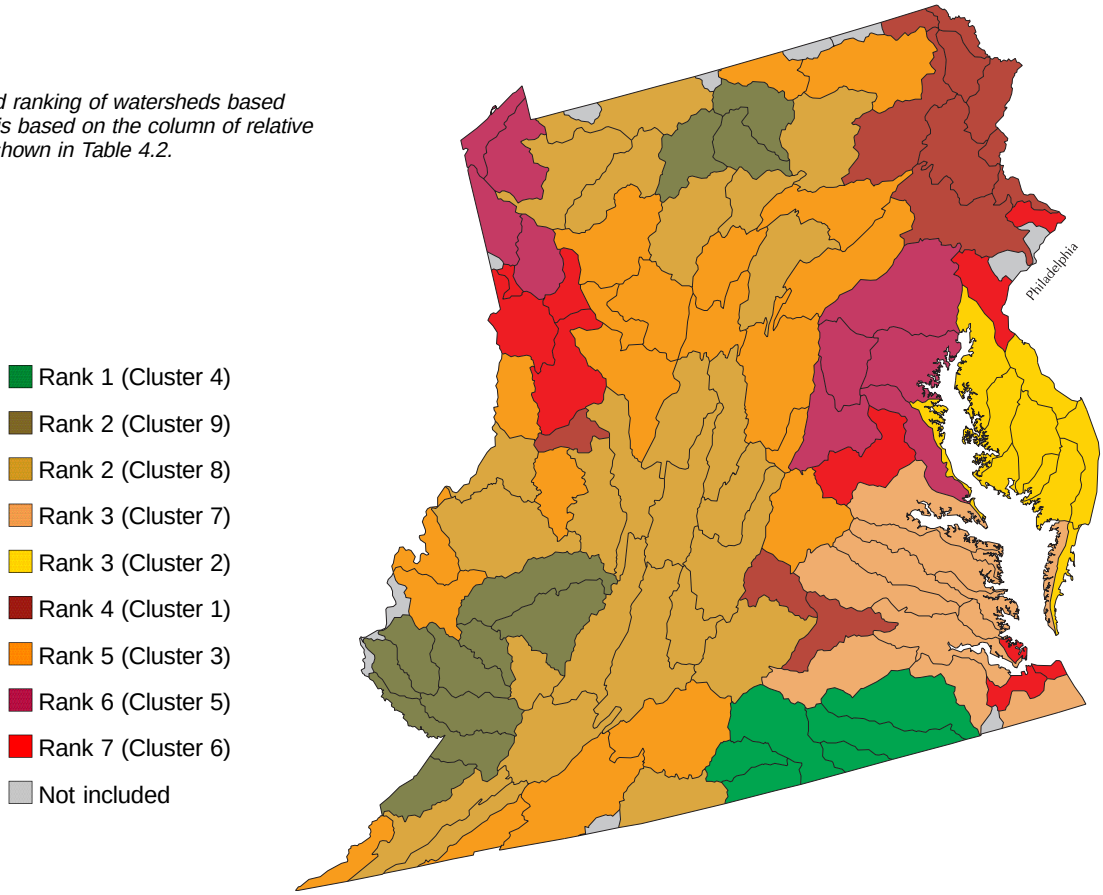


Table 4.2

Cluster mean indicator values and relative cumulative impact score (see text for explanation).

	Mean values by Indicator[1]									
Cluster	A*	B	C	D	E	F	G	H	I	RCI
1	175	21.5	2.46	6.34	8.92	84.48	20.18	2272	41.96	3
2	111	31.6	1.68	2.54	0.33	82.55	0.59	2435	0.18	2
3	88	7.5	1.89	6.94	15.24	72.63	16.33	2468	8.67	4
4	28	-3.5	1.66	1.69	6.03	93.60	5.79	1877	11.99	0
5	325	10.9	2.44	4.78	20.29	70.82	1.29	2825	2.85	5
6	982	-2.6	4.06	7.11	7.19	73.64	0.78	2607	15.67	6
7	78	66.7	1.54	1.88	1.12	88.65	6.6	2056	19.27	2
8	38	10.1	1.32	5.48	9.66	83.85	37.46	2377	4.43	1
9	28	-4.0	1.13	9.93	3.28	89.97	68.97	2290	4.26	1

[1]Indicator Codes:
A.1990 population density; B. Population change (1970 – 1990); C. Road density; D. Proportion of watershed streamlength that had roads within 30 meters; E. Proportion of watershed with cropland and pasture on slopes > 3 percent; F. Proportion of watershed streamlength with adjacent forest; G. Proportion of watershed supporting interior forest habitat at three scales; H. Average annual atmospheric sulfate wet deposition (1987 and 1993); I. Number of impoundments per 1,000 kilometers of stream length

RCI.Relative cumulative impact (the number of red values in a given row)

*Not included in RCI scoring - see discussion of cluster analysis.

Note: The correlations with other indicators in Chapter 3 that are greater than ± 0.55 are as follows.

A. Forest edge habitat in 7 hectare, 65 hectare, and 600 hectare scales, and the forest fragmentation index; B. None; C. None; D. None; E. Crop land cover on slopes > 3 percent, vegetation loss on slopes > 3 percent; F. Percent forest land cover, crop land cover on slopes > 3 percent (inversely), forest edge in 7 and 65 hectare windows (inversely), and the forest fragmentation index; G. U–index, percent forest land cover, soil loss index, total vegetation change (inversely), total vegetation change (inversely), nitrogen and phosphorous export from watershed, vegetation loss and total vegetation change in first–order stream regions (inversely), interior forest habitat at 7, 65, and 600 hectare scale; forest edge habitat at 7 hectare scale (inversely), forest fragmentation index (inversely); H. Average annual nitrate wet deposition; I. None

Cluster 4 (Rank 1)
Watersheds in this group are found along the south–central portion of the region, along the border with North Carolina. None of the indicator means for this group were colored red. The relative cumulative impact score is 0, the highest condition ranking among the nine clusters. Population pressures, road density, and atmospheric sulfate deposition are low. Values for agriculture on steep slopes and impoundment density are moderate. The score for riparian vegetation is the highest among the nine groups. The biggest adverse impact is the low value for the proportion of the watershed supporting interior forest habitat at three scales.

Cluster 9 (Rank 2)
Watersheds in this group are located in the southwestern portion of the region and north–central Pennsylvania. This group has the highest score for roads adjacent to streams, and thus a relative cumulative impact score of 1. Although road density is generally lower in these watersheds, the roads that do occur are often adjacent to streams because the watersheds are on the Appalachian Plateau. In this area, most land is on steep slopes, and so not only is stream density higher but also the roads that do appear tend to follow valleys. The watersheds in this group have the highest amounts of forest and riparian forest cover, and impacts from population, roads, agriculture, and impoundments are relatively low.

Cluster 8 (Rank 2)
Watersheds in this group are located mostly in the Ridge–and–Valley region and in northern Pennsylvania. The principal adverse impact is a relatively high amount of agriculture on steep slopes, which gave this group a relative cumulative impact score of 1.

Cluster 7 (Rank 3)
Watersheds in this group are located in southeastern Virginia on the Coastal Plain. The principal adverse impacts are high scores for impoundment density and population change, which gave this group a relative cumulative impact score of 2. Also, forests in these watersheds tend to be more fragmented than in other watersheds in the region.

Cluster 2 (Rank 3)
Watersheds in this group are largely restricted to the Delmarva Peninsula. The principal adverse impacts are a high score for population change and a low score for proportion of the watersheds supporting forests at three scales, which gave this group a relative cumulative impact score of 2.

Cluster 1 (Rank 4)
Watersheds in this group are located mainly in eastern Pennsylvania, with others scattered throughout the region. The principal adverse impacts for watersheds in this group are high scores for population density and change, road density, and number of impoundments per 1,000 stream kilometers, resulting in a relative cumulative impact score of 3. Interestingly, the score for the proportion of the watershed supporting interior forest habitat at three scales is in the upper third of all groups.

Cluster 3 (Rank 5)
Watersheds in this group are scattered throughout the Ridge–and–Valley and Appalachian Plateau Physiographic Provinces. The principal adverse impacts for watersheds in this group are high scores for roads near streams, agriculture on steep slopes, sulfate deposition, and a low score for riparian forest cover, resulting in a relative cumulative impact score of 4.

Cluster 5 (Rank 6)
Watersheds in this group are found along the northwestern margin of the Chesapeake Bay and in northwestern Pennsylvania. The adverse impacts for these watersheds are high scores for population density, road density, agriculture on steep slopes, and sulfate deposition, and low scores for riparian vegetation, and proportion of the watersheds supporting interior forest habitat at three scales. Watersheds in this group have a relative cumulative impact score of 5.

Cluster 6 (Rank 7)
Watersheds in this group are in the most urbanized areas of the region, including the Pittsburgh, Philadelphia, Washington, and Norfolk metropolitan areas. The principal adverse impacts for watersheds in this group are high scores for population density, road density, amount of roads near streams, sulfate deposition, and impoundment density, and low scores for riparian vegetation and proportion of the watersheds supporting interior forest habitat at three scales. Their relative cumulative impact score of 6 is the highest of all clusters.

In addition to interpreting the indicators presented in Chapter 3, the information in this chapter might serve other purposes, including identifying watersheds that currently are the most impacted, and by which stresses; identifying areas that currently are in desirable condition, but that might be vulnerable to adverse changes because of human–induced stresses; identifying areas that are in desirable condition for some resources or services but not for others; and identifying watersheds where restoration and risk reduction efforts might be most effective.

The discussion of watershed clusters (above) suggests which watersheds are the least– and most–impacted today in terms of the indicators used. The watersheds in clusters 4, 9, and 8 generally have desirable scores for all indicators, with only one or two exceptions. In contrast, the watersheds in clusters 5 and 6 are in the least desirable condition, because human populations are high and the values for habitat indicators are low.

The human population indicators could also be used to identify vulnerable watersheds. The watersheds in cluster 1 now have relatively desirable conditions for water and habitat, but population density is relatively high and is increasing faster than most other watersheds. Environmental conditions related to water and habitat in these watersheds may be more vulnerable than in other watersheds with less population pressure. For example, cluster 8 is similar to cluster 1 in terms of habitat indicators, but population density in cluster 8 is only about one–fifth of cluster 1, and is increasing at about half the rate as in cluster 1.

Some watersheds appear to be in a desirable condition for one environmental resource, but in a less–desirable condition relative to another. For example, the watersheds in cluster 2 are in better relative condition from a water quality perspective, but provide little interior forest habitat. The watersheds in cluster 3 have an opposite pattern, with relatively more interior forest habitat but less–desirable values for water–related indicators such as the amount of crop land cover on steep slopes.

The results of the cluster analysis might be used to guide restoration or preventative “best management practices” (BMPs). BMPs are site–specific approaches to minimizing environmental damage or controlling pollution associated with intensive land uses. Examples include the timely establishment of vegetative cover and storm water detention ponds in areas cleared for residential or commercial development. An example of restoration is the creation of artificial wetlands to replace natural wetlands lost in developed areas. Used together, BMPs and restoration efforts can address a variety of environmental concerns.

In general, most ecological restoration efforts and management practices are site-specific, requiring more detailed information than the landscape indicators can provide. The information in this atlas, however, can be used to guide broad-scale restoration efforts, and to identify areas where more intensive study and restoration may be needed. Consider the watersheds in cluster 4. These watersheds have a fairly high percentage of forest (about 70%) but the amount of forest in large, contiguous blocks (as measured by the proportion of the watershed supporting interior forest habitat at three scales) is low (about 6%). Field studies in the mid–Atlantic region have shown that some bird species require large tracts of continuous forest to survive. If the forest land in those

watersheds were configured in large blocks, more of these area–sensitive species might find suitable habitat there. This type of information can help land managers to focus their efforts where restoration and management are most needed.

These are only a few examples of how relative conditions can be interpreted regarding overall impacts, conditions for different environmental resources, watershed vulnerability, and ecological restoration. Many other interpretations are possible because the indicators used in the analysis can be related to several different aspects of environmental condition. The reader is invited to use the information in this atlas to make his or her own interpretations of landscape conditions in the mid–Atlantic region.

Acknowledgements

Many people contributed to this atlas.

We thank Curt Edmonds, Karl Hermann, Bill Kepner, Clay Lake, Bob Schonbrod, Sumner Crosby, Terry Slonecker, Dan Heggem, Rick Kutz, Tom Pheiffer, Rick Batiuk, Kent Mountford, Nita Sylvester, Kim Devonald, Stu Kerzner, Laura Jackson, Brian Spavin, Ann Pitchford, and Don Garofalo of the EPA, and Carolyn Hunsaker of the Oak Ridge National Laboratory, for their assistance and input during many phases of the project. We are especially grateful to Rick Kutz and Tom Pheiffer for organizing a series of review workshops with scientists and stakeholders who live in the mid–Atlantic region, and Rick Cooksey (U.S. Forest Service), Diane Eckles (U.S. Fish and Wildlife Service), Larry Fogelson (Maryland Office of Planning), Charlie Yuill (Univ. of West Virginia), Jeff Waldon (Fish and Wildlife Exchange), Phil Hager (Worester County Planning Dept.), Carl Hershner (Virginia Institute of Marine Sciences), Cully Hession (Philadelphia Academy of Sciences), Bill Jenkins (Maryland Dept. of Natural Resources), Rick McCorkle (U.S. Fish and Wildlife Service), Sandi Patty (Maryland Dept. of Natural Resources), Larry Pamotto (Delaware Dept. of Natural Resources), Nancy Roth (Versar, Inc.), Bob Shedlock (U.S. Geological Survey), Ann Sloan (Maryland Dept. of Natural Resources), Tom Stockton (Maryland Dept. of Natural Resources), Joe Tassone (Maryland Office of Planning), Paul Tubach (James City County Planning Dept), Lisa Wainger (Institute for Ecological Economics, Univ. of Maryland), Oliver Weatherbee (Center for Remote Sensing, Univ. of Delaware), and John Wolf (Maryland Dept. of Natural Resources), who participated in review workshops and provided comments on various parts of the atlas. We thank Steve Paulsen, Gil Veith, Ed Martinko and others in the Environmental Monitoring and Assessment Program for their gracious support over the years, and Denice Shaw of the EPA whose hard work led to completion of several region–wide databases used to calculate indicators in this atlas. We also acknowledge Jim Vogelmann, June Thormodsgard, John Dywer, and Tom Loveland of the U.S. Geological Survey, EROS Data Center, whose collective vision has made multiple–scale, regional assessments possible, and Doug Norton (EPA) for his efforts in helping EPA to adopt a broader, landscape view of the environment. We thank Tom DeMoss, Greene Jones, and Rick Linthurst of the EPA for providing the institutional leadership for the development of and support for this and other projects in the mid–Atlantic region. We are grateful to Kent Mountford, Rick Cooksey, Ron Landy, Charles P. Nicholson, the TVA Clean Water Initiative, and the BLM Phoenix Training Center (Phoenix, AZ) for photographs used in this atlas. We thank Vern Meentemeyer (Univ. of Georgia), Jim MacMahon (Utah State Univ.), Ron Foresta (Univ. of Tennessee), Kent Price (Univ. of Delaware), and Jianguo Wu (Arizona State Univ. West) for technical reviews of the atlas. We are grateful to the EPA Science Advisory Board, Ecological Processes and Effects Committee, for suggestions about the approaches used in this Atlas. We thank technical editors Donna Sutton (Lockheed Martin) and Barbara B. Smith. Atlas layout and graphic design by Garry Pyle (Tennessee Valley Authority).

The EPA, through its Office of Research and Development (ORD), partially funded and collaborated in the research described here, in cooperation with the Tennessee Valley Authority, and the Oak Ridge National Laboratory. It has been peer reviewed by the EPA and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation by EPA for use.

Glossary

Anthropogenic Cover
Land cover associated with human activities, such as agricultural fields, rock quarries, and urban areas. Literally, “land cover created by humans."

Bar Chart
A graphic representation of the frequency of different data values using rectangles with heights proportional to the frequencies.

Cluster Analysis
A statistical procedure which groups members of a population into similar categories (clusters) on the basis of more than one ecological indicator.

Coarse Scale *see* **Scale**

Comparative Assessment
An analysis of environmental characteristics which proceeds by evaluating members of a population relative to other members (as opposed to an analysis of characteristics relative to a standard or preferred condition).

Conceptual Model
An abstract framework used to organize ideas and information into a form that is more easily examined. These models are often helpful when searching for commonalties between apparently unrelated phenomena, or when defining the scope of inquiry when organizing and interpreting measurements of biological conditions.

Cumulative Environmental Impact
The net result of more than one stress applied to a given unit of the landscape.

Digital Map
An electronic representation of a portion of the earth’s surface that stores both the geographic location of an object and descriptive data about the object.

Ecological Indicator
A characteristic of the environment that is measured to provide evidence of the biological condition of a resource (Hunsaker and Carpenter 1990). Ecological indicators can be measured at different levels including organism, population, community, or ecosystem. The indicators in this volume are measures of ecosystem–level characteristics.

Fine Scale *see* **Scale**

HUC
Hydrologic Unit Code, used by the U.S. Geological Survey to reference hydrologic accounting units throughout the United States. In this atlas, used interchangeably with watershed.

Index Value
The realized measurement of an indicator for a given landscape unit.

Landscape Conditions
The apparent status or characteristics of a landscape unit as measured by one or more landscape indicators.

Landscape Ecology
The study of the distribution patterns of communities and ecosystems, the processes that affect those patterns, and changes in pattern and process over time (Forman and Godron 1986).

Landscape Indicator
A characteristic of the environment that is measured to provide evidence of the biological condition of one or more resources at the ecosystem level. See also “ecological indicator” and “landscape ecology”.

Landscape Unit
Designed to identify repeating patterns associated with dominant land uses in an area, and defined by the relative proportions of forest, agriculture, and developed (urban) land cover contained in that area.

Model
A representation of reality used to simulate a process, understand a situation, predict an outcome, or analyze a problem. A model is structured as a set of rules and procedures, including spatial modeling tools that relate to locations on the earth’s surface.

Net Primary Productivity
A measure of carbon flux over a given landscape unit, roughly, the actual amount of organic matter created by green plants, whether it accumulates in plants, is eaten by animals, or becomes dead material over a fixed time interval (after Waring and Schlesinger 1985).

Pixel
A contraction of the phrase “picture element”. The smallest unit of information in an image or raster map. Referred to as a cell in an image or grid.

Quintile
Any of the four values that divide the items of a frequency distribution into five classes with each containing one fifth of the total population. For example, one–fifth of the watersheds in a population have indicator measurements less than the first quintile. In this atlas, a “quintile” also refers to one of the five groups formed by the dividing values.

Riparian Zone
The area of vegetation located on the bank of a natural watercourse, such as a river, where the flows of energy, matter, and species are most closely related to water dynamics. In this volume, the “riparian zone” specifically refers to the linear corridors associated with streams and stream–side vegetation.

Scale
1. The spatial or temporal dimension over which an object or process can be said to exist, as in, for example, “the scale of forest habitat”.
2. The spatial, attribute, and temporal parameters associated with making an observation or measurement, usually including resolution, extent, window size, classification system (nomenclature), and lag. Important because measured values often change with the “scale of measurement”.
3. The way in which objects, parts of objects, or processes are related as the scale of measurement changes. For example, fractal models are used to describe some types of “scaling behavior”.
4. The amount of information or detail about an area. For example, “coarse–scale” maps have less detailed information than “fine–scale” maps. Related terms include “broad–scale” (covering a large area). The cartographic terms “large–scale” and “small–scale” are (contrary to expectation) equivalent to “fine–scale” and “coarse–scale”, respectively.

Spatial database
A collection of information that contains data on the phenomenon of interest, such as forest condition or stream pollution, and the location of the phenomenon on the earth’s surface.

Spatial Pattern
Generally, the way things are arranged on a map. For example, the pattern of forest patches can be described by their number, size, shape, distance between patches, etc. The spatial pattern exhibited by a map can also be described in terms of its overall texture, complexity, and other indicators.

Sediment Loading
The solid material transported by a stream, expressed as the dry weight of all sediment that passes a given point in a given period of time.

Watershed
A region or area bounded by ridge lines or other physical divides and draining ultimately to a particular watercourse or body of water.

Appendix: Additional Information about the Indicators in Chapter 3

This appendix describes the methods that were used to create the maps and charts of the indicators that are shown in Chapter 3. The information is organized by indicator. The reader may also refer to Chapter 1 for a description of some common computer operations such as overlaying, cookie–cutting, spatial filtering, and watershed ranking.

Table A.1 shows all the indicator values obtained for all watersheds in the mid–Atlantic region. The listed "HUC" number can be used to locate individual watersheds by using Figure 3.3. A few watersheds, indicated by italicized "HUC" numbers in the table, were on the edge of the region. Most of the area of these watersheds lies outside of the region, so the values obtained for these watersheds are probably less reliable than others. The unreliable values were not used in the cluster analysis in Chapter 4.

Population density and change (POPDENS and POPCHG).

The United States Census Bureau compiles population statistics by sampling units that are not watersheds, and so it was necessary to convert these (county–level) statistics to a per–watershed basis. The procedure was based on differences in road density across the region, assuming that the population is distributed in proportion to road occurrence. A map of local road densities in 1 km^2 windows across the region was prepared by using the U.S. Geological Survey Digital Line Graph map of all roads for the entire region. The total of all these window scores was then calculated for each county. The population within a given window was then estimated by dividing the road density for that window by the total road density score for the county that the window was in, and multiplying the result by the total population for the county.

The population for a watershed was then estimated by overlaying the map of watershed boundaries on the derived map of population, and summing the population estimates in that watershed. Population change was derived by repeating the procedure for Census data taken in 1970 and 1990, subtracting the 1970 per–watershed estimates from the 1990 estimates, and, for each watershed, expressing the result as a percentage of the 1970 estimate.

Human use index (UINDEX)

Two different methods were used to create the two maps of the human use index. The surface map for the mid–Atlantic region was produced by using a spatial filter. The window size was about 65 hectares and contained 729 pixels in a 27x27 pixel window. The window was moved one pixel at a time across the land cover map. At each step, the number of pixels that had agriculture or urban land cover were counted. Dividing this sum by the number of pixels in the window (729) yielded the index value which was then mapped at the location corresponding to the center of the window. A second spatial filter was then applied to "smooth" the surface map. The smoothing filter found the median index value in 9x9 pixel windows (about 7 hectares). The final map is shown at 7–hectare resolution.

The watershed map was produced by using a cookie–cutter procedure to extract the land cover information for each watershed separately. The number of pixels with agriculture or urban land cover was then counted in each watershed, and the total was divided by the total number of pixels for a given watershed to yield the per–watershed index value.

Road density (RDDENS)

The United States Geological Survey road maps are very detailed maps which are available as digital line drawings. To create the surface map of relative road density, the line drawings were first converted to raster images (or bitmaps) with a resolution of 90 meters. That is, each 90–meter by 90–meter square in the region that contained at least one road segment was coded as containing a road. Then a spatial filter was applied to this 90–meter resolution map. The window size was approximately 1 km^2 and contained 121 pixels in a 11x11 pixel window. The window was moved one pixel at a time across the land cover map. At each step, the number of pixels that were coded as containing at least one road segment were counted. The road density score was obtained by dividing this sum by the number of pixels in the window (121), and this score was then mapped at the location corresponding to the center of the window. This procedure tends to emphasize the importance of the first occurrence of a road in a given location, and to give less weight to subsequent occurrences.

To create the watershed map of road density, a different procedure was used. The line drawings representing all roads were clipped using the watershed boundaries, so that a per–watershed value could be calculated. The total length of roads in each watershed was divided by the total area of the watershed. The resulting value represents road density as road length (kilometers) per unit area (square kilometers).

Air pollution (NO3DEP, SO4DEP, OZAVG)

The source maps are based on regional–scale models (J. Lynch, Penn State University; A. LeFohn, Asle and Associates) which extrapolate measurements made at a set of sampling stations across the eastern United States. Nitrate and sulfate wet deposition estimates (in kg/ha) are from 1987 and 1993. The ozone models predict the W126 indicator which is a measure of cumulative annual exposure above a critical threshold value. Values for 1988 and 1989 were used. All of these source maps were resampled to 90–meter resolution for our analyses.

Landscape units

The land cover map was analyzed using the spatial filtering technique. The window size was about 590 hectares and contained 6,561 pixels. The window was moved one pixel at a time across the land cover map. At each step, counts were made of the number of pixels that were forest, agriculture, and urban in the window. Then, a landscape unit type was assigned to the location at the center of the window by using rules which are described in the text. To simplify the resulting map, a majority–rule spatial filter was applied and the resolution was reduced to about 7 hectares. The majority–rule filter examined all landscape pattern types within 7–hectare windows and assigned the most common type to the whole window.

Forest and agriculture land cover along streams (RIPFOR, RIPAG)

Maps of forest and agriculture land cover along streams were created by using the overlay technique. The map of streams was converted to a raster format with 30–meter pixels. This version of the streams was overlaid on the land cover map to determine the stream length that flowed through forest and agriculture land cover. The length of streams flowing through forest and agriculture land cover, respectively, was divided by the total length of streams in each watershed to arrive at the index value. A 30 meter pixel size was used because it was consistent with the pixel size of the land cover map. The proportions would change with different stream pixel sizes, depending on the amount of forest and agriculture land cover in the riparian zone defined by the pixel size.

Roads along streams (STRD)

The procedure was similar to that used for the preceding indicators. Road and stream maps were converted to a raster format with 30 meter pixels, and then overlaid. The number of pixels where both a road and a stream occurred was divided by the total number of stream pixels in the watershed.

Impoundment density (DAMS)

The U.S. Geological Survey defines large dams as those that are able to store at least 5,000 acre–feet of water. The source data were converted into a map of point locations, and overlaid on the watershed map. The number of dams in each watershed was then divided by the total stream length for the watershed to estimate the density of impoundments. The density estimate is expressed as the number of dams per 1,000 kilometers of streams.

Crop land and agriculture land on steep slopes (CROPSL, AGSL)

Agriculture on steep slopes was mapped by overlaying the slope map and the land cover map. Percent slope is calculated from the U.S. Geological Survey digital elevation model (DEM) as the vertical rise in elevation per horizontal distance traveled. After overlaying the two maps, the proportion of watershed area that was crop, or agriculture, on slopes greater than three percent was found by using the cookie–cutting technique.

The three percent threshold value was taken from U. S. Department of Agriculture studies that classified slopes into six categories. Based on this classification, slopes greater than or equal to three percent have a greater risk of soil erosion.

Potential nitrogen and phosphorus loadings to streams (STNL, STPL)

A literature survey of North American nutrient export studies (Young and others, 1996, in the *Journal of Environmental Management*) provided coefficients for estimated export (kg/ha/yr) for nitrogen and phosphorus under different types of land uses. To estimate total nutrient export potential on a per–watershed basis, the reported median coefficients for comparable agricultural uses were multiplied by the amount of land cover in the agriculture land cover classes. The coefficient–times–land use model was developed in 1980 for the United States Environmental Protection Agency by Rechow and others (US EPA 440/5–80–011, Washington, DC). The coefficients reported for nitrogen varied from 2.6 to 6.2 kg/ha/yr, with a median value of 3.9 kg/ha/yr. The values reported for phosphorous ranged from 0.3 to 1.5 kg/ha/yr, with a median value of 0.7 kg/ha/yr.

Soil loss potential (PSOIL)

The Universal Soil Loss Equation (USLE) estimates soil erosion from agricultural lands as a function of rainfall, soil type, slope, and land cover characteristics. The basic equation is:

$A = R * K * LS * C * P$, where A is long–term average annual soil loss (tons/acre/year), R is the long–term erosive potential of rainfall, K is the soil erodibility factor, LS is the length–slope factor, C is cover and management factor, and P is the support management factor (e.g., strip cropping, buffer–strip cropping). Representative values for the mid–Atlantic region would be R=200, K=0.37, LS=0.93, C=0.12, and P=0.5. An R value of 200 (tons/acre/year) is typical of the eastern seaboard in the northern part of the region (e.g., Philadelphia). A K value of 0.37 is representative of a loamy soil (e.g., Hagerstown silty clay loam at the USDA research station in State College, PA). A LS factor of 0.93 would be found on a 6% slope that extended for 200 feet. A C value of 0.12 is representative of corn with a ground cover of residue (e.g., dead) vegetation, and a P value of 0.5 is representative of farming practice of tilling and planting along contours. Under these conditions the estimated soil loss is 4.1 tons/acre/year. In contrast, if a bare soil surface was exposed to typical rainfall patterns, that surface would lose 200 tons/acre/year of soil, or about 50 times as much as the representative example. The difference is due to soil type (percent sand, silt, clay), slope, the type of cover, and the type of management.

We created a map for each parameter in the model (rainfall erosive potential, soil erodibility, length–slope, cover and support management), and simply multiplied the values in each map on a pixel–by–pixel basis. R factor values were taken from USDA Agricultural Handbook 537, soil erodiblity was taken from USDA, Soil Conservation Service digital soil maps, and length–slope values were taken from USGS DEM data. The C factor was the median value for corn under all reported crop residue conditions. The C factors for corn were used because it is the most common crop in the region, and the land cover data available did not distinguish between different agricultural crops. The support management factor was set to that for contour tillage and planting because most farmers plant crops along contours, not perpendicular to them, and more detailed information was not available.

The area of each watershed with the potential for soil losses greater than 1 ton per acre per year was then found by summing the number of pixels in each watershed that exceeded this threshold value. The indicator is the proportion of the watershed above that threshold value.

Forest land cover (FOR%)

The cookie–cutter procedure to extract the land cover information was applied to each watershed separately. The number of pixels with forest land cover was then counted in each watershed, and the total was divided by the total number of pixels for a given watershed to yield the per–watershed index value.

Forest fragmentation (FORFRAG)

Forest fragmentation was assessed here at a resolution of about one–tenth hectare by using a version of the land cover map which had only two lumped categories, forest and non–forest. The fragmentation statistic measures the probability that a randomly selected forested spot in a watershed is not adjacent to another forested spot.

Higher values indicate higher fragmentation. The statistic was calculated separately for the forest cover within each watershed in the mid–Atlantic region, rather than using a sliding window technique.

Forest edge habitat (EDGE7, EDGE65, EDGE600)

Forest edge habitat differences among watersheds were assessed by the sliding window technique. The fragmentation indicator described above was used, but calculated in a small window that was placed within a watershed. If the calculated indicator value exceeded one–half the maximum value for that amount of forest, then the center of the window was marked as suitable edge habitat. After moving the calculation window throughout the watershed, the proportion of the watershed that was labeled suitable was calculated and used as the indicator value. The exact window sizes used were 7.29ha, 65.61ha, and 590.49ha.

Forest interior habitat (INT7, INT65, INT600, INTALL)

The sliding window technique was used to assess interior forest habitat. The proportion of forest cover was calculated within a window that was placed within a watershed. If the proportion of forest exceeded a threshold value of 90%, then that place in the watershed was considered to be suitable interior habitat. After placing the calculation window everywhere in a watershed, the proportion of the watershed that was suitable habitat was determined. These proportions were then used to rank the watersheds.

The proportion of watershed area supporting three scales of interior forest habitat was calculated as the proportion of pixels in a watershed that exceeded the threshold value for all three window sizes (7.29ha, 65.61ha, and 590.49ha).

Departure of the largest forest patch size from the maximum possible for a given amount of anthropogenic cover (FORDIF)

Each forest patch was determined with a routine that finds all adjacent pixels of the same cover type and then assigns them a unique value, and also retains the original land cover value. There are as many unique values as there are patches in the watershed. From these data, we created a file of forest patches and sorted it to find the largest forest patch. A proportion was calculated using the watershed area as the denominator. The proportion was then subtracted from 1.0 minus the U-index to derive the indicator value.

Calculation of NDVI and its change (NDVIDEC, NDVIINC, NDVITOT)

NDVI is calculated from satellite spectral reflectance data in the red and infrared wavelengths, using the equation: NDVI = (infrared – red) / (infrared + red). The reason that NDVI in particular, and all vegetation indices in general, are able to distinguish plants from all other surface features is that vegetation reflectance jumps dramatically in the infrared region of light, and is strongly absorbing (not reflective) in the red region. For vegetation, typical infrared and red values might be 0.8 and 0.1 respectively, giving an NDVI value of 0.78. For other earth surface features, the infrared and red reflectance values are more similar. Because of this, the numerator tends to be close to zero (or even slightly negative) while the denominator tends to double. NDVI values for nonvegetative surfaces are typically close to or less than zero. Once the NDVI maps are made for each date, differences are calculated simply by subtraction. The resulting differences range negative to positive, centered on zero (0). Values close to zero indicate that there has not been a change in land cover. Calculating the difference of temporal satellite images usually yields an approximately normal distribution. For a normal distribution, about 70% of the values are within one standard deviation of the mean, which is zero in this case. Previous research has shown that one standard deviation is an accurate threshold to distinguish change from no change. We chose one standard deviation as our change/no change threshold.

NDVI change within watersheds (1STDEC, 1STINC, 1STTOT)

Observed values for the three aspects of vegetation change come simply from the change that occurred in the first order stream region. Expected values come from the product of the change over the whole watershed multiplied by the proportion of the watershed in the first order stream region. It was necessary to choose a threshold to decide if a calculated difference between observed and expected was significant. We chose $\pm$0.25% of the watershed area as the threshold. This threshold is arbitrary but splits the observed versus expected map for total vegetation change into approximately equal thirds.

NDVI loss on steep slopes (NDVI3%)

Vegetation loss on slopes greater than 3% was created using the overlay technique. The NDVI change data was overlaid upon the USGS DEM data which were reclassified into percent slope. Proportional values were calculated by dividing the amount NDVI loss, gain, or total change by total watershed area.

HUC	POPDENS	POPCHG	UINDEX	RDDENS	NO3DEP	SO4DEP	OZAVG	RIPFOR	RIPCROP	STRD	DAMS	CROPSL	AGSL	STNO3L	STPL	PSOIL	FOR %	FORFRAG	EDGE7	EDGE65
2040101	51.72	54	13.08	2.74	1634	2050	34.27	86.16	10.04	6.51	32.33	5.99	8.12	320	46.9	9.51	84.46	10.16	6.28	0.47
2040103	114.53	35	15.25	1.7	1570	2087	35.45	91.94	7.2	6.05	85.41	5.59	7.72	330	50.5	10.19	79.97	12.43	7.87	1.18
2040104	76.16	81	6.54	3.61	1536	2150	37.81	92.54	2.82	5.69	86.57	1.75	2.08	280	35.2	3.05	90.6	6.16	3.1	0.95
2040105	625.06	25	44.03	7.71	1629	2443	43.79	77.06	20.95	9.68	37.64	13.68	15.04	490	106.4	37.38	54.73	25.16	34.07	22.04
2040106	488.13	13	32.46	2.73	1677	2435	38.24	83.24	12.89	7.18	42.02	7.5	11.02	400	73.8	23.57	65.79	13.98	24.85	19.77
2040201	1291.56	20	64.36	6.92	1696	2634	47.08	71.17	17.36	6.87	47.12	5.48	6.98	520	113.8	31.08	34.13	42.39	58.94	45.78
2040202	3533.76	-5	67.84	16.01	1792	2817	47.72	66.29	10.27	10.65	49.04	2.11	3.18	480	98.3	11.27	31.12	39.12	59.78	52.57
2040203	816.35	-1	50.95	3.32	1850	2799	41.66	69.06	26.48	10.15	45.89	9.46	15.15	470	97	38.38	48.01	25.88	43.65	36.17
2040205	596.15	15	59.22	3.17	1882	2913	47.64	73.35	19.83	6.68	12.17	5.4	10.33	510	108.2	41.71	36.84	34.47	52.29	38.13
2040207	171.27	29	58.17	1.74	1588	2483	49.11	86.21	14.98	2.71	0	0.06	0.09	620	146.4	51.06	25.99	25.66	42.66	28.65
2050101	63.98	21	17.16	1.38	1594	1961	32.75	84.58	16.31	6.57	31.32	8.97	12.28	330	53.1	13.19	81.19	11.75	9.44	1.05
2050103	115.7	8	27.66	10.13	1872	2459	37.16	75.89	26.38	5.67	12.26	13.84	18.56	390	71.6	22.14	71.66	15.97	16.82	4.18
2050104	28	2	35.77	2.62	1984	2815	37.23	56.73	43.69	6.6	5.45	17.14	24.68	430	82.6	30.16	63.67	15.65	25.74	11.46
2050105	153.98	4	43.38	10.22	1941	2653	38.48	59.03	41.11	5.63	13.61	20.31	26.65	470	98	34.35	56.05	21.48	31.62	13.88
2050106	74.74	1	32.6	1.45	1852	2518	34.91	74.34	27.08	5.48	12.85	15.62	21.61	410	79.2	26.59	66.05	17.71	21.96	7.61
2050107	178.88	0	30.97	2.19	1814	2563	33.56	79.01	16.28	8.32	24.46	10.27	13.74	390	71.2	19.73	67.35	14.66	22.3	13.49
2050201	87.48	0	17.81	1.67	1993	2882	39.92	93.47	4.41	3.91	4.87	6.29	7.3	320	49.7	9.95	81.76	8.1	6.84	1.47
2050202	20.45	-5	3.21	0.89	2098	3020	40.02	96.29	3.15	5.67	2.76	1.12	1.52	260	29.3	1.7	96.56	1.97	0.72	0.01
2050203	26.74	1	5.19	0.98	2176	3182	37.7	94.8	4.56	5.57	2.81	1.43	1.95	270	31.9	2.23	94.01	2.87	2.35	0.87
2050204	85.36	19	29.48	1.47	2052	2934	37.93	71.5	27.31	7.81	2.44	10.8	13.9	390	72.6	23.44	69.98	8.47	17.21	14.79
2050205	61.71	4	10.95	0.99	2157	3172	36.67	87.96	11.78	5.85	3.23	4.4	6.47	300	41.8	8.12	88.67	4.7	6.39	2.19
2050206	58.67	10	30.12	1.54	2008	2886	33.18	74.58	25.1	7.86	4.11	9.32	12.89	400	74.3	21.48	69.09	9.93	20.15	16.54
2050301	145.45	6	40.54	1.77	2031	2967	36.01	67.61	32.46	7.8	9.27	12.46	18.58	440	88.3	31.74	57.87	14.07	29.45	22.74
2050302	109.05	0	29.89	1.51	1918	2780	39.37	67.52	30.92	8.22	11.8	11.69	14.67	400	74.8	23.82	69.75	7.76	18.12	14.03
2050303	50.56	6	31.5	1.38	1745	2629	42.22	70.48	30.57	7.46	3.89	12.63	16.13	410	78.5	24.46	67.12	9.18	18.08	11.87
2050304	44.5	26	28.59	1.29	1966	2872	40.43	73.57	27.98	6.56	3.42	9.32	14.04	390	69.6	24.51	70.66	8.78	16.77	10.55
2050305	279.69	21	50.46	2.25	2041	3015	41.13	66.13	33.4	7.64	8.9	6.28	10.52	480	98.2	43.67	48.37	16.34	40.67	39.6
2050306	254.35	30	69.31	2.57	2081	3148	44.35	56.85	43.68	8.22	6.43	17.72	28.41	570	128.7	63.69	29.62	30.06	57.23	50.92
2060002	207.94	30	63.37	1.69	1822	2802	48.47	76.79	26.51	2.77	0	2.23	3.77	570	130.5	58.24	33.54	27.45	44.42	30.78
2060003	707.08	12	61.31	3.77	2071	3168	47.99	64.96	26.05	7.14	0	15.01	22.29	520	111.7	39.53	36.87	30.39	51.32	39.38
2060004	695.28	50	38.56	3.51	1688	2576	49.17	86.82	8.58	4.22	0	3.87	5	420	79.6	18.75	58.92	21.42	25.55	13.34
2060005	55.52	32	60.24	1.7	1645	2530	46.69	69.4	32.14	2.8	0	0.11	0.2	570	128.4	56.14	35.96	25.28	38.09	20.33
2060006	861.58	38	49.37	2.34	1744	2691	48.81	82.02	15.46	2.92	0	8.95	12.11	490	103.7	34.06	46.49	24.5	36.55	22.86
2060007	83.15	37	32.94	1.37	1510	2324	43.52	92.07	8.78	1.18	0	0	0	520	114.8	26.94	41.64	16.69	25.84	15.16
2060008	100.37	45	52.36	1.67	1574	2441	44.64	75.81	25.9	2.99	0	0	0	560	125.6	48.67	42.39	16.95	24.15	10.86
2060009	63.4	47	37.45	1.43	1478	2303	43.62	81.64	17.75	2.32	0	0	0	490	103.5	34.02	54.06	14.19	19.78	7.91
2060010	86.09	39	47.39	1.61	1485	2330	44.27	80.79	17.68	2.82	1.31	0.02	0.02	540	121.1	38.77	28.21	22.47	34.68	22.24
2070001	13.12	30	18.22	0.85	1516	2428	49.23	76.71	23.9	4.72	9.01	9.11	11.28	340	55.8	14.91	81.25	6.6	8.07	3.16
2070002	43.24	1	16.76	1.36	1678	2584	46.14	84.93	14.1	5.82	12.26	6.68	8.21	330	50.2	10	82.43	7.49	6.32	1.46
2070003	24.53	9	14.66	1.08	1457	2335	49.07	88.96	12.34	4.67	1.97	6.26	8.23	320	48.6	11.15	84.79	6.09	5.51	0.83
2070004	69.04	37	49.48	1.69	1695	2605	48.08	66.79	35.58	5.23	7.93	9.48	15.61	470	96.4	43.14	49.89	15.67	33.73	30.95
2070005	40.46	38	42.42	1.47	1370	2285	53.01	68.33	35.69	5.61	9.03	7.59	15.08	420	79.3	39.09	57.05	10.64	25.39	18.77
2070006	42.73	53	35.74	1.38	1285	2143	53.68	75.73	30.07	5.59	4.62	7.74	14.34	400	73.5	33.46	63.84	9.38	20.35	14.56
2070007	181.1	73	55.28	1.89	1435	2309	52.87	70.63	31.96	4.51	14.99	3.98	8.64	480	97.5	53.26	43.78	17.93	39.32	32.05
2070008	617.11	49	57.69	1.92	1669	2618	50.79	65.57	35.15	3.84	13.31	11.61	23.5	490	102.1	49.93	41.28	25.65	43.43	28.62
2070009	249.76	55	66.48	1.93	2008	3058	48.83	53.31	50.22	5.71	0.72	15.15	27.37	540	117.2	64.87	32.85	28.48	59.28	53.77
2070010	1154.66	33	54.32	4.1	1608	2532	49.8	70.6	18.18	5.36	12.51	4.54	7.06	460	91.9	21.85	43.33	27.71	43.23	30.81
2070011	173.57	56	30.89	1.67	1430	2243	48.06	83.8	10.45	2.17	7.73	2.54	3.52	390	72	21.83	62.27	14.64	16.4	5.77
2080102	29.93	72	24.05	1.52	1325	2096	43.94	86	7.94	1.45	12.65	0.24	0.56	360	60.6	20.03	72.19	11.55	10.64	2.55
2080103	31.34	145	38.3	1.25	1228	2073	53.85	70.84	33.4	3.13	13.28	6.39	11.93	420	77.9	35.35	61.3	13.15	21.77	10.15
2080104	49.19	191	33.59	1.29	1306	2079	46.69	88.78	9.6	1.43	14.65	1.5	2.36	400	73.5	25.78	57.52	14.43	18.34	9.72
2080105	36.78	197	23.84	1.26	1214	1998	46.64	93.56	6.68	1.52	23.85	1.34	2.04	360	61.8	19.81	73.03	11.79	9.32	1.43
2080106	32.7	84	28.66	1.31	1159	1958	46.27	89.72	11.43	1.64	20.18	1.47	2.96	370	64.5	24.02	67.88	12.36	12.86	3.78
2080107	165.66	87	23.62	1.79	1295	2072	42.61	93.48	4.58	2.18	29.41	0.28	0.58	360	61	14.89	55.86	12.76	13.48	7.17
2080108	1898.02	35	60.93	5.7	1343	2157	40.65	65.85	9.19	7.63	17.85	0.04	0.06	480	97.7	11.01	29.32	32.08	56.68	50.23
2080109	49.77	5	43.41	1.65	1372	2154	43.78	79.12	20.02	1.44	55.57	0.11	0.18	470	96	42.02	40.34	23.79	31.15	14.27

HUC	POPDENS	POPCHG	UINDEX	RDDENS	NO3DEP	SO4DEP	OZAVG	RIPFOR	RIPCROP	STRD	DAMS	CROPSL	AGSL	STNO3L	STPL	PSOIL	FOR %	FORFRAG	EDGE7	EDGE65
2080110	39.7	1	33.78	1.18	1379	2184	43.88	84.96	15.83	2.16	6.9	0.02	0.05	500	104.5	40.75	23.42	26.56	39.3	22.74
2080201	12.45	30	12.69	0.89	1304	2139	51.11	85.95	15.34	3.72	2.54	5	6.85	310	44.8	11.06	86.63	4.48	5.37	1.3
2080202	34.04	21	24.14	1.1	1308	2159	49.47	72.23	23.82	4.37	3.82	7.59	13.9	350	57.8	22.79	75.43	6.46	10.62	4.34
2080203	37.12	35	18.69	1.33	1225	2086	51.15	87.63	13.65	3.44	12.88	2.99	5.78	320	47.6	14.98	80.38	8.07	7.16	1.55
2080204	75.53	50	24.97	1.59	1233	2107	51.54	83.87	18.87	3.29	30.34	3.69	7.58	350	56.4	21.21	74.21	11.01	10.5	2.71
2080205	258.15	32	24.65	1.75	1115	1931	46.93	91.64	8.44	2.18	36.32	1.42	2.74	350	55.9	17.93	73.47	10.6	10.64	4.12
2080206	274.03	33	34.64	2.55	1193	1961	41.79	86.14	7.8	3.18	16.93	0.29	0.5	390	71.4	18.6	59.6	15.21	19.21	10.38
2080207	66.38	74	24.28	1.45	1150	1979	46.31	92.62	7.15	1.59	24.81	1.4	2.81	340	55.1	19.17	74.39	10.75	8.4	1.55
2080208	1205.09	35	60.58	4.26	1286	2082	40.04	79.56	11.52	3.92	20.78	0.16	0.3	520	113.9	25.65	30.4	24.63	45.85	40.22
3010101	64.49	24	28.62	1.74	1102	1869	50.25	83.05	18.64	4.58	6.37	6.42	11.01	370	64	22.97	69.88	12.31	13.03	5.28
3010102	26.38	5	27.29	1.34	1118	1928	48.4	93.36	8.91	1.17	9.46	4.23	6.62	370	65	23.94	69.36	12.47	8.21	1.12
3010103	49.27	9	17.44	1.83	1006	1726	48.82	90.32	10.22	4.17	10.9	5.68	7.77	330	51.7	13.78	81.68	10.08	4.36	0.61
3010104	91.15	1	24.61	2.06	1045	1794	48.81	93.1	7.41	1.89	19.2	5.91	7.19	370	65.1	21.12	74.11	13.88	7.25	1.42
3010105	31.27	-6	29.41	1.63	1041	1790	49.3	93.1	8.68	1.73	13.73	8.65	11.26	400	73.7	27.66	69.94	13.68	7.54	0.73
3010106	31.39	0	29.16	1.91	1129	1948	44.66	93.45	7.37	1.56	10.12	5.07	7.65	380	68.8	25.2	67.14	13.89	11.47	1.94
3010201	11.28	-10	25.76	1.45	1122	1903	42.9	94.5	6.18	2.16	13.62	0.99	1.6	370	66.1	21.41	73.32	10.96	8.51	0.92
3010202	44.47	18	34.79	1.4	1158	1916	41.25	90.12	10.73	2.11	17.7	0.28	0.36	430	84.6	31.45	64.39	12.71	12.3	1.49
3010203	78.41	432	41.23	2.26	1137	1896	40.39	87.53	14.57	2.48	17.47	0.28	0.32	480	103.7	36.48	56.79	14.51	15.25	1.41
3010204	17.99	-5	28.13	1.68	1119	1909	43.47	93.95	7.6	1.78	7.52	2.9	4.38	390	70	23.39	71.02	11.67	9.9	1.42
3010205	318.68	120	37.26	1.36	1326	2185	39.91	84.22	15.45	2.75	6.56	0.04	0.04	600	142.1	28.55	51.28	9.73	16.19	9.22
3040101	111.23	12	13.62	3.5	928	1632	48.06	89.42	10.54	4.87	0	1.81	9.3	290	37.5	11.35	86.05	10.59	1.09	0
4120101	242.11	4	47.21	3.74	2122	2529	41.69	80.73	20.72	4.5	1.67	6.06	13.12	450	87.9	36.89	52.32	21.29	26.03	11.11
4130002	27.22	1	24.75	13.05	2033	2810	38.96	77.97	24.3	5.07	0	10.61	17.37	370	62.4	19.53	75.16	13.72	10.39	1.44
5010001	73.13	0	11.65	2.16	2167	3009	40.98	87.59	12.48	4.54	1.58	3.61	6.05	300	41.2	8.56	87.42	5.17	4.51	0.61
5010002	102.53	-5	26.03	9.74	2125	2781	41.41	85.32	16.48	5.29	0	7.54	16.12	360	58.4	22.93	73.75	10.09	11.11	1.76
5010003	79.32	0	13.99	1.31	2192	2949	42.74	93.63	5.73	3.27	2.6	2.81	5.87	310	42.5	10.96	85.27	5.9	5.13	0.64
5010004	124.42	3	40.42	1.65	2084	2709	43.43	77.2	24.72	3.67	4.61	7.96	19.74	420	77	37.99	58.84	16.81	17.7	2.78
5010005	33.25	3	15.1	1.32	2127	2966	41.64	93.99	5.13	3.68	2	5.14	6.62	320	47.4	9.61	84.57	6.54	6.01	1.09
5010006	72.35	5	28.89	1.94	2085	2922	40.22	85.21	14.89	6.75	5.74	13.64	16.91	390	72.7	22.19	70.59	13.06	11.58	1.84
5010007	165.53	-4	26.65	1.92	1943	2849	38.97	87.59	11.04	6.35	13.49	9.76	12.14	380	66.9	19.45	72.62	11.03	12.34	3.35
5010008	365.61	0	29.56	2.16	2032	2929	38.24	81.42	17.45	8.51	12.47	11.41	16.2	390	70.1	24	69.99	13.37	14.37	5.08
5010009	1469.23	-12	35.93	3.63	2071	2952	38.17	80	11.78	9.67	10.23	7.62	12.48	390	71.2	18.76	63.3	19.54	19.93	8.42
5020001	32.63	10	17.66	1.25	1731	2649	44.23	83.37	17.16	5.42	2.85	5.87	8.58	330	51.6	14.83	81.57	8.05	6.72	1.66
5020002	62.83	-4	26.11	1.62	1631	2588	40.49	64.56	34.57	8.53	15.9	5.72	9.13	360	62	21.23	73.14	13.53	10.84	2.2
5020003	183.11	2	22.7	1.98	1714	2656	39.19	76.38	20.95	10.11	30.81	6.02	9.41	350	57.2	16.98	76.26	11.66	8.47	2.56
5020004	38.85	5	11.12	0.98	1899	2860	45.14	94.26	5.72	3.58	3.95	4.62	6.2	300	41.9	8.19	87.64	5.53	3.48	0.47
5020005	551.28	-12	38.93	2.75	1853	2811	38.03	65.76	29.49	11.67	11.99	9.75	16.14	410	78.1	28.11	60.5	19.14	20.31	7.26
5020006	422.35	-11	31	1.91	1987	2938	41.24	81.4	17.1	6.24	9.3	11.21	15.57	400	73.5	24.8	68.13	11.96	16.55	6.47
5030101	626.81	-15	38.73	4.54	1822	2749	38.07	73.24	17.1	8.12	14.92	5.92	13.1	390	69.8	23.29	59.71	19.74	22.36	10.03
5030102	135.94	-4	55.13	2.74	1957	2667	41.81	70.66	28.77	4.22	5.98	8.21	21.2	470	93.4	47.66	42.73	25.47	30.5	9.99
5030103	344.62	-10	52.2	42.52	1689	2430	41.64	73.02	20.14	4.56	0	8.96	19.2	450	89.9	41.75	46.39	25.94	28.53	7.89
5030104	825.99	-10	39.84	3.05	1950	2795	39.19	80.12	12.03	6.72	5.9	6.85	13.39	400	71.9	23.8	59.78	20.62	21.79	6.3
5030105	546.17	-11	43.17	2.16	2093	2923	39.75	77.94	21.26	4.89	5.15	8.27	18.12	420	79.3	33.25	56.29	19.94	22.1	5.6
5030106	84.21	-9	28.82	2.98	1731	2787	36.75	77.37	21.4	8.8	10.82	5.44	14.71	360	58.7	25.04	69.54	13.68	9.53	2.33
5030201	41.53	-2	12.81	2.58	1602	2690	38.28	76.49	22.77	6.99	3.22	2.19	4.07	310	42.8	10.43	85.06	7.17	3.17	1.21
5030202	68.42	3	29.06	3.11	1498	2501	39.58	61.85	36.87	7.01	11.73	6.11	13.5	370	61.5	25.38	67.51	13.25	12.77	6.01
5030203	19.07	2	13.62	1.22	1569	2585	41.06	76.87	23.62	10.69	3.19	3.72	6.46	310	43.9	11.29	85.98	7.24	3.47	0.89
5050001	27.29	42	36.53	1.54	1085	1844	48.85	68.51	32.64	7.29	4.01	11.7	22.43	410	74.7	32.76	62.75	13.23	16.22	7.78
5050002	32.1	1	21.97	1.19	1094	1802	51.96	77.6	23.38	7.65	8.56	9.16	14.43	350	57.5	19.18	77.42	8.2	8.42	2.68
5050003	13.29	9	19.63	0.9	1406	2243	51.97	85.59	15.33	3.84	2.34	8	11.41	340	55.2	16.9	79.78	6.36	6.99	3.38
5050004	75.54	4	13.3	1.54	1212	1949	49.59	91.35	7.07	6.06	5.63	4.18	6.71	300	42.1	8.36	85.59	7.81	4.5	1.17
5050005	30.07	3	8.73	0.88	1463	2298	48.37	93	6.18	4.17	2.55	2.74	4.15	280	36	5.62	90.18	4.88	2.36	0.33
5050006	197.63	-7	8.65	1.3	1359	2223	43.21	86.14	5.6	12.91	5.8	2.23	2.79	280	33.6	2.08	90.21	5.25	3.46	0.96
5050007	58.43	-6	5.84	1.15	1581	2525	43.8	89.31	9.39	8.85	2.31	2.48	3.77	270	33	3.7	93.57	4.07	1.14	0.13
5050008	111.07	-1	20.89	1.76	1457	2409	40.05	73.43	24.37	11.52	6.58	5.51	10.12	340	52.5	15.48	78.09	9.79	8.89	5.01
5050009	113.11	-4	6.66	0.98	1251	2038	42.62	89.72	7.24	11.79	5.33	1.9	2.79	270	32	2.51	92.86	4.8	1.8	0.54

HUC	POPDENS	POPCHG	UINDEX	RDDENS	NO3DEP	SO4DEP	OZAVG	RIPFOR	RIPCROP	STRD	DAMS	CROPSL	AGSL	STNO3L	STPL	PSOIL	FOR %	FORFRAG	EDGE7	EDGE65
5070101	46.89	-1	4.96	1.06	1093	1776	45.37	91.18	4.63	13.12	10.57	1.66	2	270	30.6	1.44	94.58	4.04	0.7	0.07
5070102	89.46	-2	11.25	1.34	1352	2206	41.48	76.25	24.92	15.16	3.57	3.42	6.2	290	39.4	7.54	88.27	6.73	4.22	1.93
5070201	45.03	-14	4.79	1.44	1118	1813	44.04	89.51	5.39	15.91	9.88	1.58	2.04	270	30.4	1.43	93.86	4.07	0.66	0.05
5070202	29.52	1	5.74	1.57	1071	1724	42.91	89.89	7.25	17.76	3.54	2.06	2.66	270	31.4	2.02	93.65	4.79	0.74	0.04
5070204	156.39	10	21.75	7.21	1356	2149	41.64	67.11	29.72	8.46	0	3.91	14.1	330	47.6	17.94	72.55	12.78	11.48	5.16
5090101	256.26	-2	27.73	10.33	1467	2380	39.98	63.35	30.67	6.08	2.73	6.46	12.72	370	62.3	20.14	65.78	13.45	12.89	11.44
5090102	40.7	1	8.47	1.16	1321	2128	42.08	83.85	17.93	13.68	2.68	1.81	5.21	280	33.9	5.69	90.62	5.95	2.08	0.47
6010101	34.4	2	24.27	1.02	967	1626	43.73	73.95	28.9	9.87	1.33	10.87	17.78	360	60.9	22.65	75.2	9.07	10.92	2.74
6010102	55.96	10	42.1	2.61	892	1508	45.1	58.16	39.9	10.01	2.67	12.85	25.7	430	80.8	39.61	57.39	13.75	26.24	15.38
6010205	40.31	11	25.27	1.44	1023	1701	42.3	73.3	26.25	12.62	3.72	10.47	17.86	360	60.3	22.06	74.35	10.38	11.68	4.91
6010206	45.63	17	27.38	1.82	1115	1857	41.3	73.13	25.79	9.85	4.27	10.62	17.87	370	63.7	23.19	72.24	11.23	12.31	3.99

HUC	EDGE600	INT7	INT65	INT600	INTALL	FORDIF	NDVI DEC	NDVI INC	NDVI TOT	1ST INC	1ST TOT	1ST DEC	NDVI 3%
2040101	0	62.69	50.4	36.04	30.52	0.0155	4.7	13.07	17.77	11.11	16.19	5.08	2.83
2040103	0	54.61	39.98	26.89	22.07	0.0152	6.46	15.42	21.87	15.63	21.71	6.08	3.13
2040104	0.14	77.92	73.06	69.84	61.22	0.0152	—	—	—	—	—	—	—
2040105	9.76	23.87	16.43	9.3	8.51	0.0767	18.3	22.81	41.11	20.39	38.88	18.49	5.29
2040106	14.43	45.83	38.43	31.15	27.7	0.1048	14.35	17.9	32.25	17.08	31.36	14.28	5.81
2040201	26.42	3.08	0.3	0	0	0.1835	26.11	15.88	42	13.78	41.34	27.56	3.9
2040202	43.52	5.41	1.21	0.07	0.07	0.1493	18.91	6.61	25.52	5.95	25.38	19.43	2.69
2040203	24.7	22.3	14.83	7.44	6.77	0.3117	16.96	21.95	38.92	21.32	38.56	17.24	5.65
2040205	19.32	8.13	2.16	0	0	0.2651	27.3	12.95	40.25	9.49	32.14	22.65	7.3
2040207	9.47	6.99	1.49	0.02	0.01	0.2807	—	—	—	—	—	—	—
2050101	0	57.64	41.62	22.75	18.92	0.0125	7.62	2.8	10.42	2.59	9.93	7.34	5.65
2050103	0.81	43.02	24.07	4.04	3.36	0.0533	7.66	4.84	12.5	4.42	12.42	8	5.26
2050104	0.54	40.59	29.37	19.69	17.48	0.4922	3.62	8.12	11.74	7.74	10.98	3.24	2.34
2050105	2.15	26.52	10.85	1.03	0.6	0.0884	2.8	13.76	16.56	12.77	15.25	2.48	1.48
2050106	0.39	37.38	23.12	13.38	12.34	0.0784	7.59	8.04	15.64	7.04	13.43	6.39	4.89
2050107	4.48	44.31	33.74	22.96	20.54	0.07	10.41	8.19	18.6	6.29	14.68	8.39	6.15
2050201	0.03	63.62	52.02	39.67	35.72	0.0124	9.11	7.76	16.88	8.17	16.76	8.59	6.12
2050202	0	92.46	90.25	91.07	85.92	0.0009	0.94	1.22	2.17	1.16	2.02	0.86	0.68
2050203	0.11	88.1	84.87	81.4	78.08	0.0384	1.15	1.8	2.95	1.16	1.91	0.75	0.62
2050204	5.51	56.51	48.15	32.95	30.97	0.0636	3.26	11.6	14.86	10.58	13.39	2.81	1.53
2050205	0.14	79.36	73.96	71.3	66.1	0.0212	1.22	3.61	4.83	3.94	5.03	1.09	0.79
2050206	9.62	54.26	47.31	41.31	37.99	0.1993	7.74	10.06	17.8	9.55	17.11	7.56	3.48
2050301	7.41	39.86	31.5	19.99	18.64	0.1601	6.16	22.09	28.25	21.69	27.58	5.89	3.22
2050302	2.76	57.02	48.66	34.95	32.45	0.3166	5.48	7.77	13.25	6.2	11.18	4.98	3.19
2050303	2.4	51.45	40.55	23.64	21.18	0.2825	10.49	3.88	14.37	3.39	12.28	8.89	6.25
2050304	2.03	55.69	45.13	29.66	27.32	0.067	4.05	13.46	17.51	12.1	15.63	3.53	2.41
2050305	29.21	33.89	28.9	21.51	20.56	0.1743	12.04	17.02	29.06	16.76	28.68	11.92	2.7
2050306	35.28	10.84	5.21	1.68	1.6	0.2377	24.86	10.98	35.83	10.14	35.93	25.79	10.04
2060002	10.2	10.75	4.23	0.87	0.77	0.2897	30.52	15.38	45.9	12.01	37.87	25.86	1.71
2060003	20.41	11.6	4.06	0.23	0.17	0.2996	18.93	17.63	36.55	12.89	27.43	14.54	8.7
2060004	2.96	27.46	14.16	2.8	2.4	0.2567	11.99	14.39	26.39	13.83	24.72	10.89	2.29
2060005	2.11	11.19	2.3	0.13	0.12	0.3541	—	—	—	—	—	—	—
2060006	6.92	17.44	6.64	0.63	0.49	0.3457	14.01	20.38	34.39	19.69	33.78	14.09	3.58
2060007	5.65	21.7	10.66	0.97	0.87	0.3306	—	—	—	—	—	—	—
2060008	2.33	19	7.07	0.61	0.56	0.3035	—	—	—	—	—	—	—
2060009	1.5	31.02	15.96	4.23	3.59	0.1198	—	—	—	—	—	—	—
2060010	12.82	10.26	2.94	0.26	0.2	0.4436	—	—	—	—	—	—	—
2070001	0.48	67.14	57.23	42.4	38.02	0.1305	2.01	13.49	15.49	11.94	13.67	1.73	1.54
2070002	0.04	65.74	53.74	37.31	31.94	0.0104	8.42	9.33	17.74	8.36	16.27	7.91	6.76
2070003	0.03	70.66	60.05	46.91	41.14	0.0061	7.9	3.4	11.3	2.4	8.87	6.47	6.26
2070004	21.35	32.09	24.13	14.71	13.43	0.1475	16.79	7.43	24.23	5.52	18.35	12.83	6.05
2070005	6.21	43.11	38.02	33.32	31.93	0.3419	10.43	13.15	23.58	9.33	17.31	7.98	7.82
2070006	5.26	49.5	43.02	36.29	33.5	0.0852	21.07	4.74	25.81	3.44	19.98	16.54	16.16
2070007	16.68	25.69	20.17	15.6	14.4	0.166	—	—	—	—	—	—	—
2070008	8.66	16.72	9.03	2.49	2.39	0.2607	13.64	22.01	35.65	19.76	33.54	13.78	4.76
2070009	37.89	15.47	11.12	7.9	7.31	0.1898	19.11	13.3	32.41	12.51	30.89	18.38	7.14
2070010	13.34	15.67	7.38	2.08	1.71	0.2979	12.08	26.16	38.24	23.93	36.16	12.23	3.18
2070011	0.83	36.16	21.41	7.88	6.74	0.194	10.09	20.27	30.36	16.44	25.27	8.83	1.31
2080102	0.2	48.65	31.48	13.05	11.45	0.0682	—	—	—	—	—	—	—
2080103	1.4	39.85	27.29	15.09	14.27	0.0638	5.34	19.22	24.56	15.65	20.48	4.83	1.59
2080104	3.51	33.6	19.55	7.21	5.94	0.1415	15.42	16.07	31.49	7.9	16.23	8.33	1.53
2080105	0	46.99	28.37	8.09	6.78	0.0276	13.5	12.05	25.55	11.55	25.95	14.4	0.91
2080106	0.23	42.67	25.97	8.57	7.06	0.045	10.77	14.48	25.26	13.82	24.65	10.83	0.71
2080107	3.33	33.94	18.94	4.75	3.89	0.0561	13.01	12.81	25.82	10.15	21.97	11.82	0.38
2080108	40.91	9.37	4.83	0.87	0.84	0.2398	—	—	—	—	—	—	—
2080109	4.21	13.65	3.75	0.11	0.05	0.3904	—	—	—	—	—	—	—

HUC	EDGE600	INT7	INT65	INT600	INTALL	FORDIF	NDVI DEC	NDVI INC	NDVI TOT	1ST INC	1ST TOT	1ST DEC	NDVI 3%
2080110	15.67	5.57	0.56	0	0	0.3528	—	—	—	—	—	—	—
2080201	0.01	76.55	69.05	58.63	55.34	0.0552	2.04	6.84	8.88	6.16	7.72	1.56	1.26
2080202	0.31	61.71	53.48	44.89	43.15	0.0493	1.44	16.81	18.25	13.72	14.73	1.01	0.85
2080203	0.21	62.04	49.98	36.17	32.21	0.0662	4.25	7.87	12.13	3.97	6.34	2.37	1.37
2080204	0.3	50.62	36.44	21.03	19.05	0.017	—	—	—	—	—	—	—
2080205	1.5	50.61	34.37	16.37	13.26	0.0307	8.06	14.86	22.92	13.75	21.91	8.16	1.02
2080206	3.85	33.96	20.57	8.22	7	0.1967	16.84	14.83	31.67	12.25	28.56	16.31	0.31
2080207	0.16	49.66	32.8	16.28	13.08	0.0274	11.33	10.27	21.6	10.21	22.07	11.86	1.34
2080208	31.24	11.51	4.69	0.62	0.6	0.2171	—	—	—	—	—	—	—
3010101	2.32	45.59	32.64	19.57	17.84	0.0352	6.54	2	8.55	1.62	7.16	5.54	3.16
3010102	0.01	40.49	22.25	5.61	4.49	0.0666	8.91	5.34	14.24	4.94	14.43	9.49	2.03
3010103	0	57.67	44.12	31.31	26.14	0.0158	3.84	3.54	7.38	3.49	7.08	3.59	1.89
3010104	0.21	41.28	23.17	7.14	5.7	0.0365	5.76	8.78	14.54	9.17	15.17	6	1.76
3010105	0.02	37.9	19.92	3.5	2.72	0.0157	7.1	4.27	11.37	4.26	12.11	7.85	2.48
3010106	0	37.96	19.78	5.43	4.39	0.075	9.28	4.71	13.99	4.79	14.6	9.81	2.31
3010201	0	47.98	30.31	11.43	9.45	0.018	19.73	7.89	27.62	8.22	29.04	20.82	0.88
3010202	0.03	37.22	18.84	4.94	4.24	0.0319	27.46	6.15	33.61	6.27	34.09	27.82	0.18
3010203	0	27.86	8.76	0	0	0.02	25.83	8.58	34.41	8.32	33.75	25.43	0.09
3010204	0	44.8	27.8	11.23	9.7	0.0187	10.52	12.67	23.2	14.19	25.65	11.46	1.56
3010205	2.72	35.31	27.07	18.57	18.15	0.2227	—	—	—	—	—	—	—
3040101	0	60.67	49.03	31.11	25.15	0.0026	2.73	2.45	5.18	2.51	4.85	2.34	1.88
4120101	5.82	19.82	6.26	1.55	1.31	0.194	—	—	—	—	—	—	—
4130002	0	47.84	32.74	18.68	15.68	0.0119	—	—	—	—	—	—	—
5010001	0	76.18	67.35	55.74	51.58	0.0108	—	—	—	—	—	—	—
5010002	0	51.79	35.22	15.49	13.37	0.0294	—	—	—	—	—	—	—
5010003	0	71.56	62.53	55.53	50.1	0.0211	—	—	—	—	—	—	—
5010004	0	28.38	11.56	1.56	1.38	0.207	—	—	—	—	—	—	—
5010005	0.04	70.06	61.51	53.3	49.42	0.0135	—	—	—	—	—	—	—
5010006	0.03	44.12	27.17	9.57	8.16	0.024	10.82	9.12	19.94	6.5	14.17	7.67	7.71
5010007	0.08	50.76	37.46	23.23	20.8	0.038	8.63	9.19	17.82	9.34	18.06	8.72	5.33
5010008	0.54	44.11	29.65	15.29	13.96	0.3209	5.81	9.53	15.34	9.64	15.43	5.79	3.84
5010009	2	29.9	15.34	3	2.04	0.0516	5.81	8.21	14.01	8.79	14.51	5.72	3.57
5020001	0.08	63.21	51.2	41.13	36.21	0.0247	3.89	8.87	12.77	8.48	12.05	3.57	2.79
5020002	0.04	44.65	26.22	9.3	7.35	0.0202	4.21	14.51	18.72	13.99	17.66	3.67	2.48
5020003	0.54	49.69	31.51	17.21	13.66	0.0777	4.26	12.24	16.5	10.77	14.73	3.96	2.63
5020004	0	74.06	65.63	58.37	52.02	0.009	2.92	5.31	8.23	5.11	7.99	2.88	2.22
5020005	2.38	27.37	12.41	3.15	2.73	0.1839	5.56	7.24	12.8	5.41	9.33	3.92	3.25
5020006	1.19	46.1	34.6	23.72	20.98	0.133	6.28	10.28	16.56	10.87	17.34	6.47	3.84
5030101	2.88	28.32	13.74	2.75	2.13	0.0937	—	—	—	—	—	—	—
5030102	1.19	10.02	1.22	0	0	0.3218	—	—	—	—	—	—	—
5030103	0.06	11.38	1.75	0	0	0.134	—	—	—	—	—	—	—
5030104	0.1	25.5	9.46	0.15	0.15	0.1971	—	—	—	—	—	—	—
5030105	0.06	23.79	9.89	1.96	1.65	0.1131	5.54	16.04	21.57	13.08	17.46	4.38	2.65
5030106	0.13	39.52	21.92	9.19	6.56	0.0372	—	—	—	—	—	—	—
5030201	0.03	68.27	57.06	47.82	37.49	0.0117	—	—	—	—	—	—	—
5030202	1.41	41.77	26.32	10.25	8.43	0.2004	—	—	—	—	—	—	—
5030203	0.16	68.59	58.65	48.55	39.75	0.0099	—	—	—	—	—	—	—
5050001	2.12	38.77	26.82	16.19	14.96	0.08	13.17	4.67	17.84	4.17	15.37	11.2	7.5
5050002	0.31	59.44	47.4	32.46	29.34	0.0236	—	—	—	—	—	—	—
5050003	0.42	65.77	56.66	47.25	42.89	0.0208	4.91	3.77	8.69	3.32	8.59	5.27	3.8
5050004	0.28	67.96	57.26	47.88	39.43	0.0142	—	—	—	—	—	—	—
5050005	0	78.63	72.19	67.43	59.85	0.0144	5.05	2.73	7.77	2.17	6.48	4.31	4.27
5050006	0.06	80.31	76.16	71.8	63.56	0.0067	—	—	—	—	—	—	—
5050007	0.01	84.73	80.66	80.63	70.8	0.0025	6.12	2.02	8.14	1.19	4.83	3.64	5.69
5050008	0.61	57.63	45.7	31.3	25.78	0.2334	—	—	—	—	—	—	—
5050009	0.01	83.41	80.34	81.19	70.46	0.0027	—	—	—	—	—	—	—

HUC	EDGE600	INT7	INT65	INT600	INTALL	FORDIF	NDVI DEC	NDVI INC	NDVI TOT	1ST INC	1ST TOT	1ST DEC	NDVI 3%
5070101	0	86.64	83.9	87.77	76.09	0.0011	—	—	—	—	—	—	—
5070102	0.24	73.52	67.08	62.67	52.92	0.0801	—	—	—	—	—	—	—
5070201	0	86.65	84.27	87.63	76.84	0.0117	—	—	—	—	—	—	—
5070202	0	84.12	82.57	82.89	72.68	0.001	—	—	—	—	—	—	—
5070204	0.61	50.41	38.03	20.94	16.39	0.1134	—	—	—	—	—	—	—
5090101	5.25	42.41	28.67	11.72	8.97	0.1194	—	—	—	—	—	—	—
5090102	0	77.05	70.78	68.35	58.04	0.0025	—	—	—	—	—	—	—
6010101	0	56.19	44.82	29.9	27.45	0.0545	—	—	—	—	—	—	—
6010102	3.73	38.6	31.54	22.9	21.64	0.2629	—	—	—	—	—	—	—
6010205	0.27	54.39	43.7	30.61	26.87	0.0516	—	—	—	—	—	—	—
6010206	0	50.48	40.56	30.39	25.64	0.0684	—	—	—	—	—	—	—

Suggested Further Reading

Appleton, E.L. 1995. A cross media approach to saving the Chesapeake Bay. Environ. Sci. Tech. 29:550–555.

Bourgeron, P.S. and M.E. Jensen. 1993. An overview of ecological principles for ecosystem management. Pp. 49–60 *in* Jensen, M.E., and P.S. Bourgeron (eds.), Eastside Forest Ecosystem Health Assessment, Vol II, Ecosystem Management: Principles and Applications. United States Forest Service, Missoula, Montana.

Cooper, S.R. 1995. Chesapeake Bay watershed historical land use: impact on water quality and diatom communities. Ecol. Appl. 5:703–723.

Correll, D.L., T.E. Jordan, and D.E. Weller. 1994. The Chesapeake Bay Watershed: effects of land use and geology on dissolved nitrogen concentrations. Pp. 639–648 *in* Toward a Sustainable Coastal Watershed, Chesapeake Research Consortium Publication No. 149.

EPA (Environmental Protection Agency). 1994. Landscape monitoring and assessment research plan. 620/R–94/009, United States Environmental Protection Agency, Office of Research and Development, Washington, D.C.

EPA (Environmental Protection Agency). 1995. Water quality functions of riparian forest buffer systems in the Chesapeake Bay Watershed. Report of the Nutrient Subcommittee of the Chesapeake Bay Program. EPA 903–R–95–004, United States Environmental Protection Agency, Annapolis, MD.

ESRI (Environmental Systems Research Institute). 1994. ARC/INFO Version 7. ESRI, Inc. Redlands, California.

Forman, R. T. T., and M. Godron. 1986. Landscape Ecology. John Wiley and Sons, NY.

Franklin, J. F. 1992. Scientific basis for new perspectives in forests and streams. Pp. 25–72 *in* R. J. Naiman (ed.). Watershed Management. Springer–Verlag, NY.

Frenzel, S.A., and R.B. Swanson. 1996. Relations of fish community composition to environmental variables in streams of central Nebraska, USA. Environ. Man. 20:689–795.

Golley, F.B. 1993. Development of landscape ecology and its relationship to environmental management. Pp. 37–44 *in* Jensen, M.E., and P.S. Bourgeron (eds.), East side Forest Ecosystem Health Assessment, Vol II, Ecosystem Management: Principles and Applications. United States Forest Service, Missoula, Montana.

Hunsaker, C.T., and D.E. Carpenter (eds.). 1990. Ecological indicators for the Environmental Monitoring and Assessment Program. EPA 600/3–90/060. U.S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, NC.

Hunsaker, C.T., D.A. Levine, S.P. Timmins, B.L. Jackson, and R.V. O'Neill. 1992. Landscape characterization for assessing regional water quality. Pp. 997–1006 *in* D.H. McKenzie, D.E. Hyatt, and V.J. McDonald (eds.), Ecological Indicators. Elsevier Appl. Sci., New York.

Hunsaker, C.T., and D.A. Levine. 1995. Hierarchical approaches to the study of water quality in rivers. Bioscience 45:193–203.

Jones, K.B., J. Walker, K.H. Riitters, J.D. Wickham, and C. Nicoll. 1996. Indicators of landscape integrity. Pp 155–168 *in* J. Walker and D.J. Reuter (eds.), Indicators of catchment health: a technical perspective. CSIRO Publishing, Melbourne, Australia.

Kepner, W.G., K.B. Jones, D.J. Chaloud, J.D. Wickham, K.H. Riitters, and R.V. O'Neill. 1995. Mid–Atlantic landscape indicators project plan. EPA 620/R–95/003, U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

Kuchler, A.H. 1964. Potential natural vegetation of the conterminous United States. American Geogr. Soc. Spec. Publ. No. 36, Washington, D.C.

Lapin, M., and B.V. Barnes. 1995. Using the landscape ecosystem approach to assess species and ecosystem diversity. Cons. Biol. 9:1148–1158.

Lowrance, R.R, R.L. Todd, J. Fail, O. Hendrickson, R. Leonard, and L.E. Asmussen. 1984. Riparian forests as nutrient filters in agricultural watersheds. BioScience 34:374–377.

Noss, R.F., and A.Y. Cooperrider. 1994. Saving Nature's Legacy: Protecting and Restoring Biodiversity. Island Press, Washington, D.C.

Ojima, D.S., K.A. Galvin, and B.L. Turner II. 1994. The global impact of land–use change. BioScience 44:300–304.

O'Neill, R.V., D.L. DeAngelis, J.B. Waide, and T.F.H. Allen. 1986. A Hierarchical Concept of Ecosystems. Princeton University Press, Princeton, NJ.

O'Neill, R.V., J.R. Krummel, R.H. Gardner, G. Sugihara, B.Jackson, D.L. DeAngelis, B.T. Milne, M.G. Turner, B. Zygmunt, S.W. Christensen, V.H. Dale, and R.L. Graham. 1988. Indices of landscape pattern. Landscape Ecol. 1:153–162.

O'Neill, R.V., C.T. Hunsaker, K.B. Jones, K.H. Riitters, J.D. Wickham, P. Schwarz, I.A. Goodman, B. Jackson, and W.S. Baillargeon. 1997. Monitoring environmental quality at the landscape scale. BioScience 47(8): 513-519.

Reckhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling phosphorous loading and lake response under uncertainty: A manual and compilation of export coeffiecients. U.S. Environmental Protection Agency, EPA 440/5-80-011.

Riitters, K.H, R.V. O'Neill, C.T. Hunsaker, J.D. Wickham, D.H. Yankee, S.P. Timmins, K.B. Jones, and B.L. Jackson. 1995. A factor analysis of landscape pattern and structure metrics. Landscape Ecol. 10:23–29.

Riitters, K.H., J.D. Wickham, and K.B. Jones. 1996. A landscape atlas of the Chesapeake Bay Watershed. Second Edition. Tennessee Valley Authority, Norris, TN. 29 pp.

Riitters, K.H., R.V. O'Neill, and K.B. Jones. 1997. Assessing habitat suitability at multiple scales: a landscape–level approach. Biol. Cons. 81:191–202.

Roth, N.E., J.D. Allan, and D.L. Erickson. 1996. Landscape influences on stream biotic integrity assessed at multiple scales. Landscape Ecology 11:141–156.

Saunders, D.A., R.J. Hobbs, and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Cons. Biol. 5:18–32.

Schlosser, I.J., and J.R. Karr. 1981. Water quality in agricultural watersheds: impact of riparian vegetation during base flow. Water Resources Bull. 17:233–240.

Sparks, R.E. 1995. Need for ecosystem management of large rivers and their floodplains. BioScience 45:168–182.

Turner, S. J., R. V. O'Neill, W. Conley, M. R. Conley, and H. C. Humphries. 1991. Pattern and Scale: Statistics for Landscape Ecology. Pp. 17–41 *in* M. G. Turner and R. H. Gardner (eds.). Quantitative Methods in Landscape Ecology. Springer–Verlag, NY.

Waring, R.H., and W.H. Schlesinger. 1985. Forest Ecosystems, Concepts and Management. Academic Press, Inc., Orlando.

Wickham, J.D., and D. Norton. 1994. Mapping and analyzing landscape patterns. Landscape Ecol. 9:7–23.

Wischmeier, W. H., and D. D. Smith. 1978. Predicting rainfall erosion loss: A guide to conservation planning. Agricultural handbook 537. U. S. Department of Agriculture, Washington, D.C.

Young, W.J., F.M.Marsten, and J.R. Davis. 1996 Nutrient exports and land use in Australian catchments. Journal of Environmental Management, 57: 165-183.