Comparison of Watershed Imperviousness Estimation Approaches

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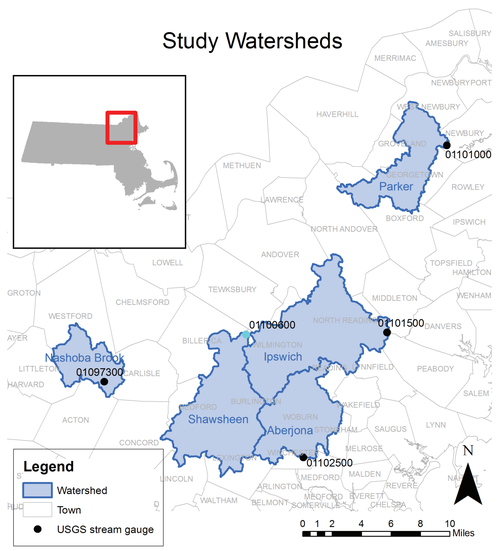
Overview

This study estimated the percent of impervious cover of five watersheds in northeastern Massachusetts using four different approaches, and compared the resulting estimates. The four approaches used different methods and data sources. Impervious cover includes surfaces such as roads, sidewalks and roofs that prevent precipitation from infiltrating into the soil. Despite the wide-ranging uses of imperviousness as an indicator in environmental and hydrologic research and policy, approaches to quantifying imperviousness vary and no clear guidelines have emerged to direct the choice of approach. This study sought to demonstrate the variation among watershed-scale imperviousness estimates based on the approach used.

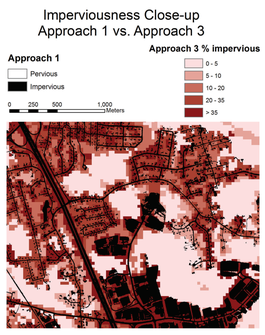


Methodology

Five watersheds with different levels of development were chosen. Four sets of watershed imperviousness estimates were generated in ArcGIS, using different methods and input datasets. Resulting estimates were compared in MS Excel.

Results

Table 1 compares the imperviousness estimates generated by the four approaches. Error statistics for Approaches 2, 3, and 4 were generated by comparing results against those from Approach 1. The figure at right shows a close-up of the Approach 1 imperviousness data on top of Approach 3 imperviousness data, to illustrate the relative precision of these data sources.



Conclusions

Approach 1 was assumed to be accurate. Of the other three approaches, Approach 3 appears most accurate, with the lowest bias, standard deviation, and root-mean-square error (RMSE). Given that Approach 3 used an inference method, with a set of coefficients, it is surprising that it should produce more accurate estimates than Approach 2, which used a direct method. Approaches 2 and 4 showed the most significant bias in watersheds with low levels of imperviousness, suggesting the special challenge of estimating imperviousness in less-developed areas. Approaches 2, 3, and 4 overestimated imperviousness 73% of the time. Given that the Approach 1 data was gathered several years after the other input datasets, and may be expected to reflect slightly greater imperviousness due to recent development, this suggests that the other three approaches are in general more likely to overestimate actual imperviousness than underestimate it.

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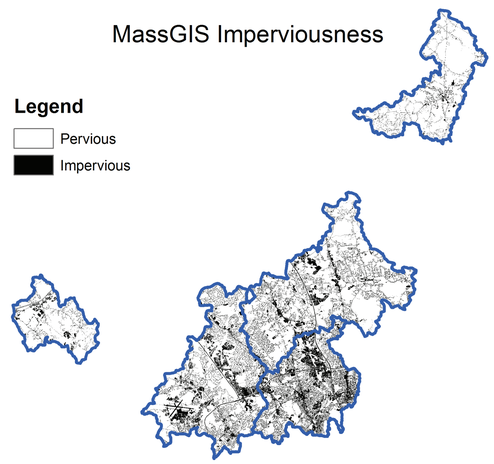
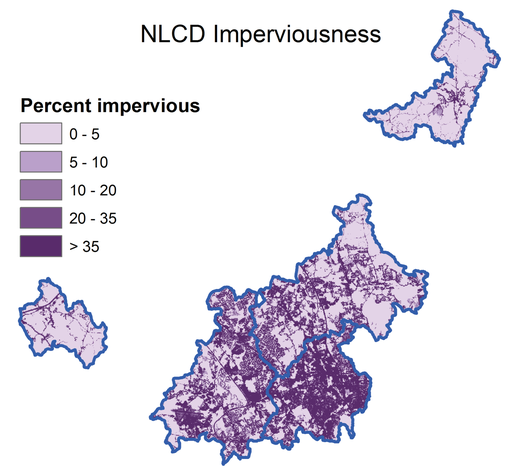
Approach 1 - Direct method based on MassGIS imperviousness

This approach was based on a Massachusetts imperviousness dataset with a cell size of one square meter and cell values of "0" for pervious or "1" for impervious. It was developed based on aerial imagery from 2005 combined with road network data. Approach 1 calculated the mean cell value for each watershed and multiplied it by 100 to represent the percentage of impervious cover of the watershed as a whole. This study assumed Approach 1 to be accurate in order to estimate the relative accuracy of the other approaches.



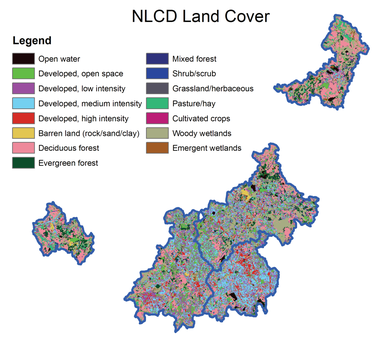
Approach 2 - Direct method based on NLCD imperviousness

This approach was based on the Percent Urban Imperviousness dataset from the National Land Cover Database (NLCD), which was developed based on 2001 satellite imagery. This dataset has a cell size of 30m by 30m, with cell values from 0 to 100, representing percent imperviousness. Approach 2 calculated the mean cell value for each watershed, which represented the percentage of impervious cover of the watershed as a whole.



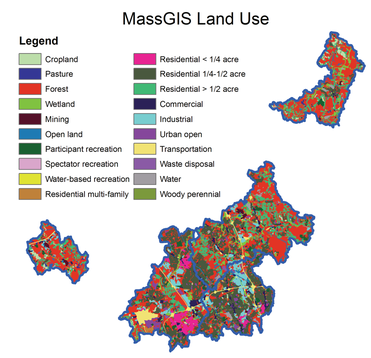
Approach 3 - Inference method based on NLCD land cover

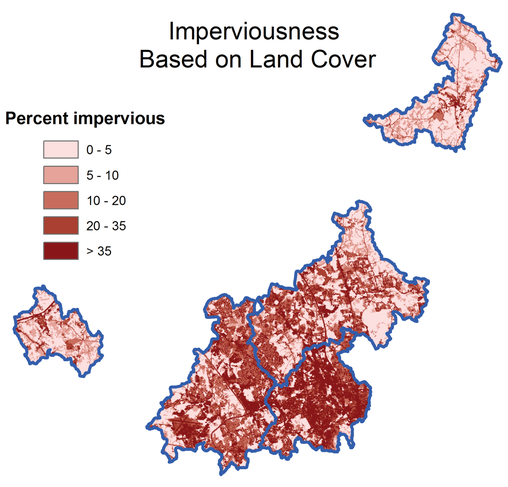
This approach was based on another dataset from the NLCD, also from 2001 and with 30m cell size. Cell values are numeric codes indicating land cover. Approach 3 translated the land cover value for each cell into a percent imperviousness value, based on a set of coefficients (Table 2) from a study done in Connecticut and upstate New York (*Civco et al 2006*). Imperviousness estimates were then calculated as the mean cell value for each watershed.

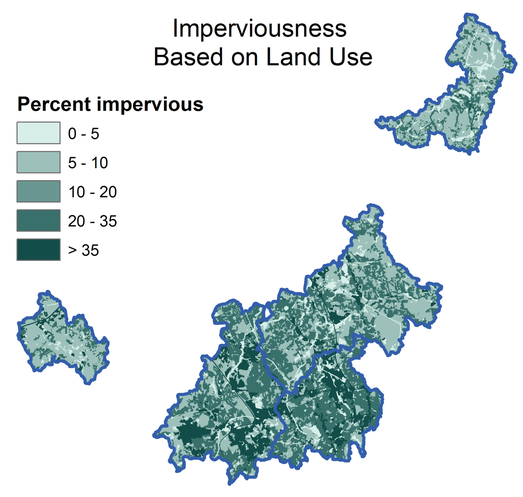


Approach 4—Inference method based on MassGIS land use

This approach was based on a land use dataset from MassGIS, interpreted from aerial color photography and updated as of 1999. Approach 4 translated the land use code for each 30m cell into a percent imperviousness value, based on a set of coefficients (Table 3) from a study done by the Massachusetts Office of Coastal Zone Management in the Parker River watershed (*Baker and Carlisle 2003*). Imperviousness estimates were then calculated as the mean cell value for each watershed.







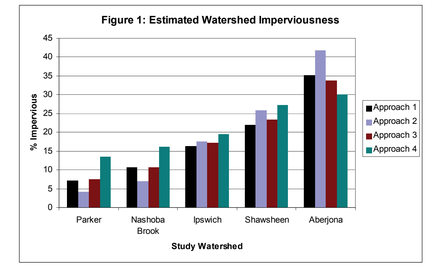
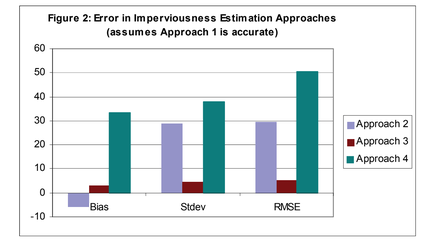


Table 1: Estimated Watershed Imperviousness

Study Watershed	Estimated Percent Impervious			
	Approach 1	Approach 2	Approach 3	Approach 4
Parker	7	4	8	14
Nashoba Brook	11	7	11	16
Ipswich	16	18	17	20
Shawsheen	22	26	23	27
Aberjona	35	42	34	30



Tables of Coefficients

Table 2: Land Cover Imperviousness Coefficients (from *Civco et al 2006*)

Land Cover Code	Description	Imperviousness Coefficient
11	Open water	1.1
21	Developed, open space	13.4
22	Developed, low intensity	29.1
23	Developed, medium intensity	48.7
24	Developed, high intensity	63.0
31	Barren land (rock/sand/clay)	24.7
41	Deciduous forest	4.1
42	Evergreen forest	8.0
43	Mixed forest	2.5
52	Shrub/scrub	6.8
71	Grassland/herbaceous	5.2
81	Pasture/hay	5.8
82	Cultivated crops	5.8
90	Woody wetlands	1.5
95	Emergent herbaceous wetlands	1.5

Table 3: Land Use Imperviousness Coefficients (from *Baker and Carlisle 2003*)

Land Use Code	Description	Imperviousness Coefficient
1	Cropland	9.0
2	Pasture	8.0
3	Forest	7.8
4	Wetland	5.5
5	Mining	6.7
6	Open land	2.9
7	Participation recreation	6.0
8	Spectator recreation	5.0
9	Water based recreation	34.3
10	Residential – multifamily	45.4
11	Residential - < ¼ acre	54.3
12	Residential – ¼ - ½ acre	30.5
13	Residential - > ½ acre	30.4
14	Salt wetland	1.5
15	Commercial	64.0
16	Industrial	54.7
17	Urban open	31.1
18	Transportation	50.8
19	Waste disposal	21.8
20	Water	2.9
21	Woody perennial	15.4

Data sources

MassGIS imperviousness: http://www.mass.gov/mgis/impervious_surface.htm
MassGIS land use: http://www.mass.gov/mgis/lus.htm
NLCD imperviousness: http://www.mrlc.gov/
NLCD land cover: http://www.mrlc.gov/
USGS stream gages: http://www.mass.gov/mgis/gages94.htm

References

Baker, J.D. and Carlisle, B.K. (2003). "Generating land use based impervious area coefficients using a random point methodology." Unpublished study, Massachusetts Office of Coastal Zone Management.

Civco, D., Chabaeva, A., and Hurd, J. (2006). "A Comparison of Approaches to Impervious Surface Characterization". IEEE International Geoscience And Remote Sensing Symposium.

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