A Comparison of Approaches to Impervious Surface Characterization

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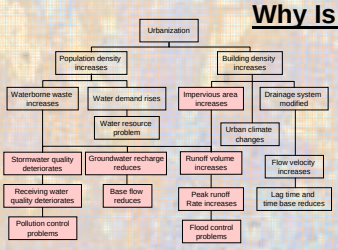
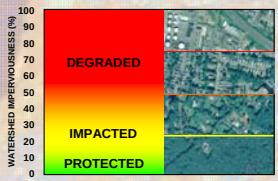
Why Is Impervious Surface Important?





Influence of Impervious Surfaces on Water Quality

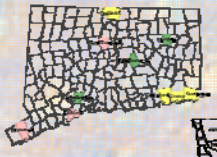
IS Measurement Methods

Interpretive Approach
- Digitizing
- Point sampling (Cover Tool method)

Modeling Approach
- Population Density-based
- **Impervious Surface Analysis Tool (ISAT)**
- **Regression Model**

Spectral Approach
- **Sub-pixel Classification**
- Artificial Neural Networks
- **Classification and Regression Tree (CART)**
- Normalized Difference Vegetation Index (NDVI)
- Vegetation-Impervious surface-Soil (VIS) model

Source Data

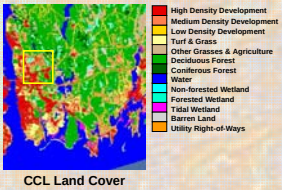


Connecticut towns from which planimetric data were obtained

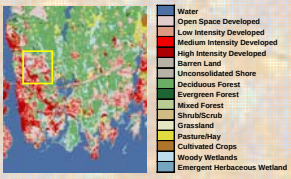
Census Tracts Town of Groton, CT

Planimetric data Town of Groton, CT

Landsat ETM Imagery



CCL Land Cover



NLCD Land Cover

Subpixel IS Estimates

CCL Imperviousness

NLCD Imperviousness

0%

100%

Photogrammetrically-derived planimetric data portraying the built landscape for ten towns in Connecticut served as validation data for each of the methods examined, and as calibration for all but one of the techniques (the NLCD 2001 impervious surface data set was developed independently of this project). Tracts for the 2000 census TIGER files served as the analysis unit over which actual and estimated imperviousness was summarized. For the ten towns there were a total of 82 census tracts. Landsat ETM data acquired in 2002 served as the basis for CCL land cover and CCL subpixel imperviousness.

Analysis Methods

Spectral Approaches

***Subpixel*: A single date Landsat ETM data was used for the extraction of CCL (Connecticut's Changing Landscape) land cover and subpixel imperviousness. Impervious surface estimates were derived directly from Landsat imagery using the Sub-pixel Classifier, an add-on module to ERDAS Imagine. Based on end members, SPC detects materials of interest as a whole or fractional component of an image pixel at 10 percent increments. Post-processing extracted only developed pixels from the land cover. Any developed pixel not containing an imperviousness value was assigned a value representing 10 – 20% imperviousness. The final result is a nine-class image representing imperviousness values from 10 percent to 100 percent at 10 percent increments.**

***CART*: As part of the NLCD 2001 program, estimates of percent imperviousness are being developed. Springtime leaf-off and summertime leaf-on Landsat ETM was used for NLCD land cover and imperviousness. Landsat ETM data and derived Tasseled Cap transform, along with ancillary data including elevation, slope, and a soil index, are used in a general classification and regression tree (CART) algorithm to produce rule-based models for prediction of continuous measures of imperviousness.**

Modeling Approaches

***ISAT*: The Impervious Surface Analysis Tool is an extension for ESRI's ArcView and ArcGIS that uses a set of coefficients to estimate the percent imperviousness for a given analysis unit. IS coefficients are derived from land cover and planimetric data. The IS estimate is calculated by taking the sum of the area of each land cover type within the analysis unit times the IS coefficient identified for that land cover type divided by the total area of the analysis unit. In these examples, ISAT was applied to both CCL land cover and NLCD land cover.**

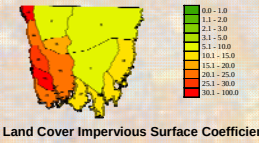
***Regression*: An extension of the land cover-based IS coefficients, regression model estimates of impervious surfaces include population density as a predictor. The general equation is:**

$$\text{Percent Imperviousness} = b_1 + (b_2 * \text{PopDen}) + (b_3 * \%A_{11}) + (b_4 * \%A_{21}) + \ldots\ldots (b_{22} * \%A_{98}),$$

where b_1 is an intercept, b_2, b_3, … b_{22} are the regression coefficients, PopDen is the population density, and $\%A_{11}$, $\%A_{21}$, …$\%A_{98}$ are percent values of different NLCD category areas within the tract.

Results

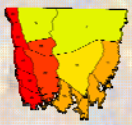
Actual Imperviousness



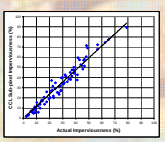
Land Cover Impervious Surface Coefficients

Category	Class #	Coefficient			Class #
	NLCD	Regression_{NLCD}	ISAT_{NLCD}	ISAT_{CCL}	CCL
High Intensity Developed	24	0.74	0.63	0.54	1
Medium Intensity Developed	23	0.43	0.49	0.34	2
Low Intensity Developed	22	0.22	0.29	0.19	3
Developed Open Space	21	0.18	0.13	0.13	4
Grassland	71	0	0.05	0.04	5
Pasture/Hay	81	0	0.05		
Cultivated	82	0	0.06		
Deciduous Forest	41	0	0.03	0.02	6
Mixed Forest	43	0	0.03		
Scrub/Shrub	52	0	0.07		
Evergreen Forest	42	0.52	0.08	0.03	7
Water	11	0	0.01	0.01	8
Palustrine Aquatic Bed	98	0	0.01		
Palustrine Emergent Wetland	96	0	0.02	0.01	9
Palustrine Forested Wetland	91	0	0.02	0.01	10
Palustrine Scrub/Shrub Wetland	92	-1.21	0.01		
Estuarine Scrub/Shrub Wetland	94	0	0.01	0.02	11
Estuarine Emergent Wetland	97	0	0.03		
Bare Land	31	-0.87	0.25	0.15	12
Unconsolidated Shore	32	0	0.17		
Utility ROW	N/A	N/A	N/A	0.02	13
Population Density	N/A	0.00	N/A	N/A	N/A

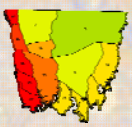
Subpixel IS Estimates



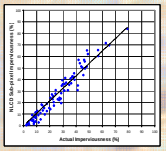
CCL Imperviousness



$R^2 = 0.95$ RMSE = 7.47

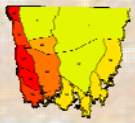


NLCD Imperviousness

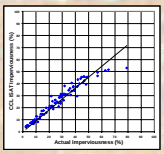


$R^2 = 0.93$ RMSE = 5.76

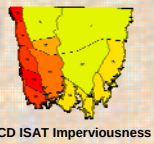
ISAT IS Estimates



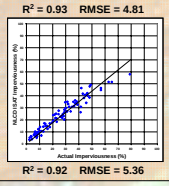
CCL ISAT Imperviousness



$R^2 = 0.93$ RMSE = 4.81

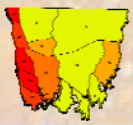


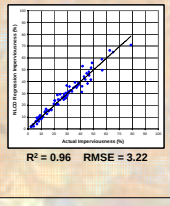
NLCD ISAT Imperviousness



$R^2 = 0.92$ RMSE = 5.36

NLCD Regression IS Estimates



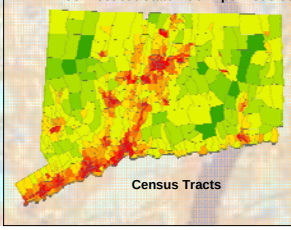


$R^2 = 0.96$ RMSE = 3.22

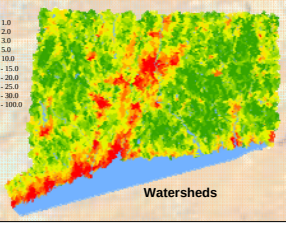
Conclusions

There are advantages and disadvantages to each of the impervious surface estimation methods examined. The higher accuracy achieved with the population and land cover-based regression model is especially appealing because of the wide availability of NLCD and population data. In addition, the model is fairly easy to implement within a GIS. It can be adapted and recalibrated to different analysis units such as census blocks or watersheds. On the other hand, the spectral approaches, while seemingly less accurate when examined at the tract level, do offer the advantage of being spatially explicit – that is, they provide positionally-specific (at the pixel resolution) imperviousness estimates, rather than a homogenous (*lumped*) measure as do the other methods.

Connecticut Statewide Impervious Surface Estimates Based on Regression Method



Census Tracts



Watersheds

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