Assessment of 2001 NLCD Percent Tree and Impervious Cover Estimates

Eric J. Greenfield, David J. Nowak, and Jeffrey T. Walton

Abstract

The 2001 National Land Cover Database (NLCD) tree and impervious cover maps provide an opportunity to extract basic land-cover information helpful for natural resource assessments. To determine the potential utility and limitations of the 2001 NLCD data, this exploratory study compared 2001 NLCD-derived values of overall percent tree and impervious cover within geopolitical boundaries with aerial photo interpretation-derived values for the same areas. Results of the comparison reveal that NLCD underestimates tree cover and to a lesser extent, underestimates impervious cover. The underestimate appears to be consistent across the conterminous United States with no statistical differences among regions. However, there were statistical differences in the degree of underestimation of tree cover among mapping zones and of impervious cover by population density class.

Introduction

Tree and impervious cover data provide important information to help environmental professionals understand and effectively manage natural resources. The United States Geological Survey (USGS) 2001 National Land Cover Database (NLCD) (USGS, 2007) presents an opportunity to extract such cover information throughout the conterminous United States.

The U.S. Department of Agriculture Forest Service is updating a 2000 assessment of the Nation's urban forest cover (Dwyer *et al.*, 2000; Nowak *et al.*, 2001) with more recent national tree cover and census data. This assessment, a requirement of the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974, will detail how urban tree resources and urbanization vary across the conterminous United States. The assessment uses 30 m resolution 2001 NLCD tree, impervious, and classified land-cover maps and the 2000 United States Census Bureau (U.S. Census) data and cartographic boundaries (U.S. Census, 2007) to provide summary statistics to state and local governments regarding their urban forest resource and associated ecosystem services. In checking satellite-derived 2001 NLCD tree cover estimates against field-derived tree cover values in various cities (Nowak *et al.*, 2006, 2007a, and 2007b), it was noted that 2001 NLCD tree cover values may be underestimating tree cover within local government boundaries (e.g., Philadelphia, Pennsylvania: field estimate = 15.7 percent tree cover, NLCD = 10.7 percent tree cover; Minneapolis, Minnesota: field = 26.4 percent, NLCD = 11.3 percent; San Francisco, California: field = 11.9 percent, NLCD = 6.1 percent).

The USGS cautions against using the data for applications at the local level (e.g., city, county) because of its relatively coarse resolution and regional generalization (USGS, 2007). However, the apparent underestimation of tree cover in urban areas warranted further exploration into whether it represents a consistent pattern of underestimation across the United States.

This study explores and analyzes the potential differences between 2001 NLCD estimates of overall percent tree and percent impervious cover within various geopolitical boundaries (i.e., counties, incorporated, or census-designated places) and overall percent cover derived by a photo interpretation method for the same geopolitical boundaries. Although a formal accuracy assessment of the 2001 NLCD is forthcoming (Stehman *et al.*, unpublished), the study reported here investigates the potential utility and limitations of 2001 NLCD tree and impervious cover data for local to national applications.

2001 NLCD

In 2007, the Multi-Resolution Land Characteristics Consortium released 2001 NLCD 30 m resolution data for tree, impervious, and classified land-cover for the conterminous United States (USGS, 2007; Homer *et al.*, 2007). The data production was a cooperative effort among 12 mapping teams from the both the private and public sectors supervised by the USGS Center for Earth Resources Observation and Science (EROS). Utilizing standardized data preparation, classification, and quality control protocols documented in Homer *et al.* (2004), 65 distinct mapping zones for the continental United States were used to develop the NLCD from circa 2001 Landsat-5 and Landsat-7 imagery (Homer and Gallant, 2001; Huang *et al.*, 2001; Yang *et al.*, 2003; Homer *et al.*, 2007). Each mapping zone represented relative homogeneity with respect to landform, soil, vegetation, spectral reflectance, and image footprints at a project scale that was affordable. Preliminary estimates of accuracy were generated from a cross-validation technique utilizing the algorithms and training data for each mapping zone (USGS, 2007; Homer *et al.*, 2007). The classified land-cover map has an average accuracy of 83.9 percent; the tree cover values

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have an average error ranging from 6 to 17 percent; and the impervious cover values have an average error ranging from 4 to 17 percent (USGS, 2007; Homer *et al.*, 2007).

This research investigates potential differences between 2001 NLCD and photo-interpreted estimates of overall percent tree and percent impervious cover values within various geopolitical units, and explores whether potential differences are related to geography or population density.

Methods

To obtain a representative sample for the continental United States that reflected general physical geographic variation (landform, climate, vegetation, soils), the 65 NLCD mapping zones were aggregated into five larger regions of similar features (Figure 1) based on established taxonomy represented in the United States Environmental Protection Agency (USEPA) ecoregions (USEPA, 2007). Four mapping zones from each of the five regions were randomly selected. Within each of the four mapping zones, one incorporated or census designated place (U.S. Census, 2007) was randomly selected from each of seven population density classes (0 to 99.9 people/mi^2; 100 to 249.9 people/mi^2; 250 to 499.9 people/mi^2; 500 to 749.9 people/mi^2; 750 to 999.9 people/mi^2; 1,000 to 4,999.9 people/mi^2; >5,000 people/mi^2); and one county with its boundary completely within the mapping zone was randomly selected (Figure 2).

NLCD 2001 estimates of overall tree and impervious cover percentages for each sampled place and county were derived from geographic information system software. Cover values were extracted from 2001 NLCD maps bounded by 2000 US Census cartographic geopolitical boundaries registered with the original NLCD 2001 layers in a USGS USA Contiguous Albers Equal Area Conic projected coordinate system.

Using the same census geographic boundaries, 200 random points (a simple random sampling design using a dot matrix) were placed in each sample county and place boundary polygon. The points were converted and transformed into a Google Earth™ compatible format (Google, Inc., 2007) and layered on Google Earth™ aerial images available during the summer of 2007. Photo interpretation was used to estimate tree and impervious cover, guided by methods described in Nowak *et al.* (1996).

A photo interpreter classified each point as either trees (yes/no), impervious surface (yes/no), or non-interpretable image. Imagery with medium to coarse resolution (e.g., 30 m resolution) or atmospheric obstructions (clouds) was considered non-interpretable. As reflected in the 2001 NLCD, tree and impervious cover designations are not mutually exclusive (e.g., tree cover, over sidewalk, or road), and the photo interpreters were instructed to determine if the tree canopy covered an impervious surface, in which case it was classified as both tree and impervious. If more than 100 points (50 percent) fell on non-interpretable imagery, the county or place was dropped from the analysis and a new county or place was randomly selected. Overall, 60 percent of the original county and 30 percent of the original place selections were replaced because of poor image quality.

Seven individuals conducted photo interpretation and one individual monitored the quality of the original interpretation by reinterpreting the original sample points as a paired comparison. Place or county selections with less than 95 percent agreement in interpretation were reinterpreted by another photo interpreter and rechecked.

Within each county and place, the percentage of tree or impervious cover (p) was calculated as the number of sample points (x) hitting the cover attribute divided by the total number of interpretable sample points (n) within the area of analysis ($p = x/n$). The standard error of the estimate (SE) was calculated as $SE = \sqrt{\frac{p*(1-p)}{n}}$ (Lindgren and

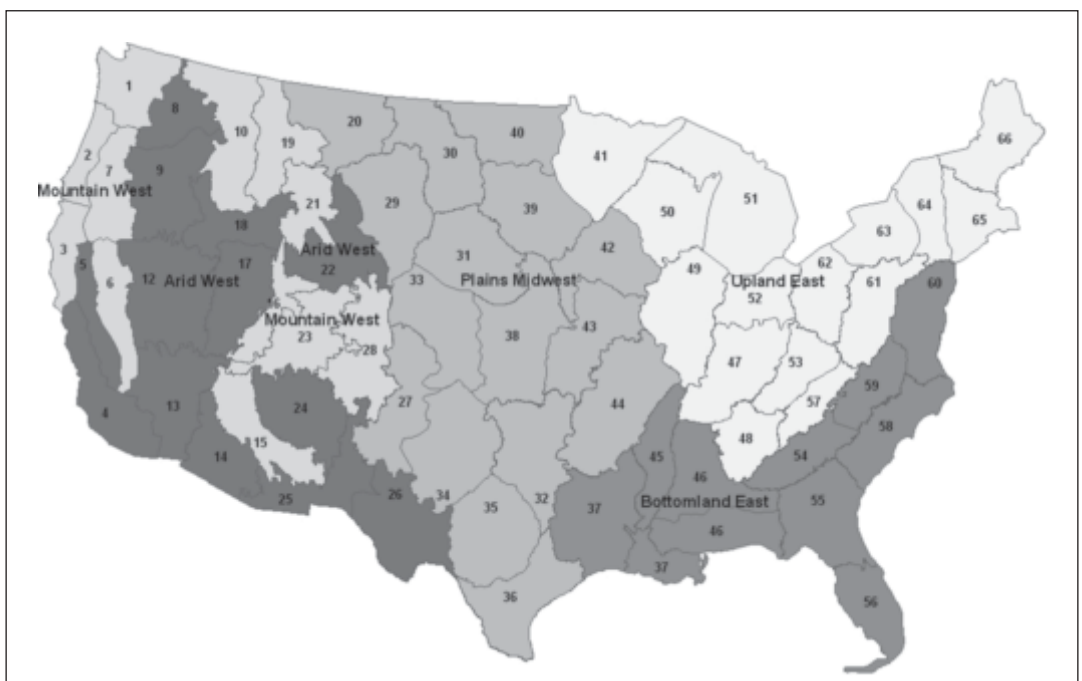

Figure 1. 2001 NLCD mapping zones aggregated into five regions based on established taxonomy represented in the United States Environmental Protection Agency (USEPA) ecoregions (USEPA, 2007). There are 65 zones (map zone 11 does not exist).

Figure 2. Sampling design illustrating selected mapping zones, counties, and places. Selected incorporated or census designated places and counties were delimited using cartographic boundary files from US Census (2007). Two-hundred random points (based on a simple random sampling design using a dot matrix) were placed in each selected geography for photo interpretation.

McElrath, 1969). To be conservative with this analysis, a 99 percent confidence interval was calculated as $p \pm 2.6 * SE$.

Wilcoxon signed rank tests ($\alpha = 0.05$) were conducted to determine if photo interpreted and NLCD values significantly differed among the places, the counties, and among all values (places and counties combined). To illustrate differences between the photo interpreted and NLCD values, photo interpreted values with a 99 percent confidence interval were contrasted with the NLCD values. To test if the differences between photo interpreted and NLCD values were influenced by regions, mapping zones, and population density classes, Kruskall-Wallis tests ($\alpha = 0.05$) were conducted. To test if photo interpreted and NLCD values differed between the collections of counties and places, Wilcoxon two sample tests ($\alpha = 0.05$) were also conducted. A Spearman correlation ($\alpha = 0.05$) was used to test if the variation of differences between photo interpreted and NLCD values were correlated with the variation of NLCD tree or impervious cover estimates.

Results

There were statistically significant differences between the photo interpretation-derived and 2001 NLCD-derived percent tree and impervious cover values. Overall, NLCD underestimated percent tree cover relative to the photo interpretation method by a mean of 9.7 percent and underestimated impervious cover by a mean of 5.1 percent (Table 1; Figure 3 and Figure 4). In 63.9 percent of the comparisons, NLCD-derived tree cover estimates were outside the 99 percent confidence interval of the photo-derived values. In 35.4 percent of comparisons, NLCD-derived impervious cover estimates were outside the 99 percent confidence interval of photo-derived values (Figures 5 and Figure 6). Illustrative of the general trend of NLCD underestimation, NLCD underestimated photo-derived tree cover by at least 1 percent in 94.5 percent of the places and 100 percent of the counties sampled. NLCD underestimated impervious cover in 95.3 percent of the places and 80 percent of the counties sampled (Table 1).

The differences between photo-derived and NLCD-derived tree and impervious cover estimates were not significant among the five regions (Table 2). However, the differences between photo and NLCD-derived values did vary significantly among mapping zones for tree cover (Table 2 and Table 3)

TABLE 1. SUMMARY OF DIFFERENCES BETWEEN PHOTO INTERPRETED AND 2001 NLCD ESTIMATES (PHOTO INTERPRETED MINUS NLCD) FOR TREE AND IMPERVIOUS COVER WITHIN COUNTIES, PLACES, AND COUNTIES AND PLACES COMBINED (ALL)

	Tree Cover Differences							
	n[a]	Mean	Median	CV[b]	Minimum	Maximum	PI > NLCD[c]	p[d]
All	147	9.7%	9.1%	74.7%	−6.0%	29.5%	95.2%	< 0.0001
Places	127	9.7%	9.1%	73.2%	−6.0%	29.5%	94.5%	< 0.0001
Counties	20	9.3%	8.8%	86.5%	0.9%	27.7%	100.0%	< 0.0001
	Impervious Cover Differences							
	n	Mean	Median	CV	Minimum	Maximum	PI > NLCD	p
All	147	5.1%	4.1%	93.8%	−4.3%	25.3%	93.2%	< 0.0001
Places	127	5.7%	4.8%	84.6%	−4.3%	25.3%	95.3%	< 0.0001
Counties	20	1.3%	0.6%	149.0%	−0.7%	6.7%	80.0%	0.0023

[a] sample size
[b] coefficient of variation
[c] percent of photo interpreted values that are at least 1 percent greater than NLCD derived values.
[d] p-value of signed rank t-test: probability that there is no statistically significant difference between photo interpreted and NLCD derived values.

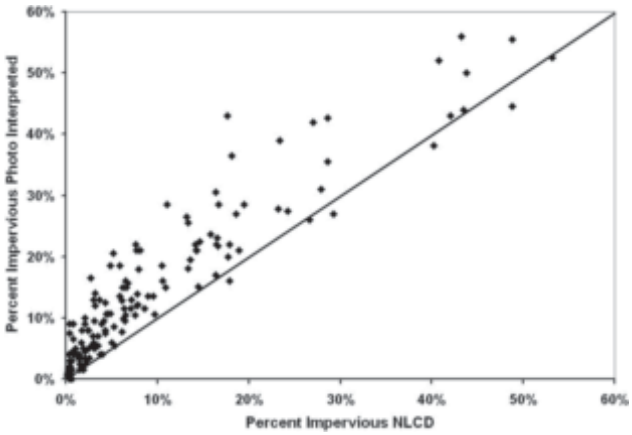

Figure 3. Relationship of 2001 NLCD-derived values to photo interpreted values for percent impervious cover. Reference line indicates a 1:1 relationship.

and among population density classes for impervious cover (Table 2, Table 4, and Table 5).

The mean difference for percent tree cover of NLCD and photo values was not significant between the collections of counties versus places, but the mean difference was significant for percent impervious cover (Table 2). NLCD underestimated impervious cover by an average of 1.3 percent in counties and 5.7 percent in places (Table 1) compared to photo-derived estimates of the same locales.

The difference between photo and NLCD impervious cover was positively correlated (greater differences with higher impervious cover values) with NLCD-derived percent impervious cover ($p = <0.0001$, $r = 0.335$). There was no significant correlation ($p = 0.33$) in tree cover differences with NLCD-derived percent tree cover.

Discussion

Differences are expected between NLCD and photo interpretation-derived values based on previously reported NLCD mapping accuracy (Homer *et al.*, 2007; USGS, 2007). However,

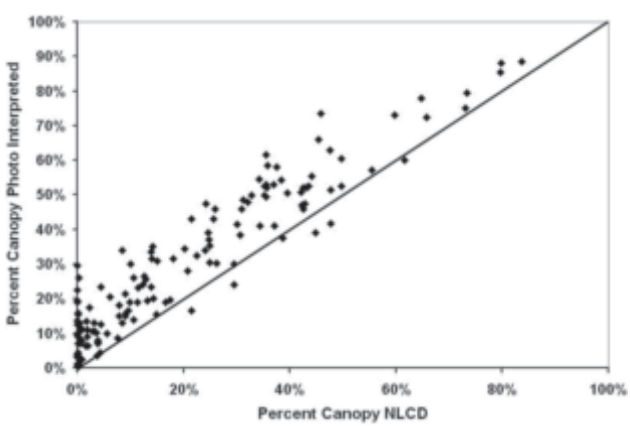

Figure 4. Relationship of 2001 NLCD-derived values to photo interpreted values for percent tree cover. Reference line indicates a 1:1 relationship.

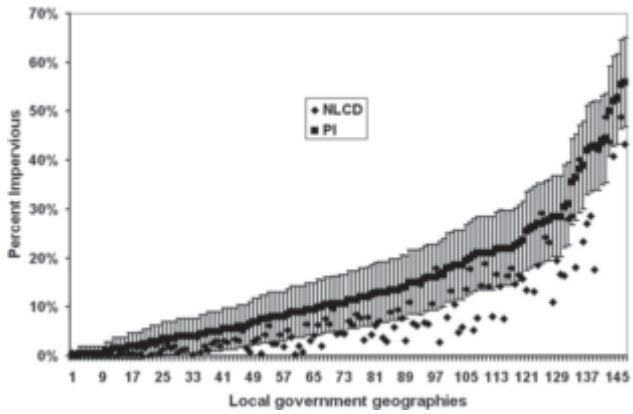

Figure 5. 2001 NLCD versus photo interpretation derived impervious cover percentages for places and counties. Error bars represent 99 percent confidence interval for the photo interpreted sample points. The figure illustrates that 35.4 percent of the comparisons of the photo interpretation derived impervious cover percentages fell outside the 99 percent confidence interval. The *x*-axis refers to individual reference numbers of the local government geographies sampled because there were too many to list. Photo interpreted data was arranged from low (left) to high impervious cover (right).

for unbiased estimates of cover the errors between over- and under-estimation should be equally distributed and not biased in one direction as this study revealed. Based on the comparison with photo-derived values, it appears that NLCD cover estimates may be biased toward underestimating tree and impervious cover values.

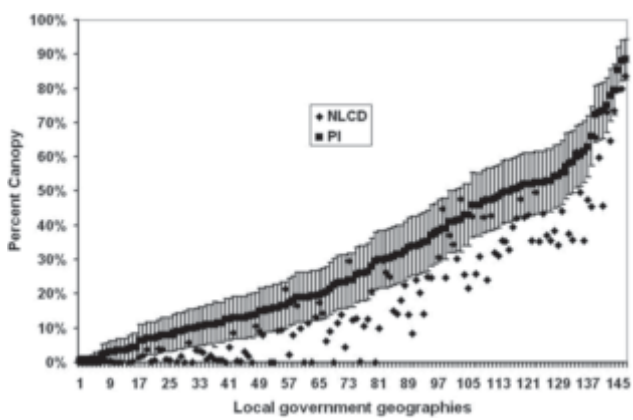

Figure 6. 2001 NLCD versus photo interpretation derived tree cover percentages for places and counties. Error bars represent 99 percent confidence interval for the photo interpreted sample points. The figure illustrates that 63.9 percent of the comparisons of the photo interpretation derived impervious cover percentages fell outside the 99 percent confidence interval. The *x*-axis refers to individual reference numbers of the local government geographies sampled because there were too many to list. Photo interpreted data was arranged from low tree cover (left) to high tree cover (right).

TABLE 2. KRUSKALL-WALLIS OR WILCOXON TWO SAMPLE TEST VALUES (PROBABILITY GREATER THAN TEST STATISTIC) FOR DIFFERENCES IN TREE AND IMPERVIOUS COVER AMONG REGIONS, MAPPING ZONES, AND POPULATION DENSITY CLASSES, AND BETWEEN COUNTY AND PLACES

	Tree Cover			
	Region	Mapping Zone	Population Density Class[a]	County vs. Place
All	0.1684	0.0014*	0.5902	0.5006
Places	0.3014	0.0145*	0.5214	NA
Counties	0.5296	NA	0.9245	NA
	Impervious Cover			
	Region	Mapping Zone	Population Density Class	County vs. Place
All	0.2723	0.2963	< 0.0001*	< 0.0001*
Places	0.1257	0.0849	0.0047*	NA
Counties	0.0604	NA	0.0026*	NA

[a] see text for density class definitions
* statistically significant at $\alpha = 0.05$

Underestimation of percent tree cover by 2001, NLCD maps has been reported for urban areas in mapping zone 63 (western New York State) (Walton, 2008). However, our study reveals that tree cover underestimation is evident beyond urban areas and across mapping zones. In addition, this study illustrates that underestimation applies to impervious cover values as well, but to a lesser degree. Because tree and impervious cover percentages were underestimated at the county level, which included both urban and rural counties, this underestimate likely occurs throughout the conterminous United States, but at varying degrees depending upon mapping zone (for tree cover) or population density class (impervious cover). Further research is warranted to explore potential differences in tree cover estimates among all mapping zones.

TABLE 3. MEAN DIFFERENCE BETWEEN PHOTO INTERPRETED AND 2001 NLCD ESTIMATES (PHOTO INTERPRETED MINUS NLCD) FOR TREE AND IMPERVIOUS COVER, BY NLCD 2001 MAPPING ZONE FOR COUNTIES AND PLACES

	Tree Cover		Impervious Cover	
Map Zone	Counties	Places	Counties	Places
1	1.7%	8.7%	1.6%	3.2%
3	27.7%	12.2%	0.2%	5.2%
8	0.9%	5.3%	−0.4%	5.9%
12	0.9%	9.4%	0.4%	7.2%
16	21.5%	8.3%	−0.4%	11.8%
19	8.6%	11.8%	0.3%	5.2%
25	10.3%	13.2%	−0.7%	7.8%
26	25.7%	14.3%	0.2%	9.1%
27	1.0%	7.8%	0.8%	5.0%
29	15.4%	8.7%	0.2%	7.0%
30	1.7%	7.8%	1.3%	3.6%
44	9.0%	11.1%	0.1%	4.6%
45	6.3%	1.7%	2.6%	9.2%
51	3.5%	9.1%	0.0%	1.6%
56	11.7%	14.0%	1.9%	6.0%
57	5.8%	8.4%	1.5%	7.0%
58	10.9%	15.5%	1.0%	4.1%
59	11.3%	14.5%	6.7%	6.0%
62	9.5%	10.9%	5.6%	3.1%
63	2.8%	1.2%	2.8%	3.9%

Some variation in estimates between NLCD and photo interpretation may be due to a time difference between the 2001 NLCD satellite based estimate and Google Earth™ aerial photo interpretation. As most of the dates of aerial images on Google Earth™ are from mid 2000s, the differences exhibited in impervious surfaces from the circa 2001 NLCD estimates may reflect rapid development i.e., urban areas will tend to increase over time leading to increased population density and impervious surfaces (Nowak and Walton, 2005). However, this difference in the date of imagery probably would not have an impact on tree cover underestimates. Tree cover would not likely increase significantly within a few years, and is more likely to decrease as population and development increases.

Differences between 2001 NLCD and photo interpretation method estimates could be caused by photo interpretation errors, but this error is likely minimal because all photo interpretation samples were re-evaluated as part of the quality control procedures.

Another possible source for differences between the two estimation methods may be a potential bias caused by the varied resolutions and quality of aerial images. Image resolution in interpretable areas often appeared to have meter to sub-meter resolution, making interpretation of cover types straightforward.

During the study, it was observed within the Google Earth™ imagery that areas of high population density had more high-resolution imagery available than rural areas. This potential for bias is not significant since sample replacements for poor quality images of places were taken from the same population density class. Counties were not sampled by population density class, but potential bias is likely small as 65 percent of the counties analyzed were in the lowest population density class. While the low resolution of Google Earth™ imagery may be problematic in some areas, it provides a convenient source of quality imagery for many areas of the conterminous United States.

The percent tree cover differences between NLCD and the photo interpretation method vary significantly among mapping zones (Tables 2 and Table 3). The variation among zones may be explained by the protocols implemented to create the 2001 NLCD (Huang *et al.*, 2001; Yang *et al.*, 2003; Homer *et al.*, 2004; Homer *et al.*, 2007). First, the mapping zones were designed to be geographically homogeneous (Homer and Gallant, 2001) so the variation may reflect the varying geography among the zones (e.g., topography, vegetation types). Second, variation among the zones could be explained by potential differences in how 12 different mapping teams conducted data preparation, classification, and quality control. Teams developed unique algorithms for each zone to produce the classified land-cover, percent tree cover, and percent impervious cover estimates (Homer *et al.*, 2007). The processing and classification scheme used sub-pixel classification derived from higher resolution training imagery selected by the individual groups developing the cover maps (Homer *et al.*, 2007). Algorithms developed from training sites selected from primarily rural areas may differ substantially from algorithms developed from training sites from more urban or heterogeneous landscapes. Further testing of NLCD accuracy among mapping zones is needed and more accurate 2001 NLCD data quality information will be available after a formal assessment is completed (Stehman *et al.*, unpublished).

No statistical differences in the 2001 NLCD underestimation of tree cover relative to the photo interpretation method were found among regions or population density classes, indicating that neither the general ecoregion (forested, grassland, and arid) nor concentrations of humans (a proxy for human development and impervious surfaces) affect the degree of tree cover underestimation.

TABLE 4. DIFFERENCES IN TREE COVER BETWEEN PHOTO INTERPRETATION AND 2001 NLCD VALUES (PHOTO INTERPRETED MINUS NLCD) SORTED BY POPULATION DENSITY CLASS FOR PLACES, COUNTIES, AND COUNTIES AND PLACES COMBINED (ALL); IN THIS STUDY, NO COUNTIES OF POPULATION DENSITY CLASSES 3, 5, 6, AND 7 WERE SELECTED

	All by population density class						
	1[a]	2[b]	3[c]	4[d]	5[e]	6[f]	7[g]
Mean	10.8%	8.1%	8.1%	10.2%	10.1%	11.0%	7.9%
Median	8.4%	7.7%	6.9%	9.2%	9.8%	12.7%	7.0%
CV[h]	85.0%	64.5%	68.9%	67.6%	68.4%	77.8%	72.0%
Minimum	0.5%	−1.1%	0.4%	0.2%	−5.8%	−6.0%	0.5%
Maximum	29.5%	17.3%	23.3%	22.7%	19.7%	22.5%	20.0%
PI > NLCD[i]	100.0%	92.0%	100.0%	100.0%	90.0%	85.0%	100.0%
n	32	25	20	22	20	20	8
	Places by population density class						
	1	2	3	4	5	6	7
Mean	11.3%	8.1%	8.1%	10.5%	10.1%	11.0%	7.9%
Median	8.2%	7.5%	6.9%	9.2%	9.8%	12.7%	7.0%
CV	81.2%	69.7%	68.9%	65.9%	68.4%	77.8%	72.0%
Minimum	0.5%	−1.1%	0.4%	0.2%	−5.8%	−6.0%	0.5%
Maximum	29.5%	17.3%	23.2%	22.7%	19.7%	22.5%	20.0%
PI > NLCD	100.0%	90.0%	100.0%	100.0%	90.0%	85.0%	100.0%
n	19	20	20	20	20	20	8
	Counties by population density class						
	1	2		4			
Mean	10.1%	8.2%		6.5%			
Median	8.6%	9.5%		6.5%			
CV	94.4%	44.9%		104.0%			
Minimum	90.0%	2.8%		1.7%			
Maximum	27.7%	11.7%		11.3%			
PI > NLCD	100.0%	100.0%		100.0%			
n	13	5		2			

[a] Population density class 1: 0–99.9 people/mi^2
[b] Population density class 2: 100–249.9 people/mi^2
[c] Population density class 3: 250–499.9 people/mi^2
[d] Population density class 4: 500–749.9 people/mi^2
[e] Population density class 5: 750–999.9 people/mi^2
[f] Population density class 6: 1,000–4,999.9 people/mi^2
[g] Population density class 7: >5,000 people/mi^2
[h] Coefficient of variation
[i] Percent of photo interpreted values that are at least 1% greater than NLCD derived values
n: sample size

Although the degree of 2001 NLCD underestimation of impervious cover compared with photo interpretation did not vary among the five regions or 65 mapping zones, population density appears to affect the degree of underestimation, with increasing population density associated with greater underestimation. The degree of underestimation was also significantly different between county and place estimates, which likely reflects population density differences between counties and places (places generally having higher population density). The reported difference in impervious cover at the county scale (1.3 percent) (Table 1), though statistically significant, is likely of little practical significance. The average reported cover difference by mapping zone or population density class is not designed to get at the true overall difference for the zone or class, but rather to determine if there is variation among cover estimate differences.

Conclusions

When compared to photo interpreted results, the 2001 NLCD appears to underestimate tree cover and, to a lesser extent, impervious cover values in the same sampled geography. These underestimates vary by mapping zone for tree cover and by population density class for impervious cover. This exploratory study reveals that further analyses are needed to understand the degree of underestimation and potential reasons for underestimation across the United States. Despite this underestimation, 2001 NLCD tree cover estimates appear to be consistent within mapping zones, indicating that relative comparison of tree cover within mapping zones are reasonable. However the extent of NLCD underestimation of cover will need to be determined for each mapping zone to obtain more accurate estimates of the actual amount of tree cover within mapping zones, or for comparison among zones,.

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TABLE 5. DIFFERENCES IN IMPERVIOUS COVER BETWEEN PHOTO INTERPRETATION AND 2001 NLCD VALUES (PHOTO INTERPRETED MINUS NLCD) SORTED BY POPULATION DENSITY CLASS FOR PLACES, COUNTIES, AND COUNTIES AND PLACES COMBINED (ALL); IN THIS STUDY, NO COUNTIES OF POPULATION DENSITY CLASSES 3, 5, 6, AND 7 WERE SELECTED

	All by population density class						
	1[a]	2[b]	3[c]	4[d]	5[e]	6[f]	7[g]
Mean	1.6%	4.6%	4.4%	6.8%	7.0%	7.4%	7.6%
Median	1.1%	3.6%	4.0%	6.0%	6.2%	7.0%	9.0%
CV[h]	112.6%	70.1%	55.2%	71.8%	59.1%	99.8%	92.7%
Minimum	−0.7%	0.0%	0.3%	−0.6%	−1.9%	−2.2%	−4.3%
Maximum	6.7%	10.9%	9.0%	17.5%	14.4%	25.3%	15.0%
PI > NLCD[i]	87.5%	100.0%	100.0%	95.5%	95.0%	90.0%	75.0%
n	32	25	20	22	20	20	8
	Places by population density class						
	1	2	3	4	5	6	7
Mean	2.5%	5.1%	4.4%	7.1%	7.0%	7.4%	7.6%
Median	2.4%	5.7%	4.0%	6.1%	6.2%	7.0%	9.0%
CV	71.5%	66.6%	55.2%	70.5%	59.1%	99.8%	92.7%
Minimum	0.3%	0.0%	0.3%	−0.6%	−1.9%	−2.2%	−4.3%
Maximum	6.7%	10.9%	9.0%	17.5%	14.4%	25.3%	15.0%
PI > NLCD	100.0%	100.0%	100.0%	95.0%	95.0%	90.0%	75.0%
n	19	20	20	20	20	20	8
	Counties by population density class						
	1	2		4			
Mean	0.3%	2.8%		4.1%			
Median	0.2%	2.6%		4.1%			
CV	224.3%	62.9%		86.1%			
Minimum	−0.7%	1.0%		1.6%			
Maximum	1.5%	5.6%		6.7%			
PI > NLCD	69.2%	100.0%		100.0%			
n	13	5		2			

Population density class 1: 0–99.9 people/mi^2
[b] Population density class 2: 100–249.9 people/mi^2
[c] Population density class 3: 250–499.9 people/mi^2
[d] Population density class 4: 500–749.9 people/mi^2
[e] Population density class 5: 750–999.9 people/mi^2
[f] Population density class 6: 1,000–4,999.9 people/mi^2
[g] Population density class 7: >5,000 people/mi^2
[h] Coefficient of variation
[i] Percent of photo interpreted values that are at least 1% greater than NLCD derived values
n: sample size

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