Criterion 8:

URBAN AND COMMUNITY FORESTS

The importance of urban and community forests

Urban and community forests are the trees and forests found in cities, towns, villages, and communities. This category of forest includes both forested stands and trees along streets, in residential lots, and parks. These trees within cities and communities provide many ecosystem services and values to both urban and rural populations. These benefits include:

- Carbon sequestration and storage
- Removal of air pollution, improving air quality; absorption of ultraviolet radiation; and reduced noise pollution
- Reduced air temperature, improving human comfort and reducing building energy use
- Reduced stormwater runoff, improving water quality
- Improved aesthetics contributing to human physiological and psychological well-being
- Community cohesion and increased property values

Key Findings for Criterion 8

- In the North, 80 percent of the population lives in urban areas which cover 6 percent of the region's land base.
- Urban and community lands together cover 8.5 percent of the North. The State with the highest percent urban or community land is New Jersey at 44.2 percent; the lowest percent is Vermont at 2.9 percent.
- Nationally, States with the greatest increase in percentage of urban land between 1990 and 2000 were in the North: Rhode Island (5.7 percent), New Jersey (5.1 percent), Connecticut (5.0 percent), Massachusetts (5.0 percent), Delaware (4.1 percent), and Maryland (3.0 percent).
- Most of the urbanization in the North in the 1990s occurred in agricultural (42 percent) and forested (37 percent) areas.
- Of the 11 conterminous States that had greater than half of all urban development occur within forests in the 1990s, seven were in the North, including the top two (Rhode Island and Connecticut).
- Overall tree cover in the North is 46.8 percent, with the highest percent tree cover in New Hampshire (88.9 percent) and the lowest in Iowa (10.4 percent).
- Within urban or community lands in the North, tree cover averages 39 percent while impervious cover averages 20 percent. Tree cover in urban or community lands ranged from a high of 67 percent in Connecticut to a low of 19 percent in Iowa.
- Tree cover in urban or community areas provides numerous and valuable ecosystem services.

Urban forest in Central Park in New York City.

Urban and community areas are defined by two U.S. Census Bureau definitions that overlap. Urban land is all the territory, population, and housing units located within urbanized areas or urban clusters, each with a core population density of 1,000 people per square mile and with surrounding areas that have lower population densities (U.S. Census Bureau 2007). Community lands are places that have geopolitical boundaries (such as cities, towns, or unincorporated named places) that may include all, some, or no urban land within their boundaries. As seen in Figure 55, urban land can be found outside community boundaries, and not all areas within communities are urban.

Urban land encompasses the more heavily populated areas (population density-based definition), and community land encompasses both urban and rural (non-urban) communities that are recognized by their geopolitical boundaries (political definition); and both definitions provide information about human settlements and the forest resources within those settlements. As some urban land exists beyond community boundaries and not all community land is urban (communities are often a mix of urban and rural land), the category of "urban or community" was created to understand forest attributes accumulated by the union of these two terms. People in the Northern States depend heavily on both urban and rural forests to sustain quality of life. The majority of people in the Northern States live in urban areas, so healthy urban trees and forests are particularly important for the quality of their environment, their health, and their well-being.

This section describes the extent of urban and community forests and their spatial distribution, and it provides estimates of some of their ecosystem services and values. Though the Montréal Criteria and Indicators could be applied to forests and trees in northern urban areas, much of the data that would be needed are not available, especially data on conservation of soil and water resources (Criterion 4), enhancement of long-term multiple socioeconomic benefits (Criterion 6), and legal, institutional and policy frameworks for sustainable management (Criterion 7).

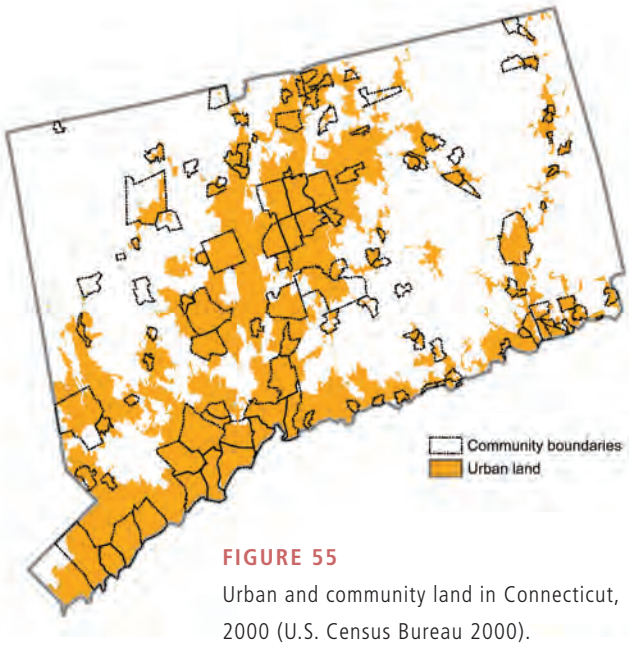


FIGURE 55
Urban and community land in Connecticut, 2000 (U.S. Census Bureau 2000).

However, data on biological diversity (Criterion 1), productive capacity (Criterion 2), ecosystem health (Criterion 3), and contributions to the global carbon cycle (Criterion 5) are partially available for cities that have completed urban forest assessments: New York, Syracuse, Baltimore, Minneapolis, Chicago, Boston, Jersey City, Philadelphia (Nowak et al. 2006a, 2006b, 2007a, 2007b). The focus of these assessments has been on monitoring, quantifying, and comparing the cumulative effects of urban forest ecosystem structure (such as species composition, size distribution, tree health, and leaf area) on ecosystem services and values (such as carbon storage and sequestration, energy use in buildings, air pollution removal, air temperature, stream flows, and water quality). Understanding and quantifying these relationships can lead to improved management plans in urban areas to sustain ecosystem and human health for future generations, but not without detailed data that are currently unavailable and have yet to be added to the U.S. Forest Service inventory and analysis protocols (Cumming et al. 2007, 2008; Nowak et al. 2007c).

Indicators for northern urban and community forests

Urban and community land in the North

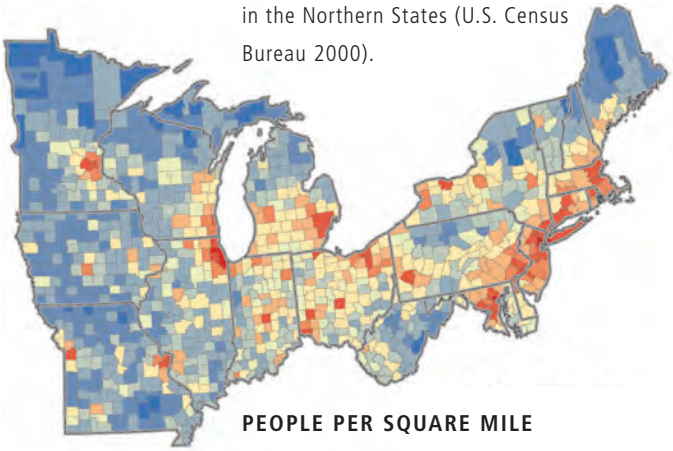
In 2000, 95 million people (80 percent) in the North lived in urban areas, and 86 million (71 percent) lived in communities (Table 25, Fig. 56). Six percent of the land was in urban areas, 6.3 percent was in communities, and 8.5 percent was in the combined urban or community category. Proportion of urban land varied from 1.1 percent in Maine to 38 percent in New Jersey (Table 26; Figs. 57 and 58). The U.S. areas with the highest percent urban land were the Northeastern States (10 percent) and the Southern Atlantic States (8 percent for Florida, Georgia, North Carolina, South Carolina, and Virginia combined). Areas with most urban land were the Northeastern (13 million acres) and North Central States (12 million acres), which together comprise the North (Nowak et al. 2005).

Urban growth in the North, 1990 to 2000

Urban land in the conterminous United States increased from 2.5 percent in 1990 to 3.1 percent in 2000, an increase in area about

FIGURE 56

Population density by county, 2000, in the Northern States (U.S. Census Bureau 2000).

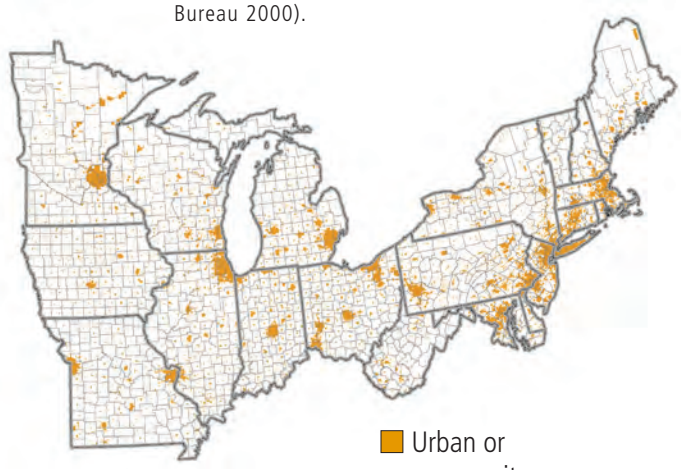


PEOPLE PER SQUARE MILE

- 3.1 to 10.0
- 10.1 to 25.0
- 25.1 to 50.0
- 50.1 to 75.0
- 75.1 to 100.0
- 100.1 to 250.0
- 250.1 to 500.0
- 500.1 to 1,000.0
- 1,000.1 to 5,000.0
- 5,000.1 to 66,940.1

FIGURE 57

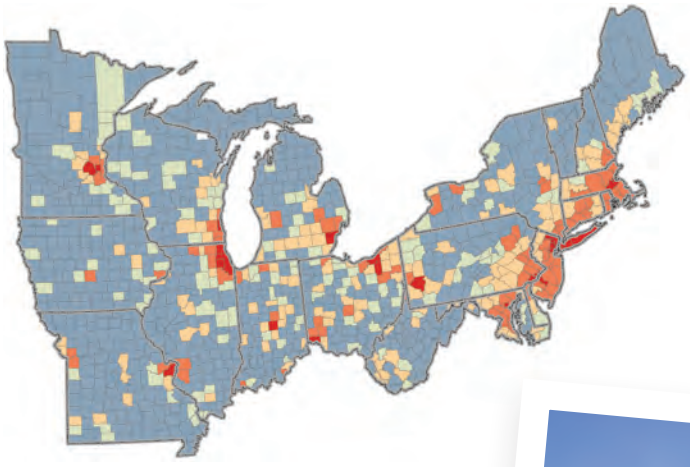
Urban or community land, 2000, in the Northern States (U.S. Census Bureau 2000).



- Urban or community land

FIGURE 58

Percent of county area classified as urban or community land, 2000, in the Northern States (U.S. Census Bureau 2000).



PERCENT

- 0
- 0.1 to 5
- 5.1 to 10
- 10.1 to 25
- 25.1 to 75
- 75.1 to 100

the size of Vermont and New Hampshire combined. States with the largest percentage increases (Table 27) were Rhode Island (5.7 percent), New Jersey (5.1 percent), and Connecticut and Massachusetts (5.0 percent each). Seven Northeastern States are among the 10 States with the greatest increase in percent urban land. States with the greatest absolute increase in urban land, were Florida (925,000 acres), Texas (871,000 acres), and California (737,000 acres).

Hartford, Connecticut

Table 25—Population characteristics in the Northern States and urban and community areas ordered from highest to lowest percent urban population.

State	Total for the State			Urban areas[a]				Communities[b]			
	Population, 2000 (1,000)	Percent change from 1990	Density (people per square mile)	Population, 2000 (1,000)	Population percent of State total	Percent change from 1990	Density (people per square mile)	Population, 2000 (1,000)	Population percent of State total	Percent change from 1990	Density (people per square mile)
New Jersey	8,414	8.9	1,136	7,939	94.4	14.9	2,847	6,059	72.0	10.5	3,064
Massachusetts	6,349	5.5	810	5,801	91.4	14.4	2,078	4,512	71.1	6.5	2,561
Rhode Island	1,048	4.5	1,004	953	90.9	10.4	2,477	746	71.1	2.5	3,446
Illinois	12,419	8.6	224	10,910	87.8	12.8	3,072	10,749	86.6	10.5	2,761
Connecticut	3,406	3.6	703	2,988	87.7	14.9	1,697	2,029	59.6	4.6	2,180
New York	18,976	5.5	403	16,603	87.5	9.5	4,241	15,351	80.9	6.1	4,164
Maryland	5,296	10.8	542	4,559	86.1	17.2	2,523	4,246	80.2	12.4	2,319
Delaware	784	17.6	401	628	80.1	29.0	2,084	345	44.0	34.6	2,004
Ohio	11,353	4.7	278	8,782	77.4	9.2	2,214	8,012	70.6	4.1	2,032
Pennsylvania	12,281	3.4	275	9,464	77.1	15.6	2,233	7,167	58.4	0.3	2,247
Michigan	9,938	6.9	175	7,419	74.7	13.2	2,233	6,384	64.2	5.1	2,219.7
Minnesota	4,919	12.4	62	3,490	70.9	14.2	2,331	3,939	80.1	16.3	996
Indiana	6,080	9.7	170	4,304	70.8	19.6	1,967	3,999	65.8	38.4	1,810
Missouri	5,595	9.3	81	3,883	69.4	10.5	2,142	3,862	69.0	8.7	1,344
Wisconsin	5,364	9.6	99	3,664	68.3	14.1	2,261	3,790	70.7	9.3	1,434
Iowa	2,926	5.4	53	1,787	61.1	6.2	2,204	2,272	77.6	6.7	1,178
New Hampshire	1,236	11.4	138	732	59.3	29.5	1,309	586	47.5	7.1	918
West Virginia	1,808	0.8	75	833	46.1	28.5	1,498	760	42.0	-1.2	1,010
Maine	1,275	3.8	41	513	40.2	-6.4	1,459	598	46.9	-2.3	498
Vermont	609	8.2	66	232	38.2	28.3	1,598	213	35.0	2.3	1,032
North total	120,079	6.9	186	95,485	79.5	13.1	2,489	85,617	71.3	8.2	2,094
Conterminous U.S. total	279,585	13.2	95	220,841	79.0	18.9	2,411	204,782	73.2	16.6	1,539

[a] *All the territory, population, and housing units located within urbanized areas or urban clusters, each with a core population density of 1,000 people per square mile and with surrounding areas that have lower population densities (U.S. Census Bureau 2007).*

[b] *Places that have geopolitical boundaries (such as cities, towns, or unincorporated named places) that may include all, some, or no urban land within their boundaries.*

Table 26—Urban and community land in Northern States ordered from highest to lowest percent urban or community land.

State and region	State land area	Proportion in urban[a] land	Proportion in community[b] land	Proportion in urban or community land
	(1,000 acres)	(percent)		
New Jersey	4,743	37.6	26.7	44.2
Massachusetts	5,018	35.6	22.5	40.4
Connecticut	3,099	36.4	19.2	39.9
Rhode Island	668	36.8	20.7	39.4
Maryland	6,252	18.5	18.7	23.4
Delaware	1,250	15.4	8.8	17.8
Ohio	26,123	9.7	9.7	12.6
Pennsylvania	28,633	9.5	7.1	12.4
New York	30,120	8.3	7.8	10.8
New Hampshire	5,749	6.2	7.1	10.3
Illinois	35,465	6.4	7.0	8.7
Indiana	22,895	6.1	6.2	8.1
Michigan	36,301	5.9	5.1	7.3
Wisconsin	34,652	3.0	4.9	5.6
Minnesota	50,866	1.9	5.0	5.2
Missouri	43,983	2.6	4.2	4.7
Maine	19,809	1.1	3.9	4.2
West Virginia	15,371	2.3	3.1	4.1
Iowa	35,681	1.5	3.5	3.6
Vermont	5,915	1.6	2.2	2.9
North total	412,594	6.0	6.3	8.5
Conterminous U.S. total	1,891,769	3.1	4.5	5.4

[a]*All the territory, population, and housing units located within urbanized areas or urban clusters, each with a core population density of 1,000 people per square mile and with surrounding areas that have lower population densities (U.S. Census Bureau 2007).*

[b]*Places that have geopolitical boundaries (such as cities, towns, or unincorporated named places) that may include all, some, or no urban land within their boundaries.*

Boston, Massachusetts

Autumn 'White Oaks' (Quercus alba) & prairie grasses, Waubonsie State Park, Iowa

Table 27—U.S. urban growth, 1990 to 2000 (Nowak et al. 2005).

State and region	Urban growth (acres)	Urban growth (percent of state)	Ranking for urban growth percent
Connecticut	159,000	5.0	3
Delaware	53,100	4.1	5
Maine	25,600	0.1	42
Maryland	199,400	3.0	6
Massachusetts	260,600	5.0	4
New Hampshire	103,100	1.7	11
New Jersey	253,100	5.1	2
New York	273,800	0.9	19
Pennsylvania	554,700	1.9	9
Rhode Island	40,500	5.7	1
Vermont	13,900	0.2	34
West Virginia	69,800	0.5	27
Northeast total	2,006,500	1.5	
Illinois	365,500	1.0	18
Indiana	287,200	1.2	15
Iowa	55,300	0.2	41
Michigan	381,900	1.0	17
Minnesota	150,800	0.3	32
Missouri	162,800	0.4	29
Ohio	363,500	1.4	13
Wisconsin	186,300	0.5	25
North Central total	1,953,400	0.7	
North total	3,959,900	1.0	
Florida	924,500	2.5	7
Georgia	694,800	1.8	10
North Carolina	653,600	2.0	8
South Carolina	286,700	1.4	12
Virginia	269,600	1.0	16
Southern Atlantic total	2,829,200	1.8	
Alabama	230,900	0.7	21
Arkansas	113,600	0.3	31

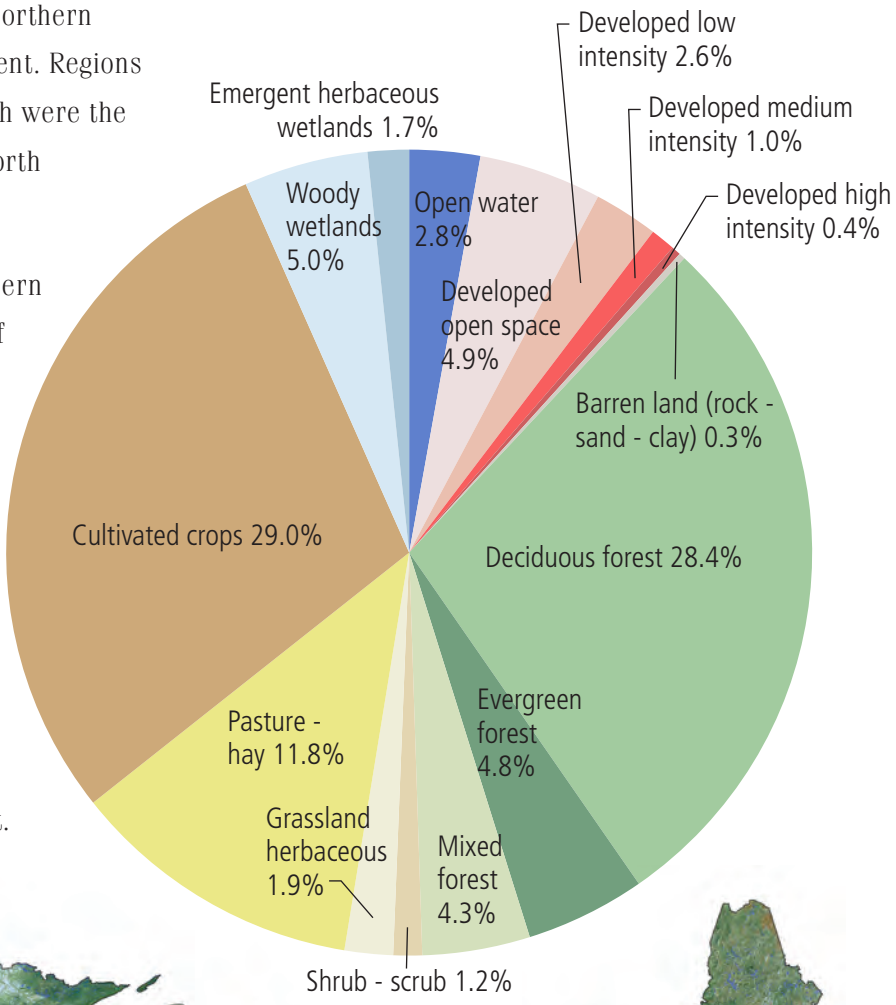
Table 27 continued

State and region	Urban area (acres)	Urban area change (percent of state)	Ranking for urban area change in 2000
Kentucky	135,200	0.5	24
Louisiana	164,200	0.5	23
Mississippi	108,600	0.4	30
Oklahoma	95,600	0.2	35
Tennessee	359,800	1.3	14
Texas	870,700	0.5	26
Mid-south total	2,078,700	0.5	
Kansas	90,400	0.2	38
Nebraska	41,200	0.1	44
North Dakota	13,000	0.0	45
South Dakota	12,900	0.0	47
Great Plains total	157,500	0.1	
Arizona	308,200	0.4	28
Colorado	165,200	0.2	33
Idaho	58,800	0.1	43
Montana	24,800	0.0	46
Nevada	132,300	0.2	37
New Mexico	129,500	0.2	39
Utah	90,200	0.2	40
Wyoming	12,000	0.0	48
Rocky Mountain total	920,900	0.2	
California	737,300	0.7	20
Oregon	119,100	0.2	36
Washington	275,700	0.6	22
Pacific Coast total	1,132,100	0.5	
Conterminous U.S. total	11,078,300	0.6	

The Motor City: Detroit, Michigan

In aggregate, the Southern Atlantic States had the largest percentage increase in urban land (1.8 percent), followed by the Northeastern States (1.5 percent). For all the Northern States, the increase was 1.0 percent. Regions with largest absolute urban growth were the South (5 million acres) and the North (4 million acres).

Most of the urbanization in Northern States occurred at the expense of agricultural (42.2 percent) and forested (37.0 percent) lands (Table 28, Fig. 59). Eleven of the 48 conterminous States had more than half of the total development occur within forests; of these, seven were Northern States, and two (Rhode Island and Connecticut) were at the top of the national list.



LAND COVER

- Open water
- Developed, open space
- Developed, low intensity
- Developed, medium intensity
- Developed, high intensity
- Barren land (rock-sand-clay)
- Deciduous forest
- Evergreen forest
- Mixed forest
- Shrub-scrub
- Grassland-herbaceous
- Pasture-hay
- Cultivated crops
- Woody wetlands
- Emergent herbaceous wetlands

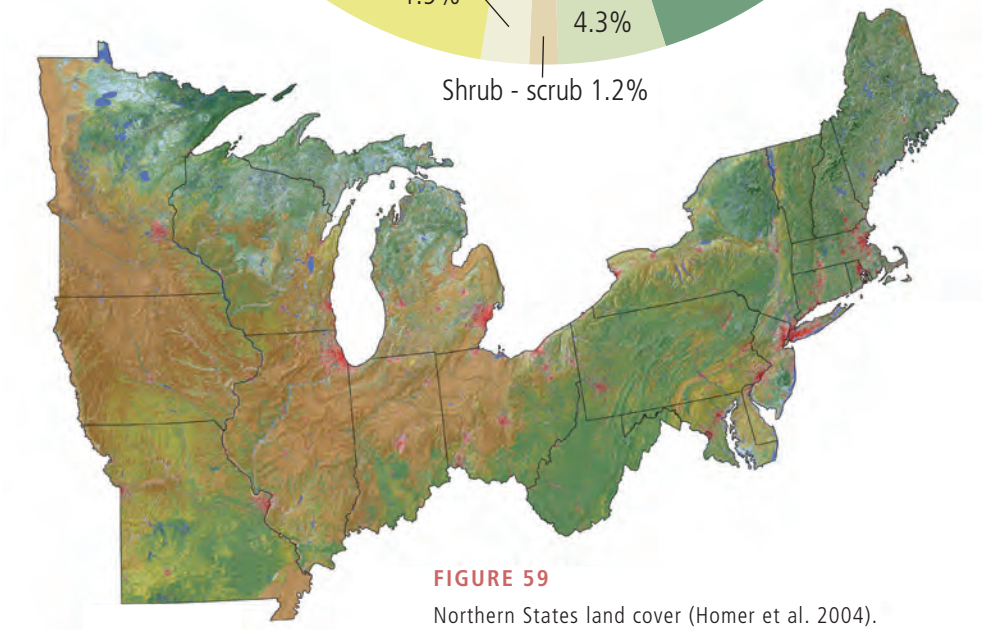


FIGURE 59

Northern States land cover (Homer et al. 2004).

Table 28—Distribution of area converted to urban uses from 1990 to 2000, by selected cover types as they existed in 1992 (USGS 2003), for Northern States ordered from greatest to least proportion of forest land subsumed (Nowak et al. 2005).

State and region	Cover type					
	Forest[a]	Agriculture[b]	Other[c]	Developed[d]	Woody wetland[e]	Herbaceous wetland[f]
	Proportion of the total area subsumed by urbanization (percent)					
Rhode Island	64.8	5.7	0.8	19.0	7.9	1.9
Connecticut	64.1	11.5	0.9	16.2	5.8	1.7
Massachusetts	62.9	7.6	1.4	17.7	6.1	4.2
West Virginia	62.2	25.4	1.8	10.4	0.2	0.1
New Hampshire	61.3	10.2	1.3	20.7	4.2	2.4
Maine	54.8	7.7	1.3	26.1	3.7	6.3
New York	51.2	28.1	0.5	17.5	1.9	0.7
New Jersey	48.4	28.0	1.0	12.7	8.6	1.3
Maryland	43.5	40.7	2.6	9.5	2.7	0.9
Pennsylvania	42.7	45.5	1.4	9.7	0.4	0.2
Vermont	39.7	28.1	1.7	22.4	5.5	2.6
Ohio	31.6	50.8	0.4	14.3	2.3	0.6
Michigan	31.2	47.5	2.1	12.2	6.1	1.0
Missouri	28.6	44.7	6.5	19.0	0.8	0.3
Delaware	28.4	45.6	1.4	15.3	5.2	4.0
Wisconsin	18.3	62.0	2.2	14.5	2.2	0.6
Minnesota	17.7	52.4	1.1	17.6	3.7	7.4
Indiana	15.2	66.8	0.8	14.9	1.9	0.5
Illinois	15.2	64.8	1.8	15.2	2.4	0.7
Iowa	12.1	52.3	8.0	25.4	1.7	0.6
All North	37.0	42.2	1.6	14.5	3.3	1.3
Conterminous U.S.	33.4	32.7	14.0	15.1	3.5	1.4

[a]*Deciduous, evergreen or mixed forests; tree canopy accounts for 25 to 100 percent of the cover.*

[b]*Pasture/hay, row crops, small grains, or fallow (75 to 100 percent of the cover); or orchards/vineyards/other nonnatural woody (25 to 100 percent of the cover).*

[c]*Bare/rock/sand/clay, quarries/strip mines/gravel pits, transitional, shrubland (25 to 100 percent of the cover), or grasslands/herbaceous (natural/seminatural; 75 to 100 percent of the cover).*

[d]*Areas characterized by a high percentage (30 percent or more) of constructed materials (such as asphalt, concrete, or buildings), or vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes (75 to 100 percent of the cover).*

[e]*Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water*

[f]*Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water*

Preliminary projections of urbanization and forests, 2000 to 2050

Given the growth patterns of the 1990s, urban land is projected to expand substantially in the future—from 3 percent of the conterminous United States in 2000 to 8 percent in 2050, an increase in area greater than the State of Montana (Nowak and Walton 2005). By 2050, four States, all in the North, are projected to have more than half of their States classified as urban land: Rhode Island (71 percent urban), New Jersey (64 percent), Massachusetts (61 percent), and Connecticut (61 percent).

Although Northeastern States tended to have the highest percentage of forest land that is projected to be urbanized by 2050, Southern States are expected to have the highest acreage increases (Fig. 60): 2.2 million for North Carolina and 1.9 million for Georgia,

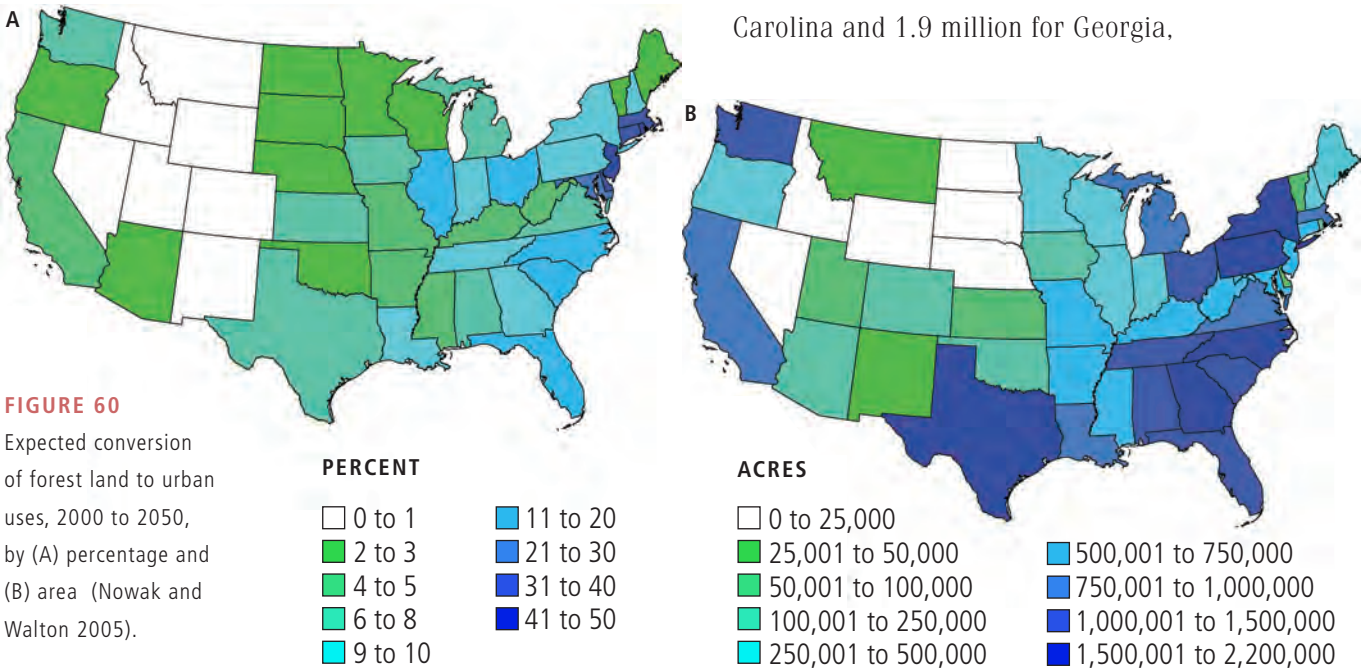


FIGURE 60
Expected conversion of forest land to urban uses, 2000 to 2050, by (A) percentage and (B) area (Nowak and Walton 2005).

followed by New York (1.7 million), Pennsylvania (1.6 million), and Texas (1.5 million). The projected total U.S. conversion of forest to urban land is about 29 million acres, an area approximately the size of Pennsylvania (Nowak and Walton 2005).

Tree and impervious cover in urban and community areas

Tree and impervious cover data in the conterminous United States are available through the National Land Cover Database using data from circa 2001 (Figs. 61 to 64). However, tree cover is likely underestimated in the database by about 9.7 percent nationally (Greenfield et al. 2009, Nowak and Greenfield 2010). To adjust for this potential underestimation, photo-interpretation of tree cover using GoogleEarth™ imagery (image dates from 2002 to 2009) was conducted for the conterminous United States (n=66,887 points) and for urban and community areas (n = 16,227 points). Based on this image interpretation, total tree cover in the North (Table 29) is 47 percent, ranging from 89 percent in New Hampshire to 10 percent in Iowa. Note that tree canopy cover includes trees on agricultural lands, on wetlands, in urban and community areas, and in other places that would not be classified as forest land. Thus, northern forest land, which has about 87 percent tree cover, is estimated to cover 42 percent of the land area (Fig. 1, Table 1) whereas 47 percent of all land is covered by trees (Figs. 61 and 63, Table 29).

In the North, tree cover averages 38 percent in urban areas, 37 percent in community land, and 39 percent in the combined urban or community category (Table 30). These values are higher than the national average because the Northern States are relatively heavily forested (Fig. 61) and urban tree cover is significantly

Table 29—Percent tree and impervious cover for Northern States based on photo-interpretation of GoogleEarth™ imagery.

State and region	Tree cover	Impervious cover
	(percent)	
New Hampshire	88.9	5.0
Maine	83.1	3.2
Vermont	81.5	1.9
West Virginia	81.4	2.0
Connecticut	72.6	7.7
Massachusetts	70.8	7.4
Rhode Island	70.3	10.9
Pennsylvania	65.8	4.6
New York	65.0	4.5
Michigan	59.5	4.1
New Jersey	57.0	12.1
Wisconsin	47.7	2.8
Maryland	42.8	6.1
Missouri	40.3	2.4
Ohio	39.9	5.5
Minnesota	34.8	2.2
Delaware	33.3	6.2
Indiana	25.7	3.7
Illinois	15.6	4.8
Iowa	10.4	3.0
All North	46.8	3.8

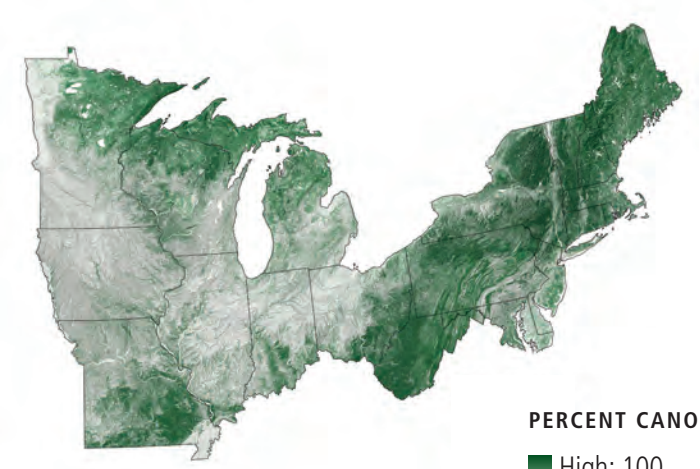


FIGURE 61
Tree canopy cover, 2001, (Homer et al. 2004).

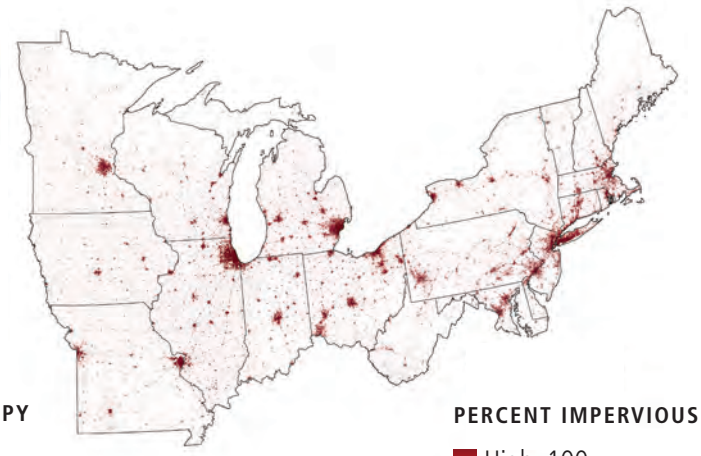


FIGURE 62
Impervious cover, 2001 (Homer et al. 2004).

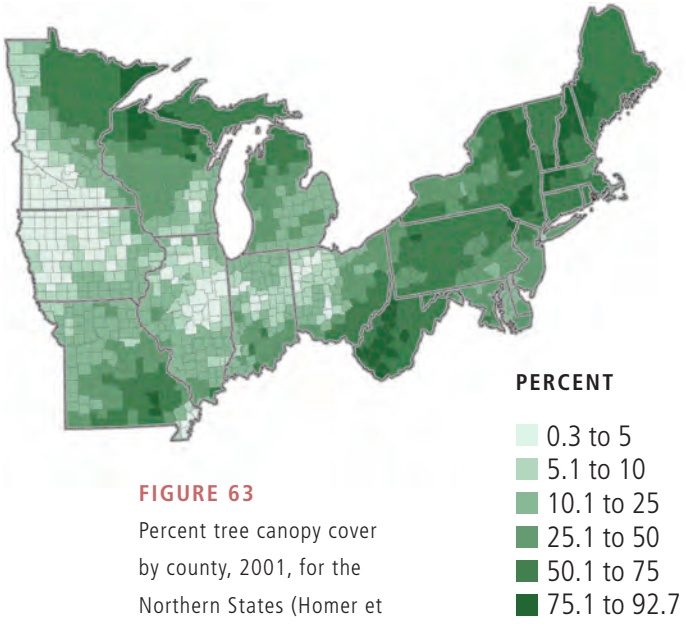


FIGURE 63
Percent tree canopy cover by county, 2001, for the Northern States (Homer et al. 2004).

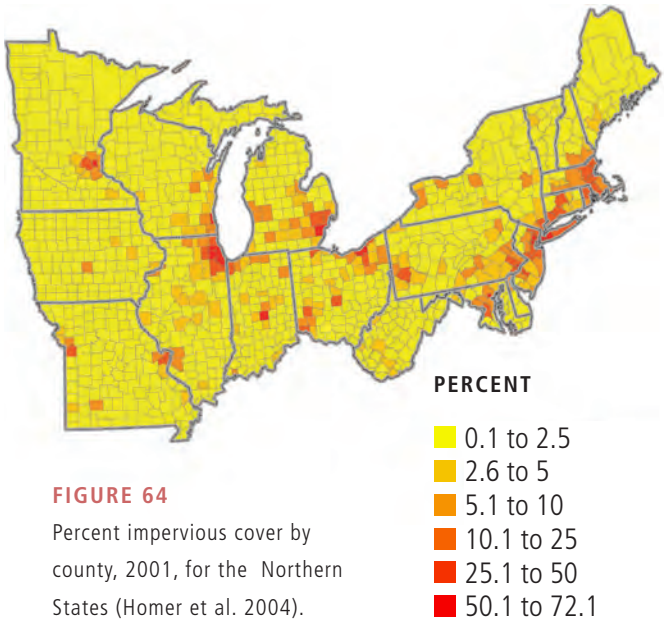


FIGURE 64
Percent impervious cover by county, 2001, for the Northern States (Homer et al. 2004).

affected by surrounding vegetation types (Nowak et al. 1996). Within urban areas in the Northern States, tree cover is highest in Connecticut (67 percent) and lowest in Indiana (22 percent). Within community areas, tree cover was highest in New Hampshire (67 percent) and lowest in Iowa (19 percent). Within the combined urban or community category, tree cover was highest in Connecticut (67 percent) and lowest in Iowa (19 percent). Figures 65 and 66 illustrate the distribution of tree cover and available space within urban or community land, based on NLCD 2001 data.

Impervious cover averages 24 percent in urban areas of the Northern States, 21 percent in communities, and 20 percent in the combined urban or community category (Table 30).

Table 30—Percent tree and impervious cover for urban, community, and urban or community land in the Northern States based on photo-interpretation of GoogleEarth™ imagery.

State and region	Urban land[a]		Community land[b]		Urban or community land	
	Tree cover	Impervious cover	Tree cover	Impervious cover	Tree cover	Impervious cover
	(percent)					
Connecticut	66.5	11.6	66.0	12.0	67.4	11.1
Massachusetts	64.5	16.7	60.9	16.1	65.1	14.5
New Hampshire	64.0	18.0	67.0	9.0	66.0	12.0
Maine	54.0	19.0	51.6	13.1	52.3	12.5
Rhode Island	54.0	26.0	40.0	36.0	51.0	24.0
Vermont	53.0	22.0	51.0	20.0	53.0	17.0
New Jersey	50.4	22.5	51.9	21.9	53.3	19.9
West Virginia	47.0	20.0	62.0	14.0	61.0	12.0
New York	41.2	27.4	41.1	24.3	42.6	22.4
Delaware	38.0	19.0	33.0	21.0	35.0	17.0
Michigan	34.6	31.5	34.0	29.0	35.0	26.8
Pennsylvania	34.0	24.6	45.0	18.6	41.0	19.1
Maryland	32.9	21.6	34.7	21.6	34.3	19.0
Missouri	31.1	22.0	29.2	18.3	31.5	18.0
Minnesota	31.0	24.1	33.8	13.2	34.0	13.3
Wisconsin	29.2	22.2	30.9	15.6	31.8	14.8
Ohio	29.0	27.1	31.0	28.1	31.5	24.5
Illinois	26.4	30.7	23.9	30.8	25.4	26.1
Iowa	24.0	27.0	18.8	20.4	19.0	19.5
Indiana	22.3	25.5	23.2	25.6	23.7	22.6
All North	38.2	24.4	36.8	21.4	39.0	19.7

[a]*All the territory, population, and housing units located within urbanized areas or urban clusters, each with a core population density of 1,000 people per square mile and with surrounding areas that have lower population densities (U.S. Census Bureau 2007).*

[b]*Places that have geopolitical boundaries (such as cities, towns, or unincorporated named places) that may include all, some, or no urban land within their boundaries.*

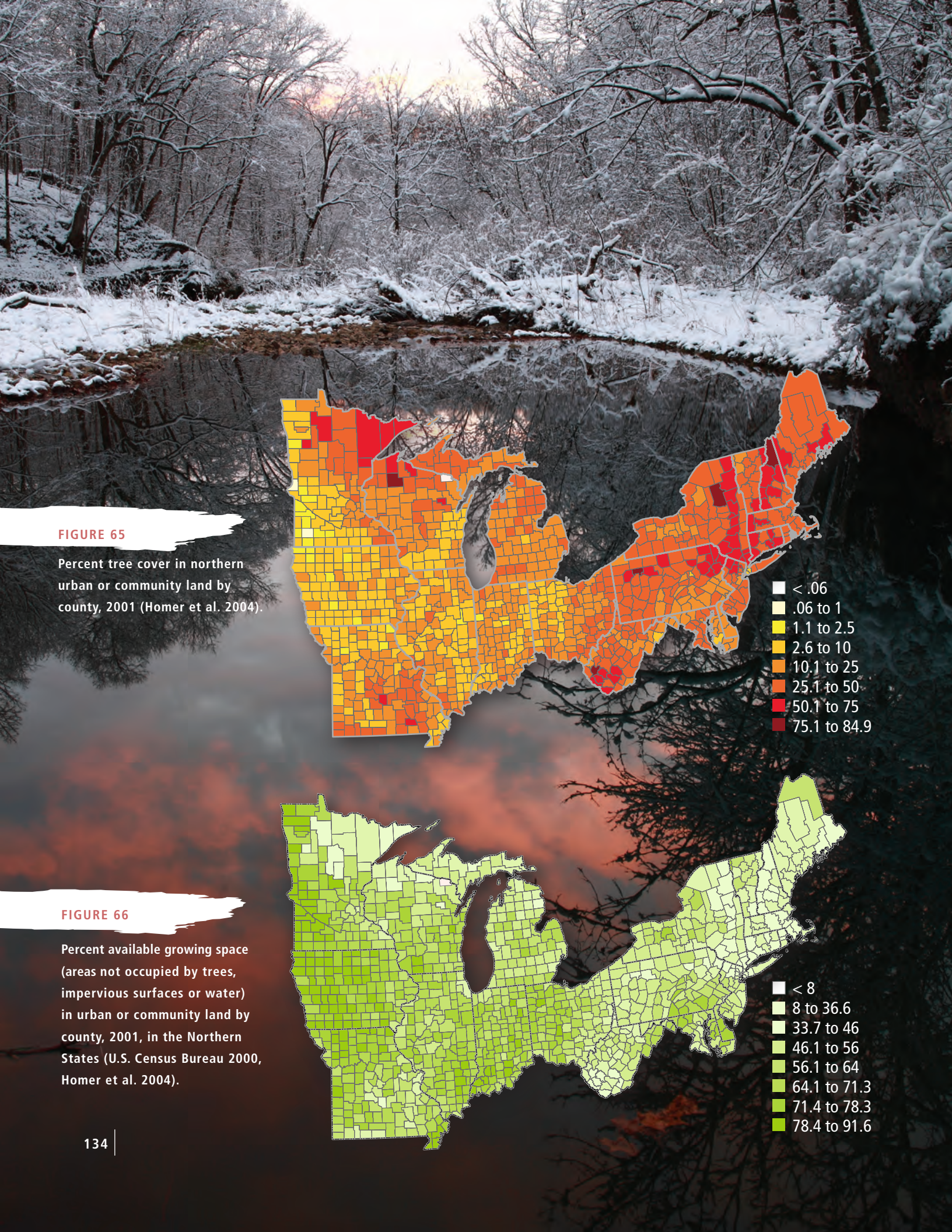


FIGURE 65

Percent tree cover in northern urban or community land by county, 2001 (Homer et al. 2004).

FIGURE 66

Percent available growing space (areas not occupied by trees, impervious surfaces or water) in urban or community land by county, 2001, in the Northern States (U.S. Census Bureau 2000, Homer et al. 2004).