

Introduction

TREES AND FORESTS are resources that significantly affect the health and well-being of people who live in urban areas where more than 80 percent of the U.S. population resides. These trees within our cities and communities provide many ecosystem services and values to both urban and rural populations. Healthy urban and rural forests are critical for sustaining quality of life for people in urban areas, but many forces could change the quantity and quality of urban trees and forests in the coming decades.



Societal and Ecological Benefits from Urban Forests

Urban forests are all of the trees and forests found in urban areas. This includes forested stands as well as trees along streets, in residential lots, and in parks. These forests provide a range of public services, in cities and beyond (Nowak and Dwyer 2007) by:

- Sequestering and storing carbon
- Removing air pollution and improving overall air quality
- Reducing air temperature
- Reducing building energy use
- Absorbing ultraviolet radiation
- Reducing runoff from precipitation and improving water quality
- Reducing noise pollution
- Improving human comfort
- Increasing property values
- Improving human physiological and psychological well-being
- Improving aesthetics
- Improving community cohesion

Although urban forests may seem to be isolated, they actually have many links to rural forests across the landscape. For example, destructive insects, diseases, and invasive species (Chapter 5) affect both urban and rural forests. Sometimes these destructive agents spread from rural forest landscapes to urban centers. At other times, people inadvertently move insects, diseases, or invasive plants to urban centers where they escape and spread into surrounding rural forests. The predicted increases in urban area that would result from increasing human populations would convert millions of acres of rural forest land (Chapters 3, 4) to urban uses. In contrast to land valuation in rural areas, the proximity of trees and people in urban areas increases the value of those trees and forests but can also increase the cost of caring for individual trees.

Key Findings

- From 1990 to 2000, urban land increased from 2.5 percent to 3.1 percent in the conterminous United States, and from 4.9 percent to 5.9 percent in the North.
- By 2050, urban land is expected to increase to 8.1 percent in the conterminous United States and to 13.7 percent in the North.
- Most of the urban expansion across the conterminous United States occurred in forests (33 percent) or agricultural land (33 percent), compared to 42 percent in agricultural land and 37 percent in forests for the North.
- Based on projected land-use changes, overall tree cover would decrease by as much as 1.6 percent in 2060 in the conterminous United States and by as much as 1.9 percent in the North.
- Projected changes in tree cover resulting from land-use change would be variable across the conterminous United States, with decreases in forested areas and increases in deserts, grasslands, and agricultural areas.
- Although U.S. urban tree cover is estimated at 35 percent, a recent study revealed that 17 out of 20 cities have recently experienced statistically significant decreases in tree cover.

This chapter describes the potential changes in urban area and the consequences for forest land area and tree cover that would likely result from urban expansion over the next 50 years. To assess the potential impact of future urbanization, four indicators are analyzed: (1) change in urban area, (2) conversion of forest area to urban land, (3) change in percentage of tree cover resulting from urban-land expansion, and (4) change in percentage of tree cover in urban areas. In addition, the potential impact of insects, diseases, and invasive species in urban areas is discussed.

CHANGE IN URBAN AREA

Urban land in the conterminous United States increased from 2.5 percent of total land area in 1990 to 3.1 percent in 2000 (Table 10.1), a small percentage increase that nevertheless added 11 million acres in urban land—an area about the size of Massachusetts and New Hampshire combined (Fig. 10.1).

Table 10.1—U.S. urban land growth estimated for 1990 to 2000 and projected for 2050 (Nowak and Walton 2005, Nowak et al. 2005).

State and region totals	State land in urban use, baseline				Change				State land in urban use, Projected 2050	
	1990		2000		2000		2000		2000	
	(thousand acres)	(percent of total)	(thousand acres)	(percent of total)	(thousand acres)	(percent total)	(thousand acres)	(percent total)	(thousand acres)	(percent of total)
Connecticut	975	30.6	1,135	35.5	159	5.0	1,942	60.9	4	4
Delaware	141	10.9	195	15.0	53	4.1	512	39.5	5	5
Maine	202	1.0	228	1.1	26	0.1	792	3.8	37	37
Maryland	957	14.3	1,157	17.3	199	3.0	2,512	37.5	6	6
Massachusetts	1,537	29.2	1,797	34.2	261	5.0	3,206	61.0	3	3
New Hampshire	259	4.4	362	6.1	103	1.7	1,018	17.1	13	13
New Jersey	1,552	31.2	1,805	36.2	253	5.1	3,167	63.6	2	2
New York	2,266	7.2	2,540	8.1	274	0.9	5,824	18.5	11	11
Ohio	2,205	8.3	2,568	9.7	364	1.4	6,058	22.9	8	8
Pennsylvania	2,175	7.5	2,730	9.4	555	1.9	6,408	22.1	9	9
Rhode Island	213	30.2	254	35.9	41	5.7	498	70.5	1	1
Vermont	81	1.3	95	1.5	14	0.2	328	5.3	31	31
West Virginia	292	1.9	361	2.3	70	0.5	1,193	7.7	26	26
All Northeast States	12,854	8.2	15,225	9.7	2,370	1.5	33,457	21.2	NR	NR
Illinois	1,939	5.4	2,304	6.4	366	1.0	5,279	14.6	17	17
Indiana	1,136	4.9	1,424	6.1	287	1.2	3,857	16.7	14	14
Iowa	468	1.3	523	1.5	55	0.2	1,780	4.9	33	33
Michigan	1,797	4.8	2,179	5.8	382	1.0	5,111	13.7	19	19
Minnesota	859	1.6	1,010	1.9	151	0.3	2,577	4.8	34	34
Missouri	1,006	2.3	1,168	2.6	163	0.4	3,078	6.9	29	29
Wisconsin	875	2.4	1,061	3.0	186	0.5	2,980	8.3	25	25
All North Central States	8,079	3.0	9,669	3.6	1,590	0.6	24,662	9.2	NR	NR
All Northern States	20,934	4.9	24,894	5.9	3,960	1.0	58,119	13.7	NR	NR



State and region totals	State land in urban use, baseline		State land in urban use, Projected 2050
	1990	2000 Change	
Alaska	1,000	1,000	1,000
Arizona	1,000	1,000	1,000
Arkansas	1,000	1,000	1,000
California	1,000	1,000	1,000
Colorado	1,000	1,000	1,000
Connecticut	1,000	1,000	1,000
Delaware	1,000	1,000	1,000
District of Columbia	1,000	1,000	1,000
Florida	1,000	1,000	1,000
Georgia	1,000	1,000	1,000
Hawaii	1,000	1,000	1,000
Idaho	1,000	1,000	1,000
Illinois	1,000	1,000	1,000
Indiana	1,000	1,000	1,000
Iowa	1,000	1,000	1,000
Kansas	1,000	1,000	1,000
Kentucky	1,000	1,000	1,000
Louisiana	1,000	1,000	1,000
Maine	1,000	1,000	1,000
Maryland	1,000	1,000	1,000
Massachusetts	1,000	1,000	1,000
Michigan	1,000	1,000	1,000
Minnesota	1,000	1,000	1,000
Mississippi	1,000	1,000	1,000
Missouri	1,000	1,000	1,000
Montana	1,000	1,000	1,000
Nebraska	1,000	1,000	1,000
Nevada	1,000	1,000	1,000
New Hampshire	1,000	1,000	1,000
New Jersey	1,000	1,000	1,000
New Mexico	1,000	1,000	1,000
New York	1,000	1,000	1,000
North Carolina	1,000	1,000	1,000
North Dakota	1,000	1,000	1,000
Ohio	1,000	1,000	1,000
Oklahoma	1,000	1,000	1,000
Oregon	1,000	1,000	1,000
Pennsylvania	1,000	1,000	1,000
Rhode Island	1,000	1,000	1,000
South Carolina	1,000	1,000	1,000
South Dakota	1,000	1,000	1,000
Tennessee	1,000	1,000	1,000
Texas	1,000	1,000	1,000
Utah	1,000	1,000	1,000
Vermont	1,000	1,000	1,000
Virginia	1,000	1,000	1,000
Washington	1,000	1,000	1,000
West Virginia	1,000	1,000	1,000
Wisconsin	1,000	1,000	1,000
Wyoming	1,000	1,000	1,000
U.S. Total	1,000	1,000	1,000

State and region totals	State land in urban use, baseline		State land in urban use, Projected 2050
	1990	2000 Change	
Alaska	1,000	1,000	1,000
Arizona	1,000	1,000	1,000
Arkansas	1,000	1,000	1,000
California	1,000	1,000	1,000
Colorado	1,000	1,000	1,000
Connecticut	1,000	1,000	1,000
Delaware	1,000	1,000	1,000
District of Columbia	1,000	1,000	1,000
Florida	1,000	1,000	1,000
Georgia	1,000	1,000	1,000
Hawaii	1,000	1,000	1,000
Idaho	1,000	1,000	1,000
Illinois	1,000	1,000	1,000
Indiana	1,000	1,000	1,000
Iowa	1,000	1,000	1,000
Kansas	1,000	1,000	1,000
Kentucky	1,000	1,000	1,000
Louisiana	1,000	1,000	1,000
Maine	1,000	1,000	1,000
Maryland	1,000	1,000	1,000
Massachusetts	1,000	1,000	1,000
Michigan	1,000	1,000	1,000
Minnesota	1,000	1,000	1,000
Mississippi	1,000	1,000	1,000
Missouri	1,000	1,000	1,000
Montana	1,000	1,000	1,000
Nebraska	1,000	1,000	1,000
Nevada	1,000	1,000	1,000
New Hampshire	1,000	1,000	1,000
New Jersey	1,000	1,000	1,000
New Mexico	1,000	1,000	1,000
New York	1,000	1,000	1,000
North Carolina	1,000	1,000	1,000
North Dakota	1,000	1,000	1,000
Ohio	1,000	1,000	1,000
Oklahoma	1,000	1,000	1,000
Oregon	1,000	1,000	1,000
Pennsylvania	1,000	1,000	1,000
Rhode Island	1,000	1,000	1,000
South Carolina	1,000	1,000	1,000
South Dakota	1,000	1,000	1,000
Tennessee	1,000	1,000	1,000
Texas	1,000	1,000	1,000
Utah	1,000	1,000	1,000
Vermont	1,000	1,000	1,000
Virginia	1,000	1,000	1,000
Washington	1,000	1,000	1,000
West Virginia	1,000	1,000	1,000
Wisconsin	1,000	1,000	1,000
Wyoming	1,000	1,000	1,000
U.S. Total	1,000	1,000	1,000

Table 10.1 continued

State and region totals	State land in urban use, baseline					State land in urban use, Projected 2050				
	1990		2000		Change	2000		2000		Change
	(thousand acres)	(percent of total)	(thousand acres)	(percent of total)	(thousand acres)	(percent of total)	(thousand acres)	(percent of total)	(thousand acres)	(percent of total)
Arizona	766	1.0	1,074	1.5	308	0.4	3,702	5.1	32	32
Colorado	650	1.0	815	1.2	165	0.2	2,609	3.9	36	36
Idaho	202	0.4	261	0.5	59	0.1	982	1.8	43	43
Montana	142	0.2	167	0.2	25	0.0	755	0.8	47	47
Nevada	216	0.3	348	0.5	132	0.2	1,578	2.2	41	41
New Mexico	352	0.5	482	0.6	130	0.2	1,611	2.1	42	42
Utah	352	0.6	442	0.8	90	0.2	1,379	2.5	40	40
Wyoming	96	0.2	108	0.2	12	0.0	401	0.6	48	48
All Intermountain States	2,776	0.5	3,696	0.7	921	0.2	13,018	2.4	NR	NR
All Rocky Mountain States	3,666	0.5	4,744	0.6	1,078	0.2	16,525	2.2	NR	NR
Oregon	539	0.9	658	1.1	119	0.2	2,199	3.5	38	38
Washington	1,092	2.5	1,368	3.1	276	0.6	4,018	9.2	23	23
All Pacific Northwest States	1,631	1.6	2,026	1.9	395	0.4	6,216	5.8	NR	NR
California	4,349	4.3	5,086	5.0	737	0.7	15,160	15.0	16	16
All Pacific Southwest States	4,349	4.3	5,086	5.0	737	0.7	15,160	15.0	NR	NR
All Pacific Coast States	5,980	2.9	7,112	3.5	1,132	0.5	21,376	10.3	NR	NR
48 State total ^a	48,163	2.5	59,242	3.1	11,079	0.6	156,214	8.1	NR	NR
U.S. total ^b	48,473	2.1	59,635	2.6	11,163	0.5	N.d.	N.d.	NR	NR

NR = no ranking

N.d. = no data

^aIncludes Washington, D.C.^bIncludes Alaska, Hawaii, and Washington, D.C.

In the Northern United States, from 1990 to 2000, urban area increased by 4 million acres or 1.0 percent of the land area. The States with the largest percentage increase were in the Northeast: Rhode Island (urbanization

subsumed 5.7 percent of the State land area), New Jersey (5.1 percent), Connecticut (5.0 percent), and Massachusetts (5.0 percent).

Nationally, States with the largest acreage increase were Florida (925,000 acres), Texas (871,000 acres), and California (737,000 acres). Of the ten U.S. States with the largest percentage increase, seven were in the Northeast, and

FIGURE 10.1

Relative change in urban land area for the (A) conterminous United States and (B) the North (Nowak et al. 2005).





three were in the Southeast. In aggregate, from 1990 to 2000, the Southeast had the largest increase in area and percent of urban land: 2.8 million acres (1.8 percent of total land area). In comparison, the Northeast States added 2.4 million acres of urban land (1.5 percent of total land area) (Table 10.1).

Based on the urban growth patterns of the 1990s, the expectation is that urban land area in the conterminous United States will increase substantially—from 3.1 percent in 2000 to 8.1 percent in 2050 (Fig. 10.2, Table 10.1). In the Northern States, urban land is expected to more

than double, from 25 to 58 million acres. As discussed in Chapter 3, roughly a third of the total urban area expansion would be into forest land, but the proportion of forest land affected would vary greatly depending on geographic location.

From 2000 to 2025, the area of developed land in the United States is expected to increase by 79 percent (Alig et al. 2004). The landscape changes resulting from urbanization and other types of development will have significant impacts on land management and efforts to sustain environmental quality in urban and urbanizing areas.

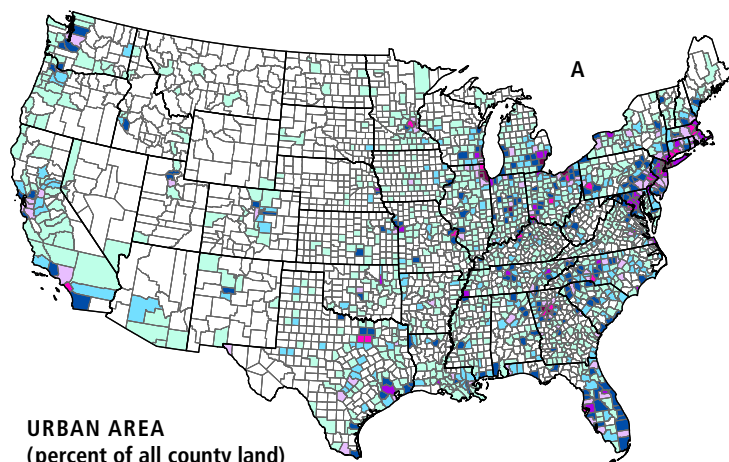
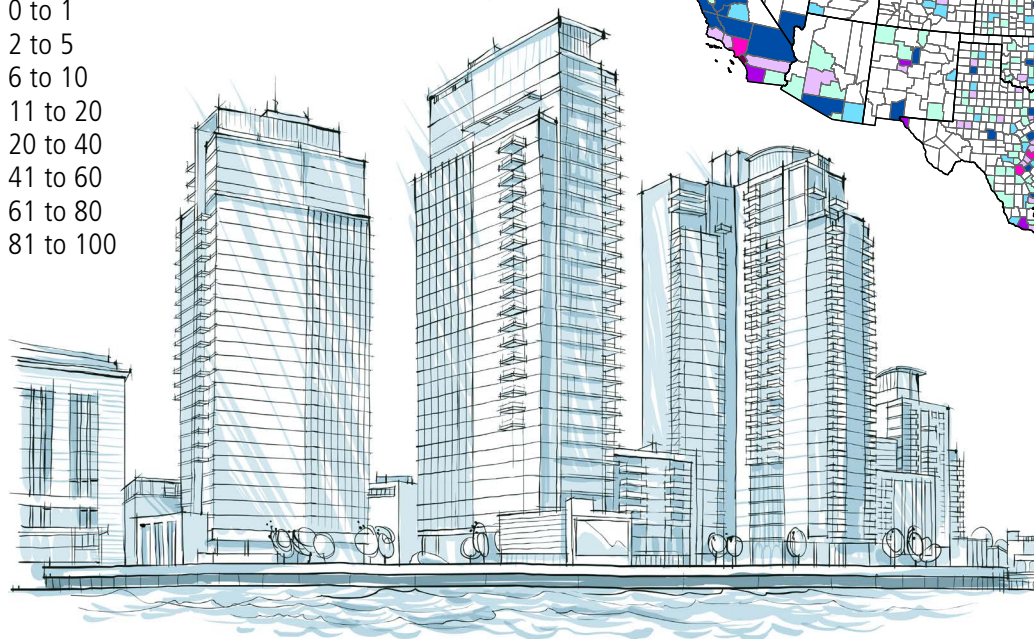
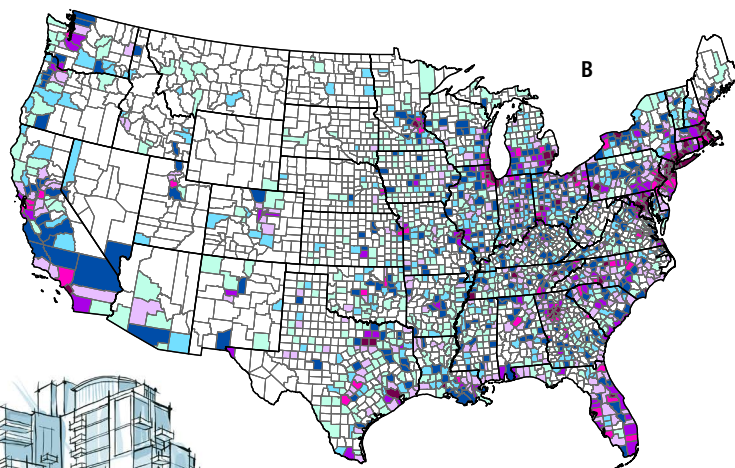


FIGURE 10.2
County-level estimates of U.S. urban land
(A) in 2000 and (B) projected for 2050
(Nowak and Walton 2005).



Future urban growth patterns will be affected by population growth and other demographic shifts, changes in personal income, and other economic and socioeconomic factors (Alig et al. 2004).

In the North, most urban growth is projected to occur around areas that are already heavily urbanized, with significant expansion expected along the east coast from Massachusetts to Maryland. In four States in the Northeast, more than half of the land area is projected to be urban by 2050 (Table 10.1): Rhode Island (71 percent), New Jersey (64 percent), Massachusetts (61 percent), and Connecticut (61 percent).

CONVERSION OF FOREST AREA TO URBAN LAND

Past Rates of Conversion

From 1990 to 2000, most of the urban expansion across the United States occurred in forests (33 percent of the expansion) or agricultural land (33 percent), with wide variations among States. In the Northern States (Appendix 10, Fig. 10.3), more urban expansion occurred in agricultural land (42 percent) than in forests (37 percent). The Northern States with the largest percentage of urban expansion into forests (Table 10.2) were Rhode Island (65 percent), Connecticut (64 percent), and Massachusetts (63 percent).

Developed versus Urban Areas

The National Resource Inventory (NRI) defines developed land as urban and built-up land and rural transportation land (USDA NRCS 2001). The developed land category includes: (1) large tracts of urban and built-up land; (2) small tracts of built-up land (<10 acres); and (3) land outside of these built-up areas that is used for roads, railroads, and associated rights-of-way (USDA NRCS 2001). NRI defines urban and built-up areas as land uses "consisting of residential, industrial, commercial, and institutional land" as well as several public infrastructure land-use categories such as railroads, landfills, and sewage treatment plants. Within NRI inventories of urban and built-up

areas, highways and other transportation facilities are included if they are surrounded by urban areas (Alig et al. 2004).

Urban areas are defined as all the territory, population, and housing units that are located within either urbanized areas or urban clusters. Urban areas have a core population density of 1,000 people or more per square mile, but they also include some surrounding areas with lesser population density. As defined by the U.S. Census Bureau (2007), urbanized areas have a total population of 50,000 people or more and urban clusters have a population of 2,500 to 49,999 people.

FIGURE 10.3

Percentage of land within various land-cover categories converted to urban land in the North, 1990 to 2000 (Nowak et al. 2005).

Developed land 14.7%

Areas characterized by a high percentage (30 percent or more) of constructed materials or vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes (75 to 100 percent of the cover).

Woody wetlands 3.3%

Areas where forest or shrubland vegetation accounts for 25 to 100 percent of the cover and the soil or substrate is periodically saturated with or covered by water.

Other 1.7%

Bare, rock, sand, clay, quarries, strip mines, gravel pits, transitional areas, or shrubland (25 to 100 percent of the cover); or natural, seminatural grasslands and herbaceous plants (75 to 100 percent of the cover).

Herbaceous wetlands 1.4%

Areas where perennial herbaceous vegetation accounts for 75 to 100 percent of the cover and the soil or substrate is periodically saturated with or covered by water.

Forest land 37%

Deciduous, evergreen, or mixed forests, with 25 to 100 percent tree cover.

Agricultural land 42%

Pasture, hay, row crops, small grains, or fallow (75 to 100 percent of the cover); or orchard, vineyards, or other planted woody vegetation (25 to 100 percent of the cover).

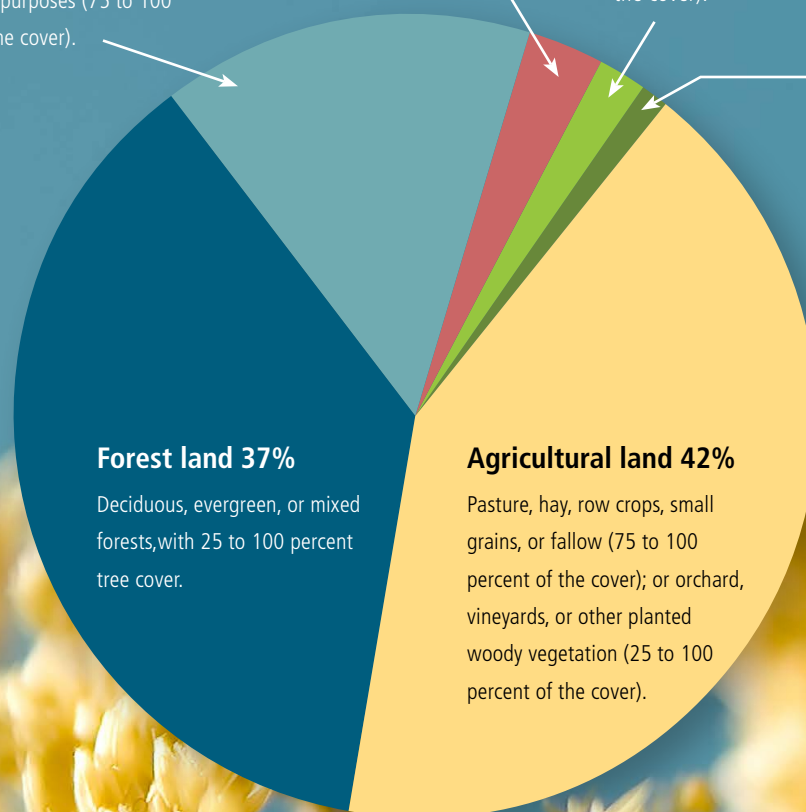


Table 10.2—U.S. States with the greatest percentage and largest acreage of urban land expansion within various land-cover categories, 1990 to 2000 (Nowak et al. 2005, 2010).

Land-cover category	Top 5 States based on percentage gain			Top 5 States based on acreage gain		
	State	Urban land increase		State	Urban land increase	
		Area (thousand acres)	Change (percent ^a)		Area (thousand acres)	Change (percent ^a)
Forests	Rhode Island	26	65	Georgia	444	64
	Connecticut	102	64	North Carolina	366	56
	Georgia	444	64	Pennsylvania	237	43
	Massachusetts	164	63	Texas	184	21
	West Virginia	43	62	Florida	174	19
Agricultural areas	Nebraska	28	69	Texas	357	41
	Indiana	192	67	Pennsylvania	252	46
	Illinois	237	65	Illinois	237	65
	Wisconsin	116	62	Indiana	192	67
	Idaho	32	55	Ohio	185	51
Woody wetlands	Florida	133	14	Florida	133	14
	New Jersey	22	9	North Carolina	33	5
	Rhode Island	3	8	Georgia	28	4
	Massachusetts	16	6	Michigan	23	6
	Michigan	23	6	New Jersey	22	9
Herbaceous wetlands	Minnesota	11	7	Florida	57	6
	Maine	2	6	Minnesota	11	7
	Florida	57	6	Massachusetts	11	4
	Massachusetts	11	4	Georgia	9	1
	Delaware	2	4	Texas	8	1

^aPercent of total urban expansion within land-cover type.





The Northern States with the largest total acreage of urban expansion into forests (Table 10.2) were Pennsylvania (237,000 acres) and Massachusetts (164,000 acres), States already known for their vast forests and large urban areas. In other States, urban areas expanded into other land-use types in differing proportions.

Projected Rates of Conversion

Nationwide by 2050, about 5.3 percent of forest land that is currently outside urban areas is projected to be subsumed by urban growth. This amount can be substantially higher at the individual State level, with Rhode Island (48 percent), New Jersey (40 percent),

Massachusetts (37 percent), Connecticut (36 percent), and Delaware (33 percent) projected to lead all States (Fig. 10.4).

Although the Northeastern States are expected to have the highest percentage of forest land converted to urban uses, the Southern States would have more total acreage converted to urban areas (Fig. 10.5): 2.2 million acres in North Carolina, followed by 1.9 million acres in Georgia, 1.7 million acres in New York, 1.6 million acres in Pennsylvania, and 1.5 million acres in Texas. The total additional U.S. forest land projected to be subsumed by urbanization from 2000 to 2050 would be about 29 million acres, an area about the size of Pennsylvania (Fig. 10.6).

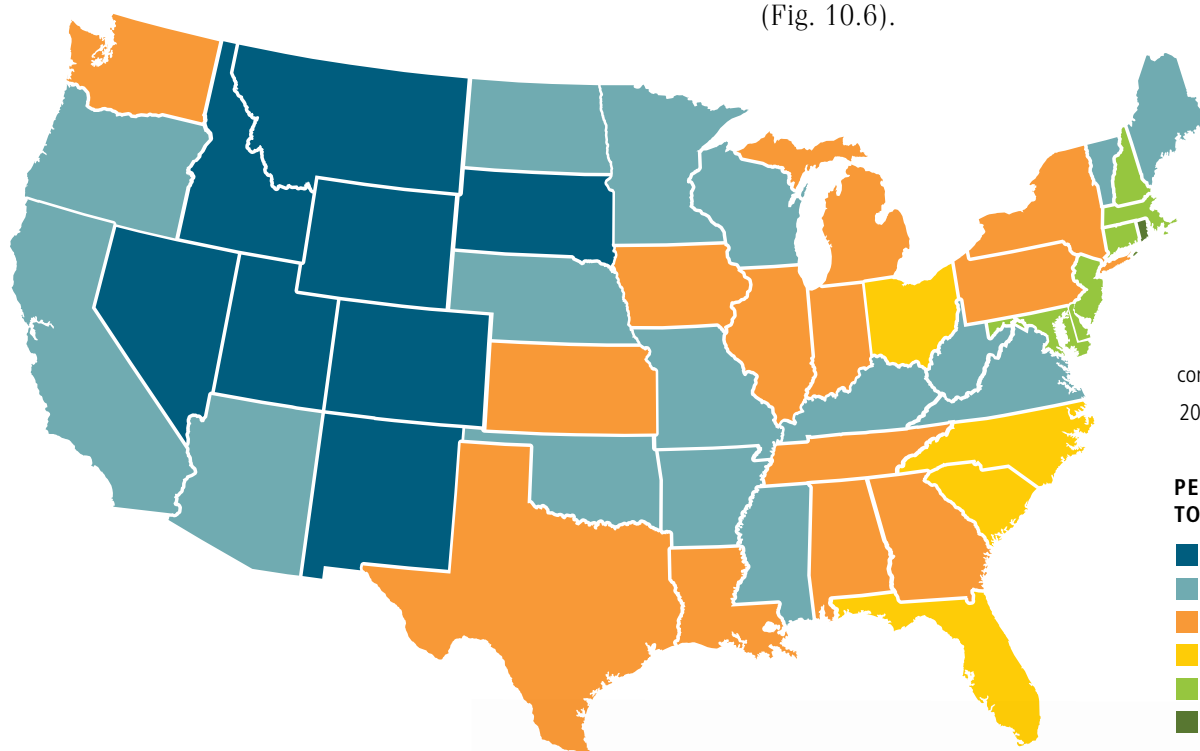
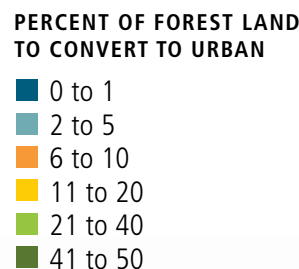


FIGURE 10.4
Percentage of U.S. non-urban forest land projected to be converted to urban land, 2000 to 2050 (Nowak and Walton 2005).



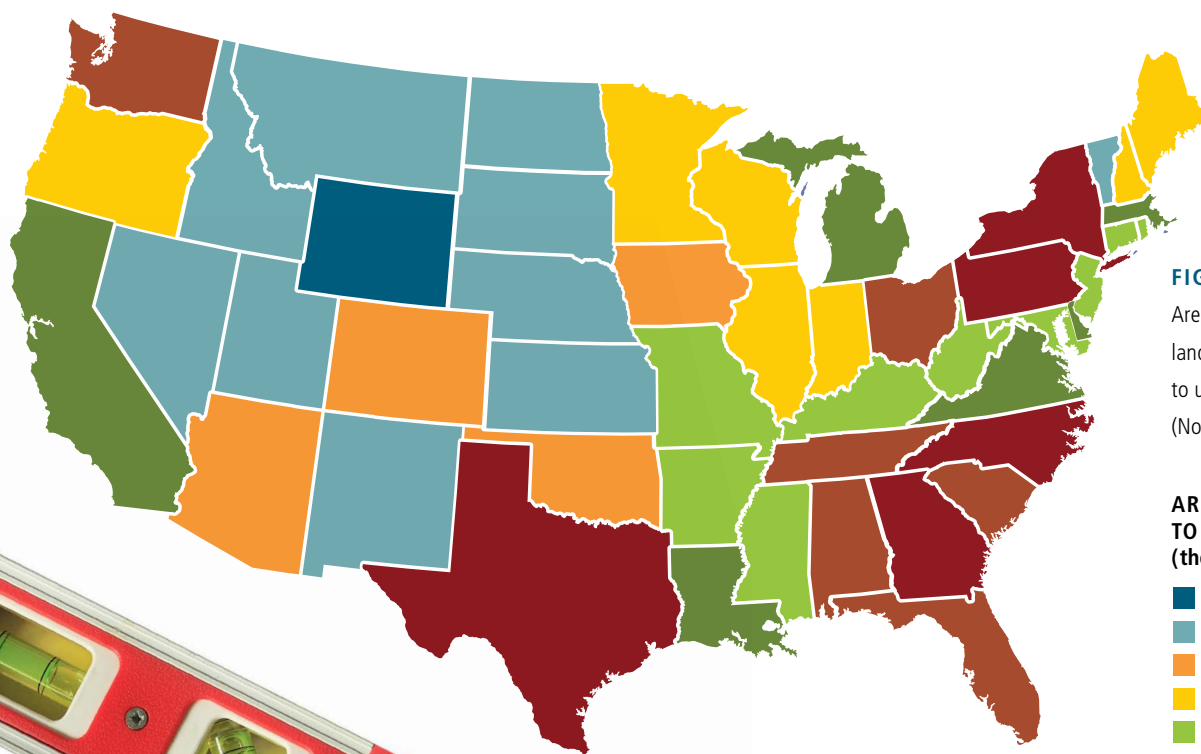


FIGURE 10.5

Area of U.S. non-urban forest land projected to be converted to urban land, 2000 to 2050 (Nowak and Walton 2005).

AREA OF FOREST LAND TO CONVERT TO URBAN (thousand acres)

- 5 to 10
- 11 to 100
- 101 to 250
- 251 to 500
- 501 to 750
- 751 to 1,000
- 1,001 to 1,500
- 1,501 to 2,200

FIGURE 10.6

Forest land converted and projected to be converted to urban land, 1990 to 2050, for the (A) conterminous United States and (B) the North (Nowak and Walton 2005).

Forest land subsumed by urban land growth, 1990 to 2000

4.1 million acres, slightly greater than the area of Connecticut and Rhode Island

Forest land subsumed by urban land growth, 1990 to 2000

1.6 million acres, slightly greater than the area of Delaware

A

B

Projected forest land subsumed by urban land growth, 2050

29.2 million acres, slightly greater than the area of Pennsylvania

Projected forest land subsumed by urban land growth, 2050

11.6 million acres, slightly greater than the area of New Hampshire, Massachusetts, and Rhode Island



EFFECTS OF URBAN LAND EXPANSION ON TREE COVER

Expansion of urban land affects the tree cover in a landscape, but not always as one would imagine. For example, although expansion of urban areas into forests reduces tree cover as roads and buildings are constructed, substantial tree cover often still remains. Urban expansion into agricultural areas can increase tree cover as trees are planted in proximity to new homes or as trees naturally migrate into former agricultural fields that have not yet been developed.

Land-use change forecasts were used to estimate potential changes in tree cover for counties of the conterminous United States through 2060 (USDA FS 2012, Wear 2011). Tree cover predictions under three storylines (Fig. 10.7, Table 10.3) were developed by applying the land-use change forecasts to adjusted tree cover values in the 2001 National Land Cover Database (Nowak and Greenfield 2010) and then projecting estimated tree cover forward to 2060 (Greenfield and Nowak 2013).

FIGURE 10.7

Change in U.S. tree cover, 2000 to 2060 under three greenhouse storylines (IPCC 2007)—(A) A1B assumes moderate greenhouse gas emissions, moderate gains in population growth with large gains in income and energy consumption, but with a balanced renewable/fossil fuel portfolio; (B) A2 assumes moderate greenhouse gas emissions, large gains in population growth and energy consumption with moderate gains in income; and (C) B2 assumes low greenhouse gas emissions, moderate gains in population growth, income, and energy consumption (USDA FS 2012).

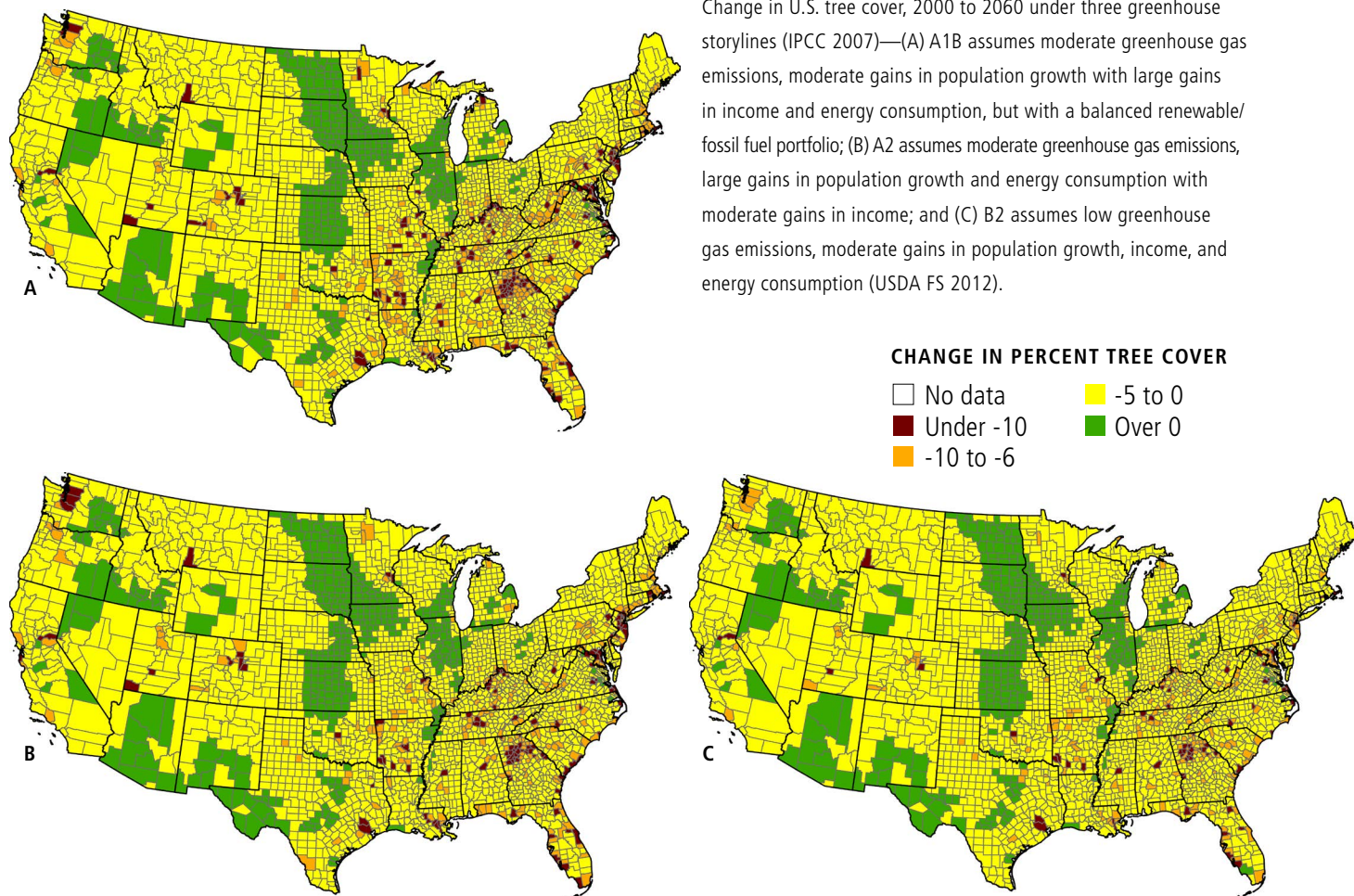


Table 10.3—Projected change in U.S. tree cover, by State, under three greenhouse gas emissions storylines (IPCC 2007), 2000 to 2060 (Greenfield and Nowak 2013, USDA FS 2012).

State and region	Storyline A1B ^a		Storyline A2 ^b		Storyline B2 ^c	
	Change	Relative change	Change	Relative change	Change	Relative change
----- (percent ^d) -----						
Connecticut	-2.8	-3.9	-3.3	-4.5	-1.7	-2.3
Delaware	-2.4	-5.9	-2.6	-6.4	-1.6	-4.0
Maine	-1.5	-1.7	-1.2	-1.4	-0.9	-1.0
Maryland ^e	-6.3	-12.2	-5.9	-11.6	-4.5	-8.8
Massachusetts	-4.1	-5.9	-4.4	-6.4	-2.7	-3.9
New Hampshire	-3.4	-4.0	-3.0	-3.6	-2.3	-2.7
New Jersey	-7.3	-13.1	-8.4	-15.1	-4.9	-8.8
New York	-1.4	-2.1	-1.2	-1.8	-0.8	-1.1
Ohio	-0.9	-2.3	-0.8	-2.0	-0.5	-1.3
Pennsylvania	-2.6	-4.0	-2.2	-3.4	-1.4	-2.2
Rhode Island	-9.2	-14.8	-10.0	-16.1	-5.5	-8.9
Vermont	-3.5	-4.5	-2.5	-3.2	-2.3	-3.0
West Virginia	-4.6	-5.6	-2.9	-3.6	-2.7	-3.3
All Northeast states	-2.6	-3.9	-2.2	-3.4	-1.6	-2.4
Illinois	-0.5	-3.3	-0.3	-1.9	-0.4	-2.6
Indiana	-2.4	-8.6	-1.6	-5.7	-1.4	-5.2
Iowa	-0.2	-1.5	-0.1	-0.8	-0.1	-1.1
Michigan	-1.9	-3.3	-1.6	-2.7	-1.2	-2.1
Minnesota	-1.6	-4.6	-1.3	-3.7	-1.0	-3.1
Missouri ^f	-3.0	-7.1	-2.2	-5.3	-1.9	-4.7
Wisconsin	-0.9	-1.9	-0.7	-1.5	-0.6	-1.2
All North Central States	-1.5	-4.4	-1.1	-3.3	-1.0	-2.8
All Northern States	-1.9	-4.1	-1.5	-3.3	-1.2	-2.6
Florida	-4.6	-8.5	-4.9	-9.1	-3.6	-6.7
Georgia	-6.6	-9.9	-5.1	-7.6	-4.5	-6.8
North Carolina	-3.9	-6.1	-3.3	-5.1	-2.7	-4.2
South Carolina	-4.3	-6.6	-3.7	-5.8	-2.9	-4.4
Virginia ^g	-3.1	-4.6	-2.4	-3.5	-2.2	-3.2
All Southeast States	-4.7	-7.4	-4.0	-6.4	-3.3	-5.2
Alabama	-3.2	-4.5	-2.4	-3.4	-2.0	-2.8
Arkansas	-4.7	-8.5	-3.6	-6.5	-3.2	-5.8
Kentucky	-5.0	-9.0	-3.9	-7.0	-3.1	-5.6
Louisiana	-3.0	-5.9	-2.3	-4.4	-1.9	-3.6
Mississippi	-3.0	-4.9	-2.2	-3.5	-1.9	-3.1
Oklahoma	-1.3	-4.8	-1.0	-4.0	-0.9	-3.3
Tennessee	-4.3	-7.3	-3.9	-6.5	-2.8	-4.7



Table 10.3 continued

State and region	Storyline A1B ^a		Storyline A2 ^b		Storyline B2 ^c	
	Change	Relative change	Change	Relative change	Change	Relative change
	(percent ^d)					
Texas	-1.2	-5.4	-0.8	-3.6	-0.8	-3.8
All South Central States	-2.4	-6.1	-1.8	-4.6	-1.6	-4.0
All Southern States	-3.0	-6.6	-2.4	-5.3	-2.1	-4.5
Kansas	-0.1	-1.0	-0.1	-1.0	-0.1	-0.8
Nebraska	-0.2	-3.6	-0.1	-2.4	-0.1	-2.1
North Dakota	-0.1	-1.7	0.0	-1.5	0.0	-1.6
South Dakota	0.3	6.1	0.2	4.4	0.2	4.3
All Great Plains States	0.0	-0.3	0.0	-0.3	0.0	-0.2
Arizona	0.1	0.3	0.1	0.4	0.0	0.2
Colorado ^h	-1.7	-6.8	-1.5	-6.2	-1.2	-4.7
Idaho	-0.4	-0.9	-0.3	-0.7	-0.2	-0.5
Montana	-1.2	-4.5	-1.0	-3.6	-0.8	-3.0
Nevada	-0.4	-2.8	-0.3	-2.5	-0.3	-2.2
New Mexico	-0.2	-1.0	-0.1	-0.8	-0.1	-0.7
Utah	-1.2	-6.4	-1.2	-6.2	-0.9	-4.9
Wyoming	-0.2	-1.6	-0.2	-1.2	-0.2	-1.1
All Intermountain States	-0.7	-3.0	-0.6	-2.6	-0.5	-2.1
All Rocky Mountain States	-0.5	-2.8	-0.4	-2.4	-0.3	-2.0
Oregon	-1.0	-2.4	-1.0	-2.4	-0.7	-1.7
Washington	-1.6	-3.3	-1.7	-3.6	-1.1	-2.4
All Pacific Northwest States	-1.2	-2.8	-1.3	-2.9	-0.9	-2.0
California ⁱ	-1.4	-4.0	-1.5	-4.1	-1.0	-2.9
All Pacific Southwest States	-1.4	-4.0	-1.5	-4.1	-1.0	-2.9
All Pacific Coast States	-1.3	-3.3	-1.4	-3.4	-0.9	-2.4
48 State total	-1.6	-4.7	-1.3	-3.9	-1.1	-3.2

^aA1B-Moderate greenhouse gas emissions, moderate gains in population growth with large gains in income and energy consumption, but with a balanced renewable/fossil fuel portfolio.

^bA2-High greenhouse gas emissions, large gains in population growth and energy consumption with moderate gains in income.

^cB2-Low greenhouse gas emissions, moderate gains in population growth, income, and energy consumption.

^dChange = percent tree cover in 2060 minus percent tree cover in 2000. Relative change = 100 X (tree cover in 2060 minus tree cover in 2000) divided by tree cover in 2000.

^eMaryland analysis covers 23 of the State's 24 counties (Wear 2011).

^fMissouri analysis covers 114 of the State's 115 counties (Wear 2011).

^gVirginia analysis covers 97 of the State's 135 counties (Wear 2011).

^hColorado analysis covers 62 of the State's 63 counties (Wear 2011).

ⁱCalifornia analysis covers 57 of the State's 58 counties (Wear 2011).

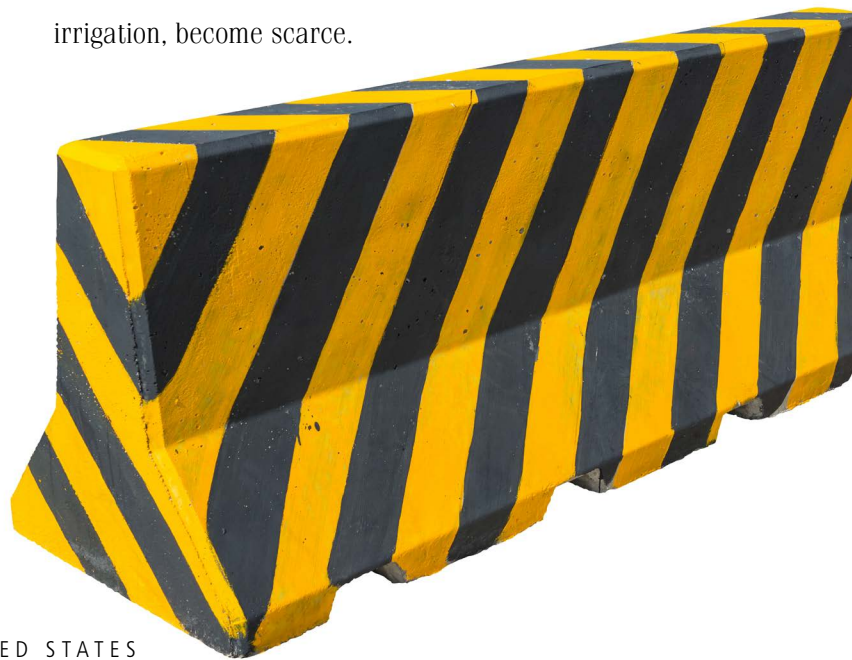


The simulations were derived from demographic, macroeconomic, and climate change models and data compiled in the United States Forest Assessment System (Wear 2011). Forecasts of land-use allocations represent the competing economic values (land rents) of forests versus developed, agricultural, and other land uses as influenced by the storyline population and income dynamics. The assumptions and projection methodology for tree cover are consistent with, but separate from, those used to forecast change in forest conditions (Chapter 2).

All three projections predicted similar changes in percentage of tree cover from 2000 to 2060. Nationally, tree cover would decrease by 1.6 percent under storyline A1B, by 1.3 percent under A2, and by 1.1 percent under B2. Note that changes are expressed in absolute rather than relative terms; that is, if tree cover drops from 20 percent to 18 percent, the change would be expressed as 2-percent reduction.

With the exception of several county-level increases in midwestern areas, tree cover is projected to decrease across all three storylines in the Northern States (Table 10.3). The largest decrease would be in Rhode Island: 5.5 percent under storyline B2, 9.2 percent under A1B, and 10.0 percent under A2. The State with the smallest decrease would be Iowa: 0.1 percent under storylines A2 and B2, and 0.2 percent under A1B.

The effects of expanding urbanization on surrounding rural land would be different for forests than for agricultural land. Tree cover would decrease in the more forested counties east of the Mississippi River and along the northwestern Pacific coast, but would increase in many agricultural, grassland, and desert counties of midwestern and western areas. Percentage tree cover tends to be greater in urban areas built on grassland, deserts, and agricultural land than in the rural areas that surround those urban areas; the opposite is true for urban areas built in counties dominated by forests (Nowak and Greenfield 2012b). The projected increases in tree cover for urban areas in counties dominated by desert, grassland, and agricultural areas are attributable to landscaping associated with urbanization. Projections of increases in these areas assume favorable conditions for sustaining tree populations; increases would not occur if necessary resources, such as water for irrigation, become scarce.





Providence, RI

CHANGE IN TREE COVER IN URBAN AREAS

Urban tree cover in the conterminous United States has been estimated at 27 percent (Dwyer et al. 2000, Nowak et al. 2001) based on Advanced Very High Resolution Radiometer data and Landsat thematic mapper data from the early 1990s (Zhu 1994). Urban tree cover tended to be greatest in urban areas that were developed in forested ecoregions (34 percent), followed by grasslands (18 percent) and deserts (9 percent). These results are consistent with earlier estimates of urban tree cover by ecoregion types (based on aerial photo interpretation of 58 U.S. cities), where tree cover averaged 31 percent in forest cities, 19 percent in grassland cities, and 10 percent in desert cities (Nowak et al. 1996). The percentage of tree cover in urban areas tends to decrease as population density increases and can vary within a city based on the distribution of land-use types and ecoregions; for example, vacant land in forested regions often supports tree cover, but vacant land in desert regions is often devoid of trees (Nowak et al. 1996, 2001; Nowak and Greenfield 2012b). Understanding the factors most associated with urban tree cover can improve projections of tree cover and inform policies that modify urban tree cover.

Based on photo-interpretation of the conterminous States from circa 2005, U.S. urban tree cover is estimated at 35 percent (Nowak and Greenfield 2012b). In the North

Table 10.4—U.S. urban tree cover, circa 2005, by State (Nowak and Greenfield 2012b).

State and region	Tree cover
	(percent of total urban area)
Connecticut	67
Delaware	38
Maine	54
Maryland	33
Massachusetts	65
New Hampshire	64
New Jersey	50
New York	41
Ohio	29
Pennsylvania	34
Rhode Island	54
Vermont	53
West Virginia	47
All Northeast states	44
Illinois	26
Indiana	22
Iowa	24
Michigan	35
Minnesota	31
Missouri	31
Wisconsin	29
All North Central States	29
All Northern States	38
Florida	35
Georgia	52
North Carolina	48
South Carolina	47
Virginia	35
All Southeast States	42
Alabama	53
Arkansas	43
Kentucky	27

Table 10.4 continued



State and region

Tree cover

(percent of total urban area)

Louisiana	32
Mississippi	41
Oklahoma	19
Tennessee	39
Texas	32
All South Central States	35
All Southern States	39
Kansas	28
Nebraska	19
North Dakota	15
South Dakota	21
All Great Plains States	24
Arizona	16
Colorado	17
Idaho	13
Montana	9
Nevada	12
New Mexico	12
Utah	15
Wyoming	9
All Intermountain States	15
All Rocky Mountain States	17
Oregon	40
Washington	33
Alaska	38
All Pacific Northwest States	35
California	20
Hawaii	30
All Pacific Southwest States	20
All Pacific Coast States	25
48 State total	35
U.S. total	35

(Table 10.4), tree cover in urban areas is highest in Connecticut (67 percent) and Massachusetts (65 percent) and lowest in Indiana (22 percent) and Iowa (24 percent). Because of the different methods used and the limitations of the analyses, the increases in estimated urban tree cover in 2005 from previous years do not necessarily indicate a real increase or a temporal trend in urban tree cover. To measure temporal trends in city and urban tree cover more accurately, a paired-photo-interpretation was conducted in 20 U.S. cities (Nowak and Greenfield 2012a). Results revealed that urban tree cover is declining nationally by about 0.2 percent (4 million trees) per year and that eight of the nine northern cities analyzed had statistically significant declines in tree cover averaging about 0.9 percent per year (Table 10.5). Because tree cover is an indicator of the extent to which trees and forests are providing critical services to local urban residents, assessing the size of this resource and whether it is increasing or decreasing is critical. Even though tree cover seems to have declined, more data are needed to determine if this is a trend that will continue into the future.



Table 10.5—Changes in tree and impervious cover change in 20 U.S. cities (Nowak and Greenfield 2012a). Values in boldface type indicate the change is statistically significant from zero at $\alpha=0.1$.

City	Analysis period	Urban cover change for the analysis period			
		Absolute change ^a		Relative change ^b	
		Tree ^c	Impervious ^d	Tree ^c	Impervious ^d
------(percent)-----					
New Orleans, LA	2005 to 2009	-9.6	0.4	-29.2	0.9
Houston, TX	2004 to 2009	-3.0	1.3	-9.8	3.5
Albuquerque, NM	2006 to 2009	-2.7	1.8	-6.6	5.1
Baltimore, MD	2001 to 2005	-1.9	2.1	-6.3	4.7
Atlanta, GA	2005 to 2009	-1.8	1.7	-3.4	6.5
Miami, FL	2003 to 2009	-1.7	1.0	-7.1	1.7
Tacoma, WA	2001 to 2005	-1.4	3.6	-5.8	8.9
Kansas City, MO	2003 to 2009	-1.2	2.0	-4.2	11.2
Nashville, TN	2003 to 2008	-1.2	1.1	-2.4	6.2
New York, NY	2004 to 2009	-1.2	1.4	-5.5	2.3
Minneapolis, MN	2003 to 2008	-1.1	0.8	-3.1	1.8
Boston, MA	2003 to 2008	-0.9	1.7	-3.2	3.6
Los Angeles, CA	2005 to 2009	-0.9	1.8	-4.2	3.4
Detroit, MI	2005 to 2009	-0.7	1.2	-3.0	2.6
Portland, OR	2005 to 2009	-0.6	1.5	-1.9	3.5
Spokane, WA	2002 to 2007	-0.6	2.0	-2.5	5.8
Chicago, IL	2005 to 2009	-0.5	0.0	-2.7	0.0
Pittsburgh, PA	2004 to 2008	-0.3	0.0	-0.8	0.0
Denver, CO	2005 to 2009	-0.3	1.4	-3.1	3.6
Syracuse, NY	2003 to 2009	1.0	-0.5	4.0	-1.0
20 city average		-1.5	1.3	-5.0	3.7
18 city average ^e		-1.1	1.4	-3.8	3.9

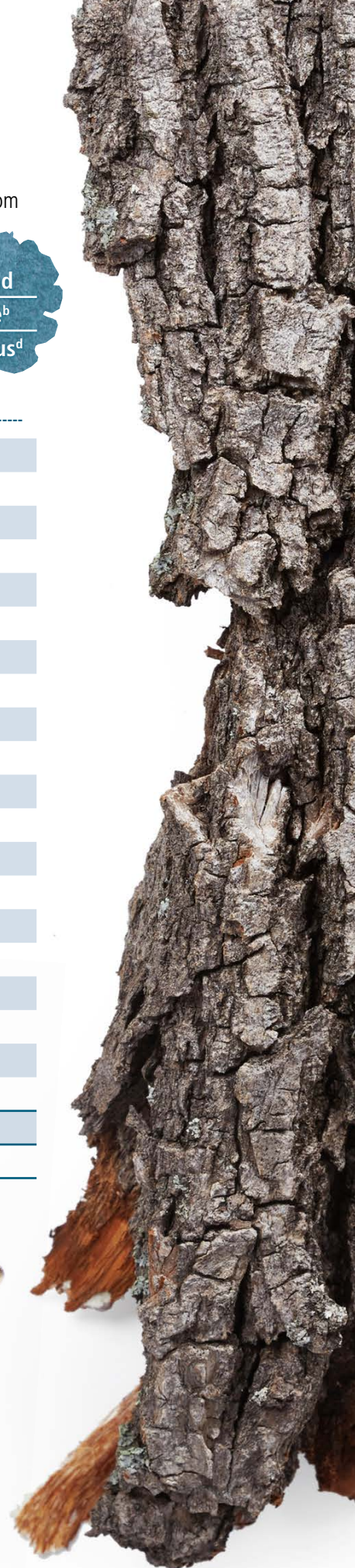


Table 10.5 continued

City	Analysis period	Average change per year			
		Absolute change ^a		Relative change ^b	
		Tree ^c	Impervious ^d	Tree ^c	Impervious ^d
------(percent)-----					
New Orleans, LA	2005 to 2009	-2.49	0.09	-8.27	0.21
Houston, TX	2004 to 2009	-0.60	0.26	-2.03	0.69
Albuquerque, NM	2006 to 2009	-0.91	0.60	-2.26	1.67
Baltimore, MD	2001 to 2005	-0.48	0.51	-1.62	1.16
Atlanta, GA	2005 to 2009	-0.46	0.43	-0.85	1.58
Miami, FL	2003 to 2009	-0.28	0.16	-1.22	0.27
Tacoma, WA	2001 to 2005	-0.36	0.89	-1.49	2.15
Kansas City, MO	2003 to 2009	-0.20	0.34	-0.71	1.78
Nashville, TN	2003 to 2008	-0.24	0.22	-0.48	1.21
New York, NY	2004 to 2009	-0.23	0.27	-1.13	0.45
Minneapolis, MN	2003 to 2008	-0.22	0.15	-0.63	0.35
Boston, MA	2003 to 2008	-0.19	0.35	-0.65	0.71
Los Angeles, CA	2005 to 2009	-0.23	0.45	-1.06	0.85
Detroit, MI	2005 to 2009	-0.18	0.30	-0.77	0.64
Portland, OR	2005 to 2009	-0.15	0.38	-0.49	0.87
Spokane, WA	2002 to 2007	-0.11	0.39	-0.50	1.14
Chicago, IL	2005 to 2009	-0.13	0.00	-0.69	0.00
Pittsburgh, PA	2004 to 2008	-0.08	0.00	-0.19	0.00
Denver, CO	2005 to 2009	-0.08	0.35	-0.78	0.88
Syracuse, NY	2003 to 2009	0.17	-0.09	0.65	-0.17
20 city average		-0.37	0.30	-1.29	0.82
18 city average ^e		-0.27	0.31	-0.90	0.87

^aAbsolute change = percent of city land in first year of analysis minus percent of city land in the last year.

^bRelative percent change = absolute change (percent of city in first year minus percent of city in second year) divided by percent of city in first year.

^cTree and shrub cover includes shrub/scrub/chaparral cover in Albuquerque.

^dImpervious surfaces include building, roads, and other impervious combined.

^eTwo cities were excluded from this average to factor out effects of losses associated with extreme disturbances: the storm damage from Hurricane Katrina in New Orleans and mortality from the emerald ash borer infestation in Detroit.



Numerous natural and societal factors affect tree cover, both in positive and negative ways. For example, trees naturally regenerate and are planted, but they also succumb to storm damage, insects and diseases, old age, and land clearing for development. Continued monitoring of U.S. urban tree cover is needed to identify local and national changes. Because of numerous factors that can influence tree cover in cities and urban areas over the long term, the ability to predict future urban tree cover over the next 50 years is extremely limited. Nevertheless the recent, short-term trend is slightly downward.



Hartford, CT

POTENTIAL IMPACTS OF EMERALD ASH BORER AND INVASIVE TREE SPECIES

In addition to urban development and climate change, two other dominant factors will shape urban forests of the future: (1) insects and diseases, and (2) invasive tree species. Numerous insects and diseases are affecting tree health in urban areas across the United States (Chapter 5). One of the more recent and devastating insects introduced into the United States is the emerald ash borer (*Agrilus planipennis*), an exotic beetle that was discovered in southeastern Michigan near Detroit in 2002. This insect kills ash trees and has the potential to substantially alter urban forest composition in some cities in the North. The emerald ash borer is prevalent throughout much of the Northern States (USDA 2014) and may kill at least 50 percent of ash trees (*Fraxinus* spp.) within 15 years in infested areas (Krist et al. 2014). Based on field data from various northern cities collected between 1996 and 2009 (Nowak et al. 2013a), this insect could kill up to 11 percent of some city tree populations within the next 15 years, which will equate to millions of urban trees killed in northern cities (Table 10.6).





Boston, MA

Table 10.6—Estimated number of trees, percent of total tree population, percent carbon storage, and percent leaf area lost within the next 15 years due to emerald ash borer in select northern cities. All cities are within emerald ash borer infested areas except for New York (USDA 2014). For city sampling information, see Nowak et al. (2013a).

Philadelphia, PA

City	Number of trees	Tree population	Carbon storage	Leaf area
------(percent)-----				
Minneapolis, MN	105,900	11.0	5.1	12.4
Milwaukee, WI	286,650	9.2	5.7	6.9
Chicago, IL	201,350	6.0	4.2	5.8
Baltimore, MD	106,150	4.7	2.8	3.0
Philadelphia, PA	62,800	3.2	2.5	2.3
Morgantown, WV	15,350	2.9	0.9	1.3
Woodbridge, NJ	24,800	2.7	3.0	3.3
Boston, MA	15,550	1.3	0.9	0.5
Scranton, PA	13,000	1.3	1.4	0.9
Washington, DC	20,050	1.1	1.1	1.0
Hartford, CT	5,200	1.0	0.5	1.1
Moorestown, NJ	5,300	1.0	0.6	0.9
Freehold, NJ	450	1.0	0.4	0.4
Syracuse, NY	9,350	0.9	0.4	1.1
New York, NY	13,800	0.3	0.1	0.2
Jersey City, NJ	0	0.0	0.0	0.0



Chicago, IL

Invasive trees and shrub species (Chapter 5) also have the potential to substantially alter urban forest composition in the coming years through prolific regeneration. The invasive characteristics of some species pose problems associated with their spreading into the surrounding landscape, displacing native species and altering local ecosystems (e.g., Pimentel et al. 2000). In Syracuse, NY, only 35 percent of new trees (plantings or natural regeneration) occurring between 2001 and 2009 were native species, with 52 percent

classified as invasive species (Nowak 2012). Regeneration was dominated by European buckthorn (*Rhamnus cathartica*), which tripled in population during this period (Nowak et al. 2013b). Species classified as invasive (based on State invasive species lists) can reach one-third of the total tree population in some northern cities (Table 10.7). These invasive species have and will continue to alter urban tree composition in the coming years, and thereby alter urban forest structure and ecosystem services derived from these forests.



Table 10.7—Characteristics of trees classified as invasive in select northern cities showing numbers of trees; numbers of species; and their relative proportion of the total population, carbon storage, and leaf area. For city sampling information, see Nowak et al. (2013a).

City	Number of trees	Number of tree species	Tree population	Carbon storage	Leaf area
------(percent)-----					
Milwaukee, WI	1,112,000	12	33.3	20.6	30.7
Syracuse, NY	326,300	5	29.8	13.9	21.4
Freehold, NJ	14,000	7	29.4	27.4	30.2
Jersey City, NJ	38,300	7	28.0	25.6	28.4
Boston, MA	267,400	5	22.6	14.6	25.5
Chicago, IL	570,400	10	16.1	17.6	14.7
New York, NY	778,600	2	15.0	9.3	10.7
Philadelphia, PA	294,300	6	13.8	10.4	12.4
Woodbridge, NJ	126,000	9	12.8	7.3	10.7
Hartford, CT	60,500	4	10.7	5.5	7.0
Moorestown, NJ	52,000	8	8.8	6.1	8.5
Baltimore, MD	178,900	4	7.2	4.1	4.8
Washington, DC	130,900	7	6.8	3.0	5.4
Minneapolis, MN	57,800	2	5.9	8.3	10.9
Scranton, PA	71,000	7	5.8	11.4	14.1
Morgantown, WV	19,500	1	3.4	1.2	1.7



CONCLUSIONS

Four trends are evident:

(1) urban land is expanding at the expense of rural land, particularly forest and agricultural land; (2) urbanization will change tree cover nationally with results varying by region, with some regions gaining tree cover and others, including the Northern States, losing tree cover; (3) tree cover in urban areas has been on the decline in recent years; and (4) insects, disease, and invasive species will alter urban forest structure.

These trends indicate that urban land is subsuming rural forest land at the same time that the importance of urban trees and forests is increasing. Although urban forests will be a minor component of the forest landscape nationally, they are critical in terms of their influence on rural forests, both environmentally and politically. Many insects, invasive plants, pollutants, and human disturbances emanate from urban areas and spread into rural forests. In addition, because of their close proximity to more than 80 percent of the northern population, urban forests will directly affect the vast majority of people by influencing their perspectives, votes, and decisions about natural resources. Thus, urbanization will likely be the most dominant forest influence, and urban forests will be the most influential forest of the 21st century.

As populations and urban areas increase, urban forest benefits become more significant. From 1990 to 2000, urban land in the United States

increased by 11 million acres and the urban population increased by 39 million people. Urban land is projected to almost triple in size by 2050 but will still remain a relatively small proportion of the total land area of the conterminous United States (8 percent). Northern urban land expanded by 4 million acres from 1990 to 2000, and it is projected to be 14 percent of total northern land area by 2050. The highest levels of urbanization have been and are projected to occur in Northeastern States, where much of the urban land is converted from forests and results in decreased tree cover. In the Northeast, 48 percent of the converted urban land from 1990 to 2000 came at the expense of forests. Urbanization in desert, grassland, and agricultural areas can increase tree cover relative to the surrounding landscape, but by 2060, a net decrease in tree cover for all land is predicted, ranging from 1.1 to 1.6 percent for the conterminous United States and from 1.2 to 1.9 percent for the Northern States.

Urban tree cover in the conterminous United States is currently estimated at 35 percent, with higher levels found in forested areas and lower levels found in deserts, grasslands, and agricultural areas. However, a recent study that included nine northern cities found that tree cover decreased in eight of them. Numerous natural and societal factors affect tree cover change, both positively and negatively. Continued monitoring and management of urban forests is necessary to sustain their essential benefits for current and increasing future urban populations.



Literature Cited

- Alig, R.; Kline, J.; Lichtenstein, M. 2004.** Urbanization on the US landscape: looking ahead in the 21st century. *Landscape and Urban Planning*. 69(2–3): 219–234.
- Dwyer, J.F.; Nowak, D.J.; Noble, M.H.; Sisinni, S.M. 2000.** Assessing our Nation's urban forests: connecting people with ecosystems in the 21st century. Gen. Tech. Rep. PNW–460. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 540 p.
- Greenfield, E.J.; Nowak, D.J. 2013.** Tree cover and aridity projections to 2060: a technical document supporting the Forest Service 2010 RPA assessment. Gen. Tech. Rep. NRS–125. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 35 p.
- Intergovernmental Panel on Climate Change [IPCC]. 2007.** Climate change 2007: the physical science basis. Summary for policymakers. Geneva, Switzerland: IPCC Secretariat. 18 p. <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf>. (accessed July 15, 2008).
- Krist, F.J.; Ellenwood, J.R.; Woods, M.E.; McMahan, A.J.; Cowardin, J.P.; Ryerson, D.E.; Sapio, F.J.; Zweifler, M.O.; Romero, S.A. 2014.** 2013–2027 National insect and disease forest risk assessment. FHTET-14-01. Washington, DC: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. 199 p.
- Nowak, D.J. 2012.** Contrasting natural regeneration and tree planting in 14 North American cities. *Urban Forestry and Urban Greening*. 11: 374–382.
- Nowak, D.J.; Dwyer, J.F. 2007.** Understanding the benefits and costs of urban forest ecosystems. In: Kuser, J., ed. *Urban and community forestry in the Northeast*. New York: Springer: 25–46.
- Nowak, D.J.; Greenfield, E.J. 2010.** Evaluating the National Land Cover Database tree canopy and impervious cover estimates across the conterminous United States: a comparison with photo-interpreted estimates. *Environmental Management*. 46(3): 378–390.

- Nowak, D.J.; Greenfield, E.J. 2012a.** Tree and impervious cover change in U.S. cities. *Urban Forestry and Urban Greening*. 11: 21-30.
- Nowak, D.J.; Greenfield, E.J. 2012b.** Tree and impervious cover in the United States. *Landscape and Urban Planning*. 107: 21-30.
- Nowak, D.J.; Greenfield, E.J.; Hoehn, R.; LaPoint, E. 2013a.** Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution*. 178: 229-236.
- Nowak, D.J.; Hoehn, R.E.; Bodine, A.R.; Greenfield, E.J.; O'Neil-Dunne, J. 2013b.** Urban forest structure, ecosystem services and change in Syracuse, NY. *Urban Ecosystems*. doi: 10.1007/s11252-013-0326-z.
- Nowak, D.J.; Noble, M.H.; Sisinni, S.M.; Dwyer, J.F. 2001.** Assessing the U.S. urban forest resource. *Journal of Forestry*. 99(3): 37-42.
- Nowak, D.J.; Rowntree, R.A.; McPherson, E.G.; Sisinni, S.M.; Kerkmann, E.; Stevens, J.C. 1996.** Measuring and analyzing urban tree cover. *Landscape and Urban Planning*. 36: 49-57.
- Nowak, D.J.; Stein, S.M.; Randler, P.B. [et al.]. 2010.** Sustaining America's urban trees and forests. Gen. Tech. Rep. NRS-62. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 27 p.
- Nowak, D.J.; Walton, J.T. 2005.** Projected urban growth and its estimated impact on the U.S. forest resource (2000-2050). *Journal of Forestry*. 103(8): 383-389.
- Nowak, D.J.; Walton, J.T.; Dwyer, J.F.; Kaya, L.G.; Myeong, S. 2005.** The increasing influence of urban environments on U.S. forest management. *Journal of Forestry*. 103(8): 377-382.
- Pimentel, D.; Lach, L.; Zuniga, R.; Morrison, D. 2000.** Environmental and economic costs of nonindigenous species in the United States. *BioScience*. 50 (1): 53-65.
- U.S. Census Bureau. 2007.** Urban and rural classification. Washington, DC: U.S. Department of Commerce, Census Bureau. <https://www.census.gov/geo/reference/urban-rural.html> (accessed August 15, 2015).

U.S. Department of Agriculture [USDA]. 2014. Cooperative emerald ash borer project: Initial county EAB detections in North America. Washington, DC: U.S. Department of Agriculture. [map]. http://www.emeraldashborer.info/files/MultiState_EABpos.pdf (accessed September 24, 2014).

U.S. Department of Agriculture, Forest Service. 2012. Future of America's forest and rangelands: Forest Service 2010 Resources Planning Act assessment. Gen. Tech. Rep. WO-87. Washington, DC: U.S. Department of Agriculture, Forest Service. 198 p.

U.S. Department of Agriculture, Natural Resources Conservation Service [USDA NRCS]. 2001. Summary report: 1997 national resources inventory. Revised. Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service; Ames, IA: Iowa State University, Statistical Laboratory. 89 p.

Wear, D.N. 2011. Forecasts of county-level land uses under three future scenarios: a technical document supporting the Forest Service 2010 RPA assessment. Gen. Tech. Rep. SRS-141. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 41 p.

Zhu, Z. 1994. Forest density mapping in the lower 48 states: a regression procedure. Res. Pap. SO-280. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 11 p.

