Chapter 5

URBAN INFLUENCES ON FORESTS

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Introduction

A common concern voiced in each Assessment focus group was the loss of agricultural sites and natural habitats to urban use. As children, group members fondly recalled playing in fields and forests. Today, those open spaces are gone, covered by shopping centers, housing subdivisions, or other urban land uses. The conversion of open lands to urban uses is not new. What is different today is the rapid rate of conversion (Boyce and Martin 1993).

Since the 1970s, the South's population has increased dramatically causing extensive urbanization across the region. A strong economy, new telecommunication technology, new transportation systems, and land use planning policies have stimulated development from the edges of cities to formerly remote rural areas. This chapter assesses some of the key urban effects on forest ecosystems and identifies future research and educational needs to address these effects.

Urban Effects on Forest Ecosystems

Urbanization directly alters forest ecosystems by removing or fragmenting forest cover. Urbanization also indirectly alters forest ecosystems by modifying hydrology, altering nutrient cycling, introducing nonnative species, modifying disturbance regimes, and changing atmospheric conditions. Collectively, these changes significantly affect forest health and modify the goods and services provided by forest ecosystems. A list of selected ecosystem goods and services, where goods are valued as items with monetary value in the market place and services are valued economically but rarely bought or sold (Christensen and others 1996), follows.

Ecosystem "goods" include

- Food products,
- Decorative products,
- Wood products,
- Medicinal plants,
- Wild genes for domestic plants and animals, and
- Tourism and recreation.

Ecosystem "services" include

- Maintaining hydrologic cycles,
- Regulating climate,
- Cleansing water and air,
- Maintaining the gaseous composition of the atmosphere,
- Pollinating crops and other important plants,
- Generating and maintaining soils,
- Storing and cycling essential nutrients,
- Absorbing and detoxifying pollutants, and
- Providing beauty, inspiration, and research.

Most ecosystem research has not examined urban effects on ecosystems in the wildland-urban interface. In this section, I draw upon ancillary research in urban and rural landscapes to illustrate the direct and indirect effects of urbanization on forest ecosystems in the interface.

"There is no general recognition of natural capital. That land with weeds on it is worth something—for absorption, filtration, habitat, and oxygen." Mississippi

Figure 5.1
The Appalachian Highlands are greatly impacted by urbanization due to the sensitive ecosystems found there.

Deforestation and Fragmentation

The most obvious landscape effects of human activities are the reduction of total forest area and the fragmentation of remaining forests into smaller, isolated patches. Agriculture is the primary cause for deforestation (Alig and others 2000). However, forest losses to urban uses have increased since the 1970s (Boyce and Martin 1993). In addition, urbanization of agricultural land has caused conversion of forests to agriculture in other places to offset losses (Alig and Healy 1987). In the South, the Piedmont has the greatest rate of forest land conversion to urban uses, but the greatest impact of urbanization may be in the Appalachian Highlands and Coastal Plain because of the sensitive ecosystems found in those regions (Boyce and Martin 1993) (**fig. 5.1**).

Table 5.1—Tree canopy losses[a] in selected areas in the South

Location	Forested area[b]	Time period	Tree canopy loss[b]
	M acres	*Year*	*Percent*
Atlanta *metropolitan area*	1,747	1974-96	26
Chattanooga, TN	110	1974-96	21
Houston *metropolitan area*	692	1972-99	8
Roanoke, VA	313	1973-77	9
Fairfax County, VA	125	1973-97	20

[a] Because measuring canopy losses and fragmentation are scale dependent, a comparison across different studies is difficult. The author uses analyses by American Forests because the same protocol is employed to analyze each region. This use, however, does not imply an endorsement of techniques or models developed to obtain these values.

[b] This value represents area and the loss of canopy cover as classified by a 30-meter Landsat pixel as having at least 50 percent tree cover.

Source: American Forests 2002.

Photo by Hans Riekerk, University of Florida

Figure 5.2
Forest fragmentation is accelerated by the construction of buildings, roads, and parking lots.

Rapid urban expansion occurs not only around major metropolitan areas but also around small towns and villages (see chapter 2). Forest losses to urbanization have not been analyzed comprehensively. Although forest losses in specific places have been studied, findings often are not comparable because of different techniques and scales to measure change and different definitions of forest cover and losses. Analyses conducted by American Forests (2002) show that forest cover for four metropolitan areas—Atlanta, Chattanooga, Houston, and Roanoke—and Fairfax County, a county near Washington, DC, declined by over 585,000 acres over a 24-year period (**table 5.1**).

Regional conversion rates, however, provide little ecological information on site content and landscape context. For example, the data presented in table 5.1 convey no information about losses of critical and threatened ecosystems, rates of fragmentation, size distribution of existing forest cover by particular forest types, or the location and nature of affected watersheds. Such information is critical to understanding the direct and indirect effects of urbanization on ecosystem components and processes and ultimately on goods and services provided by ecosystems. An analysis of the effects of fragmentation has not yet been conducted for the entire South, but some regional studies have been done (Rudis 1995; Turner 1990; Turner and others 1996; Wear and Greis, in press; Wear and others 1998). In general, rates of forest loss are fastest along major communication corridors, near major urban centers, and near recreational areas such as national forests and parks; they are slowest in areas with slow economic development (Boyce and Martin 1993).

Fragmentation, one of the most significant negative effects of human activities on biodiversity (Noss 1987), is accelerated in the interface because of the construction of buildings, roads, and parking lots (Zipperer 1993) (**fig. 5.2**). Fragmentation affects native biodiversity by reducing habitat size, reducing the amount of forest interior habitat, isolating existing populations, and modifying microclimates (Noss and Csuti 1994, Saunders and others 1991). Isolation is increased further by the loss of corridors connecting natural habitats and by natural habitats being embedded in urban landscapes that inhibit organism movement. With restricted organism movement, genetic flow among populations is drastically reduced, leading potentially to inbreeding and local extinctions. For example, the Florida panther (*Felis concolor*) suffers from a high frequency of inbreeding and may be on the verge of extinction (White and Wilds 1998).

Photo by Joseph Schaefer, University of Florida

Figure 5.3
In urbanizing landscapes, edges become dominant features.

In the interface, development creates new edge habitat and alters habitat shape from irregular to highly regular and linear (Godron and Forman 1983, Zipperer 1993). By increasing edge habitat, development increases the number of edge species but decreases the number of interior species (Nilon and others 1994). Edges occur naturally and contribute to the habitat heterogeneity of a landscape. In urbanizing landscapes, however, edges become dominant features principally because of new roads (**fig. 5.3**). Roads also have numerous other ecological effects. A listing of known road effects on species, communities, and landscapes (Baker and Knight 2000) follows:

- Species (fine scale)
  - Direct effects
    - Direct habitat loss/gain to roads and adjoining built area
    - Direct mortality on roads
  - Road-effect zone
    - Habitat loss/gain due to avoidance areas surrounding roads and built area
    - Increased access
      - Increased mortality from hunting
      - Increased harassment of wildlife near roads
      - Increased woodcutting and trampling along roads
      - Increased human-set fires/other disturbances
      - Increased dumping
    - Potential indirect effects of landscape changes
      - Increased edge species/decreased interior species
      - Perils to small populations
      - Loss/gain of important natural disturbance patches
    - Pollution effects
      - Increased lighting
      - Increased dust and fumes
      - Increased noise
  - Connectivity effects
    - Barrier/deterrent to movement
    - Conduit effects
      - Spread of nonnative species
      - Enhanced/decreased movement of native species
- Community and landscape (broad scale)
  - Preferential loss of ecologically valuable communities
  - Fragmentation and isolation of patches
  - Increase in edge area
  - Decrease in interior area
  - Ratios of edge area or interior area to total patch area
  - Decreasing complexity of patch shape
  - Decreasing variation in patch area, edge area, and interior area
  - Fewer large patches and more small patches
  - Landscape texture (local diversity) higher
  - Expansion of other fragmenting land uses from road network
  - Changes in natural disturbance regimes.

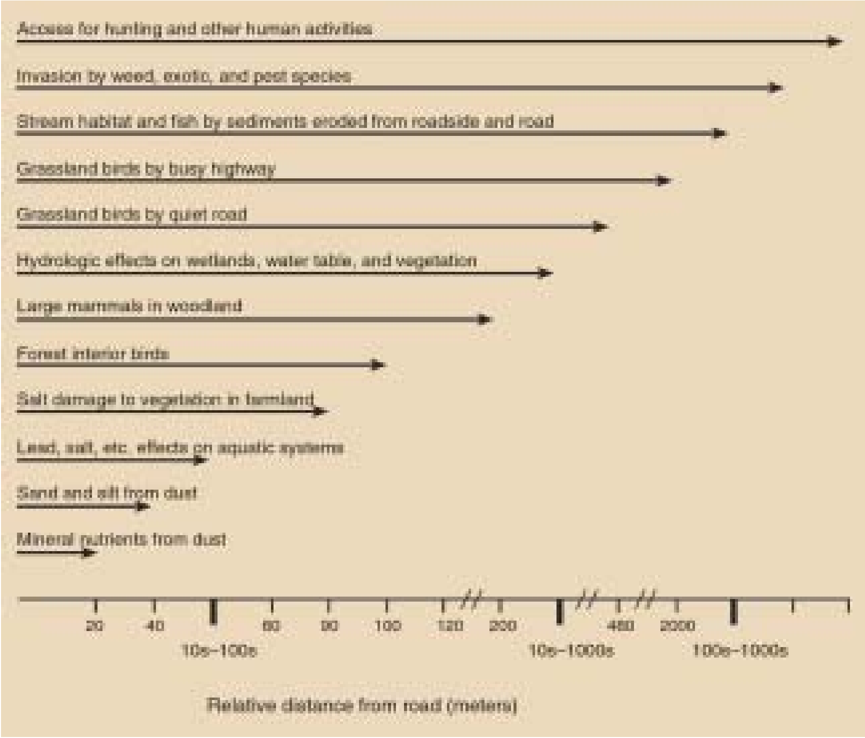


Figure 5. 4
The effect of roads on the adjacent land cover. The horizontal axis is not linear but illustrative to show ranges of effects (Forman 1995).

At the forest edge, the physical environment and biotic community are altered, a phenomenon called the edge effect [see Forman (1995) for a discussion of edges and boundaries]. Physical changes include greater wind turbulence, greater temperature fluctuation, increased lateral light penetration, and drier site conditions. Biotic changes include a proliferation of nonnative species, an increase in plant and animal generalists, an increase in parasitism and predation, and an alteration of ecological processes such as nutrient cycling. These effects vary across a range of spatial and temporal scales for different forest types and species (**fig. 5.4**).

" . . . . If you drive by some parts [of north Georgia] you will see a ridgetop covered with houses or a stream bank that used to be a pastoral setting that now has houses every 50 feet sitting right on top of the streambank." Georgia

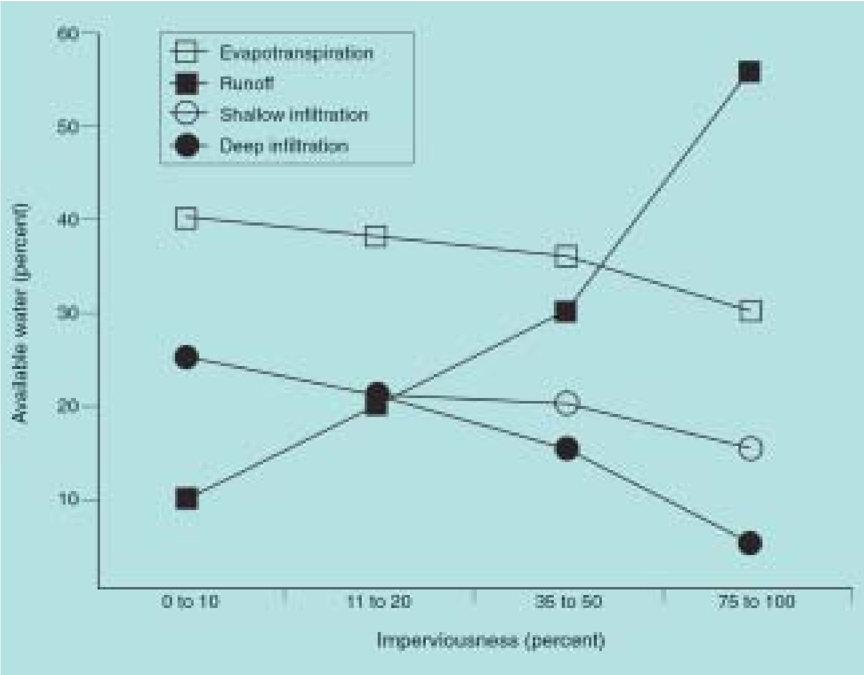


Figure 5.5
Changes in evapotranspiration, runoff, and shallow and deep infiltration with increasing impervious surface cover in a watershed (Arnold and Gibbons 1996, Paul and Meyer 2001).

Hydrology

Urbanization alters water flow in the interface (**fig. 5.5**). Changes include increased amount of impervious surfaces, decreased infiltration, increased surface runoff, and altered flooding regimes (**fig. 5.6**). Impervious surfaces include rooftops, driveways, roads, and parking lots. In low-density residential development (<1 house per acre), the roads may account for more than 60 percent of the impervious surface and exert a greater affect on aquatic systems than rooftops (Schueler 1994). Storm runoff from roads and parking lots often flows directly into streams. Runoff from rooftops often flows out over yards with pervious surfaces. An increase of just 10 percent in impervious surfaces significantly changes streambank stability, water quality and quantity, and biodiversity of aquatic systems (Schueler 1994) (**table 5.2**).

Besides increasing the amount of impervious surfaces, urbanization drains wetlands, channelizes streams, and increases the amounts of sediments, nutrients, and biocides entering the aquatic system. Erosion and sedimentation occur not only from constructing new roads and buildings but also from eroding beds and banks of streams. Sediment loads from inadequately controlled construction sites typically are 10 to 20 times greater per unit of land area than those from agricultural land and 1,000 to 2,000 times those from forests (Weiss 1995). Streambank stability decreases rapidly above a level of 10 percent impervious cover because of increased stream velocity and volume from storm runoff (Schueler 1994). Recent analyses of watersheds by the U.S. Geological Survey (1999) show that urban and urbanizing landscapes have a defining pollution signature for insecticides and herbicides. Conductivity, suspended soils, and concentrations of ammonium, hydrocarbons, and metals in surface and subsurface waters increase with urbanization (U.S. Geological Survey 1999).

Photo by Larry Korhnack, University of Florida

Figure 5.6
Increased impervious surfaces lead to decreased infiltration, increased surface runoff, and altered flooding regimes.

Table 5.2—The effect of different percentages of impervious surface on stream attributes

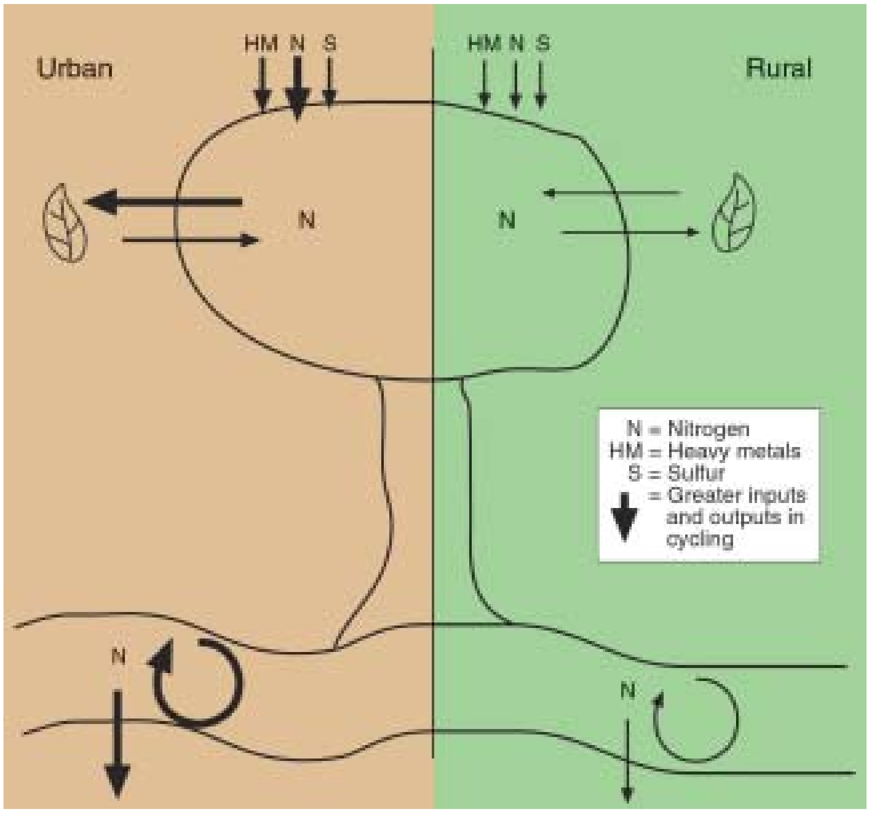
	Impervious surface (percent)		
Stream attribute	0-10	11-25	25-100
Stream stability	Stable	Unstable	Highly unstable
Water quality	Good	Fair	Fair-poor
Stream biodiversity	Good-excellent	Fair-good	Poor

Source: Schueler 1994.

Development in the wildland-urban interface often occurs in the headwaters of many streams and rivers. These very small creeks and streams are home to many endemic species that are extremely sensitive to environmental changes and pollution. Urbanization alters headwaters by covering or ditching them, removing riparian vegetation, increasing water temperature, and altering water quality (Marsh and Marsh 1995, Pluhowski 1970). Research is needed not only to document the extent of land use changes caused by urbanization at headwaters but also to measure biotic and abiotic effects downstream.

Nutrient Cycling

Urban landscapes are a mosaic of different human population densities, building densities, and amounts of impervious and pervious surfaces (Stearns and Montag 1974). Embedded in these urban landscapes are native forest stands. When compared to rural forest ecosystems of similar composition, structure, and geology, forests in urban landscapes differ environmentally, compositionally, and structurally and have different rates for certain ecosystem processes (McDonnell and others 1997) (**fig. 5.7**). Over time, urbanization affects forest ecosystems even if the forests have not been disturbed by development. Mere proximity to urban land use can cause changes. Work needs to be conducted to determine at what level of urbanization shifts in ecosystem species composition, structure, and processes occur, and the corresponding lag times between the respective responses.



Urban		Rural
+	Soil temperature	–
+	Soil hydrophobicity	–
–	Microinvertebrates	+
+	Earthworms	–
–	Fungal hyphae	+
+	Nonindigenous plants	–
–	Stem density	+
–	Leaf letter depth	–
+	Decomposition	–
+	Nitrogen-mineralization	–
+	Nitrification rates	–

Figure 5.7
Generalized illustration depicting structural and functional differences of forests in urban and rural landscapes having similar physical environments and species composition and structure (Kostel-Hughes 1995; McDonnell and others 1997; Pouyat and others 1994, 1996; Rudnicky and McDonnell 1989).

Biodiversity

Biodiversity is an integrator of environmental changes and land transformation on a landscape. Urbanization alters the composition of plant and animal species in both terrestrial and aquatic systems. In general, as one moves from the rural to urban landscape, plant species richness increases, but decreases for amphibians, reptiles, mammals, and birds (Kowarik 1990). Along this urban continuum, the number of native species decreases whereas the number of exotic species increases. Native species are missing from urban landscapes because their habitats may be absent or too small to maintain a viable population. Species also may be unable to adapt physiologically or behaviorally to an urban environment. A study of avian species in the Lake of the Ozarks region revealed that as development increases, habitat specialists decline. Other species, such as those that inhabit edges and are habitat generalists, increase with development (Nilon and others 1994).

Urbanization is not the only human activity that has altered biodiversity locally and regionally. Past and current agricultural and natural resource management practices significantly affect biodiversity (White and Wilds 1998). Five large mammals—bison (*Bison bison*), elk (*Cervus* e. *canadensis*), gray wolf (*Canis lupus*), jaguar (*Felis onca*), and ocelot (*Felis pardalis*)—have been extirpated from the South because of past agricultural and natural resource management practices (Echternacht and Harris 1993) (**table 5.3**). Collectively, agriculture, forestry practices, and urbanization significantly reduce the extent of ecosystems in the South. A listing of critically endangered and endangered ecosystems (85-percent loss) in the South (Noss and others 1995, White and Wilds 1998) follows:

Table 5.3—The number of native, endemic, extinct, extirpated, and federally listed vertebrates in the South

Vertebrate group	Species				
	Native	Endemic	Extinct	Extirpated	Listed endemics
Fishes	535	257	3	2	23
Amphibians and reptiles	242	83	0	0	8
Birds	237	0	2	3	4
Mammals	101	7	0	5	13

Source: Echternacht and Harris 1993, White and Wilds 1998.

Geographic area	Ecosystem type
	> 98-percent loss: critically endangered
Southeast	Old-growth deciduous forests
Tennessee, North Carolina, Virginia	Southern Appalachian spruce-fir
Coastal Plain	Longleaf pine
Florida	Rockland slash pine
West Gulf Coastal Plain	Loblolly-shortleaf pine
Southeast	Canebrakes
Kentucky	Bluegrass-savannah-woodland
Alabama, Mississippi	Blackbelt prairie, Jackson prairie
Florida	Dry prairie
Louisiana	Wet and mesic coastal prairies
Virginia, North Carolina	Atlantic white-cedar
Kentucky	Native prairies
Cumberland Plateau, Tennessee	High-quality oak-hickory
	85- to 98-percent loss: endangered
Central Appalachians	Red spruce
Coastal Plain, Tennessee	Upland hardwoods
Tennessee	Old-growth oak-hickory
Tennessee	Cedar glades
Texas, Louisiana	Longleaf pine
Louisiana	Mississippi terrace prairies, calcareous prairie, Fleming glades
Louisiana	Live oak, live-oak hackberry
Louisiana	Prairie terrace-loess oak forest
Louisiana	Shortleaf pine-oak-hickory
Louisiana	Mixed hardwood-loblolly pine
Louisiana	Xeric sandhill
Louisiana	Stream terrace, sandy woodland savannah
Coastal Plain	Gulf coast pitcher-plant bogs
Virginia	Pocosins
North Carolina	Mountain bogs
Blue Ridge, Tennessee	Appalachian bogs
Highland Rim, Tennessee	Upland wetlands
Tennessee	Aquatic mussel beds
Virginia	Ultramafic glades

For example, agriculture and forestry practices initially reduced the longleaf pine (*Pinus palustris* Mill.) and wiregrass (*Aristida stricta* L.) ecosystems in the Coastal Plain from over 24 million acres to <2 million acres (Noss 1989). Urbanization further reduces the extent of these ecosystems. This change significantly affects the biodiversity of the region. Decline in the population of the gopher tortoise (*Gopherus polyphemus*), a keystone species, was especially damaging. Over 350 species depend on the tortoise and its burrows. As the tortoise is locally extirpated, many of the species depending on it may also disappear.

Likewise, major problems involving nonnative species in the South are not just the result of urbanization but also the consequence of past agricultural, forestry, and wildlife practices (Williams and Meffe 1998). Examples include balsam wooly adelgid (*Adelges picea*), kudzu [*Pueraria montana* (Lour.) Merr.] (**fig. 5.8**), and the wild boar (*Sus scrofa*). Urbanization may increase the susceptibility of a forest to colonization by nonnative species. Forest communities with modified soils, low native biodiversity, absences of predator species, simple food webs, and a high frequency of human disturbances are more vulnerable to invasion by nonnative species than intact communities (Lodge 1993, Meffe and Carroll 1994, Williams and Meffe 1998). These traits often characterize forest communities in urban and urbanizing landscapes (McDonnell and others 1997). We are only beginning to understand how nonnative species alter ecosystem composition, structure, processes, goods, and services. Research needs to consider the positive as well as the negative effects of nonnative species in an ecosystem.

Photo by Hallie Dozier, Louisiana State University

Figure 5.8
Kudzu (*Pueraria montana*) is an invasive nonnative species that is altering ecosystems throughout the South.

"Very often when you're developing a forested environment, that kind of disturbance promotes exotic species that may not compete well in a forested environment but do very well when the area is disturbed." Georgia

Over 6,500 nonnative species occur in the United States (Williams and Meffe 1998). In the South the number of introduced plant species ranges from 362 in Oklahoma to 1,017 in Florida; most States have between 500 to 700 introductions (Williams and Meffe 1998). Fish, amphibians, reptiles, and mammals have also been introduced into the South. Some of these introductions—especially the fish, amphibians, and reptiles—resulted from pets being released into the wild (Williams and Meffe 1998). Since humans are the primary cause for introductions of nonnative species, the potential for additional introductions increases as human population density increases.

High population densities of native species also affect ecosystem composition and structure. Examples include the Canada goose (*Branta canadensis*), raccoon (*Procyon lotor*), and white-tailed deer (*Odocoileus virginianus*) (**figs. 5.9A, 5.9B**). High populations of Canada geese pollute water bodies and contribute significantly to the eutrophication of small ponds and lakes. Population densities of raccoons have increased dramatically in some parts of the South (Southern Appalachian Man and the Biosphere 1996). For example, only 43 percent of the counties in the Appalachian Mountains and Shenandoah Valley (135 counties) had moderate densities of raccoons (5 to 10 individuals per square mile) in 1970. By 1995, nearly 96 percent of those counties had moderate to high densities of raccoons (>10 per square mile). Because the raccoon is a vector for rabies and a predator of ground-nesting animals, this increase, caused by human development, has significant implications for human health and species diversity in the region.

Photo by Larry Korhnack, University of Florida

(A)

Photo courtesy of Virginia Department of Forestry

(B)

Figure 5.9
High population densities of native species, such as (A) raccoons and (B) white-tailed deer, can affect ecosystem structure and function.

A similar increase in white-tailed deer population has occurred. For example, in the Southern Appalachians, only 30 percent of the counties had moderate deer densities (15 to 30 individuals per square mile) in 1970. By 1995, nearly 70 percent of the counties had moderate to high densities (>30 individuals per square mile) (Southern Appalachian Man and the Biosphere 1996). This increase resulted from changes in landscape configuration, lack of predators, and increased food supplies. At moderate to high population density, white-tailed deer can reduce agricultural production, damage urban plants, and denude understory vegetation in forest stands. The loss of understory vegetation significantly affects breeding success of ground-nesting species. The increased number of homes in the interface also contributes to increased white-tailed deer densities by reducing hunter access. Similarly, with the increase in human population in the interface, population densities of domestic dogs and cats are expected to increase. Domestic pets also can significantly affect ground-nesting species (Churcher and Lawton 1987).

Disturbance Regime

Ecosystems are dynamic. Changes occur because ecological, physical, and social components change through time and because of natural and human disturbances. Urbanization is a disturbance agent. Like natural disturbances, urbanization alters composition, structure, and spatial arrangement of ecosystems on the landscape. Unlike natural disturbances, however, changes caused by urbanization often are longer lasting. For example, intensive lawn and horticultural management systems inhibit natural succession. In addition, as the interface is developed, landscape heterogeneity changes. Urbanization decreases the number of native habitat types and increases the number of human structures and habitats (Pickett 1998).

Suppressing disturbances alters landscape heterogeneity (Turner and others 1998). In the South, one of the single most disruptive changes in the natural disturbance regime has been fire suppression (see chapters 6 and 8). The policy decision to suppress fires has endangered the existence of fire-dependent communities and species, enabled xeric communities to become more mesic in species composition, increased the size and severity of forest fires, and reduced landscape heterogeneity (Buckner and Turrill 1998, Stuart 1998) (**fig. 5.10**). Fire suppression also alters the frequency and severity of other disturbances, such as those caused by insects and pathogens (Covington and others 1994).

In human-dominated systems, fires often are suppressed to minimize the losses of personal property and structural damage. To minimize fuel buildup around structures, prescribed burns are conducted. These fires, conducted in late winter or early spring, burn cooler and have different ecological effects than hot fires occurring during the hotter and drier periods (Buckner and Turrill 1998). For example, cool fires may lack the heat and intensity to open serotinous cones of Table Mountain pine (*P. pungens* Lamb.). Cool fires also may create a landscape that is more homogeneous than a landscape with both cool and hot fires.

Fire creates new habitat. Both native and nonnative species quickly colonize this habitat (Stuart 1998). Cool burns and high population densities of nonnative species in urbanizing landscapes may create a more favorable condition for colonization and growth of nonnative species. The effect of cooler, prescribed burns on native and nonnative species needs to be assessed. Changes should be measured at different spatial and temporal scales.

Atmospheric Effects

Air pollutants of concern in southern forest ecosystems include oxides of nitrogen (NO_X) and sulfur (SO_X) and tropospheric or ground-level ozone (O_3). Each of these pollutants occurs naturally, but human activities increase their concentrations in the atmosphere. At high concentrations, these pollutants injure plant tissues, alter ecosystem processes, and predispose forests to other environmental stresses (Berish and others 1998).

Automobiles are the major sources of NO_X (Berish and others 1998). These compounds can react with volatile organic compounds to form O_3 or they can be deposited directly on forests. When deposited, they may alter productivity rates, and increase nitrification and nitrate leaching in terrestrial systems (Aber and others 1989). Although NO_X deposition is greatest in urban landscapes (Lovett and others 2000), increased vehicle travel throughout the interface may enhance NO_X deposition in rural areas.

Utility companies burning fossil fuels are the major sources for SO_X, a precursor to acidic deposition (Berish and others 1998). Long-term exposure to acidic deposition alters soil pH, leaches base cations from the soil, and causes surface water acidification (Berish and others 1998, Likens and others 1996). The greatest cumulative deposition rate of SO_X in the United States was measured in a spruce-fir forest in the Appalachian Highlands (Johnson and Lindberg 1992, Peine and others 1998). The SO_X originated from an adjacent State when the Tennessee Valley Authority increased electricity production to supply new and existing developments and the tourist industry during the summer. Climate patterns carried the pollution over the spruce-fir forest, demonstrating the regional impacts of pollution. New Federal regulations limiting SO_X emissions may reduce the effect of SO_X on forest ecosystems.

Like NO_X and SO_X, O_3 increases with urbanization. Typical summertime daily maximum O_3 concentration in urban and suburban landscapes ranges from 100 to 400 parts per billion (ppb) as compared to 50 to 120 ppb for rural landscapes (National Research Council 1992). Short-term exposure to relatively high concentrations (>150 ppb) can cause acute visible foliar injury in sensitive plants (Krupa and others 1998). Because O_3 enters a plant through leaf stomata, which close when soil moisture is limiting, soil moisture is an important variable affecting uptake and subsequent tissue damage. Greater rainfall at higher elevations may make forests there more susceptible to O_3 damage than forests at lower elevations (Berish and others 1998). Pollution damage to sensitive ecosystems in the Appalachian Highlands may increase as regional and local NO_X and O_3 concentrations increase.

Forest Health

In each of the previous sections, urbanization effects were discussed as independent events. These effects, however, act together. For example, atmospheric deposition alters nutrient availability in the soil and injuries plant tissue. These effects subsequently predispose the forest to pests and pathogens.

How do we know if a forest is healthy? This question was the focus of a workshop attended by scientists, philosophers, managers, environmentalists, and industrial representatives (Constanza and others 1992). They developed the following definition: "an ecological system is healthy and free from 'distress syndrome' if it is stable and sustainable—that is, it is active and maintains its organization and

Photo courtesy of Florida Division of Forestry

Figure 5.10
Many southern ecosystems are dependent on fire for maintaining ecological processes.

Broad and Fine Scales

In the wildland-urban interface, natural habitats are rapidly transformed into urban land uses with significant ecological consequences. Land use planners must reconcile economic development with environmental protection. To understand the ecological effects of urbanization, we need to look at entire landscapes (broad scale) as well as affected sites (fine scale). Traditionally, effects on soils, vegetation, species composition, and hydrology have been analyzed only on a fine scale.

autonomy over time and is resilient to stress" (Haskell and others 1992). Distress syndrome refers to the inability of an ecological system to recover naturally. Urbanization ultimately predisposes a forest ecosystem to a distress syndrome because of a suite of direct and indirect effects including land use conversion, fragmentation, pollution, loss of keystone species, introduction of nonnative species, and altered disturbance regime. With time, the original composition, structure, and function of the forest ecosystem will change in urban and urbanizing landscapes (Zipperer and Pouyat 1995). These new forests will be composed of native and nonnative species that have adapted to the stresses created by the urban landscape. The quality and quantity of ecosystem goods and services provided by these forests have yet to be determined.

" I think we have taken the wrong focus when saving a tree or patch of woods. Rather we need to take a systems approach. We need to look at the natural system and all the components . . ." Virginia

To address urban effects on forest health, an integrative and interdisciplinary approach is necessary. The approach must include terrestrial and aquatic systems and account for ecological processes operating at different spatial and temporal scales. Likewise, the approach must account for the complexity of interactions among the social, ecological, and physical components of an ecosystem.

Needs

Forests will always exist in the South. Their composition, structure, and function will continue to change because of environmental and human effects. During the urbanization process, we need to maintain forest health to provide the goods and services enjoyed and used by humans. To accomplish that objective, we need to sustain ecological and social integrity through an ecosystem approach to management (McCormick 1998). To meet these goals, new research should be conducted and educational tools should be developed.

Research is needed to:

- Quantify population distributions of native and nonnative species.
- Assess the synergistic effects of various land conversions, altered disturbance regimes, and atmospheric pollution on natural habitats and the establishment, growth, and maturity of native and nonnative species.
- Assess how nonnative species are altering the composition, structure, and function of the numerous ecosystems of the South.
- Understand how current fire management policies influence native and nonnative species colonization and growth.
- Monitor urban effects on ecosystem processes such as nutrient and carbon cycling, hydrology, and productivity over the long term. Monitoring is needed across the entire South rather than just at a few localities.

An Ecosystem Approach

Land use decisions often are based principally on socioeconomic elements of an ecosystem. Biological and physical elements should also be considered in a holistic or ecosystem approach to land use decisions. Since humans derive benefits from all the elements in ecosystems, anything less than an ecosystem approach may yield the wrong conclusions.

An ecosystem approach acknowledges the biophysical and social complexities of ecosystems and the importance of maintaining those complexities to meet human needs. Energy, organisms, and materials flow into and out of ecosystems and are not confined by political or management boundaries. A broad scale or landscape perspective is needed to assess how development alters these flows. A broad perspective also helps planners to see cumulative changes across the landscape.

- Develop protocols for restoring or rehabilitating ecosystems affected by urbanization.
- Move beyond smart growth models and start to predict the impacts of land use changes on landscape heterogeneity as well as ecosystem composition, structure, and function. Wear and others (1998) are modeling land use changes in an urban and urbanizing context. This work needs to be expanded to landscapes throughout the region, and results need to be applied to land use decisions.
- Identify the linkages among ecological, social, and physical components of the ecosystem and how social policies and socioeconomic conditions alter those linkages at different spatial and temporal scales.

Education needs are to:

- Establish a center or clearinghouse for research information so that results can be synthesized and packaged for various user groups-natural resource managers, land use planners, and landowners. The center must not only provide information; it also must provide a focus for education. Satellite learning centers also may need to be established to effectively transfer information to different user groups. Currently, scientific information exists to make sound land management decisions, but the information is not being used (McCormick 1998).
- Develop information vehicles to enhance traditional approaches for groups and individuals without Internet connections. The Internet provides a new avenue for dissemination, but access needs to be enhanced, and information needs to be packaged according to user group.
- Develop workshops and short courses not only for natural resource managers but also for mayors, county planning commissioners, and staffers from Governors' and legislators' offices on the importance of a holistic approach to land use planning. These workshops should also provide protocols for land use decisions.
- Update management procedures to reflect current techniques being applied by the management community and evaluated by the research community. Users—researchers and managers—need to be linked through the center so that new needs are identified and new information is disseminated.

Conclusion

Fire blackens the earth temporarily, but asphalt blackens it permanently. While this Assessment acknowledges that fire is an important wildland-urban interface issue, it also recognizes the long-term consequence of losing basic ecosystem goods and services to urbanization. Even if all development stopped today, forests would continue to be affected by urban uses through indirect stresses such as air pollution, global climate change, altered disturbance regimes, and introduction of exotic species. We are just beginning to understand the long-term ecological consequences of these indirect effects on forest ecosystems.

The question is not whether we should develop, but rather how best to use the land to maintain or enhance the goods and services provided by ecosystems (Turner and others 1998). Since the greatest threat to species, habitats, and cultures of the South is the increase in human population, land management decisions need to incorporate the principles of an ecosystem approach to decisionmaking (Dale and others 2000, Flores and others 1998, Zipperer and others 2000). Without ecological planning and collaboration, we are faced with continual urban sprawl and the loss of the ecological uniqueness and cultural diversity that define the South.

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