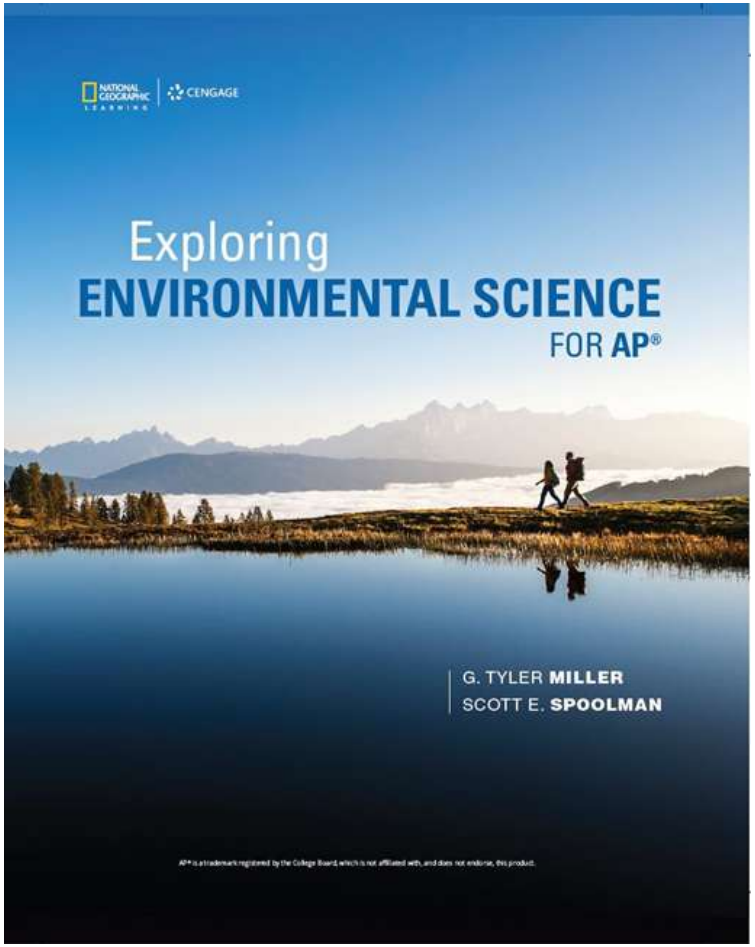
# Exploring Environmental Science for AP®

1st Edition




## Chapter 10

Sustaining Terrestrial Biodiversity: Forests, Public Lands, Grassland, Wetlands, and Cities

# Core Case Study: Costa Rica–A Global Conservation Leader (1 of 2)

- Costa Rica once covered in tropical forest
  - Suffered widespread deforestation between 1963 and 1983
  - Still harbors great biodiversity
  - Microclimates provide variety of habitats
  - More than 25% of its land is nature reserves and national parks
- Government pays landowners to restore forests

# Core Case Study: Costa Rica–A Global Conservation Leader (2 of 2)

# 10.1 How Should We Manage and Sustain Forests and Public Lands?

- Forest ecosystems provide ecosystem services far greater in value than the value of wood and other raw materials
- Forests can be preserved by halting government subsidies that hasten their destruction, by protecting gold-growth forests, and sustainably harvesting trees

# Forests Provide Important Economic and Ecosystem Services (1 of 2)

- Forests remove $CO_2$ from the atmosphere
  - Helps stabilize atmospheric temperatures
- Forests store water and release it slowly
- Forests provide habitats for two-thirds of world's terrestrial species
- Forests provide biofuel, industrial wood, and traditional medicines

# Forests Provide Important Economic and Ecosystem Services (2 of 2)

# Forests Vary in Age and Structure (1 of 2)

- Old-growth or primary forest
  - Uncut or undisturbed for 200 years or more
  - Reservoirs of biodiversity
- Second-growth forest
  - Trees from secondary ecological succession
- Tree plantation (tree farm, commercial forest)
  - Same-age trees clear-cut and replanted to supply industrial wood

# Forests Vary in Age and Structure (2 of 2)

Aleksander Bolbot/Shutterstock.com

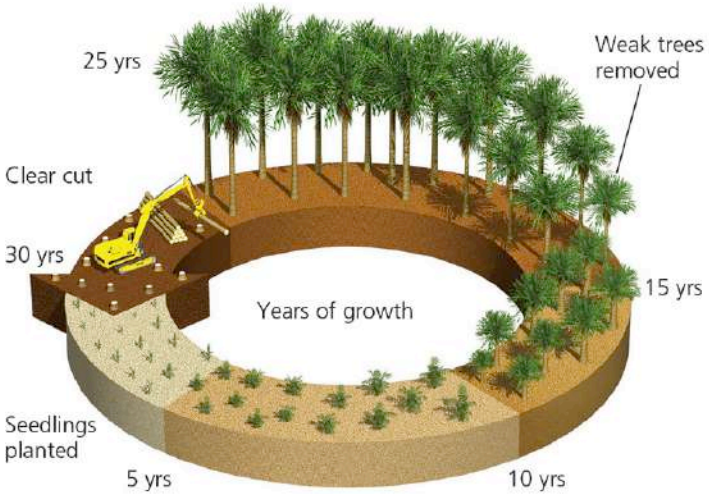
# Putting a Price on Nature's Ecosystem Services (1 of 3)

- Ecological economists estimate value of earth's ecosystem services
  - Waste treatment ($22.5 trillion per year)
  - Recreation ($20.6 trillion per year)
  - Erosion control ($16.2 trillion per year)
  - Food production ($14.8 trillion per year)
  - Nutrient cycling ($11.1 trillion per year)

# Putting a Price on Nature's Ecosystem Services (2 of 3)

- Since 1997, the world has been losing ecosystem services valued at $20.2 trillion per year
- Ongoing source of ecological income
  - If used sustainably
- Need to use full-cost pricing to include value of ecosystem services in prices of forest goods and services

# Putting a Price on Nature's Ecosystem Services (3 of 3)

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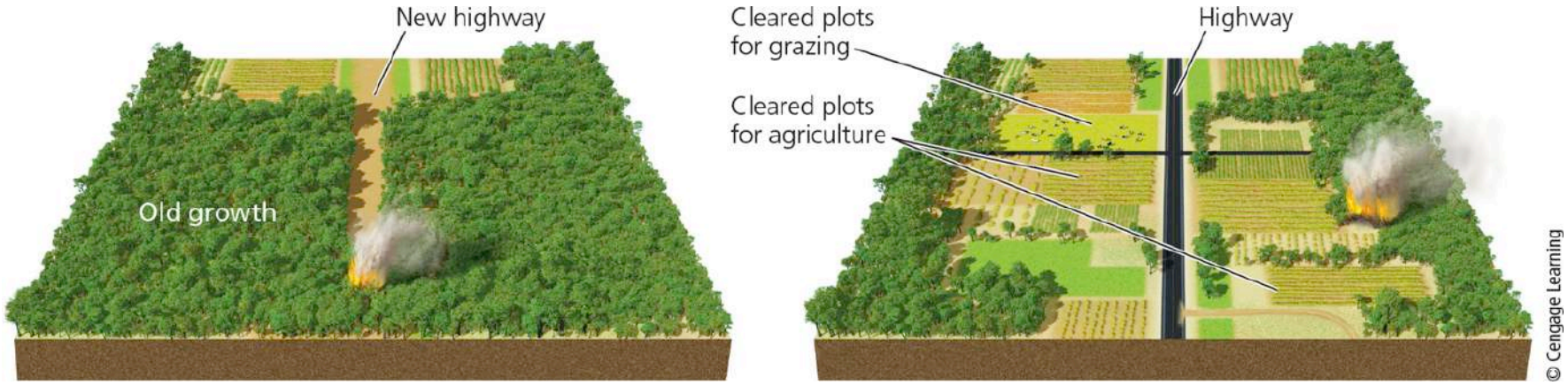
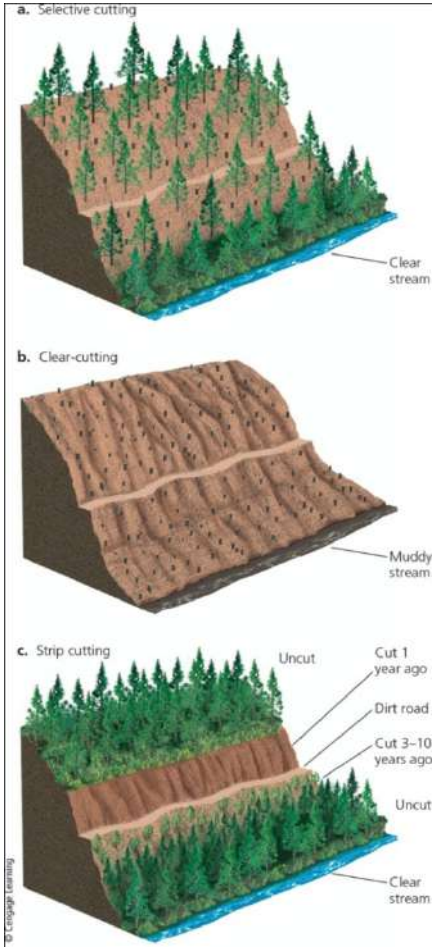
# Ways to Harvest Trees (1 of 3)

- First step: building logging roads
- Selective cutting
  - Intermediate-age or mature trees cut singly or in small groups
- Clear-cutting
  - Removing all trees in an area
- Strip cutting
  - Clear-cutting in strips

# Ways to Harvest Trees (2 of 3)



# Ways to Harvest Trees (3 of 3)



# Fires Affect Forest Ecosystems (1 of 2)

- Surface fires
  - Usually burn leaf litter and undergrowth
  - Provide several ecological benefits
- Crown fires
  - Extremely hot–burn whole trees
  - Kill wildlife
  - Increase topsoil erosion
- Climate change lengthening fire seasons

# Fires Affect Forest Ecosystems (2 of 2)

David J Moorhead, University of Georgia, Bugwood.org

age fotostock/Alamy Stock Photo

# Almost Half of the World's Forests Have Been Cut Down (1 of 3)

- Deforestation
  - Temporary or permanent removal of large expanses of forest for agriculture, settlements, or other uses
  - Tropical forests
    - Especially in Latin America, Indonesia, and Africa
  - Boreal forests
    - Especially in Alaska, Canada, Scandinavia, and Russia

# Almost Half of the World's Forests Have Been Cut Down (2 of 3)

## Natural Capital Degradation

### Deforestation

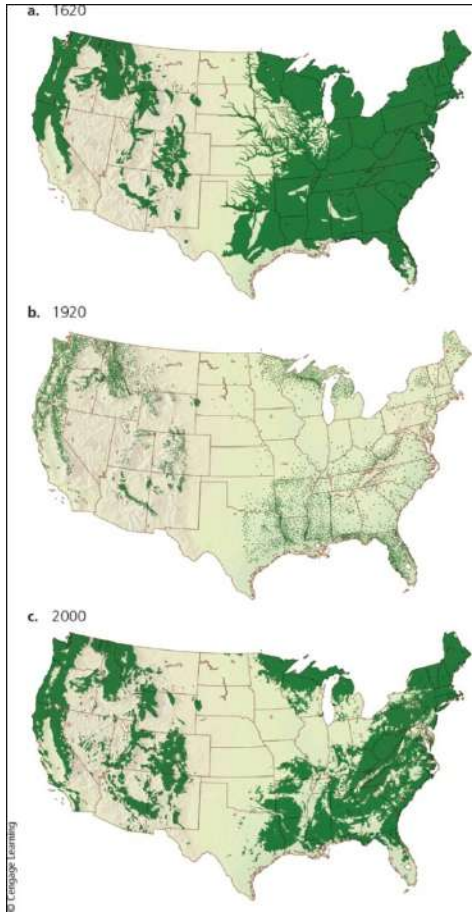
- Water pollution and soil degradation from erosion
- Acceleration of flooding
- Local extinction of specialist species
- Habitat loss for native and migrating species
- Release of $CO_2$ and loss of $CO_2$ absorption

# Almost Half of the World's Forests Have Been Cut Down (3 of 3)

# Case Study: Managing Public Lands in the United States

- Forests of the eastern U.S. decimated between 1620 and 1920
  - Grown back naturally through secondary ecological succession
- Large areas of old-growth and second-growth forests cut down and replaced with biologically simplified tree plantations
  - Growing threat: hardwood forests cleared to produce wood pellets for export

# Forests Are Disappearing Rapidly in the U.S.



# Tropical Forests are Disappearing Rapidly (1 of 2)

- Majority of loss since 1950
  - Mostly in Africa, Southeast Asia, South America
  - Clearing trees accelerates climate change
- Indonesia leads world in tropical deforestation
  - Destroying rain forest to produce palm oil

# Tropical Forests Are Disappearing Rapidly (2 of 2)

- Various causes
  - Population growth
  - Poverty of subsistence farmers
  - Ranching
  - Lumber
  - Plantation farms–palm oil
  - Global trade

# How Can We Manage and Sustain Forests?

- Methods to sustain forests
  - Emphasize the value of their ecosystem services
  - Halt government subsidies that hasten their destruction
  - Protect old-growth forests
  - Harvest trees no faster than they are replenished
  - Plant trees to reestablish forests

# Managing Forests More Sustainably (1 of 2)

- Widely used approaches
  - Maximum sustainable yield
    - Harvest maximum amount of trees that will not reduce future yield
  - Ecosystem-based management
    - Minimize harmful harvesting impacts on ecosystem
  - Adaptive management
    - Harvest forests, evaluate results, and modify approach

# Managing Forests More Sustainably (2 of 2)

- Solutions
  - More Sustainable Forestry
    - Include ecosystem services of forests in estimates of their economic value
    - Identify and protect highly diverse forest areas
    - Stop logging in old-growth forests
    - Stop clear-cutting on steep slopes
    - Reduce road-building in forests and rely more on selective and strip cutting
    - Leave most standing dead trees and larger fallen trees for wildlife habitat and nutrient cycling
    - Put tree plantations only on deforested and degraded land
    - Certify timber grown by sustainable methods

# Improving Management of Forest Fires (1 of 2)

- The U.S. Smokey Bear educational campaign
  - Pros and cons of fires
- Prescribed burns
  - Remove flammable material and underbrush
- Allow fires on public lands to burn
  - As long as structures not threatened

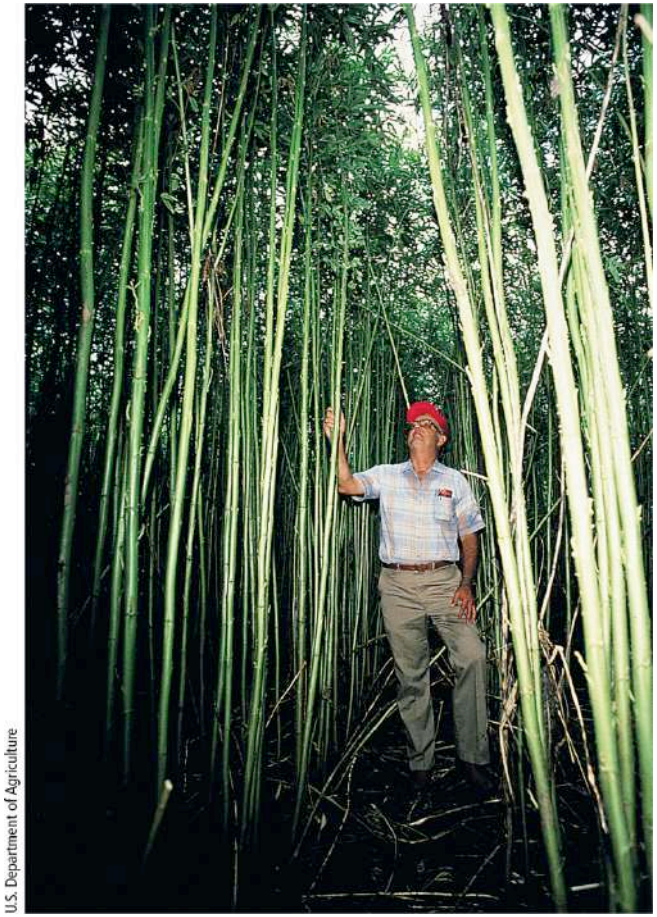
# Improving Management of Forest Fires (2 of 2)

- Protect structures in fire-prone areas
  - Thin nearby trees and vegetation
  - Eliminate use of highly flammable construction materials
- Use drones with infrared sensors to detect fires and monitor progress in fighting them

# Reducing the Demand for Harvested Trees

- Improve the efficiency of wood use
  - 60% of U.S. wood use is wasted
- Make tree-free paper
  - Kenaf
  - Rice straw
  - Hemp
- Reduce use of throwaway paper products

# Solutions: Fast-Growing Plant: Kenaf



U.S. Department of Agriculture

# Reducing Tropical Deforestation (1 of 2)

- Debt-for-nature swaps and conservation concessions
  - Protect forests in return for aid
- Crack down on illegal logging
- End government subsidies for logging roads
- Purchase only sustainably produced wood
- Plant forests on degraded land

# Reducing Tropical Deforestation (2 of 2)

## Solutions

### Sustaining Tropical Forests

**Prevention**

Protect the most diverse and endangered areas

Educate settlers about sustainable agriculture and forestry

Subsidize only sustainable forest use

Protect forests through debt-for-nature swaps and conservation concessions

Certify sustainably grown timber

Reduce poverty and slow population growth


**Restoration**

Encourage regrowth through secondary succession

Rehabilitate degraded areas

Concentrate farming and ranching in already-cleared areas

# 10.2 How Can We Manage and Sustain Grasslands?

- Methods to sustain the productivity of grasslands
  - Control the numbers and distribution of grazing livestock
  - Restore degraded grasslands

# Some Rangelands Are Overgrazed (1 of 3)

- Rangelands
  - Unfenced grasslands in temperate and tropical climates that supply forage for animals
- Pastures
  - Managed grasslands or fenced meadows used for grazing livestock

# Some Rangelands Are Overgrazed (2 of 3)

- Moderate levels of grazing healthy for grasslands
- Overgrazing of rangelands
  - Reduces grass cover
  - Compacts the soil
    - Lessens capacity to hold water
  - Leads to erosion of soil by water and wind
  - Promotes invasion of plant species that cattle won't eat

# Some Rangelands Are Overgrazed (3 of 3)

USDA, Natural Resources Conservation Service

# Managing Rangelands More Sustainably (1 of 2)

- Rotational grazing
  - Cattle moved around regularly
- Fence off damaged areas
- Holistic herd management
  - Short term trampling by moving herd aerates the soil
    - Increases nutrient recycling and soil fertility by pressing decaying grasses into the soil

# Managing Rangelands More Sustainably (2 of 2)

# 10.3 How Can We Manage and Sustain Wetlands?

## Wetlands are disappearing

- The United States has lost more than half of its coastal and inland wetlands since 1900.
- Other countries have lost even more, and the rate of loss of wetlands throughout the world is accelerating.

# Wetlands Are Disappearing

For centuries, people have drained, filled in, or covered over swamps, marshes, and other wetlands:

- to create rice fields or other cropland
- to accommodate expanding cities and suburbs
- to build roads
- to extract minerals, oil, and natural gas
- to eliminate breeding grounds for insects that cause diseases such as malaria

# Preserving and Restoring Wetlands

- Only about 6% of the country's remaining inland wetlands are federally protected, and state and local wetland protection is inconsistent and generally weak.
- Private investment bankers make money by buying wetland areas and restoring or upgrading them or creating new wetland. This creates wetlands banks or credits that the bankers sell to developers.
- However, is difficult to restore, enhance, or create wetlands.

# Case Study: Can We Restore the Florida Everglades? (1 of 4)

- To help preserve the Everglades system, in 1947, the US government established Everglades National Park.

- However, this protection effort did not work because
- of a massive water distribution and land development project to the north.

- Much of the original Everglades has been drained, paved over, polluted by agricultural runoff, and invaded by a number of plant and animal species.

# Case Study: Can We Restore the Florida Everglades? (3 of 4)

Its biodiversity has been decreasing, mostly because of habitat loss, pollution, and invasive species.

- About 90% of the wading birds in Everglades National Park have vanished.
- In addition, populations of vertebrates, from deer to turtles, are down 75–95%.

# Case Study: Can We Restore the Florida Everglades? (4 of 4)

The world's largest ecological restoration project, known as the Comprehensive Everglades Restoration Plan, has several ambitious goals:

- Restoration of the flow of the Kissimmee River
- Removal of canals and levees that block natural water flows south of Lake Okeechobee
- Conversion of large areas of farmland to marshes
- Creation of 18 large reservoirs and underground water storage areas for the lower Everglades and south Florida's population
- Building a canal–reservoir system for catching the water now flowing out to sea and pumping it back into the Everglades.

# 10.4 How Can We Sustain Terrestrial Biodiversity and Ecosystem Services?

- Establish and protect wilderness parks
- Identify and protect biological hotspots
  - Highly threatened areas of biodiversity
- Protect ecosystem services
- Restore damaged ecosystems
- Share areas that we dominate with other species

# Restoring Damaged Ecosystems

- Map world's terrestrial ecosystems and create inventory of species
- Identify resilient and fragile ecosystems
- Protect the most endangered ecosystems and species
  - Emphasis on protecting plant biodiversity and ecosystem services
- Restore degraded ecosystems
- Provide incentives to landowners

# Strategies for Sustaining Terrestrial Biodiversity (1 of 2)

- Protect species from extinction
- Set aside wilderness areas
- Establish parks and nature preserves where people can interact with nature
- Identify and protect biodiversity hotspots
- Shift new development to lands already cleared or degraded
- Protect important ecosystem services

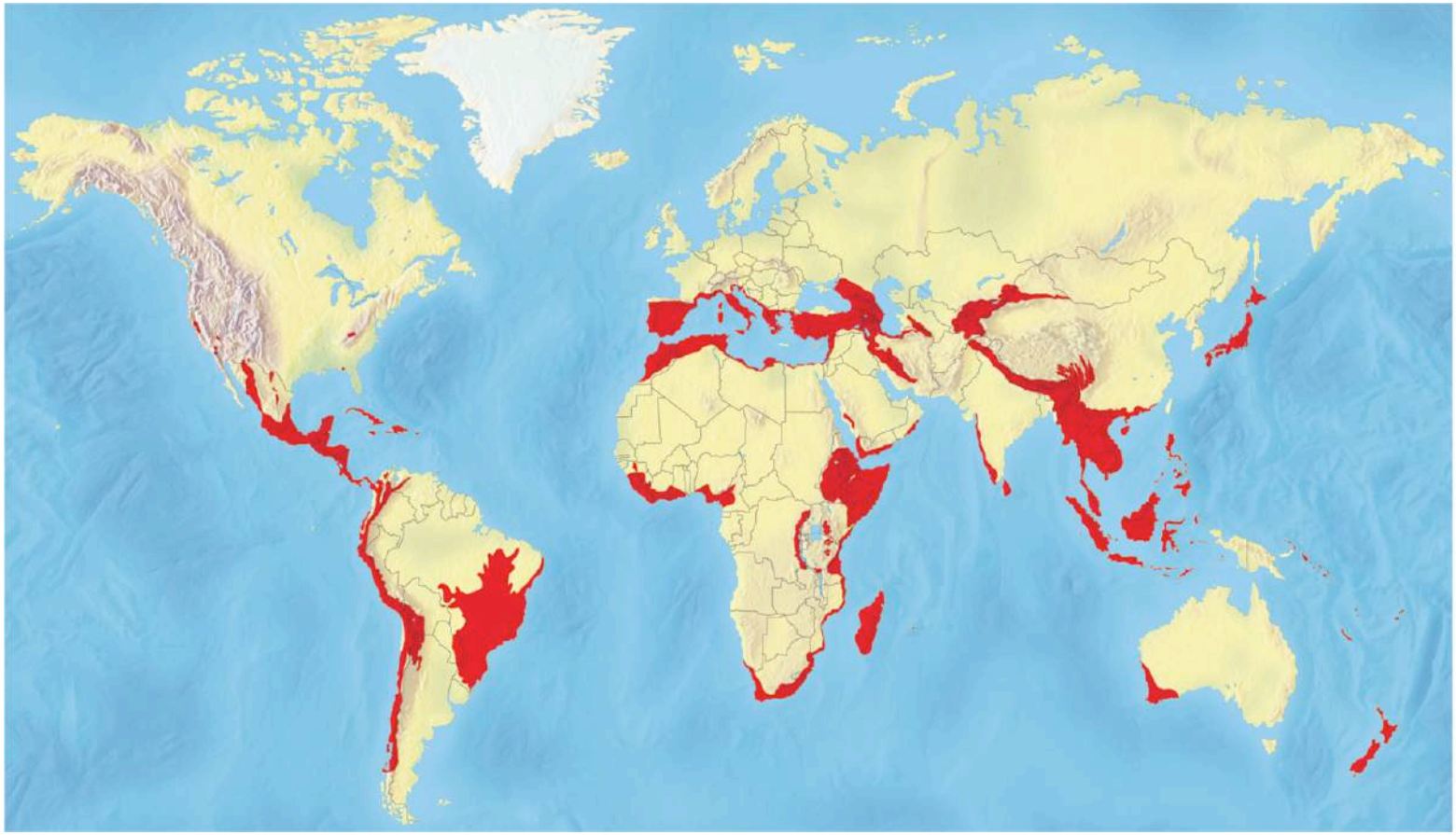
# Strategies for Sustaining Terrestrial Biodiversity (2 of 2)

- Increase crop productivity on existing cropland
- Rehabilitate and restore partially damaged ecosystems
- Share areas we dominate with other species

# Protecting Biodiversity Hotspots (1 of 2)

- 34 biodiversity hot spots
  - Cover 2% of Earth's surface, but 50% of flowering plant species and 42% of terrestrial vertebrates
  - 1.2 billion people
  - Only 5% of the total area of these hotspots is truly protected

# Protecting Biodiversity Hotspots (2 of 2)



# Establishing Wilderness Areas

- 1964 Wilderness Act
  - U.S. government may set aside undeveloped tracts of public land
- Only 5% of U.S. land is protected as wilderness
  - More than half of it in Alaska
- As human population and ecological footprint expand, increasingly difficult to establish new wilderness areas

# Establishing Parks and Other Nature Reserves

- More than 6,600 national parks in 120 countries
  - Most too small to sustain large animal species
  - Some so popular that human use is degrading
- Parks in less-developed countries have the greatest diversity
  - Subject to illegal poaching, logging, mining, and other uses

# Stresses on U.S. Public Parks

- The U.S. has 59 major national parks
- Factors that degrade parks
  - Popularity
  - Off-road vehicle use
  - Cell phone towers
  - Nonnative species
  - Nearby air pollution and traffic
  - Overdue maintenance and repairs

# Designing and Managing Nature Reserves

- Large nature reserves typically sustain more species and provide greater habitat diversity than small reserves
- Habitat corridors can benefit species
  - Allows migration in response to climate change
- Buffer zone concept
  - Strictly protect inner core of reserve
  - Sustainable resource extraction in buffer zone

# Science Focus 10.1 Reintroducing the Gray Wolf to Yellowstone National Park (1 of 2)

- Number of gray wolves declined between 1850 and 1900
  - Killed by humans
- 1996: Relocated 41 gray wolves caught in Canada to Yellowstone
  - 2014: 104 wolves in Yellowstone national park

# Science Focus 10.1 Reintroducing the Gray Wolf to Yellowstone National Park (2 of 2)

Volodymyr Burdiak/Shutterstock.com

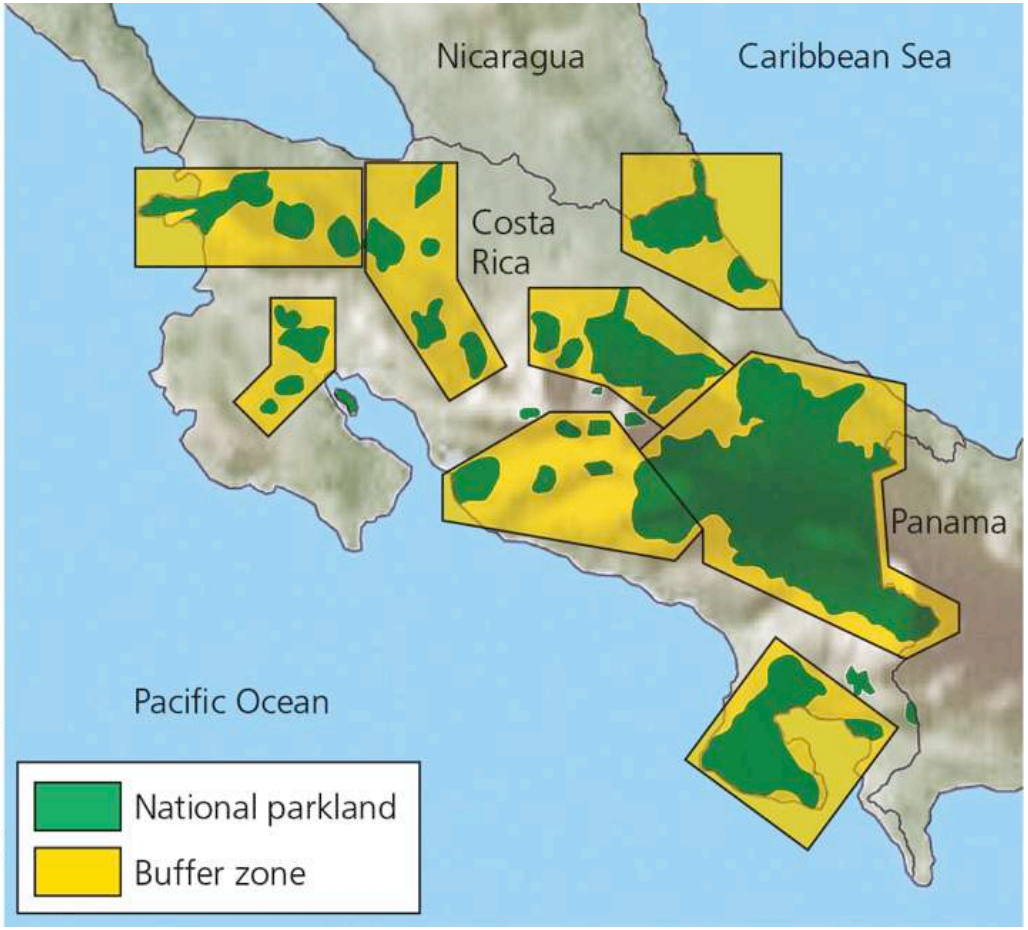
# Case Study: Identifying and Protecting Biodiversity in Costa Rica (1 of 3)

- Costa Rica protects a larger portion of its land than any other country
- Principles of biodiversity
  - Respect biodiversity and understand the value of sustaining it
  - Rely less on fossil fuels and more on direct solar energy
  - Place a value on ecosystem services and help implement full-cost pricing

# Case Study: Identifying and Protecting Biodiversity in Costa Rica (2 of 3)

- Megareserves–large conservation areas
  - Designed to sustain about 80% of the country's biodiversity
  - Protected inner core surrounded by two buffer zones that local people can use
- Large ecotourism industry

# Case Study: Identifying and Protecting Biodiversity in Costa Rica (3 of 3)



# Protecting Ecosystem Services

- Identify highly stressed life raft ecosystems
  - Areas with high poverty levels
  - Most people depend on ecosystem services for survival
  - Residents, public officials, and conservation scientists would work together
    - Win–win principle of sustainability

# Restoring Damaged Ecosystems (1 of 2)

- Ecological restoration examples
  - Replanting forests
  - Reintroducing keystone native species
  - Removing harmful invasive species
  - Removing dams
  - Restoring grasslands, coral reefs, wetlands, and stream banks

# Restoring Damaged Ecosystems (2 of 2)

- Four-step strategy for carrying out rehabilitation
  - Identify causes of the degradation
  - Stop the degradation by eliminating or sharply reducing those factors
  - Reintroduce keystone species, if possible
  - Protect from further degradation

# Sharing Areas We Dominate with Other Species (1 of 2)

- Reconciliation ecology
  - Invent and maintain habitats for species diversity where people live, work, and play
- Community-based conservation
  - Plant garden as food for bees, butterflies, and other pollinators
  - Eliminate or reduce pesticide use
  - Provide nesting boxes for birds

# Sharing Areas We Dominate with Other Species (2 of 2)

- What Can You Do?
  - Sustaining Terrestrial Biodiversity
    - Plant trees and take care of them
    - Recycle paper and buy recycled paper products
    - Buy sustainably produced wood and wood products and wood substitutes such as recycled plastic furniture and decking
    - Help restore a degraded forest or grassland
    - Landscape your yard with a diversity of native plants

# 10.5 How Can Cities Become More Sustainable and Livable?

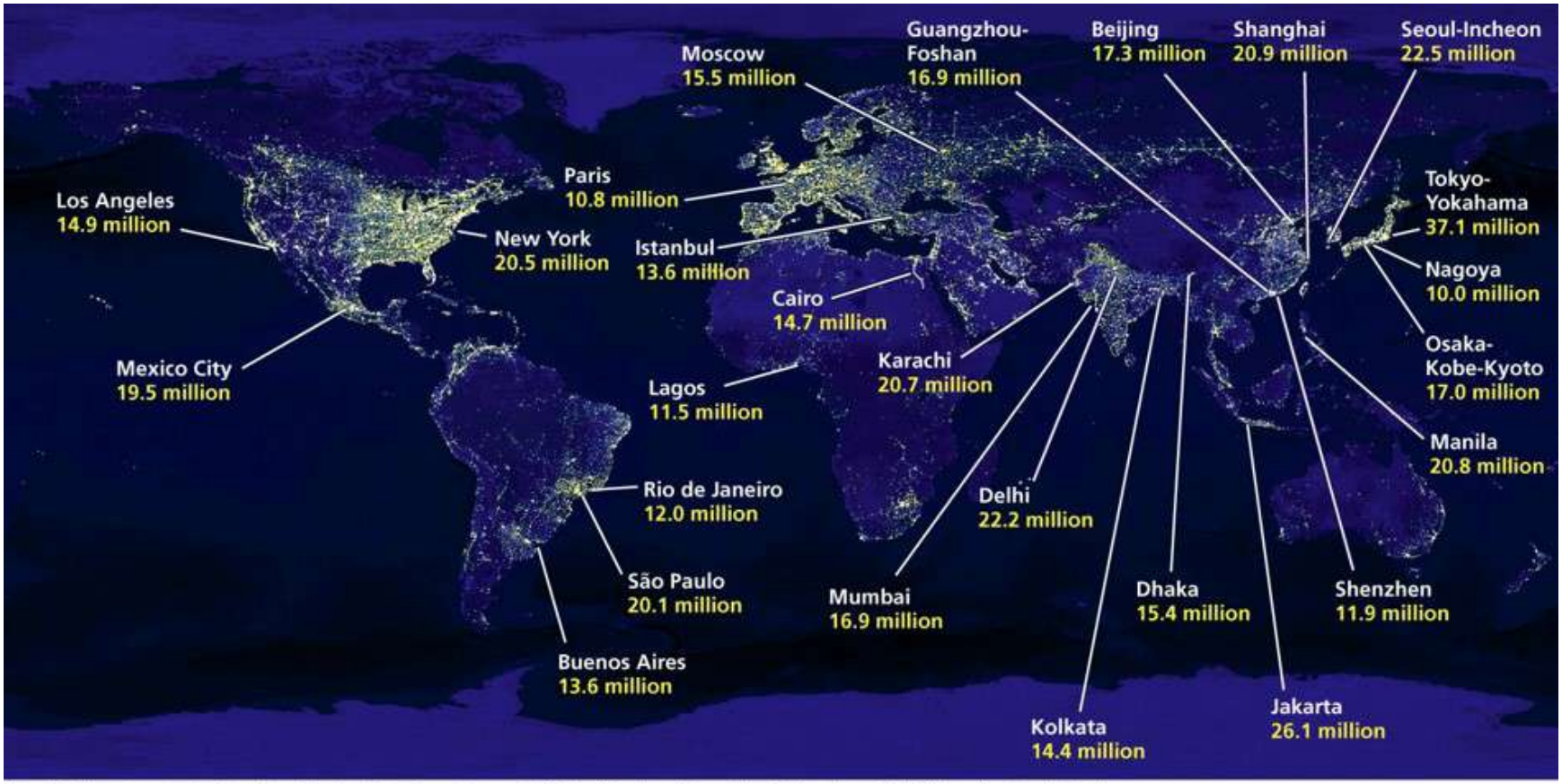
- Most cities are unsustainable because of high levels of resource use, waste, pollution, and poverty.

- An *eco-city* allows people to choose walking, biking, or mass transit for most transportation needs; recycle or reuse most of their wastes; grow much of their food; and protect biodiversity by preserving surrounding land.

# Three Important Urban Trends

- Three major trends
  - Proportion of global population living in urban areas is increasing
  - Number and size of urban areas is mushrooming
    - Megacities; hypercities
  - Poverty is becoming increasingly urbanized
    - Mostly in less-developed countries

# Megacities, or major urban areas. with 10 million or more people, in 2015.



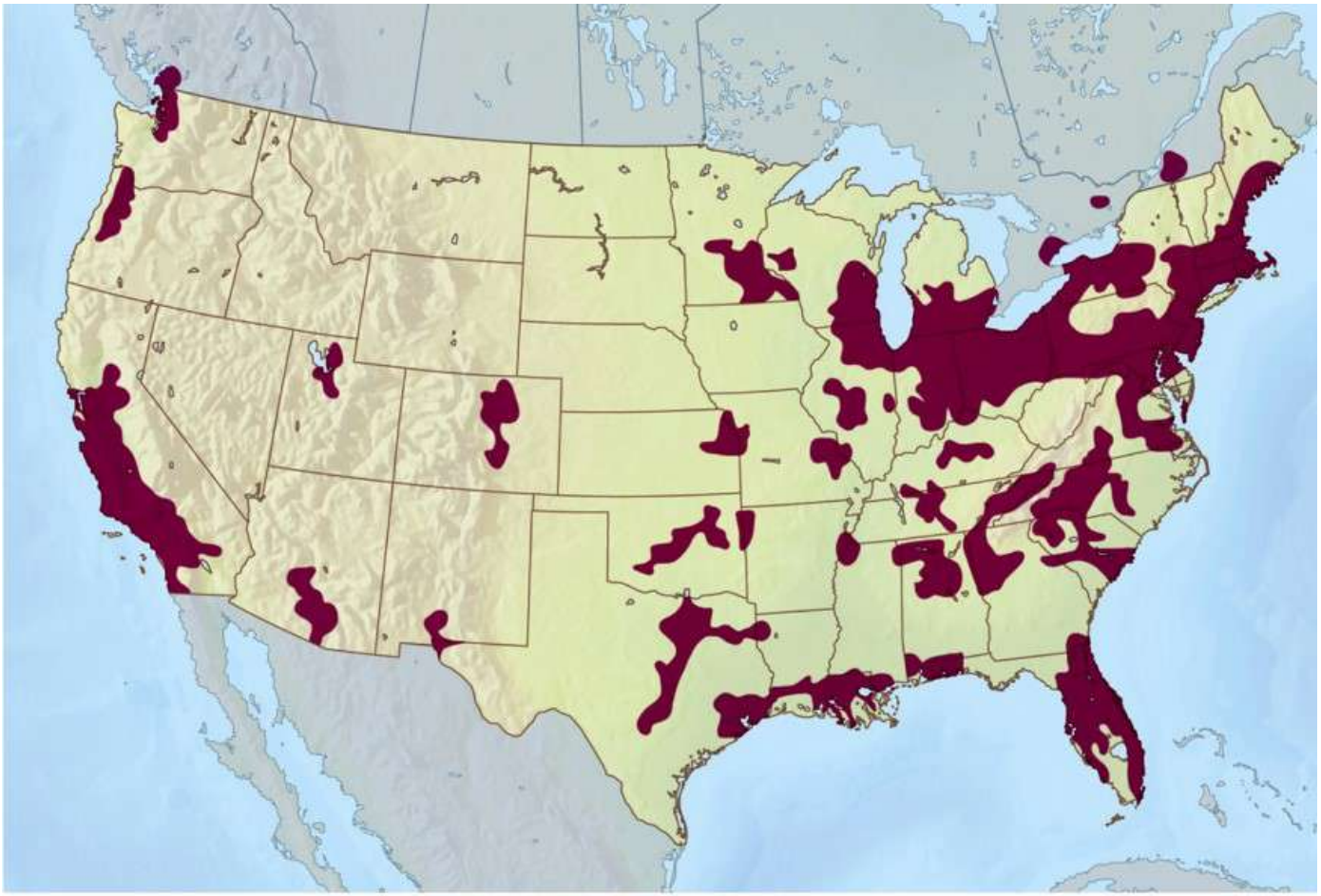

(Compiled by the authors using data from National Geophysics Data Center, Demographia, National Oceanic and Atmospheric Administration, and United Nations Population Division.)

# Urbanization in the United States

- Between 1800 and 2016, the percentage of the US population living in urban areas increased from 5% to 82%

- Three phases between 1800 and 2008
  - Migration from rural areas to large central cities
  - Migration from large central cities to suburbs and smaller cities
  - Migration from North and East to South and West

# Major urban areas in the United States with more than 1 million people each



(Compiled by the authors using data from National Geo-physical Data Center/National Oceanic and Atmospheric Administration, U.S. Census Bureau.)

# Urbanization Has Advantages and Disadvantages (1 of 3)

Advantages:

- Centers of economic development, innovation, education, technological advances, and jobs
- Recycling economically feasible
- Preservation of biodiversity outside of urban areas
- Mass transportation

# Urbanization Has Advantages and Disadvantages (2 of 3)

## Disadvantages

- Huge ecological footprints
  - Consume 75% of the world's resources
- Lack of vegetation
- Water problems
  - Deprive wild and rural areas of water; flooding
- Concentration of pollution/health problems
  - Air and water pollution
  - Solid and hazardous wastes

# Urbanization Has Advantages and Disadvantages (3 of 3)

## Disadvantages

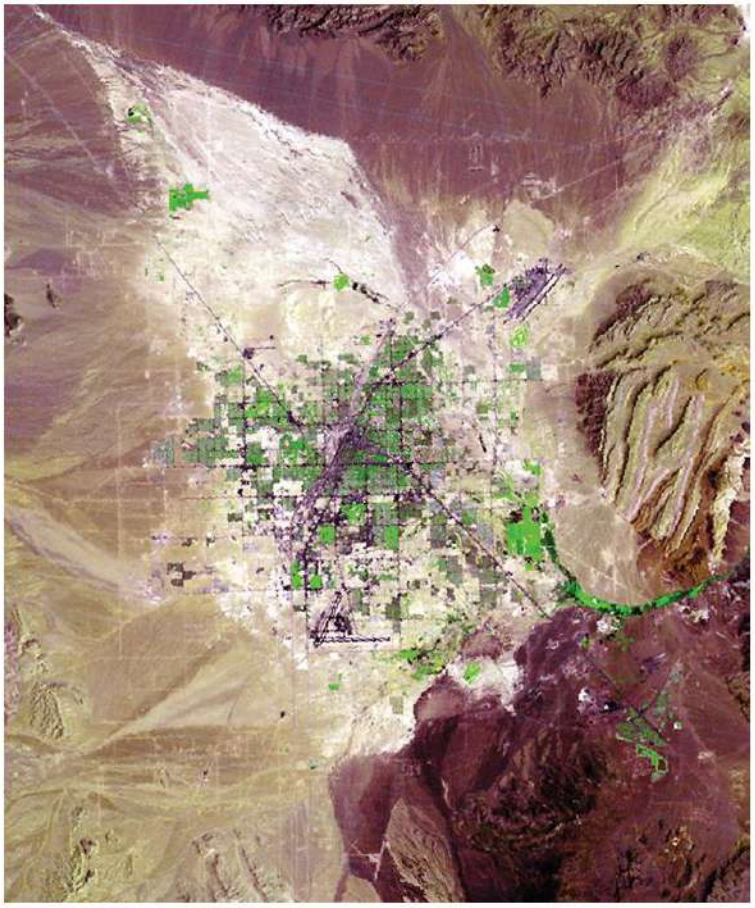
- Urban heat islands
  - Leads to higher energy consumption and greenhouse gas emissions
- Altered climate and light pollution
  - Cities tend to be warmer, rainier, foggier, and cloudier than rural areas
  - Artificial light has affected some species

# Cities depend on nonurban areas for matter and energy resources, and they generate large outputs of pollution, waste matter, and heat.

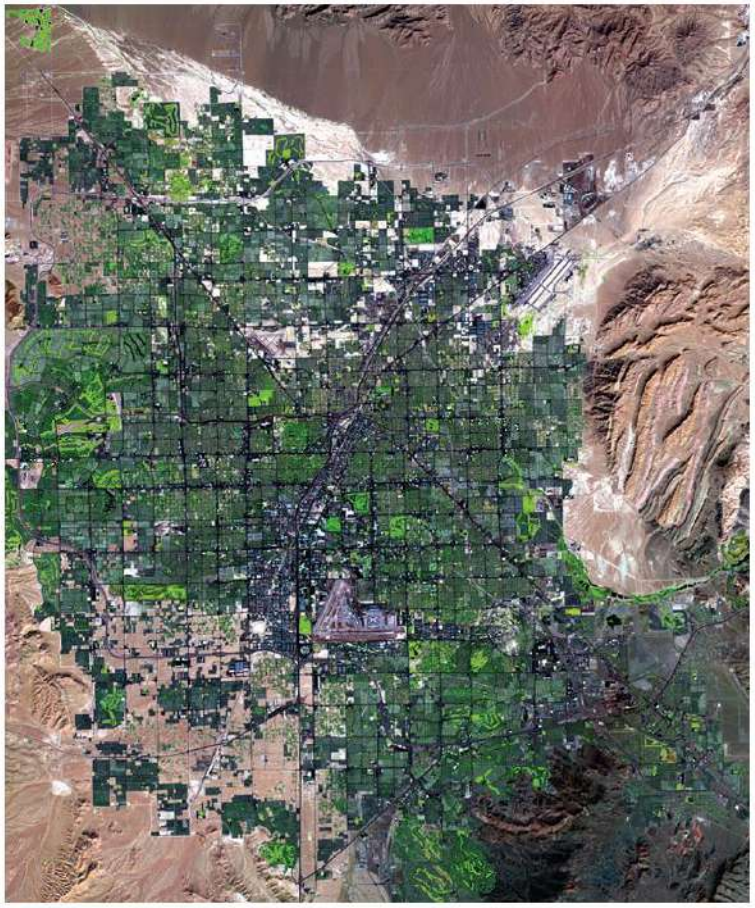
# Cities Can Grow Upward or Outward

- Compact cities
  - Hong Kong, China
  - Tokyo, Japan
  - Mass transit
- Dispersed cities
  - U.S. and Canada
  - Car-centered cities

# *Urban sprawl* in and around Las Vegas, Nevada, between 1973 and 2013.



1973 A



2013 B

Courtesy of US Geological Survey.

US Department of the Interior/US Geological Survey

# Natural Capital Degradation in Urban Sprawl

## Natural Capital Degradation

### Urban Sprawl

**Land and Biodiversity**

Loss of cropland

Loss and fragmentation of forests, grasslands, wetlands, and wildlife habitat


**Water**

Increased use and pollution of surface water and groundwater

Increased runoff and flooding

**Energy, Air, and Climate**

Increased energy use and waste

Increased emissions of carbon dioxide and other air pollutants


**Economic Effects**

Decline of downtown business districts

More unemployment in central cities

# Alternatives to Cars (1 of 4)

## Trade-Offs

### Bicycles

**Advantages**

Are quiet and nonpolluting

Take few resources to manufacture

Burn no fossil fuels

Require little parking space

**Disadvantages**

Provide little protection in an accident

Provide no protection from bad weather

Are impractical for long trips

Bike lanes and secure bike storage not yet widespread

Photo: Tyler Olson/Shutterstock.com

# Alternatives to Cars (2 of 4)

## Trade-Offs

### Buses

**Advantages**

Reduce car use and air pollution

Can be rerouted as needed

Cheaper than heavy-rail system

Photo: Isaak/Shutterstock.com

**Disadvantages**

Can lose money because they require affordable fares

Can get caught in traffic and add to noise and pollution

Commit riders to transportation schedules

# Alternatives to Cars (3 of 4)

## Trade-Offs

### Rapid Rail

**Advantages**

Much more energy efficient per rider than cars and planes are

Produces less air pollution than cars and planes

Can reduce need for air travel, cars, roads, and parking areas

**Disadvantages**

Costly to run and maintain

Causes noise and vibration for nearby residents

Adds some risk of collision at car crossings

Photo: Alfonso d'Agostino/Shutterstock.com

# Alternatives to Cars (4 of 4)

## Trade-Offs

### Mass Transit Rail

**Advantages**

Uses less energy and produces less air pollution than cars do

Uses less land than roads and parking lots use

Causes fewer injuries and deaths than cars

Photo: Steve Rosset/Shutterstock.com

**Disadvantages**

Expensive to build and maintain

Cost-effective only in densely populated areas

Commits riders to transportation schedules

# Land-Use Planning

Through land-use planning, governments can control the uses of certain parcels of land by legal and economic methods.

- Zoning can be used to control growth and to protect areas from certain types of development. But zoning has its drawbacks:
  - Developers can influence or modify zoning decisions in ways that threaten or destroy wetlands, prime cropland, forested areas, and open space.
  - Zoning often favors high-priced housing, factories, hotels, and other businesses over protecting environmentally sensitive areas and providing low-cost housing.

# Smart Growth

- Smart growth
  - Reduces dependence on cars
  - Controls and directs sprawl
  - Protects ecologically sensitive areas
  - Uses zoning laws to channel growth

## Solutions

### Smart Growth Tools

**Limits and Regulations**

Limit building permits

Draw urban growth boundaries

Create greenbelts around cities

**Zoning**

Promote mixed use of housing and small businesses

Concentrate development along mass transportation routes

**Planning**

Ecological land-use planning

Environmental impact analysis

Integrated regional planning


**Protection**

Preserve open space

Buy new open space

Prohibit certain types of development

**Taxes**

Tax land, not buildings

Tax land on value of actual use instead of on highest value as developed land

**Tax Breaks**

For owners agreeing not to allow certain types of development

For cleaning up and developing abandoned urban sites

**Revitalization and New Growth**

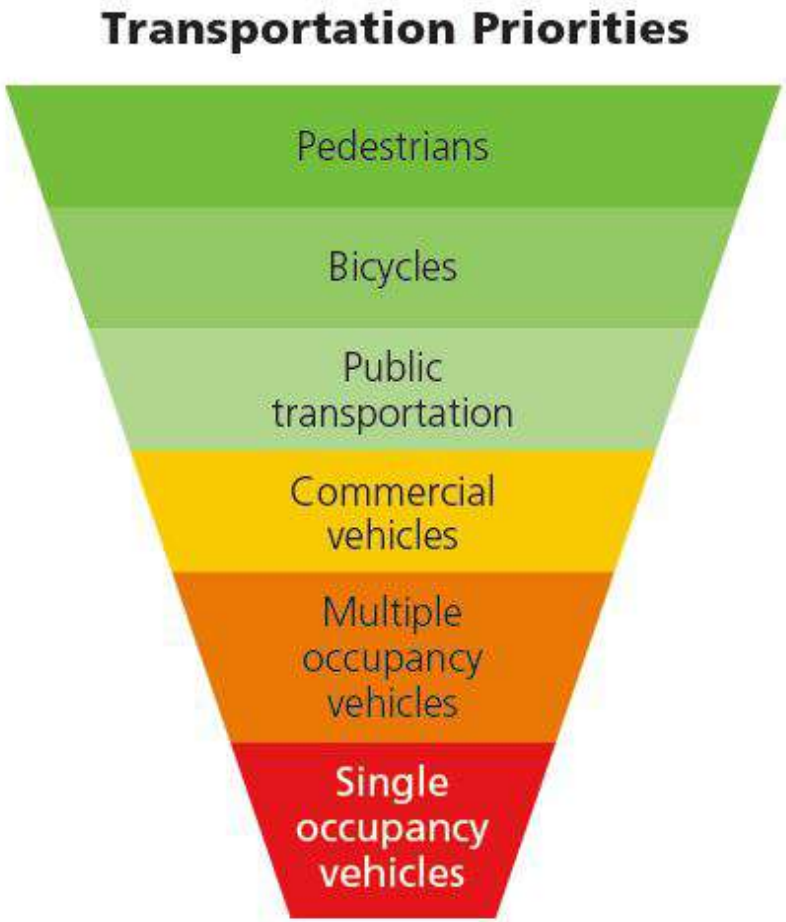
Revitalize existing towns and cities

Build well-planned new towns and villages within cities

# The Eco-City Concept

- An eco-city allows people to:
  - Choose walking, biking, or mass transit for most transportation needs
  - Buildings, vehicles, and appliances meet high energy-efficiency standards
  - Abandoned lots and industrial sites are cleaned up and used.
  - Much of their food is grown locally
  - Protect biodiversity by preserving surrounding land

# Transportation Priorities in More-Sustainable Cities

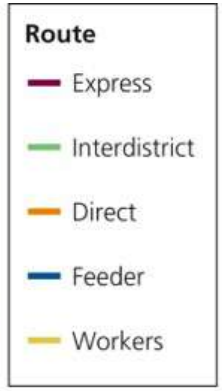


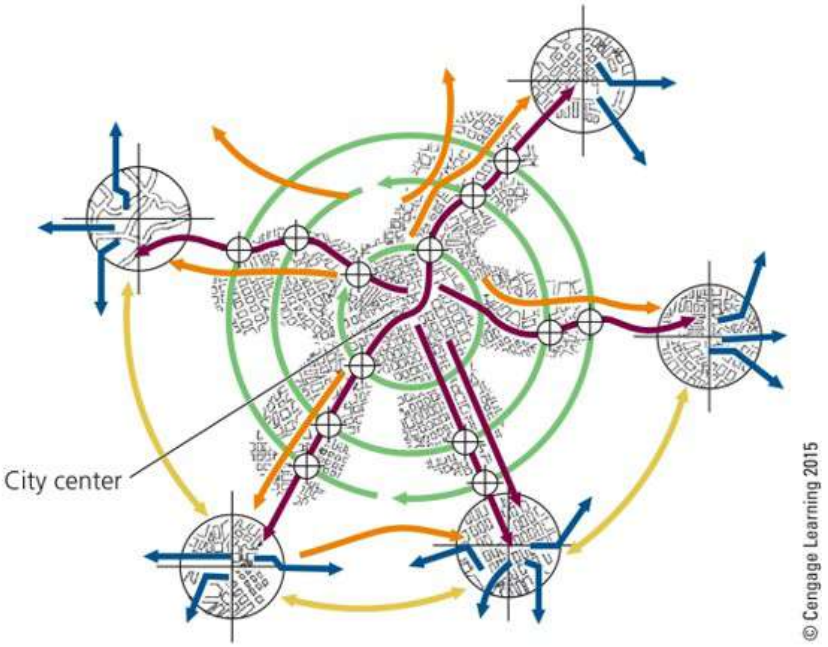
# Case Study: The Eco-City Concept in Curitiba, Brazil

- Ecological capital of Brazil
- Superb bus rapid-transit system
  - 72% of the city's commuters use the system
  - Cars banned for 49 blocks in the center of the city
  - Only high-rise apartment buildings allowed near major bus routes, with retail stores in each building, which reduces the need for residents to travel
- Recycles roughly 70% of its paper and 60% of its metal, glass, and plastic
- Care for the poor includes free medical and dental care, childcare, and job training

# The Rapid-Transit System in Curitiba

Carlos Cazalis/Corbis



# Key Ideas (1 of 3)

- We can sustain forests by emphasizing the economic value of their ecosystem services, halting government subsidies that hasten their destruction, protecting old-growth forests, harvesting trees no faster than they are replenished, and planting trees to reestablish forests.

# Key Ideas (2 of 3)

- We can sustain terrestrial biodiversity and ecosystem services by protecting severely threatened areas and ecosystem services and restoring damaged ecosystems.

# Key Ideas (3 of 3)

- Most urban areas are unsustainable with their large and growing ecological footprints and high levels of poverty but they can be made more sustainable and livable.