CHAPTER 4

LAND

LAND CHAPTER CONTENTS

4.1 INTRODUCTION

The land within the boundaries of the United States, covering nearly 2.3 billion acres, provides food, fiber, and shelter for all Americans, as well as terrestrial habitat for many other species. Land is the source of most extractable resources such as minerals and petroleum; produces renewable resources and commodities such as livestock, vegetables, fruit, grain, and timber; and supports other uses such as residential, industrial, commercial, and transportation. Additionally, land and the ecosystems that it is part of provide services such as trapping chemicals as they move through soil, storing and breaking down chemicals and wastes, and filtering and storing water. The use of land, what is applied to or released on it, and its condition change constantly, including the types and amounts of resources that are extracted, distribution and nature of cover types, amounts and types of chemicals used and wastes managed, and perceptions of the value of land.

Numerous agencies and individuals have responsibilities for managing and protecting land in the United States, both in terms of resources associated with land (e.g., timber, minerals) and protection of land (e.g., wilderness designations, regulatory controls). Between 30 and 40 percent of the nation is owned or managed by public agencies.[1] The other 60 to 70 percent is managed by private owners, under a variety of federal, state, and local laws. Local governments have primary responsibilities for regulating land use, while state and federal agencies regulate chemicals and waste which are frequently used and/or stored on or released to land. EPA is interested in land because human activities on land such as food and fiber production, land development, manufacturing, or resource extraction, may involve the creation, use, or release of chemicals and pollutants that can affect the environment and human health.

EPA works with other federal agencies, states and partners to protect land resources, ecosystems, environmental processes, and uses of land through regulation of chemicals, waste, and pollutants, and through clean up and restoration of contaminated lands. The complexities of responsibilities underscore the challenges of collecting data and assessing trends on the state of land.

In this chapter critical land questions are addressed by describing national trends in naturally occurring and human uses of land, stressors that affect land, and associated exposures and effects among humans and ecological systems. ROE indicators are presented to address five fundamental questions about the state of the nation's land:

- **What are the trends in extent of land cover and their effects on human health and the environment?** Land cover refers to the actual or physical presence of vegetation or other materials (e.g., rock, snow, buildings) on the surface of the land (it varies from land use—see next question below). It is important from the perspective of understanding land as a resource and its ability to support humans and other species. Changes in land cover can affect other media (e.g., air and water).
- **What are the trends in land use and their effects on human health and the environment?** Land use represents the economic and cultural activities practiced by humans on land. Land use can have effects on both human health and the environment, particularly as land is urbanized or used for agricultural purposes.

[1] U.S. Census Bureau. 2005. Statistical abstract of the United States. Washington, DC. (2003 data) <http://www.census.gov/prod/2005pubs/06statab/geo.pdf>

- **What are the trends in wastes and their effects on human health and the environment?** Numerous types of wastes are generated as part of most human activities. Trends in wastes include trends in types and quantities of, and mechanisms for, managing wastes. Waste trends reflect the efficiency of use and re-use of materials and resources and potential for land contamination.
- **What are the trends in chemicals used on the land and their effects on human health and the environment?** Various chemicals are produced or used on land for many purposes. .The quantity and diversity of chemicals and the potential for interactions among them have created challenges in understanding the full effects of their use. Pesticides, fertilizers, and toxic chemicals are examples of chemicals applied or released on land.
- **What are the trends in contaminated land and their effects on human health and the environment?** Contaminated lands are those lands that have been affected by human activities or natural events such as manufacturing, mining, waste disposal, volcanoes, or floods that pose a concern to human health or the environment. The worst contaminated lands are tracked and cleanups are overseen by EPA.

These ROE questions are posed without regard to whether indicators are available to answer them. This chapter presents the indicators available to answer these questions, and also points out important gaps where nationally representative data are lacking.

4.1.1 Overview of the Data

Data are collected by many agencies with varying responsibilities for managing and protecting land and its resources. Several different sources and types of data are used to develop the indicators that address the questions in this chapter. They include:

- **Satellite imagery.** Data used in the land cover question are derived from the analysis of satellite data.[2] A national data set of U.S. land cover called the National Land Cover Dataset (NLCD) is currently available for the early to mid-1990s. Analyses of more recent data are currently underway to provide better trend data. Multiple agencies, including EPA, have jointly funded satellite data processing efforts and are working together to derive a common classification approach for the data.
- **National surveys.** The data used in the land use question are primarily derived from two national surveys: the USDA Natural Resources Conservation Service, National Resources Inventory (NRI)[3] and the USDA Forest Service, Forest Inventory and Analysis.[4] These surveys are collected over specific areas for specific agency purposes. The NRI data are collected only on non-federal lands, and FIA data address only forest and timberlands. These limitations contribute to the need to rely on multiple data sets for national estimates.

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[2] U.S. Geological Survey. 2005. National land cover dataset, 1992. <http://landcover.usgs.gov/natllandcover.php>

[3] USDA Natural Resources Conservation Service. 2004. National resources inventory: 2002 annual NRI. <http://www.nrcs.usda.gov/technical/land/nri02/landuse.pdf>

[4] USDA Forest Service. 2005. Forest inventory and analysis national program. <http://www.fia.fs.fed.us>

- **Regulatory data.** The data used for most of the chemical, waste, and contaminated land questions are derived from self-reporting or government-collected measurements to address regulatory requirements. For example, the chemical release information reported under the chemical question is derived from the Toxics Release Inventory (TRI) based on industry reporting. These data, in general, represent only a small sample of the total picture of waste, chemicals, and land contamination. State and local governments collect additional data, but the lack of consistency in approaches make compilation of national data difficult.

This chapter presents only data that meet the ROE indicator definition and criteria (see Chapter 1, Introduction). Note that non-scientific indicators, such as administrative and economic indicators, are not included in this definition. Thorough documentation of the indicator data sources and metadata can be found online at [insert url]. All indicators were peer-reviewed during an independent peer review process (see insert url for more information). Readers should not infer that the ROE indicators included reflect the complete state of knowledge on the nation's land. Many other data sources, publications, and site-specific research projects have contributed to the current understanding of land trends, but are not used in this report because they did not meet some aspect of the ROE indicator criteria.

4.1.2 Organization of This Chapter

The remainder of this chapter is organized into five sections corresponding to the five questions that EPA seeks to answer about land. Each section introduces the question and its importance, presents the ROE indicators to help answer the question, and discusses what the ROE indicators, taken together, say about the question. Several of the National Indicators also provide information organized by EPA Regions, and one Regional Indicator addresses specific issues at a sub-EPA region scale. Each section concludes by highlighting the major challenges to answering the question and identifying important gaps and emerging issues.

The table below shows the ROE indicators used to answer each question in this chapter and the location where they are presented.

Table 4.1.1. Land—ROE Questions and Indicators

Question	Indicator Name	Section	Page #
What are the trends in land cover and their effects on human health and the environment?	Land Cover (N/R) Forest Extent and Type (N/R) Land Cover in the Puget Sound/Georgia Basin (R)	4.2.2 6.2.2 4.2.2	4-11 6-14 4-17
What are the trends in land use and their effects on human health and the environment?	Land Use (N) Urbanization and Population Change (N/R)	4.3.2 4.3.2	4-24 4-31
What are the trends in wastes and their effects on human health and the environment?	Quantity of Municipal Solid Waste Generated and Managed (N) Quantity of RCRA Hazardous Waste Generated and Managed (N)	4.4.2 4.4.2	4-40 4-43
What are the trends in chemicals used on the land and their effects on human	Fertilizer Applied for Agricultural Purposes (N)	4.5.2	4-50

Question	Indicator Name	Section	Page #
health and the environment?	Toxic Chemicals in Production-Related Wastes Released, Treated, Recycled, or Recovered for Energy Use (N)	4.5.2	4-54
	Pesticide Residues in Food	4.5.2	4-58
	Reported Pesticide Incidents (N)	4.5.2	4-61
What are the trends in contaminated land and their effects on human health and the environment?	High-Priority Cleanup Sites with No Human Contact to Contamination in Excess of Health-Based Standards (N)	4.6.2	4-70
	High-Priority Cleanup Sites Where Contaminated Groundwater Is Not Continuing to Spread Above Levels of Concern (N)	4.6.2	4-73

N = National Indicator
R = Regional Indicator
N/R = National Indicator displayed at EPA Regional scale

4.2 WHAT ARE THE TRENDS IN LAND COVER AND THEIR EFFECTS ON HUMAN HEALTH AND THE ENVIRONMENT?

4.2.1 Introduction

Land cover—the surface components of land that are physically present and visible—provides a means to examine landscape patterns and characteristics. Patterns and landscape characteristics are important in understanding the extent, availability, and condition of lands; ecological system extent, structure, and condition; and the potential for dispersion and effects of chemicals and other pollutants in and on the environment. Land cover represents a starting point from which a variety of monitoring activities can be performed. EPA considers land cover information to be critically important for a number of reasons, including the ability to assess nonpoint sources of pollution, understanding landscape variables for ecological analyses, assessing the behavior of chemicals, and analyzing the effects of air pollution.

Land cover, in its naturally occurring condition, integrates and reflects a given site's climate, geology and soils, and available biota over a time span of decades or longer. Land cover can be affected on shorter time scales by naturally occurring disturbances (e.g., storms, floods, fires, volcanic eruptions, insects, landslides) and human activities. Land cover represents the results of both naturally occurring conditions and disturbances and human activities such as population change, industrial and urban development, deforestation or reforestation, water diversion, and road-building. Depending on one's perspective, the changes wrought by natural processes and human activities can be perceived as improvements or degradations of the state of land cover.

Land cover is also important because it affects other environmental variables including water quality, watershed hydrology, habitat and species composition, climate, and carbon storage. Land cover influences the mass and energy exchanges between the surface and the atmosphere and thus influences weather and climate.[5] Land cover is also a primary ingredient of ecological structure and function, with changes affecting species habitat and distribution. Land cover changes in watersheds can alter hydrologic regimes, runoff patterns, and flood buffering.[6]

4.2.2 ROE Indicators

The question of trends in and effects of land cover is addressed by two National Indicators and one Regional Indicator (see Table 4.2.1). Nationwide land cover information is derived from two data collection programs: the National Land Cover Dataset (NLCD) and the Forest Inventory and Analysis (FIA). The NLCD is described in more detail in the Land Cover indicator summary (p. 4-11), and the FIA is described in the Forest Extent and Type indicator summary (p. 6-14).

The classification approach used in the Land Cover indicator is primarily based on the use of satellite data processing. Where satellite data were not available or processed, survey data have been included to

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[5] Marland, G., et al. 2003. The climatic impacts of land surface change and carbon management, and the implications for climate-change policy. Clim. Pol. 3:149-157.

[6] de Sherbinin, A. 2002. Land-use and land-cover change: a CIESIN thematic guide. Palisades, NY: Center for International Earth Science Information Network of Columbia University. <http://sedac.ciesin.columbia.edu/tg/guide_main.jsp>

develop the national statistics.[7] The classification approach used in the Land Cover in Puget Sound/Georgia Basin indicator (p. 4-17), while also based on satellite data, is different from the Land Cover National Indicator, and is described in the Regional Indicator discussion. More detailed definitions of land cover types are included in the glossary.

Data for the Land Cover in Puget Sound/Georgia Basin indicator are derived from the NOAA Coastal Change Analysis Program (C-CAP) and Landsat satellite data of both the U.S. and Canadian portions of the Puget Sound Basin. This indicator depicts two cover classes: forest and urban.

The data presented in the Forest Extent and Type indicator are derived from national surveys of forest land and timberland in the U.S. These data reflect total extent of forest land both nationally and by EPA Region, as well as trends in many species types on timber land.

Table 4.2.1. ROE Indicators of Trends in Land Cover and Their Effects on Human Health and the Environment

NATIONAL INDICATORS	LOCATION
Land Cover (N/R)	4.2.4 – p. 4-11
Forest Extent and Type (N/R)	6.2.2 – p. 6-14
REGIONAL INDICATORS	
Land Cover in the Puget Sound/Georgia Basin	4.2.2 – p. 4-17

N/R = National Indicator displayed at EPA Regional scale

[7] Categories included in the land cover map (Exhibit 4-1) are derived from satellite data and include: Agricultural lands, which consist of herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber. Developed lands have at least 30 percent constructed materials (e.g., asphalt, concrete, buildings). Forest consists of naturally occurring or semi-naturally occurring woody vegetation, generally 25-100 percent cover and greater than 6 meters tall. Grassland is dominated by upland grasses and forbs that are not subject to intensive management, but may be used for grazing. Shrubland is characterized by naturally or semi-naturally occurring woody vegetation with aerial stems and less than 6 meters tall. “Other” includes ice/snow, bare rock, quarries/mines, and “transitional” areas. Based on the use of FIA data in Exhibits 4-2 and 4-3, for Alaska and Hawaii, the forest category includes land defined as: “Land at least 10 percent stocked by forest trees of any size.”

INDICATOR: Land Cover

Land cover represents the actual or physical presence of vegetation (or other materials where vegetation is non-existent) on the land surface. Land cover is also often described as what can be seen on land when viewed from above. Land cover represents one means to categorize landscape patterns and characteristics, and is critical in understanding the condition of the environment, including the availability of and changes in habitat, and dispersion and effects of chemicals and other pollutants in and on the environment. For the purposes of this indicator, land cover is described in terms of six major classes: forest, grass, shrub, developed, agriculture, and other (includes ice/snow; bare rock; quarries/mines; wetlands; and "transitional" areas of sparse vegetative cover with less than 25 percent of cover that are dynamically changing from one land cover to another, often because of land use activities such as timber harvesting or fire). "Water" represents a seventh category, but is not discussed as a "land" cover type in this chapter. See the Water Chapter for more details. More information about forest land can be found in the Forest Extent and Type indicator (p. 6-14), and wetland acreage is discussed in greater detail in the Wetlands indicator (p. 3-53).

In 1992, several federal agencies agreed to operate as a consortium - known as the Multi-Resolution Land Characteristics (MRLC) Consortium, to acquire and analyze satellite-based remotely sensed data for environmental monitoring programs (MRLC Consortium, 2006). The initial result of the MRLC was development of the 1992 National Land Cover Dataset (NLCD), which is the only comprehensive recent classification of land cover in the continental United States. In many locations, the best available Landsat images were collected between 1991 and 1993, with data in a few locations ranging from 1986 to 1995.

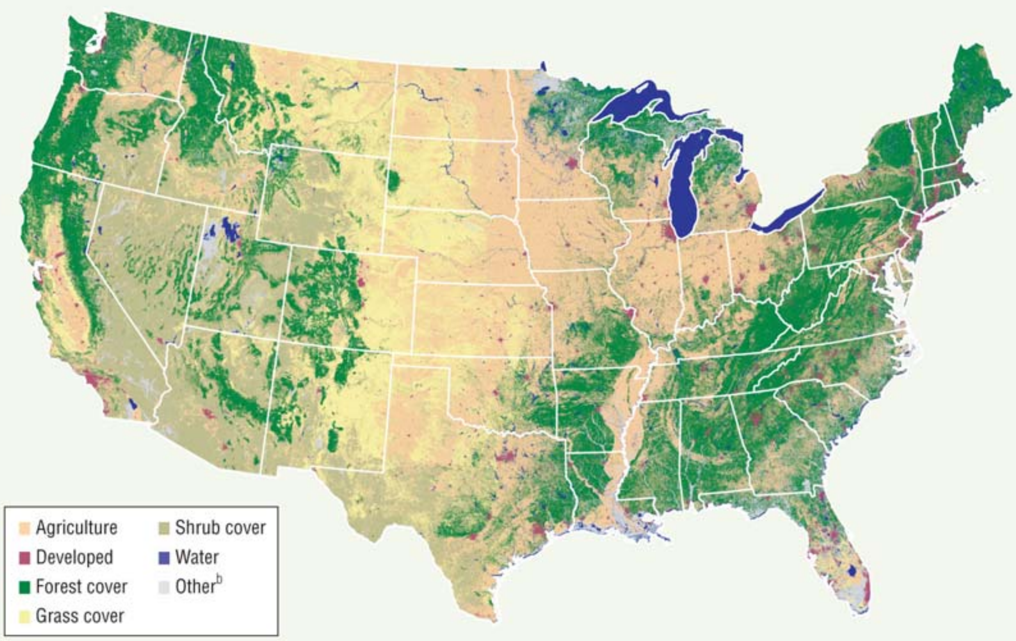
This indicator represents data from the 1992 NLCD and the U.S. Forest Service Forest Inventory and Analysis (FIA), which uses a statistical survey design and comparable methods to assess the extent, type, age, and health of forests on private and public land in all states. The 1992 NLCD provides a synoptic classification of land cover, but does not include Alaska and Hawaii, thereby classifying only 1.92 billion acres out of approximately 2.3 billion acres of land in the United States. To supplement NLCD, data from the 1992 FIA were used to provide forest cover estimates in those two states (130.9 million acres). For this indicator, the 21 land cover classes created in the NLCD were aggregated into the six major land cover types described above, along with water (Heinz Center, 2005).

What the Data Show

The combination of the NLCD for the contiguous 48 states and FIA for forest cover estimates in Alaska and Hawaii shows approximately 694 million acres of forest, 510 million acres of agriculture, 350 million acres of shrub, 307 million acres of grass, and 41 million acres of developed cover types (Exhibits 4-1 and 4-2).

NLCD and FIA data show variation in cover types by EPA Region, with forest dominating in Regions 1, 2, 3, 4, and 10; agriculture in Regions 5 and 7; grass in Region 8; and shrub in Region 9 (Exhibit 4-3). Region 6 consists of nearly equal coverage of grass, shrub, agriculture, and forest cover. More than two-thirds of the grass acreage in the nation is located in Regions 6 and 8, nearly two-thirds of shrub acreage is in Regions 6 and 9, and nearly half the forest acreage in Regions 4 and 10 (including Alaska).

Exhibit 4-1. Land cover of the contiguous U.S., based on 1992 NLCD[a]

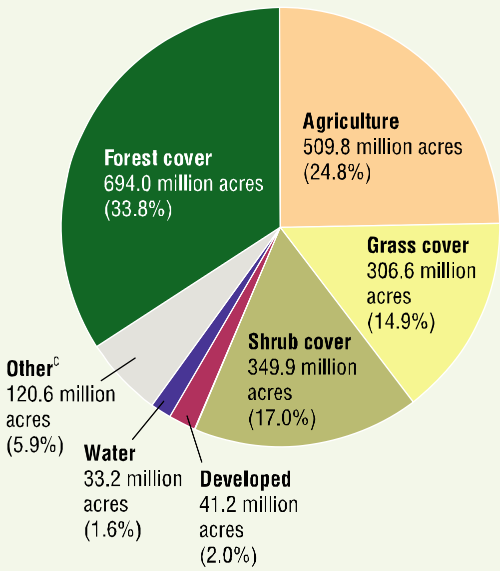


[a]See text box on page x-xx for definitions of land cover categories.

[b]"Other" includes ice/snow, rock, quarries/mining, wetlands, and transitional areas.

Data source: *1992 National Land Cover Dataset (NLCD)*

Exhibit 4-2. Land cover types in the U.S., based on 1992 NLCD and FIA[a,b]



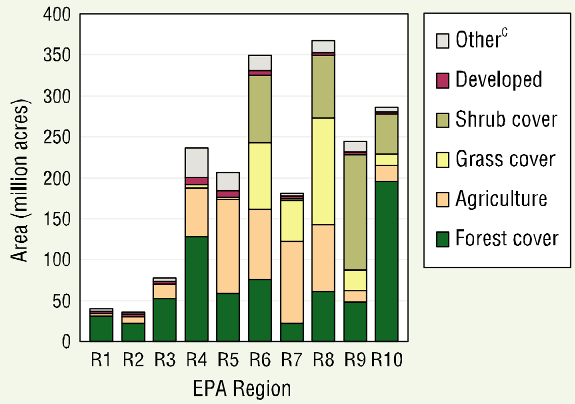
[a]**Coverage:** All surface area of the contiguous 48 states, plus forest land in Alaska and Hawaii.

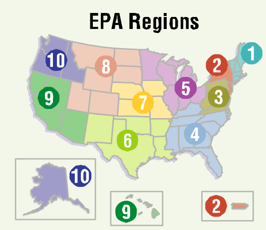
[b]See text box on page x-xx for definitions of land cover categories.

[c]"Other" includes ice/snow, rock, quarries/mining, wetlands, and transitional areas.

Data source: *Data for the contiguous 48 states from the 1992 National Land Cover Dataset (NLCD). Data for Alaska and Hawaii forest land from the USDA Forest Service, 1992 Forest Inventory and Analysis (FIA).*

Exhibit 4-3. Land cover types in the U.S. by EPA Region, based on 1992 NLCD and FIA[a,b]





[a]**Coverage:** All land area of the contiguous 48 states (excluding water), plus forest land in Alaska and Hawaii.

[b]See text box on page x-xx for definitions of land cover categories.

[c]"Other" includes ice/snow, rock, quarries/mining, wetlands, and transitional areas.

Data source: *Data for the contiguous 48 states from the 1992 National Land Cover Dataset (NLCD). Data for Alaska and Hawaii forest land from the USDA Forest Service, 1992 Forest Inventory and Analysis (FIA).*

Definitions of Land Cover Categories for Exhibits 4-1, 4-2, and 4-3

agricultural (NLCD definition): Areas characterized by herbaceous vegetation that has been planted; is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation must account for 75 to 100 percent of the cover. Includes the *orchards/vineyards/other* subcategory, which covers areas planted or maintained for the production of fruits, nuts, berries, or ornamentals. Excludes *urban/recreational grasses*, which fall under the “developed” category.

developed (NLCD definition): Areas characterized by a high percentage (30 percent or greater) of constructed materials (e.g., asphalt, concrete, buildings). Includes the *urban/recreational grasses* subcategory, which covers vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

shrubland (NLCD definition): Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.

grassland (NLCD definition): Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often used for grazing.

forest: **(NLCD definition)** Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25 to 100 percent of the cover.

(FIA definition) Land at least 10 percent stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10 percent stocked with forest trees and forest areas adjacent to urban and built-up lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. A forested area must be at least 1 acre in size to be classified as forest land. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide. (FIA data are used in Alaska and Hawaii, due to lack of NLCD availability.)

Source: USGS, 2005b; Powell et al., 1994.[0]

Indicator Limitations

- Trend data are not available for this indicator. Land cover data for the entire nation at adequate resolution to support this indicator are currently only available as a one-time snapshot, and are nearly fifteen years old (NLCD data represent an approximately 1992 vintage dataset). The MRLC Consortium is developing a vintage 2001 database, but until this project is completed, there are no consistent, comprehensive, nationwide data to describe trends in land cover at the national or EPA Regional levels. The 1992 NLCD will serve as a baseline for future inventories.

- FIA data for forest land in Alaska and Hawaii were used to complement the NLCD because NLCD data do not exist for these states. . On-going data collection under both FIA and NLCD are needed to assess land cover trends.
- National estimates of land cover vary, depending on the survey, data sources, classification, timing, etc., resulting in varying estimates of the extent of a given land cover category depending on the data set used. Techniques relying on satellite data to generate land cover estimates classify what is visible from above, meaning they may underestimate developed cover in heavily treed urban areas and underestimate forest cover where trees have been harvested. For example, FIA estimates of forestland in 1992 are nearly 8 percent above NLCD, National Resources Inventory (NRI) estimates for developed land are 110 percent above NLCD, and NRI estimates for agriculture land are less than 1 percent below NLCD (USDA Natural Resources Conservation Service, 2004). There are more variations in acreage based on data set comparisons at the regional level, with FIA estimating almost 42 percent (9 million acres) more forestland in EPA Region 9 than NLCD, NRI estimating more than 213 percent (3.7 million acres) more developed land in Region 8 than NLCD and 158 percent (8 million acres) more in Region 6. NRI also estimates 8 percent (10 million acres) less agricultural land in Region 5 than NLCD.
- No standardized land cover classification system is currently used among federal agencies. As a result of this limitation, there is no consistency in the assessment of land cover trends across agencies.

Data Sources

Land cover data for the contiguous 48 states were obtained from the National Land Cover Dataset (NLCD) (USGS, 2005a) (http://landcover.usgs.gov/natllandcover.php). These data were grouped into the major land cover categories as described by the Heinz Center (2005) [see technical note for the Heinz Center's "Ecosystem Extent" indicator]. Forest cover estimates for 1992 in Alaska and Hawaii were obtained from a report published by the USDA Forest Service's Forest Inventory and Analysis (FIA) program (Powell et al., 1994).

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INDICATOR: Land Cover in the Puget Sound/Georgia Basin

Changes in land use and corresponding changes in land cover can alter the basic functioning and resilience of ecological systems. Watersheds are one type of system that experiences a cascade of effects among its critical physical, chemical, and biological processes when land cover changes (NWP, 1995; Thom and Borde, 1998). For instance, removal of vegetation can increase erosion, leading to impacts on soil and water quality; and increases in developed land typically result in a corresponding increase in impervious surfaces with consequences for runoff among other issues. While individual impacts to a landscape may appear as small changes, the combined impacts of particular land uses or land management practices on watersheds can have substantial effects on water quality, species composition, and flooding patterns (PSAT, 2002, 2004). Such combined impacts are often referred to as 'cumulative effects.' As a result of their potential to broadly and substantially influence environmental condition, land cover and use are important factors to monitor.

This indicator compares changes in two land-cover metrics for the Puget Sound and Georgia Basin in Washington state and part of British Columbia, Canada. The metrics include percent change of urban and forest land cover. Data cover the period from 1995 to 2000 for the U.S. portion of the basin and from 1992 to 1999 for the Canadian side of the basin. The metrics represent the change in total urban or forested land area divided by total land area in the watershed. Forest and urban land cover are two of the most important factors affecting the condition of watersheds in the Puget Sound Basin (Alberti and Marzluff, 2004; Alberti, 2005). In contrast to the nationwide land cover indicator, which is based on NLCD data, the underlying data for this indicator are derived from four assembled USGS Landsat scenes covering the US portion of the Puget Sound Basin and from a combined scene covering the Canadian land area. The land cover data for all USGS 6^{th} field watersheds in the basin was produced from NOAA Coastal Change Analysis Program (C-CAP) data and from Canadian Baseline Thematic Mapping (BTM) data. The USGS Hydrologic Units (HUCs) and Canadian watershed groupings provide topographically delineated watersheds which are aggregated, or 'nested', into larger sub-basin and basin units.

What the Data Show

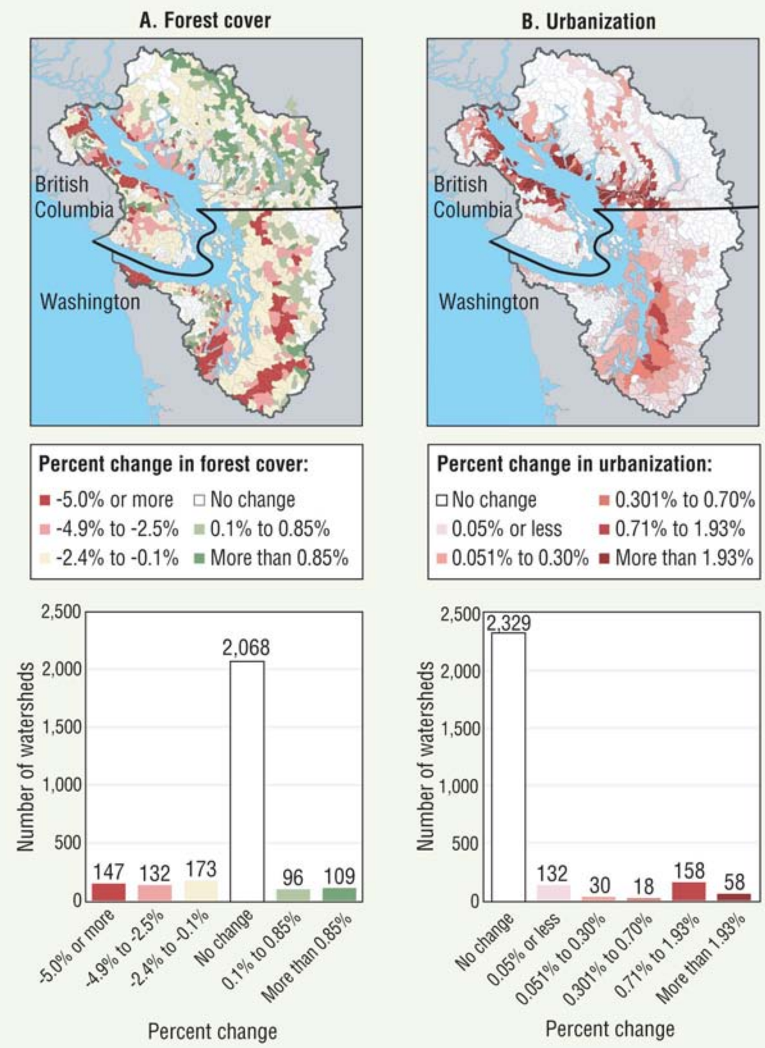
Forest Cover

Of the 2,725 watersheds assessed, little or no change in forest cover was observed in 2,068 watersheds (76 percent) (Exhibit 4-4, panel A). However, 279 watersheds (10 percent) saw at least 2.5 percent of their mature forest cover converted to some other land cover, often bare ground, immature vegetation, or industrial/urban uses. At the same time, another group of 205 watersheds (8 percent), generally those at higher elevations, indicated a net increase in forest cover as young stands or cleared areas have re-grown into more mature forest cover classes.

Urbanization

During the same period, little or no change in urban land cover was observed in approximately 90 percent of the 2,725 assessed watersheds within the basin (Exhibit 4-4, panel B). However, urbanization increased across many low elevation watersheds and shoreline areas, with 158 watersheds (6 percent) expanding the urban portion of the watershed by between 0.7 and 1.93 percent, and another 58 watersheds (2 percent) showing increases of more than 1.93 percent. Research has shown that once roughly 10 percent of a watershed's drainage area becomes paved or otherwise impervious, there is a high potential for physical, chemical, and biological impairments to both water quality conditions and other aquatic resources (NWP, 1995; Alberti and Marzluff, 2004). Recent assessments find that numerous Puget Sound watersheds are nearing or exceeding this level of development (Alberti et al., 2004).

Exhibit 4-4. Land cover change in watersheds of the Puget Sound/Georgia Basin, 1992-2000[a,b]



[a]**Coverage:** 2,725 watersheds within the Puget Sound/Georgia Basin, located in the state of Washington and the Canadian province of British Columbia. U.S. watersheds are 12-digit Hydrologic Unit Code (HUC12) watersheds.

[b]U.S. data reflect changes from 1995 to 2000, while Canadian data reflect changes from 1992 to 1999.

Data source: *U.S. data from NOAA, Coastal Change Analysis Program (C-CAP). Canadian data from Canadian Baseline Thematic Mapping (BTM). Cartography by CommEnSpace.*

Indicator Limitations

- While the U.S. C-CAP data and the Canadian BTM data have similar and overlapping time periods, as currently presented, the U.S. data reflect change from 1995 to 2000 and the Canadian data reflect change from 1992 to 1999.
- The size of the data pixels and the minimum mapping unit size affects the classification of certain features such as narrow riparian corridors, and can affect the percentages in the indicators.

Data Sources

The full analysis has not been published, but it is based on publicly available datasets compiled by CommEnSpace (http://www.commenspace.org). Raw data for the U.S. portion of this indicator are available from NOAA's Coastal Change Analysis Program (C-CAP) (NOAA, 2006) (http://www.csc.noaa.gov/crs/lca/locate.html), and Canadian data are available from the British Columbia Integrated Land Management Bureau (2001) (http://ilmbwww.gov.bc.ca/cis/initiatives/ias/btm/index.html).

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4.2.3 Discussion

What These Indicators Say About Trends in Land Cover and Their Effects on Human Health and the Environment

The data presented for the Land Cover indicator (p. 4-11) are only available for one point in time, 1992, and thus do not provide trend information. The data do, however, represent a baseline for future land cover trend assessments. The data show that the largest extent of a cover type nationwide is forest land, followed by agriculture, shrubland, grassland, and developed land.

The Land Cover in Puget Sound/Georgia Basin indicator (p. 4-17) shows that land cover in the majority of the approximately 2,700 sub-watersheds comprising the Puget Sound and Georgia Basin did not change appreciably during the time periods covered by the indicator. The data in this Regional Indicator allow for discrimination of patterns of watersheds where land cover has changed even in the relatively short interval of five years. For example, forest cover tended to decrease in coastal and mid-elevation watersheds, while showing a net increase at higher elevations. Developed land cover increased somewhat in approximately 8 percent of the sub-watersheds, mainly in watersheds at low elevations and along the shore. These and related trends may have consequences for human health and ecologic conditions in the areas where land cover is changing. For example, increases in developed land cover may be associated with increases in impervious surface area, which can cause changes in surface water runoff quantity and quality to the point where detrimental effects on aquatic resources may occur.[8]

The Forest Extent and Type indicator (p. 6-14) provides trend data for forest land cover, and shows that the total amount of forest land in the U.S. has remained relatively constant over recent years. On a regional basis, however, there have been shifts, including increases in forest cover in EPA Regions 2, 3, and 5, and decreases in Regions 6 and 9. The species composition of forest cover has also shifted.[9]

Limitations, Gaps, and Challenges

The lack of trend data is a key limitation of the Land Cover indicator (p. 4-11) as well as a gap in the data. The changing availability of technology since the 1970s, such as satellites and computing capacity to process large volumes of data, has provided new tools in the effort to track trends in land cover. The use of these tools continues to be constrained due to complexities in land cover and costs of processing. This is one reason that trend data for national land cover using satellite data are not currently available.

Another gap is the lack of indicators for human health effects related to trends in land cover. While land cover extent may represent a measure of ambient conditions and is a critical input to many other analyses (e.g., models of the water cycle, carbon cycle, ecological system function), it provides limited insight in answering the question of effects on human health.

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[8] U.S. EPA. 2005. Estimating and projecting impervious cover in the southeastern United States. EPA/600/R-05/061. Athens, GA. <http://www.epa.gov/athens/publications/reports/Exum600R05061EstimatingandProjectingImpervious.pdf>

[9] These changes and their effects on the environment are described in Chapter 6.

There are several challenges related to addressing the question of trends in land cover. Two critical ones are, first, that land cover characteristics can vary, depending on the scale of mapping or measurement and, second, the classification systems that are used to describe land cover vary by agency and their needs. The variability of species and structure within land cover types can be important in how land cover is affected by pollutants or the type of habitat that is provided. While mapping or measuring the details of species and structure of forest or shrubland is possible on a local basis, it is very difficult to do consistently nationally. There are many different types or categories of land cover that can be defined at very different levels of detail, and different classification schema often make comparability among data sets and across time frames difficult. The major sources of data used to track land cover are based on national surveys using unique classifications that have been maintained over time to allow valid comparisons of important characteristics to be made. At the same time, technology is changing what can be measured, mapped, and classified. Data that can be collected from ground surveys or in some cases inferred from aerial photo interpretation such as understory species are seen differently in automated satellite data processing. Coordinating, integrating, and using data collected at a variety of scales and based on diverse data sources and classifications are challenges in tracking trends in and effects of land cover.

4.3 WHAT ARE THE TRENDS IN LAND USE AND THEIR EFFECTS ON HUMAN HEALTH AND THE ENVIRONMENT?

4.3.1 Introduction

Land use represents the economic and cultural activities that are practiced at a place, such as agricultural, residential, industrial, mining, and recreational uses. Land use changes occur constantly and at many scales, and can have specific and cumulative effects on air and water quality, watershed function, generation of waste, extent and quality of wildlife habitat, climate, and human health. Land use differs from land cover in that some uses may not always be physically obvious (e.g., land used for producing timber but not harvested for many years or land used for grazing but without animals will not be visible). Public and private lands frequently represent very different uses. Urban development seldom occurs on public lands, while private lands are infrequently protected for wilderness uses. .

EPA is concerned about the use of land because of the potential effects of land use and its by-products on the environment. For example, land development creates impervious surfaces through construction of roads, parking lots, and other structures. Impervious surfaces contribute to non-point source water pollution by limiting the capacity of soils to filter runoff. Impervious surface areas also affect peak flow and water volume, which heighten erosion potential and affect habitat and water quality. Increased storm water runoff from impervious surfaces can deliver more pollutants to water bodies that residents may rely on for drinking and recreation.[10] Storm runoff from urban and suburban areas contains dirt, oils from road surfaces, nutrients from fertilizers, and various toxic compounds. Point source discharges from industrial and municipal wastewater treatment facilities can contribute toxic compounds and heated water. Impervious surfaces also affect groundwater aquifer recharge.

Some land development patterns, in particular dispersed growth such as “suburbanization,” can contribute to a variety of environmental concerns such as increased air pollution due to increased vehicle use. This can result in increased concentrations of certain air pollutants in developed areas that may exacerbate human health problems such as asthma.[11] Another potential effect of land development is the formation of “heat islands,” or domes of warmer air over urban and suburban areas, caused by the loss of trees and shrubs and the absorption of more heat by pavement, buildings, and other sources. Heat islands can affect local, regional, and global climate, as well as air quality.[12]

Agricultural land uses can affect the quality of water and watersheds. The types of crops planted, tillage practices, and various irrigation practices can limit the amount of water available for other uses. Livestock grazing in riparian zones can change landscape conditions by reducing stream bank vegetation and increasing water temperatures, sedimentation, and nutrient levels. Runoff from pesticides, fertilizers, and nutrients from animal manure can also degrade water quality. Additionally, agricultural land uses may

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[10] U.S. EPA. 2005. Estimating and projecting impervious cover in the southeastern United States. EPA/600/R-05/061. Athens, GA. <http://www.epa.gov/athens/publications/reports/Exum600R05061EstimatingandProjectingImpervious.pdf>

[11] Schwartz J. 2004. Air Pollution and Children's Health. Pediatrics 113:1037-1043

[12] U.S. EPA. 2003. Cooling summertime temperatures: strategies to reduce urban heat islands. EPA/430/F-03/014. Washington, DC. <http://www.epa.gov/heatisland/resources/pdf/HIRIbrochure.pdf>

result in loss of native habitats or increased wind erosion and dust, exposing humans to particulate matter and various chemicals.[13]

Some land uses can accelerate or exacerbate the spread of invasive species. Certain land use practices, such as overgrazing, land conversion, fertilization, and the use of agricultural chemicals can enhance the growth of invasive plants.[14] These plants can alter fish and wildlife habitat, contribute to decreases in biodiversity, and create health risks to livestock and humans. Introduction of invasive species on agricultural lands can reduce water quality and water availability for native fish and wildlife species.

Research is beginning to elucidate the connections between land use changes and infectious disease. For example, fragmentation of forest habitat into smaller patches separated by agricultural activities or developed land increases the "edge effect" and promotes the interaction among pathogens, vectors, and hosts.[15]

In some cases, changes in land use may have positive effects, such as increasing habitat as a result of deliberate habitat restoration measures; and reclamation of lands for urban/suburban development as a result of cleanup of previously contaminated land.

4.3.2 ROE Indicators

The question of trends in land use is addressed by two ROE indicators: Land Use and Urbanization and Population Change (Table 4.3.1). The primary information sources for these indicators are the National Resources Inventory (NRI) prepared by the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS); the Forest Service's Forest Inventory and Analysis (FIA) Program; the National Agricultural Statistical Service (NASS) Census of Agriculture; and population data collected by the U.S. Census Bureau. The glossary includes definitions of the categories used in the indicators.

Table 4.3.1. ROE Indicators of Trends in Land Use and Their Effects on Human Health and the Environment

NATIONAL INDICATORS	LOCATION
Land Use (N/R)	4.3.2 – p. 4-24
Urbanization and Population Change (N/R)	4.3.2 – p. 4-31

N/R = National Indicator displayed at EPA Regional scale

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[13] Schenker, M. 2000. Exposures and health effects from inorganic agricultural dusts. Environ. Health Persp. 108(Suppl 4):661-664. <http://ehp.niehs.nih.gov/members/2000/suppl-4/661-664schenker/schenker-full.html>

[14] U.S. Fish and Wildlife Service. 2002. Invasive species encroachment is one of the biggest threats to native ecosystems that resource managers face today. <http://invasives.fws.gov/index7.html>

[15] Patz, J.A., et al. 2004. Unhealthy landscapes: policy recommendations on land use change and infectious disease emergence. Environ. Health Persp. 112:1092-1098.

INDICATOR: Land Use

Land use is the purpose of human activity on the land. Unlike land cover, land *use* may not always be visible. For example, a unit of land designated for use as timberland may appear identical to an adjacent unit of protected forestland, or if recently harvested, it may appear not to be in forest land cover at all. Land use is generally designated through zoning or regulation and is one of the most obvious effects of human inhabitation of the planet. It can affect both human health and ecological systems, as for example, changing the hydrologic characteristics of a watershed, the potential of land to erode, the condition or contiguity of plant and animal habitat, or the spread of vector-borne diseases.

This indicator tracks trends in acreages of major land uses over the period 1977–2002 using several data sources. These sources do not always cover the same time period, sample the same resource or geography, or use the same definitions, but each of the sources provides an important piece of the land use picture over time. Definitions for the various land use categories in this indicator can be found at on the following pages.

The National Resources Inventory (NRI) conducted by the USDA Natural Resources Conservation Service was used to track trends in “crop and pasture” land (row crop, orchard, and pasture uses) and “developed” land (residential, commercial, industrial, and transportation uses). The NRI developed estimates every five years on non-federal lands in the contiguous U.S. between 1977 and 1997, and *annual* estimates based on a smaller sample size beginning in 2001.

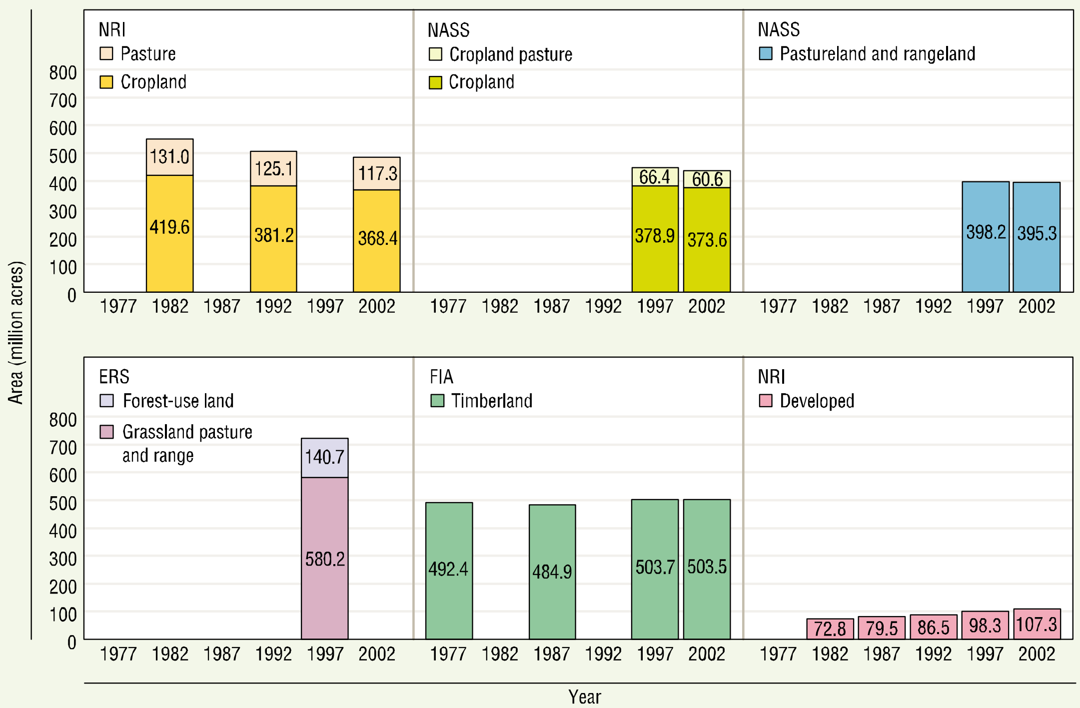
The Forest Inventory and Analysis (FIA) surveys conducted by the USDA Forest Service were used to track trends in forest and timberlands. The FIA surveys include both private and public land in all 50 states. The FIA previously assessed forest and timberland acreage every ten years, but the data are now updated on a rolling basis using surveys that sample a different portion of FIA sites every year.

The USDA National Agricultural Statistical Service (NASS) Census of Agriculture was used to track trends in the extent of “crop and pasture” land and “farm rangeland” (typically improved pasture). NASS data are available for 1997 and 2002 only. Data on the extent of grass and forested rangeland (typically “unimproved” grazing land) are available from the USDA Economic Research Service (ERS) for one year only, 1997.

What the Data Show

The acreage of lands used for growing food and forage crops has declined since 1982, while developed land has increased, and timberland has remained approximately constant (Exhibit 4-5). As of 2002, estimates from both NRI and NASS indicate that about 370 million acres were used for food crop production, approximately 16 percent of the U.S. land area. Estimates of pasture or land used to support forage for livestock vary, depending on the definitions. The NRI classified 117 million acres as pasture, while the NASS classified about 60 million acres as cropland used for pasture. NASS classifies nearly 400 million additional acres as pasture or rangeland for grazing. The broader ERS estimate of land available for grazing totals about 580 million acres, and includes rangeland, grassland, shrubland, and cropland pasture. If forest lands used for grazing are also included, the total ERS estimate for these lands was 720 million acres in 1997. The NASS shows a slight decrease in the extent of cropland (5 million acres), pasture (6 million acres), and rangeland (3 million acres) between 1997 and 2002. The NRI data suggest that these declines are part of a longer trend, with NRI cropland and pasture declining by slightly more than 64 million acres (12 percent) between 1982 and 2002.

Exhibit 4-5. Land use trends in the U.S., 1977-2002[a]



[a]See text box on page x-xx for definitions of land use categories.

Data source: *ERS data from Vesterby and Krupa, 2001. FIA data from the USDA Forest Service, Forest Inventory and Analysis (FIA) Program and from Smith et al., 2004. NASS data from USDA, 2004. NRI data from the USDA Natural Resources Conservation Service and from USDA, 2000.*

According to the NRI, nearly 5 percent (or 107.3 million acres) of U.S. land area was considered developed[16] as of 2002 (Exhibit 4-5). This represents a gain of 47 percent (34.5 million acres) since 1982. While the amount of developed land is a small fraction of the total, its ecological impact can be disproportionately high relative to other land use types. Paving and the creation of other impervious surfaces can change local hydrology, climate, and carbon cycling, leading to increased surface runoff, pollution, and degradation of wetlands and riparian zones.

Forest lands are managed by a complex array of interests to meet multiple purposes, including providing habitat for a variety of species, recreation, and timber production. While forest is a land *cover* classification, “timberland” is a land *use* classification that reflects forest land capable of producing at least 20 cubic feet per acre per year of industrial wood and not withdrawn from timber utilization by statute or regulation. Approximately 504 million acres of U.S. forest land, or 22 percent of the total U.S. land area, qualified as timberland in 2002 (Exhibit 4-5). This total reflects a net gain of about 11 million acres (2 percent) between 1977 and 2002, which FIA attributes largely to reversion of abandoned lands and reclassification of some National Forest lands to align with classifications used on other land ownerships (Smith et al., 2004).

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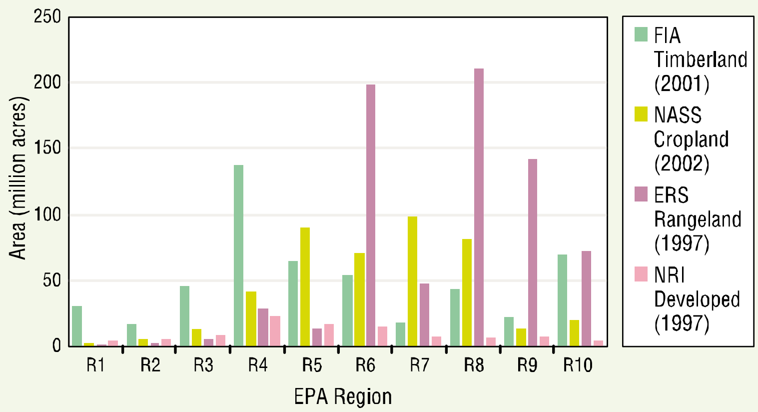
[16] The Land *Use* classification for developed land uses NRI data and is considerably different from the Land *Cover* classification for developed which uses NLCD data, as described in Section 4.2.

Land use varies substantially by EPA Region (Exhibit 4-6). According to the most recent data for each land use type, Regions 6, 8, and 9 together have more than three-quarters of the nation's grazing land , while Region 4 has the largest portion of timberland (27 percent of total U.S. timberland). Trends also vary widely among regions. Nearly 84 percent of the cropland lost between 1987 and 1997 was in five EPA Regions (Regions 4, 5, 6, 7, and 8) (Exhibit 4-7, panel A). Increases in developed land are responsible for part of this decline; for example, developed land increased by nearly 40 percent from 1987 to 1997 in Region 4 (Exhibit 4-7, panel B). Other factors include the federal Conservation Reserve Program (CRP), which has assisted private landowners in converting about 35 million acres of highly erodable cropland to vegetative cover since 1985 (as of 2004) (USDA Farm Service Agency, 2004).

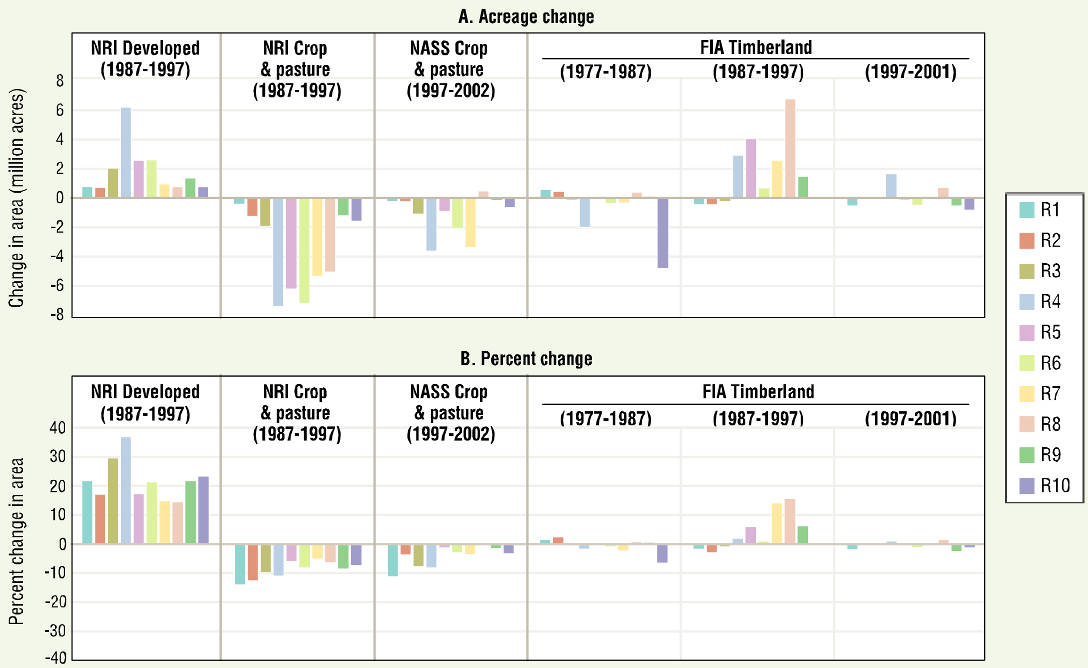
Exhibit 4-6. Land use in the U.S. by EPA Region, 1997-2002[a]

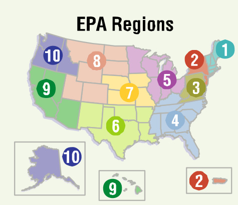


[a]See text box on page x-xx for definitions of land use categories.

Data source: *ERS data from Vesterby and Krupa, 2001. FIA data from the USDA Forest Service, Forest Inventory and Analysis (FIA) Program and from Smith et al., 2004. NASS data from USDA, 2004. NRI data from the USDA Natural Resources Conservation Service and from USDA, 2000.*

Exhibit 4-7. Changes in land use in the U.S. by EPA Region, 1977-2001[a]





[a]See text box on page x-xx for definitions of land use categories.

Data source: *FIA data from the USDA Forest Service, Forest Inventory and Analysis (FIA) Program and from Smith et al., 2004. NASS data from USDA, 2004. NRI data from the USDA Natural Resources Conservation Service and from USDA, 2000.*

Definitions of Land Use Categories for Exhibits 4-5, 4-6, and 4-7

NRI (USDA Natural Resources Conservation Service, 2000b [Appendix 3])

developed: Belonging to one of three land use categories: *large urban and built-up areas, small built-up areas*, and *rural transportation land*.

- **Large urban and built-up areas.** Category composed of developed tracts of at least 10 acres—meeting the definition of *Urban and built-up areas*.
- **Small built-up areas.** Category consisting of developed land units of 0.25 to 10 acres, which meet the definition of *Urban and built-up areas*.
- **Rural transportation land.** Category which consists of all highways, roads, railroads and associated right-of-ways outside *urban and built-up areas*; also includes private roads to farmsteads or ranch headquarters, logging roads, and other private roads (field lanes are not included).
- **Urban and built-up areas.** Category consisting of residential, industrial, commercial, and institutional land; construction sites; public administrative sites; railroad yards; cemeteries; airports; golf courses; sanitary landfills; sewage treatment plants; water control structures and spillways; other land used for such purposes; small parks (less than 10 acres) within urban and built-up areas; and highways, railroads, and other transportation facilities if they are surrounded by urban areas. Also included are tracts of less than 10 acres that do not meet the above definition but are completely surrounded by Urban and built-up land. Two size categories are recognized in the NRI: areas of 0.25 acre to 10 acres, and areas of at least 10 acres.

cropland: A land use category that includes areas used to produce adapted crops for harvest. Two subcategories of cropland are recognized: cultivated and noncultivated. Cultivated cropland is land in row crops or close-grown crops, as well as land (e.g., hayland or pastureland) that is in a rotation with row or close-grown crops. Noncultivated cropland includes permanent hayland and horticultural cropland.

pastureland: Land managed primarily for the production of introduced forage plants for livestock grazing. Pastureland cover may consist of a single species in a pure stand, a grass mixture, or a grass-legume mixture. Management usually consists of cultural treatments: fertilization, weed control, reseeding or renovation, and control of grazing. For the NRI, this category includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether or not it is being grazed by livestock.

FIA (Smith et al., 2004)

forest land: Land at least 10 percent stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10 percent stocked with forest trees and forest areas adjacent to urban and built-up lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. A forested area must be at least 1 acre in size to be classified as forest land. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.

timberland: Forest land that is producing or can produce crops of industrial wood and is not withdrawn from timber utilization by statute or administrative regulation. (Areas qualifying as timberland must be able to produce more than 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.)

NASS (USDA National Agricultural Statistical Service, 2004)

cropland: A category including cropland harvested, cropland idle or used for cover crops or soil improvement but not harvested and not pastured, cropland on which all crops failed, and cropland in cultivated summer fallow. Not included is cropland used only for pasture or grazing.

cropland pasture: Cropland used only for pasture or grazing, which could have been used for crops without additional improvement. Also included are acres of crops hogged or grazed but not harvested prior to grazing. However, cropland pastured before or after crops were harvested counts as harvested cropland rather than cropland for pasture or grazing.

pastureland and rangeland: All grazable land—irrigated or dry—that does not qualify as cropland or woodland pasture. In some areas, this is high-quality pastureland but cannot be cropped without improvements. In others, it can barely be grazed and is only marginally better than waste land.

ERS (Verterby and Krupa, 2001)

grassland pasture and range: All open land used primarily for pasture and grazing, including shrub and brush land types of pasture; grazing land with sagebrush and scattered mesquite; and all tame and native grasses, legumes, and other forage used for pasture or grazing. Because of the diversity in vegetative composition, grassland pasture and range are not always clearly distinguishable from other types of pasture and range. At one extreme, permanent grassland may merge with cropland pasture; grassland is also often found in transitional areas with forested grazing land.

forest-use land grazed: Forested pasture and range consisting mainly of forest, brush-grown pasture, arid woodlands, and other forested areas that have grass or other forage growth. The total acreage includes woodland pasture in farms plus estimates of forested grazing land not in farms. For many states, the estimates include many areas grazed only lightly or sporadically. The Census of Agriculture, the National Resources Inventory, and the Forest Inventory and Analysis are the principal sources of data (USDA/NASS, 1999a; USDA/NRCS, 2000; USDA/FS, 2000). Historical data from these and other sources were useful in developing the 140-million-acre approximation.

Indicator Limitations

- Estimates are derived from a variety of inventories and samples, conducted over different time periods and for different purposes, which limits the ability to integrate the data and track changes over time.
- NRI does not report land use data for Alaska, which encompasses 365 million acres of the 2.3 billion acres nationwide. NRI also does not provide data on federal lands (representing 20 percent of the contiguous U.S. land and one third of Alaska). Because federal land is seldom used for agriculture or urban development, and relatively little developed or agricultural land occurs in Alaska, the NRI data likely offer a reasonable approximation of national trends in these categories.
- NRI data use three subcategories of types of developed land: large built-up areas, small built-up areas, and rural transportation land. Because ecological effects from developed land depend on the density of development and many other factors, the limited NRI categories are not discriminating enough to support detailed analyses of ecological effects of developed land.
- Changes in NRI sampling design currently limit the amount of sub-national data available (e.g., estimates are not available for states in the 2001-2002 timeframe, as they have been previously in five-year increments: 1982, 1987, 1992, and 1997).
- The FIA data are aggregated from state inventories in many cases, and dates of data collection for these inventories vary by state—for example, ranging from 1980 to 2001 for reporting 2002 estimates.
- Some land uses may not be physically visible, but designated administratively (e.g., lands that are reserved for parks or wilderness may appear similar to lands that are managed for natural resources).
- Land use designations are most frequently managed and monitored by local governments, each using different approaches and classifications, making national summaries difficult.
- The extent of lands used for energy production, resource extraction or mining is not known and represents a data gap.
- Lands specifically protected for certain uses such as wilderness or parks have been periodically inventoried for the nation. These statistics are currently not reported in a form that allows comparison with other statistics.

Data Sources

Data were obtained from several original sources and compiled by EPA Region. ERS data were obtained from Vesterby and Krupa (2001). FIA data were obtained from the FIA database (USDA Forest Service, 2005) (http://www.fia.fs.fed.us/tools-data/data/); some data were also published in Smith et al. (2004). NASS data were published in USDA National Agricultural Statistical Service (2004). Some NRI data are available from an online database (USDA Natural Resources Conservation Service, 2005) (http://www.nrcs.usda.gov/technical/NRI/) and a recent summary report (USDA Natural Resources Conservation Service, 2000); the rest can be obtained on CD.

References

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USDA Farm Service Agency. 2004. The Conservation Reserve Program: summary and enrollment statistics, 2004. <http://www.fsa.usda.gov/Internet/FSA_File/fy2004.pdf>

USDA Forest Service. 2005. Forest Inventory and Analysis, national FIA data base systems. Accessed 2005. <http://www.fia.fs.fed.us/tools-data/data/>

USDA National Agricultural Statistical Service. 2004. 2002 census of agriculture, United States summary and state data. Report AC-02-A-51. <http://www.nass.usda.gov/census/census02/volume1/us/us2appxc.pdf> (QA/QC); <http://www.nass.usda.gov/census/census02/volume1/USVolume104.pdf>

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USDA Natural Resources Conservation Service. 2005. National Resources Inventory. Accessed 2005. <http://www.nrcs.usda.gov/technical/NRI/>

Vesterby, M., and K.S. Krupa. 2001. Major Uses of Land in the United States, 1997. Statistical bulletin no. 973. U.S. Department of Agriculture, Economic Research Service. <http://www.ers.usda.gov/publications/sb973/sb973.pdf>

INDICATOR: Urbanization and Population Change

Population change is a driver affecting numerous environmental outcomes. The total number of people and their distribution on the landscape can affect the condition of the environment in many ways; for example, increasing population often means increased urbanization, including conversion of forest, farm, and other lands for housing, transportation, and commercial purposes. In recent years many communities in the U.S. have seen an increase in developed land area that outpaces population growth. This pattern is of concern for numerous health and environmental reasons (Frumkin et al., 2004). For example, studies indicate that when land consumption rates exceed the rate of population growth, per capita air pollutant emissions from driving tend to be higher. Urbanization and population growth also tend to increase the amount of impervious surfaces and the quantity and types of products that humans produce, use, and discard, thereby affecting waste generation and management, water quality, and chemical production and use.

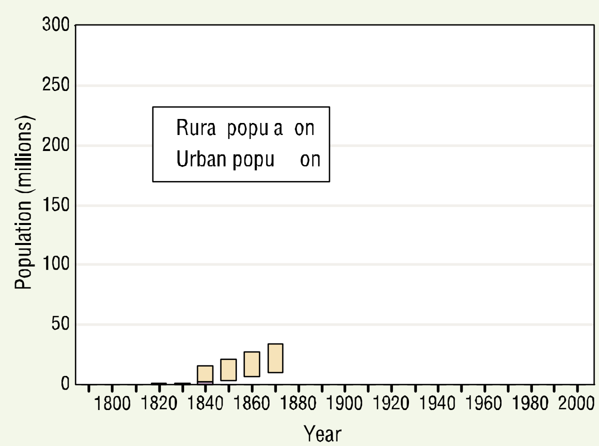
The information presented in this indicator is based on population data collected and analyzed on a decadal basis by the U.S. Census Bureau—as well as annual "intercensal" population estimates—and data collected by the USDA Natural Resources Conservation Service National Resources Inventory (NRI) to track "developed" land (residential, commercial, industrial, and transportation uses). Between 1977 and 1997 the NRI developed estimates every five years on non-federal lands in the contiguous U.S. Since 2001 the NRI has developed annual estimates, but based on a smaller sample size. This indicator captures trends in overall population growth for both rural and urban populations; the amount of developed land relative to the amount of population change, nationally and by EPA Region; and overall population density, nationally and by EPA Region.

What the Data Show

The U.S. population grew from a little over 4 million people in 1790 to over 281 million in 2000; urban population is estimated to have grown 1000-fold over that period (Exhibit 4-8). The population has nearly doubled since 1950, when the total stood at 150.7 million.

Between 1982 and 2002, the amount of developed land in the U.S. in the 48 contiguous states (not including the District of Columbia) and Hawaii grew by more than 34 million acres, representing a cumulative increase of approximately 47 percent (Exhibit 4-9). The Census Bureau estimates that during the same period, the population of the 48 states grew by slightly more than 56 million people, or just over 24 percent. Between 1982 and 2002, the amount of developed land increased at nearly twice the rate of the population.

Exhibit 4-8. Population and urbanization in the U.S., 1790-2000[a]



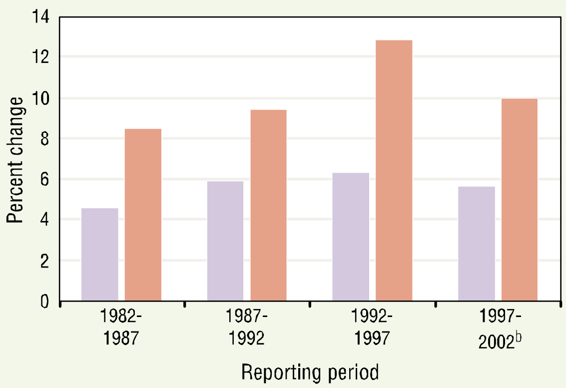
[a]**Coverage:** 50 states and the District of Columbia.

Data source: *U.S. Census Bureau. See specific citations in text.*

There are substantial variations in population and development trends in different parts of the U.S. (Exhibit 4-10). Between 1982 and 1997, EPA Region 4 experienced a 27 percent increase in population (10.8 million people) and a 55 percent increase in the amount of developed land. This increase in developed land represents over 8 million acres and nearly 33 percent of the total US increase in acreage developed during that time. Among the Western EPA Regions (8, 9, and 10), the amount of land developed closely matched population growth. The developed acres per capita actually decreased in the much of the west (Regions 8 and 9). In the Northeast, in contrast, the rate of increase in developed land was nearly four times that of population (Regions 1, 2, and 3). Regions in the Midwest and South (Regions 4-7) fell in-between, with percentage increases in developed land ranging from 1.6 to 3.2 times the rate of population change.

Population density also varies across the nation. In 2005, EPA Region 2 was the most densely populated Region, at 512 people per square mile; EPA Region 10 was the least densely populated, with an average of approximately 15 people per square mile (including Alaska) (Exhibit 4-11). The national average in 2005 was 83.8 people per square mile. Region 2 has had more than twice the population density of all other EPA Regions for the last fifty years. The largest increase in population since 1950 occurred in Region 9, where population (and density) increased by roughly 280 percent. Region 4 had the second-largest increase, at 140 percent.

Exhibit 4-9. Percent change in population and developed land in the contiguous U.S. and Hawaii, 1982-2002[a,b]

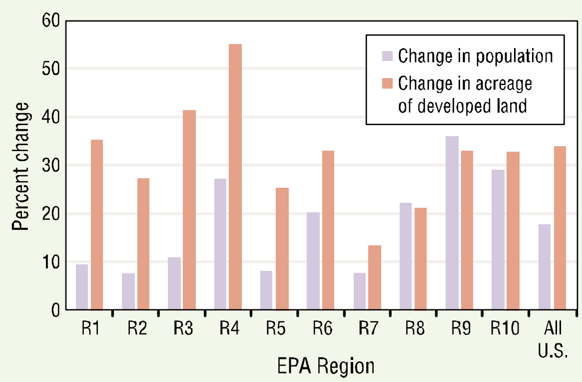


[a]**Coverage:** Contiguous 48 states (excluding the District of Columbia) and Hawaii.

[b]Based on changes in the NRI inventory approach, Hawaii was not sampled in 2002. Thus, the percent change in developed land from 1997 to 2002 is based on the 48 contiguous states only.

Data source: *Population data from the U.S. Census Bureau. Land use data from USDA Natural Resources Conservation Service, National Resources Inventory. See specific citations in text.*

Exhibit 4-10. Percent change in population and developed land in the contiguous U.S. and Hawaii, by EPA Region, 1982-1997[a]



[a]**Coverage:** Contiguous 48 states (excluding the District of Columbia) and Hawaii.

Data source: *Population data from the U.S. Census Bureau. Land use data from USDA Natural Resources Conservation Service, National Resources Inventory. See specific citations in text.*

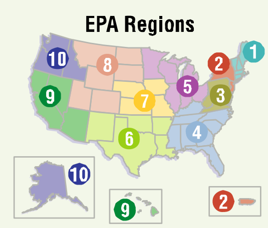
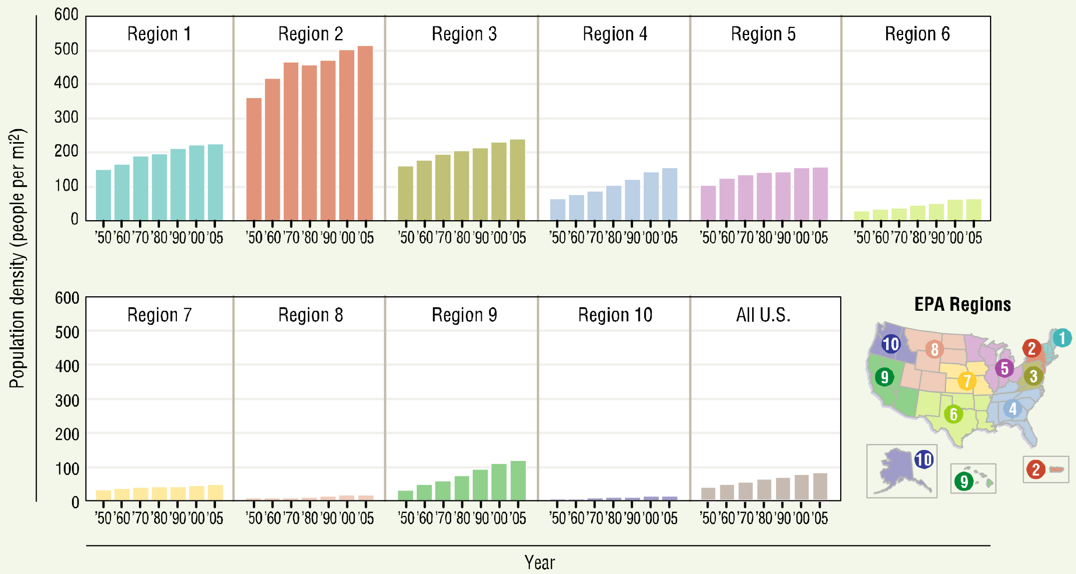


Exhibit 4-11. Population density in the U.S. by EPA Region, 1950-2005[a]



[a]**Coverage:** 50 states and the District of Columbia.

Data source: *U.S. Census Bureau. See specific citations in text.*

Indicator Limitations

Census data:

- Intercensal figures are estimates based on administrative records of births, deaths, and migration, and thus differ from the decennial census data in methodology and accuracy.
- Sampling and non-sampling errors exist for all Census data as a result of errors that occur during the data collection and processing phases of the census.
- Puerto Rico and Virgin Islands data are not available for all years, and thus have not been included, affecting the accuracy of the statistics for Region 2.
- The criteria for estimating urban population have changed over time as defined by the Census Bureau.

Natural Resources Inventory (NRI) data:

- NRI sampling procedures changed in 2000 to an annual survey of fewer sample sites than had previously been sampled (starting in 1977, NRI sampled 800,000 points every five years). Fewer sample points mean increased variance and uncertainty and an inability to develop estimates on a state or regional basis, thus even though national data are available for 2002, state-level data for compilation at the EPA Regional level are only available through 1997. State estimates will be available in the future as more points are sampled annually.
- NRI collects some data across the entire nation, including Puerto Rico and the Virgin Islands. Land use statistics, however, are not reported on federal lands or for Alaska and the District of Columbia.

Data Sources

Urban and rural population data for Exhibit 4-8 were obtained from two U.S. Census Bureau publications: data from 1790 to 1990 are from U.S. Census Bureau (1993); 2000 data are from U.S. Census Bureau (2004).

In Exhibit 4-9, population change was calculated from annual population estimates published in U.S. Census Bureau (1996, 2002b, 2005) (estimates for 1982/1987, 1992/1997, and 2002, respectively). Changes in acreage of developed land were calculated based on acreage figures reported every five years by the USDA's National Resources Inventory (NRI). NRI data were obtained from two publications (USDA Natural Resources Conservation Service, 2000b and 2004) (1982-1997 and 2002 data, respectively).

Exhibit 4-10 is based on annual population estimates by state, published in U.S. Census Bureau (1996 and 2002b); and NRI developed land estimates by state, published in USDA National Resources Conservation Service (2000a). The figure was developed by grouping the published state data by EPA Region, then calculating percent change between 1982 and 1997.

Population density by EPA Region (Exhibit 4-11) was calculated based on three published datasets: population every 10 years from 1900 to 2000 by state (U.S. Census Bureau, 2002a); population estimates for 2005 by state (U.S. Census Bureau, 2005); and land area by state (U.S. Census Bureau, 2002c).

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4.3.3 Discussion

What These Indicators Say About Trends in Land Use and Their Effects on Human Health and the Environment

The indicators point out that the development of land for human residential and commercial purposes is occurring at a rapid pace. In the 20-year period between 1982 and 2002, the acreage of developed land increased by nearly 50 percent from its 1982 level. Population growth in a similar time frame grew at only half the rate of land development, indicating that more land is being developed per capita now than 25 years ago. Across EPA regions, such rates of change in developed land and population vary both independently and with respect to each other. Over the same 20-year time frame, the extent of cropland and pastureland has slowly declined, with larger decreases in those regions experiencing either increased land development or reforestation.

Limitations, Gaps, and Challenges

There is generally a lack of comprehensive data on the types and rates of land use and land cover change, and even less systematic evidence on the causes and consequences of these changes. On a global scale, the National Research Council identified land use dynamics as one of the grand challenges for environmental research.[17]

Two examples of land uses not addressed by the indicators, that can have effects in different ways on condition and extent of land, are the formal protection or reservation of land for habitat or natural resources, and mining and extraction activities. Some data are collected locally and for federal lands (e.g., National Park acreage) or tracked for economic indicators, but the national picture of the extent of land reservation and mining is not generally available.

A key challenge in answering this question is that estimates of the extent of various land uses differ across data sources and each source uses different classifications, measurement approaches, methodologies for analysis and interpretation, and sampling timeframes. The data are collected by many different agencies, which manage land use for many different purposes. The data collection efforts currently in place are derived from specific interests, such as tracking changes in the extent of agricultural or farmland, or understanding how much land is used for timber production. These data collection efforts tend to develop and use their own classifications and categorization, making it difficult to integrate and use the data over time, across inventories, or as a national picture.

Another challenge is understanding the effects that trends in land use have on human health. No indicators are available, as effects have not been shown or quantified on a national basis. Urban and landscape planners have conducted site-specific studies on individual land uses, but little is known about overall national trends in land use and potential impacts on human health.

An additional challenge is that a variety of state, county, and municipal laws, regulations, and practices govern the use of land, but aside from regulations addressing protection of species and their habitats, there are no national land use regulations that apply to all non-federal lands. There are also relatively few

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[17] National Research Council, Committee on Grand Challenges in Environmental Sciences. 2001. Grand challenges in environmental sciences. Washington, DC: National Academy Press.

state-level efforts to organize land use data; most activities occur over specific local, usually urbanizing, geographic areas. This means that land use records are not maintained state-wide or nationally, as they are in other nations, which contributes to challenges in tracking and monitoring land use changes. This also means that strategies to plan land use across jurisdictions are difficult to develop.

Finally, a challenge in developing data to determine trends, is that delineation of land use, generally a function of laws, policies, or management designations, may not always be possible to infer from examining the ground via surveys. Analysis of zoning maps or property records at the local level may be necessary.

4.4 WHAT ARE THE TRENDS IN WASTES AND THEIR EFFECTS ON HUMAN HEALTH AND THE ENVIRONMENT?

4.4.1 Introduction

Every resident, organization, and activity conducted by humans in the United States generates some type of waste. There are many different types of wastes generated, including municipal solid waste, agricultural and animal wastes, medical wastes, radioactive waste, hazardous waste, industrial non-hazardous wastes, construction and demolition debris, extraction and mining wastes, oil and gas production wastes, fossil fuel combustion wastes, and sewage sludge (see the glossary for detailed descriptions of these wastes). In general, waste generation represents inefficient use of materials. These discarded materials, some of which are hazardous, must be managed through reuse, recycling, storage, treatment, and disposal. Hazardous wastes are either specifically listed or identified as hazardous by EPA or a state, or exhibit one or more of the following characteristics: ignitability, corrosivity, reactivity, or toxicity. Generation of hazardous wastes and their management have the potential to contaminate and compromise land and negatively affect human health and environmental conditions. Tracking trends in the quantity, composition, and effects of waste provides insight into the efficiency with which the nation uses (and re-uses) materials and resources and provides a means to better understand the effects of wastes on human health and ecological conditions.

The amount of waste produced is influenced by economic activity, consumption, and population growth. Affluent societies, such as the United States, generally produce large amounts of municipal solid waste (e.g., food wastes, single-serving containers, packaged goods, disposable goods, electronics) and commercial and industrial wastes (e.g., demolition debris, incineration residues, refinery sludges). Among industrialized nations, the United States generates the largest amounts of municipal solid waste per person on a daily basis.[18]

Current approaches to waste management evolved primarily due to health concerns and odor control. Waste often was deposited outside of developed areas on nearby lands, frequently wetlands. Excavation of land specifically for deposition of wastes followed, often accompanied by burning of wastes to reduce volume, a practice eventually determined to be a contributor to degraded air quality in urban areas. Burning of wastes occurred at multiple levels, from backyard burning to large, open-burning dumps of municipal solid wastes to onsite burning of commercial and industrial wastes. Land disposal created problems such as groundwater contamination, methane gas formation and migration, and disease vector hazards.

The amount of land being used to manage the many types of waste generated is not known. Most municipal solid wastes and hazardous wastes are managed in land disposal units. Land disposal of hazardous wastes includes landfills, surface impoundments, land treatment, land farming, and underground injection. Modern landfill facilities are engineered with containment systems and monitoring programs. Waste management practices prior to RCRA regulations left legacies of contaminated lands in many cases, which are addressed in Section 4.6 of this chapter.

Landfills represent one of the largest human-related sources of methane gas in the United States. Between 1997 and 2003, landfills accounted for slightly more than one-fourth of the estimated methane emissions

[18] Clark, R., and E. Capponi, eds. 2005. OECD in figures 2005: statistics on the member countries. Organization for Economic Cooperation and Development (OECD) Observer. Paris, France.

attributed to human activity.[19] Methane gas is released as wastes decompose, as a function of the total amount and makeup of the wastes, as well as management facility location, design and practices.[20] EPA is interested because gas emissions can be affected by recycling and changing product use. For example, recycling aluminum or office paper can reduce environmental effects (e.g., by reducing the need to mine Bauxite or harvest trees), and reduce the amount of waste, thereby reducing greenhouse gas production. [21]

Although data do not exist to directly link trends in waste with effects on human health and the environment, the management of waste may result in waste and chemicals in waste entering the environment. Hazardous waste, by definition, has the potential to negatively affect human health and the environment, which is why it is so strictly regulated. The effects associated with waste vary widely and are influenced by the substances or chemicals found in waste and how they are managed. Priority Chemicals, which are documented contaminants of air, land, water, plants, and animals and are found in waste, have been tracked by EPA since 1991. Between 1991 and 2001, quantities of 17 of the Priority Chemicals were reduced by more than 50 percent.[22]

4.4.2 ROE Indicators

The ROE indicators for this question focus on the national trends in the amount of municipal solid waste and hazardous waste generated and their management practices. Municipal solid waste trends are presented for more than four decades. Trends in the generation and management of municipal solid waste are based on estimations from a materials flow, or mass balance approach since 1960. Changes in the amount of RCRA hazardous waste generated and managed are based on mandated biennial submissions from generators and treatment, storage and disposal facilities.

Table 4.4.1. ROE Indicators of Trends in Wastes and Their Effects on Human Health and the Environment

NATIONAL INDICATORS	LOCATION
Quantity of Municipal Solid Waste Generated and Managed	4.4.2 – p. 4-40
Quantity of RCRA Hazardous Waste Generated and Managed	4.4.2 – p. 4-43

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[19] U.S. EPA. 2006. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004. EPA 430-R-06-002. April. <http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2006.html>

[20] More information on air emissions related to waste management practices, including nitrogen oxide (NO_x) and carbon monoxide (CO), is included in Chapter 2.

[21] U.S. EPA. 2002. Solid waste management and greenhouse gases: a life-cycle assessment of emissions and sinks. Second edition. EPA/530/R-02/006. Washington, DC. <http://www.epa.gov/epaoswer/non-hw/muncpl/ghg/greengas.pdf>

[22] U.S. EPA. 2005. National Priority Chemicals Trends Report (1999-2003). EPA 530-R-05-022. December. <http://www.epa.gov/epaoswer/hazwaste/minimize/trend05/sec2.pdf>

INDICATOR: Quantity of Municipal Solid Waste Generated and Managed

Municipal solid waste (also called trash or garbage) is defined at the national level as wastes consisting of everyday items such as product packaging, grass clippings, furniture, clothing, bottles and cans, food scraps, newspapers, appliances, consumer electronics, and batteries. These wastes come from homes, institutions such as prisons and schools, and commercial sources such as restaurants and small businesses. EPA's definition of municipal solid waste (MSW) does not include municipal wastewater treatment sludges, industrial process wastes, automobile bodies, combustion ash, or construction and demolition debris. Once generated, MSW must be collected and managed, including reuse, recovery for recycling (which includes composting), combustion, and landfill disposal. Many wastes that are disposed in landfills represent a loss of materials that could be reused, recycled, or converted to energy to displace the use of virgin materials.

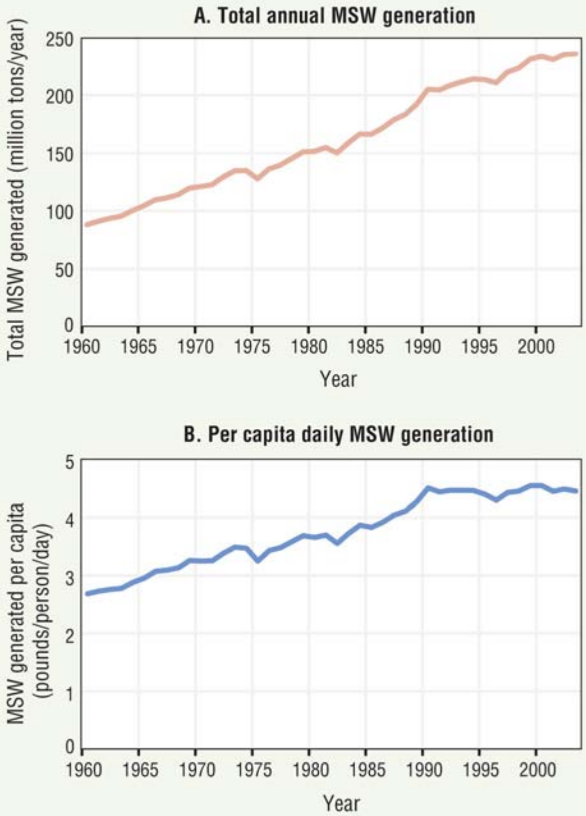
Prior to the 1970s, municipal solid waste disposal generally consisted of depositing wastes in open or excavated landfills, accompanied by open burning to reduce waste volumes. Often industrial wastes were co-disposed with municipal garbage and refuse in urban and rural landfills. Historically, environmental problems associated with landfills have included groundwater contamination, emissions of air pollutants such as toxic fumes and greenhouse gases, land contamination, and increases in vector populations (e.g., rodents, flies, mosquitoes). Wastes have the potential to cause various types of environmental concerns depending on the way in which they are disposed. Hazardous substances can migrate into the environment causing harm to people and biota; stockpiled scrap tires may ignite, often burning for months and causing air pollution; waste piles can create habitats for pests, e.g., rodents, insects (includes mosquitoes, and other biting-insect pests), or disease vectors; and the physical presence of a waste management area can disrupt an ecosystem. Most wastes generated in the United States are disposed of in landfills, which are subject to federal or state requirements to minimize environmental impacts. Municipal solid waste landfills are discrete areas of land or excavations that receive trash/garbage, as well as various other types of wastes that are not included in this indicator, such as non-hazardous sludges, hazardous wastes from small quantity generators, non-hazardous industrial wastes, municipal wastewater treatment sludges, and construction and demolition debris.

This indicator shows trends in the national generation and management of MSW on an annual basis from 1960 to 2003. The information presented on MSW consists of estimates generated annually using a materials flow methodology and mass balance approach that relies on production data (by weight) for materials and products that eventually enter the waste stream. These data are collected from industry associations, businesses, and government agencies.

What the Data Show

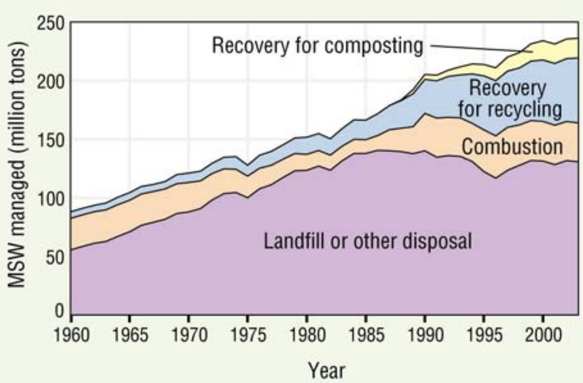
The quantity of MSW generated grew steadily from 88 million tons (MT) in 1960 to over 236 MT in 2003, an increase of 168 percent (Exhibit 4-12, panel A). During this time, the U.S. population increased by 62 percent (U.S. Census Bureau, 2004). On a per capita basis, MSW generation thus increased from 2.7 pounds per person per day in 1960 to 4.5 pounds per person per day in 1990 (panel B). Since 1990, MSW generation has remained around 4.5 pounds per person per day.

Exhibit 4-12. Municipal solid waste generation in the U.S., 1960-2003



Data source: *MSW data from U.S. EPA, 2005. Per capita rate based on population data from U.S. Census Bureau, 2005.*

Exhibit 4-13. Municipal solid waste management in the U.S., 1960-2003



Data source: *U.S. EPA, 2005*

Of the 88 MT of MSW generated in 1960, 6 percent was recovered through recycling and composting, 31 percent was combusted, and 63 percent was landfilled (Exhibit 4-13). MSW quantities sent to landfills or other disposal peaked in the mid-1980s at 140 MT and then began to decline as recycling and combustion increased. The quantity of MSW disposed of in landfills has remained fairly constant since 1999 with an average of 131 MT per year, a 6.6 percent decrease from the peak years. In 2003, of the 236 MT generated, 31 percent was recycled, 14 percent was combusted, and 55 percent was landfilled. Since 1990, the quantity sent to combustion has held steady at roughly 14 to 17 percent of generation.

Indicator Limitations

- The data in this indicator are derived from economic statistics on materials generation and estimates of the lifecycle of goods, rather than on direct measurements of wastes disposed. As a result of this methodology and especially of differences in definitions, the figures reported in this indicator do not match estimates of MSW reported elsewhere (e.g. BioCycle – which includes construction and demolition debris, industrial wastes, agricultural wastes, etc. in its estimates). However the waste categories in this indicator are rigorously defined and consistent from year-to-year, therefore allowing for reliable long-term trend analyses.
- Landfill data represent the amount of waste disposed in landfills, but do not indicate the capacity or volume of landfills, nor do they indicate the amount of land used for managing MSW. Land used for recycling facilities and waste transfer stations also is not included in this indicator.
- The data also do not indicate the status or effectiveness of landfill management or the extent to which contamination of nearby lands does or does not occur.

Data Sources

Exhibits 4-12 and 4-13 were previously published in U.S. EPA (2005). That report also provides tables with numerical values for certain key years during the period of record (1960, 1970, 1980, 1990, 1995, and 2000-2003). However, the full 44-year dataset is not publicly available.

Per capita MSW recovery was calculated using published annual estimates of the U.S. resident population (U.S. Census Bureau, 2004 [Table 2]).

References

U.S. Census Bureau. 2004. Statistical abstract of the United States 2004-2005: the national data book. Washington, DC. <http://www.census.gov/prod/2004pubs/04statab/pop.pdf>

U.S. EPA. 2005. Municipal solid waste generation, recycling, and disposal in the United States: facts and figures for 2003. EPA/530/F-05/003. <http://www.epa.gov/epaoswer/non-hw/muncpl/msw99.htm>

INDICATOR: Quantity of RCRA Hazardous Waste Generated and Managed

Hazardous waste is waste with a chemical composition or other property that makes it capable of causing illness, death, or some other harm to humans and other life forms when mismanaged or released into the environment. Historically, uncontrolled dumping of wastes, including hazardous industrial wastes, was commonplace, with numerous entities handling and disposing of these materials. Landfills and surface impoundments containing these materials were unlined and uncovered, resulting in contaminated groundwater, surface water, air, and soil. Even with tight control of hazardous wastes from generation to disposal, the potential exists for accidents that could result in the release of hazardous wastes and their hazardous constituents into the environment. Through the Resource Conservation and Recovery Act (RCRA) and the subsequent 1984 Hazardous and Solid Waste Amendments (HSWA), Congress sought to better control waste management and disposal and to conserve valuable materials and energy resources.

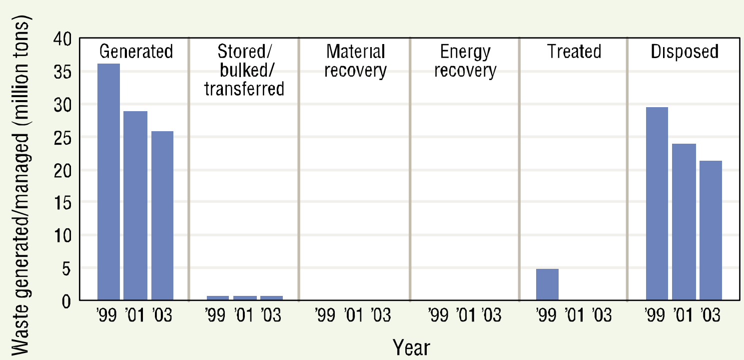
Facilities that treat, store, or dispose of hazardous wastes are termed RCRA treatment, storage and disposal facilities (TSDFs). Some hazardous waste generators treat, store, and dispose of their hazardous waste on-site, while others ship their waste to TSDFs. Most hazardous wastes are eventually disposed in landfills, surface impoundments (which eventually become landfills), land application units, or by deep well injection. All hazardous wastes disposed of must meet certain treatment standards required by the Land Disposal Restrictions (LDR) prior to disposal.

EPA, in partnership with the states, collects extensive data on the RCRA hazardous waste generation and management practices of TSDFs and large quantity generators (businesses that generate more than 2,200 pounds of RCRA hazardous waste, 2.2 pounds of RCRA acute hazardous waste, or 220 pounds of spill cleanup material contaminated with RCRA acute hazardous waste in one month). These data are collected every two years, and this indicator tracks changes in RCRA hazardous wastes generated and managed for the years 1999, 2001, and 2003.

What the Data Show

Between 1999 and 2003, the quantity of RCRA hazardous wastes generated decreased by 29 percent from 36.1 million tons (MT) to 25.8 MT (Exhibit 4-14). Due to RCRA hazardous waste regulations and data collection procedures all of the individual management categories discussed below cannot be added together to obtain the total quantity generated. For example, under RCRA, all hazardous waste must be treated to meet technology-based land disposal treatment standards before it is placed in or on the ground, unless the waste, as generated, meets those standards. To minimize the potential to count portions of hazardous waste generated twice, the quantities recovered and quantities disposed of by deep well

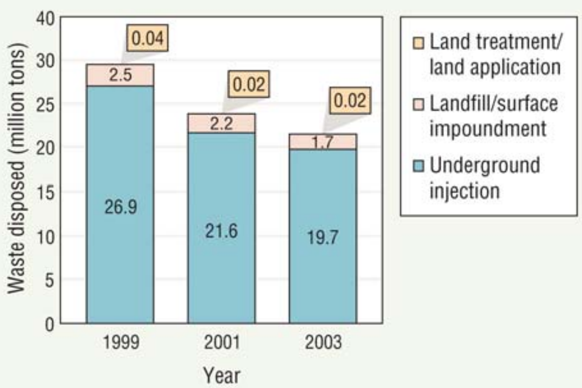
Exhibit 4-14. RCRA hazardous waste generation and management in the U.S., 1999-2003[a]



[a]Individual management practice quantities do not add up to the total quantity generated. See text for details.

Data source: *U.S. EPA, RCRAInfo national database*

Exhibit 4-15. RCRA hazardous waste disposal in the U.S. by practice, 1999-2003



Data source: *U.S. EPA, RCRAInfo national database*

injection were included, while quantities stored, transferred, or disposed by landfill, surface impoundment, land application, or treatment were not included in the total quantity generated.

In addition to the 36.1 MT of RCRA waste generated in 1999, another 0.7 MT were stored/bulked/transferred for some time prior to final disposition (at which time they would be included in wastes recovered, treated, or disposed) (Exhibit 4-14). In 2003, that number rose to 0.8 MT.

Looking at management prior to disposal, in 1999, 7 percent of RCRA hazardous waste was sent to material recovery activities such as metal or solvent recovery, while 9 percent fell into this category in 2003 (Exhibit 4-14). The proportion of RCRA hazardous waste sent for energy recovery increased from 4 percent of RCRA wastes generated in 1999 to 7 percent in 2003. The proportion sent to treatment declined from 14 percent in 1999 to 8 percent in 2003.

The quantity of RCRA hazardous wastes ultimately disposed dropped between 1999 and 2003, from 29.4 MT to 21.4 MT; however the relative proportions of waste in the three disposal categories remained fairly stable (Exhibit 4-15). In both years, 91 to 92 percent of the disposed RCRA hazardous wastes were deep-well injected. The proportion disposed in landfills or surface impoundments that became landfills also remained stable at 8 to 9 percent between 1999 and 2003. The land application and land treatment categories saw a slight decline, but in both years accounted for less than 1 percent of the RCRA hazardous waste disposed.

Indicator Limitations

- Data are not collected from small quantity generators (see Introduction), but some wastes coming from these sources *are* included in the RCRA hazardous waste management data from treatment, storage, and disposal facilities that receive the wastes.
- Data are limited to wastes referred to as “RCRA hazardous waste” which are either specifically listed as hazardous or meet specific ignitability, corrosivity, reactivity, or toxicity criteria found in the U.S. Code of Federal Regulations Title 40, Part 261. Materials that are not wastes, whether hazardous or not, are not regulated by RCRA nor included in the data summarized here.
- States have the authority to designate additional wastes as hazardous under RCRA, beyond those designated in the national program. State-designated hazardous wastes are not tracked by EPA or reflected in the aggregated information presented.
- The comparability of year-to-year amounts of RCRA hazardous waste generated and managed can be influenced by factors such as delisting waste streams (i.e., determining that a particular listed waste stream coming from a particular facility is not hazardous) or removing the hazardous characteristic of a waste stream.

- Most hazardous waste generated in the US is in the form of wastewater. The majority of these wastewaters are: 1) sent untreated to publicly-owned treatment works (POTW); 2) treated and sent to a POTW; or 3) discharged directly to surface waters through a National Pollutant Discharge Elimination System (NPDES) permit. Hazardous wastewaters generated and subsequently sent to POTWs or discharged through a NPDES permit are not included in this indicator. Any materials generated from these processes, such as sludge, that are considered hazardous waste are managed under hazardous waste regulations.

Data Sources

This indicator is based on data reported by individual facilities, which can be found in EPA's RCRAInfo database (U.S. EPA, 2005) (http://www.epa.gov/epaoswer/hazwaste/data/index.htm#rcra-info).

References

U.S. EPA. 2005. RCRAInfo national database. Data as of August 31, 2005. <http://www.epa.gov/epaoswer/hazwaste/data/index.htm#rcra-info>

4.4.3 Discussion

What These Indicators Say About Trends in Wastes and Their Effects on Human Health and the Environment

The indicators show that municipal solid waste generation in the United States continued to rise between 1960 and 2003, both in absolute terms and on a per capita basis. However, since 1990, the daily per capita generation of municipal solid waste has been relatively constant showing that the total increase in waste is a function of population growth. On the other hand, hazardous waste, which is primarily generated through industrial processes, decreased to some extent in the time period shown from 1999-2003

Materials recovery, or recycling, is an important component of waste management, as it takes materials that might be considered waste and removes them from the cycle to generate re-usable marketable materials for manufacturing. Recycling efforts related to municipal solid waste have increased over the four decades showing the steepest increases between 1980 and 2000, most likely due to the increased awareness about the benefits of recycling and the implementation of policies by state and local governments tying waste generation directly to the cost of waste services. Municipal solid waste recycling efforts have been steady since 2000, with nearly a third of all municipal solid waste being recycled or composted.

Recycling of hazardous wastes has remained relatively constant over the time span represented by the indicators, although there has been a decrease in the amount of waste sent for materials recovery and an increase in the amount of waste sent for energy recovery.

Although recycling is on the rise, most wastes are disposed. Disposal of municipal solid wastes in landfills saw a rise from 1960 to the early 1980s, with dips in 1975 and 1982. During the early 1990s disposal declined, but then began to rise again in the late 1990s and has fluctuated since. Similarly, most hazardous wastes are also land disposed, although they are required to meet strict standards for protecting human health and the environment prior to disposal.

Limitations, Gaps, and Challenges

While numerous waste-related data collection efforts exist at the local, state and national levels, none result in nationally consistent or comprehensive data to provide a full understanding of the amount and locations of waste generation and management.

The two types of waste addressed in the indicators represent only a small percentage of the total amount of waste generated in the United States. Other types of waste comprise the majority of total waste generated, although exact amounts and percentage of total waste are unknown. Quantities of “end-of-stream” wastes, such as municipal solid waste, provide an indication of changing trends in consumption and economic growth, but do not provide information on the other amounts of waste generated by up-stream activities, including resource extraction and manufacturing. EPA is interested in better understanding the comparative amounts of the various types of waste generated, but national data are dated, inconsistent, or generally not available in common units to develop a comprehensive picture of the waste generated in the United States.

The amount of waste generated and managed may describe ambient conditions in terms of wastes in the environment, but does not provide any indication of the effects on human health or environmental condition. There have been changes in the management of wastes over the past few decades, designed to reduce hazardous and potential exposures, but data that more concretely measure the overall exposure and therefore effects on human health and the environment caused by wastes and waste management practices are still lacking.

4.5 WHAT ARE THE TRENDS IN CHEMICALS USED ON THE LAND AND THEIR EFFECTS ON HUMAN HEALTH AND THE ENVIRONMENT?

4.5.1 Introduction

Many chemicals and chemical products are considered essential to modern life because of the benefits they provide. Some break down quickly, while others persist for long periods of time in the environment and may bioaccumulate in the food chain (e.g., persistent, bioaccumulative toxics [PBTs]).

Introduction of chemicals into the environment occurs through acts of nature (e.g., volcanoes, hurricanes), spills on land, emissions to air, and discharges to water. Chemicals can be released through large- and small-scale industrial and manufacturing activity, in the production and storage of food and consumer products, and in efforts to manage or eradicate insect-borne diseases (e.g., West Nile virus, Lyme disease), or through personal actions such as use of and improper disposal of household products (e.g., lawn care materials, pharmaceuticals, cleaning products, batteries, paint, automotive products) or wastes. Deliberate application of chemicals to the land is widespread in agricultural production to increase crop yields and control fungi, weeds, insects, and other pests.

Tracking trends in the use and disposition of chemicals in the United States is important to better understand the potential for those chemicals to affect human health and the environment. Many chemicals pose little known hazard to human health or environmental condition, while others pose risk. Many chemicals are recognized as carcinogens.[23] The effects of chemicals on human health and other ecological receptors through environmental exposure can be acute and very toxic, subtle and cumulative over time, or nonexistent. Chemicals can be of concern because of their pervasiveness, potential to accumulate, possibilities of interaction, and often long-term unknown effects on people and the environment (e.g., cancer, mercury in fish). Humans and wildlife may be affected by certain chemicals through direct exposure, including accidental ingestion or inhalation, accumulation and uptake through the food chain, or dermal contact.

Similarly, ecosystems and environmental processes may be compromised or contaminated through the migration and accumulation of chemicals (e.g., via uptake by plants, fugitive dust and volatilization, and migration to water supplies). For example, excessive nutrient loading from over-fertilization can result in runoff that causes adverse effects in aquatic ecosystems.[24] Widespread exposures to, or misuse of pesticides can harm non-targeted plants and animals (including humans), as well as lead to development of pesticide-resistant pest species.

It is difficult to make generalizations about the effects of chemicals and chemical usage, not only because there are thousands of chemicals, but also because individual chemicals have unique ways of being

[23] U.S. Department of Health and Human Services. 2005. Report on carcinogens. Eleventh edition. Washington, DC: Public Health Service, National Toxicology Program.

[24] Boesch, D.F., D.M. Anderson, R.A. Horner, S.E. Shumway, P.A. Tester, and T.E. Whitledge. 1997. Harmful algal blooms in coastal waters: options for prevention, control, and mitigation. NOAA coastal ocean program decision analysis series no. 10.

absorbed and handled by living organisms. The risks associated with chemicals are dependent on many factors, including exposure and toxicity–which can be acute or chronic–and can occur at multiple stages of the chemical life cycle. Different stages in the life cycle of chemicals, such as manufacturing, transport, application or use, runoff, or accumulation pose different hazards to humans and the environment.

4.5.2 ROE Indicators

The amounts and types of chemicals applied or released to land through agricultural fertilizers are examined as a National Indicator displayed at EPA Regional scale. Three other National Indicators are examined, including toxic chemicals in production related wastes, pesticide residues in food, and occurrences of pesticide-related injury and illness (Table 4.5.1).

Trends in the amount of fertilizer used are based on sales data provided by major crop-producing states through an annual survey conducted since 1960. Acreage estimates are from an agricultural census of the 48 contiguous states which has been conducted every five years since 1954. Trends in the quantities of Toxics Release Inventory (TRI)-reported chemical releases are based on annual reports required since 1998 from facilities that meet certain size and usage criteria. Trends in the detection of pesticide residues in food are derived from randomly sampled data collected daily since 1993 from participating states for over 50 different commodities. Trends in reported pesticide incidents are from a pesticide surveillance system that collects data annually from Poison Control Centers around the nation.

Table 4.5.1. ROE Indicators of the Trends in Chemicals Used on the Land and Their Effects on Human Health and the Environment

INDICATORS	LOCATION
Fertilizer Applied for Agricultural Purposes (N/R)	4.5.2 – p. 4-50
Toxic Chemicals in Production-Related Wastes Released, Treated, Recycled, or Recovered for Energy Use	4.5.2 – p. 4-54
Pesticide Residues in Food	4.5.2 – p. 4-58
Reported Pesticide Incidents	4.5.2 – p. 4-61

N/R = National Indicator displayed at EPA Regional scale

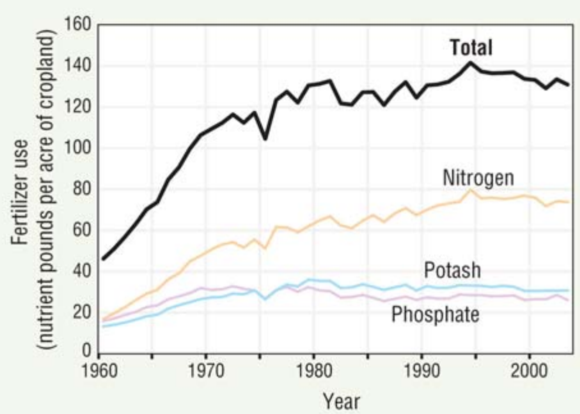
INDICATOR: Fertilizer Applied for Agricultural Purposes

Commercial fertilizers are applied to agricultural crops to increase crop yields. Prior to the 1950s, most farming occurred on small family farms with limited use of chemicals. The shift since then to larger corporate farms has coincided with the use of chemical fertilizers in modern agricultural practices. The three major types of commercial fertilizer used in the United States include nitrogen, phosphate, and potash.

Nitrogen (N) is found primarily in the organic fraction of soils, but can also occur as nitrate. Nitrate is both extremely soluble and mobile and can lead to nuisance algal growth, mostly in downstream estuaries, and cause contamination of drinking water. Phosphorus (P) occurs in soil in several forms, both organic and inorganic. Phosphorus loss in sediment due to erosion is common and phosphate, while less soluble than nitrate, can easily be transported with soil in runoff. Phosphorus/phosphate runoff can lead to nuisance algae and plant growth, often in freshwater streams, lakes, and estuaries. Potash is the oxide form of potassium (K) and its principal forms as fertilizer are potassium chloride, potassium sulfate, and potassium nitrate. When used at recommended application rates, there are few to no adverse effects from potassium, but it is a common component of mixed fertilizers used for high crop yields and is tracked in the fertilizer use surveys conducted.

This indicator shows use of the three major fertilizers (expressed as N, P, or K) in pounds per acre of land used for crop production per year from 1960 to 2003. Data are from an annual survey for agricultural crops conducted by the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) and from the Economic Research Service's Major Land Use series. Acreage used for crop production includes cropland harvested and crop failure as estimated by the NASS series. Cropland estimates as used in this indicator are a subset of agricultural land estimates discussed in the Land Cover and Land Use indicators. NASS also produces an annual *Agricultural Chemical Usage* report of 4-5 targeted field crops that is based on data compiled from the Agricultural Resources Management Survey (ARMS). The ARMS surveys farmers in major agriculture producing states that together account for a large percentage of crop acreage for corn, soybeans, and cotton. Results are presented for year 2000 by EPA Region.

Exhibit 4-16. Commercial fertilizer use in the U.S., 1960-2003[a]



[a]Based on sales data. Per-acre use based on the acreage of harvested or failed cropland, as determined by USDA's National Agricultural Statistics Service.

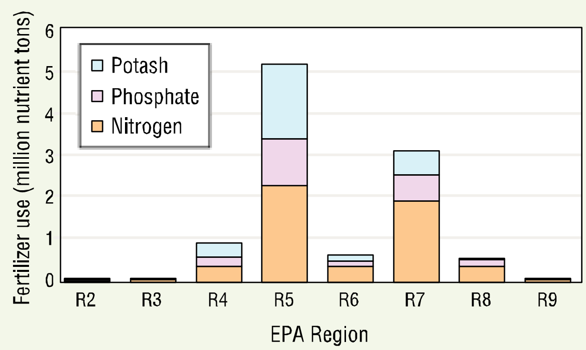
Data source: *USDA Economic Research Service and USDA National Agricultural Statistics Service. See specific citations in text.*

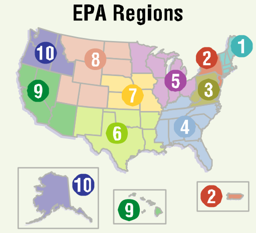
What the Data Show

Based on fertilizer sales data, NASS estimates show that total use of the three major commercial fertilizers has steadily increased, from 46.2 nutrient pounds per acre per year (lbs/acre/yr) in 1960 to 130.9 lbs/acre/yr in 2003, an increase of 183 percent (Exhibit 4-16). During this period, cropland used for crop production generally has fluctuated between 300 and 350 million acres with the largest increases occurring between 1972 (296 million acres) and 1981 (357 million acres) (Vesterby and Krupa, 2001). Following this increase, federal land conservation programs were instituted that removed cropland from production and decreased acreage harvested by 16 percent. Since 1996, cropland used for crop production has remained between 321 and 328 million acres (Vesterby and Krupa, 2001). Aggregate commercial fertilizer use has fluctuated between 121 and 142 lbs/acre/yr over the last twenty years, with peak usage in 1994. Since 1960, nitrogen accounted for the steepest increase in use, from 17.0 lbs/acre/yr to 73.8 lbs/acre/yr in 2003, and now accounts for over 56 percent of total fertilizer use, up from nearly 37 percent in 1960. During the same period, phosphate and potash use grew more slowly and remained steady between 25 and 36 lbs/acre/yr each since the late 1960s. Both phosphate (down 20 percent) and potash (down 15 percent) usage declined on a per acre basis since reaching their peak usages in the 1970s, and now account for approximately 20 percent and 24 percent of total fertilizer usage, respectively.

Estimates from annual NASS *Acreage* reports show that similar amounts of land have been planted with corn each year since 1995. Since 1995, the acreage planted in corn has totaled between 77 and 80 million acres, an increase from 66 million acres planted in 1970 (USDA, 2004). While grown in most states, corn production is concentrated in the middle of the country (EPA Regions 5 and 7). The acreage of land planted in cotton was 15.5 million acres in 2000 and has averaged between 12-14 million acres since 1990. Major cotton-producing states include 17 southern states located in EPA Regions 4, 6, and 9. Soybeans represent the fastest growing crop in total acreage, increasing from 57.8 million acres in 1990 to 74.3 million acres in 2000 (USDA National Agricultural Statistics Service, 2004). The majority of soybean acreage (80 percent) is concentrated in the upper Midwest in EPA Regions 5 and 7.

Exhibit 4-17. Fertilizer use for three common crops (corn, cotton, and soybeans) in major agriculture-producing states, by EPA Region, 2000[a]





[a]**Coverage:** States surveyed by USDA's Agricultural Resource Management Survey (ARMS) Program in 2000 for corn, cotton, and soybeans. Each commodity was surveyed in a different subset of states, which together account for a substantial portion of the nation's production of that particular commodity. No states in Regions 1 or 10 were surveyed by the ARMS Program for corn, cotton, or soybeans.

***Data source:** USDA National Agricultural Statistics Service, 2001*

Overall, production of these three crops in the ARMS states used slightly more than 10.8 MT/yr of fertilizer in 2000 (Exhibit 4-17), or about one half of the 21.6 MT/yr estimated by USDA's Economic Research Service for all crops produced in the entire United States. Of this amount, slightly less than half (5.25 MT/yr) was applied in EPA Region 5 (Exhibit 4-17), most of which was used for corn. An additional 3.2 MT/yr was applied in EPA Region 7, primarily on corn or soybeans. Most of the remaining fertilizer was used in EPA Regions 4 and 6, primarily on cotton.

Indicator Limitations

- USDA national estimates of fertilizer use are based on sales data provided by states, and not on actual fertilizer usage, and are susceptible to differing reporting procedures or accuracy from state to state.

- Data to identify cropland used for crop production are from the major land use series which is based on the 48 contiguous states and include unpublished NASS data.

- Within the ARMS, not all states report fertilizer data every year for each crop type, making it difficult to establish year-to-year trends (a decrease in fertilizer use for a specific crop might be attributed to failure of a state to report, rather than an actual decrease of use).
- ARMS sampling is limited to program states, which represent 83 to 98 percent of crop acreage (across all surveyed crops) for the year 2000, depending on crop type.
- The NASS Acreage report has estimates of acreage in production for the entire nation by crop, while fertilizer sales data are based only on USDA program states. Even though USDA program states represent the majority of U.S. planted acreage (often over 90 percent), the ability to generalize the data to the country as a whole is unknown, as non-program states, while representing a small percentage of a crop, might have much different application rates due to climate, weather, etc.
- Fertilizer applied to trees that are considered agricultural-type crops (e.g., nut producing trees) are included in field crop summaries; but fertilizer applied in silviculture (e.g., southern pine plantations) are not covered by the NASS data collection system.
- Loading of nutrients in aquatic systems is not necessarily correlated directly with fertilizer use, but rather to the levels of fertilizer applied in excess of amounts used by crops, natural vegetation, and soil biota.

Data Sources

Exhibit 4-16 is based on two sets of summary data from the USDA's Economic Research Service. Annual estimates of fertilizer use from 1960 through 1998, by nutrient, were obtained from USDA Economic Research Service (2003); unpublished post-1998 data were obtained via e-mail correspondence (Wen Huang, WHUANG@ers.usda.gov). Fertilizer use per acre was calculated based on annual estimates of the amount of cultivated (harvested or failed) cropland from 1960 to 2003 published in Lubowski et al. (2006) [see summary tables, http://www.ers.usda.gov/Data/MajorLandUses/MLUsummarytables.pdf].

Exhibit 4-17 is based on fertilizer use data from USDA's 2000 ARMS survey, which were obtained from USDA National Agricultural Statistics Service (2001). The published data are by state, so additional aggregation was required to report by EPA Region.

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Vesterby, M., and K.S. Krupa. 2001. Major Uses of Land in the United States, 1997. Statistical bulletin no. 973. U.S. Department of Agriculture, Economic Research Service. <http://www.ers.usda.gov/publications/sb973/sb973.pdf>

INDICATOR: Toxic Chemicals in Production-Related Wastes Released, Treated, Recycled, or Recovered for Energy Use

Toxic chemicals are contained in waste materials produced by a wide variety of industrial activities, in both public (e.g., sewage treatment plants) and private facilities. These chemical wastes are really a composite matrix of various chemicals, some of which may be hazardous or toxic, and therefore are subject to reporting under the Toxics Release Inventory (TRI) program. Some of these chemicals are released onsite or offsite to air, water, or land (including surface impoundments and underground injection wells). The rest are treated, recycled, or combusted for energy recovery. Reductions in the quantities of TRI chemicals are desirable from both environmental and economic perspectives. TRI chemicals have known toxic properties rendering them potentially hazardous to workers in both production and waste management facilities, and more generally to ecosystems and human health. As elements of overall business strategies, companies target waste reduction in ways that reduce costs and increase profits.

This indicator tracks trends in the amounts of toxic chemicals in production-related wastes that contain reported TRI chemicals which are either released to the environment, or are treated, recycled, or combusted for energy recovery. Toxic chemicals in non-production related waste, such as might be associated with catastrophic events and remedial actions (cleanup), are not included in this indicator because they are not directly related to routine production practices.

TRI contains information on more than 650 chemicals and chemical categories from nine industry sectors, including manufacturing operations, certain service businesses, and federal facilities. Facilities are required to report to TRI if they employ 10 or more employees, have a TRI-covered Standard Industrial Classification code, and manufacture or process more than 25,000 pounds or otherwise use more than 10,000 pounds of the 650 listed chemicals during a calendar year (U.S. EPA, 2002b). In 2003, almost 24,000 facilities reported to TRI (U.S. EPA, 2005a).

TRI is national in coverage and includes all U.S. territories. Because the reporting requirements for TRI have varied somewhat between 1998 and 2003 (the most recent year for which annual data reports are available in TRI), only chemicals that were reported consistently from year to year over this period are included in this indicator. A key category of chemicals in wastes omitted in this analysis is Persistent, Bioaccumulative and Toxic (PBT) chemicals. Facilities that manufacture, process, or otherwise use PBT chemicals have lower reporting thresholds, which were established in 2000 and 2001, making the comparison with earlier datasets difficult. Metal mining sector land releases are analyzed separately because a 2003 court decision altered the scope of TRI reporting of these quantities (U.S. EPA, 2004).[25]

What the Data Show

In 2003 the quantities of TRI chemicals associated with production-related wastes tracked in this indicator totaled 23.9 billion pounds (Exhibit 4-18). These quantities have decreased by more than 4 billion pounds (14.3 percent) since 1998. The decrease was gradual over time with the exception of the year 2000, which saw an increase of 4.3 billion pounds from the previous year, followed by a return to prior levels and

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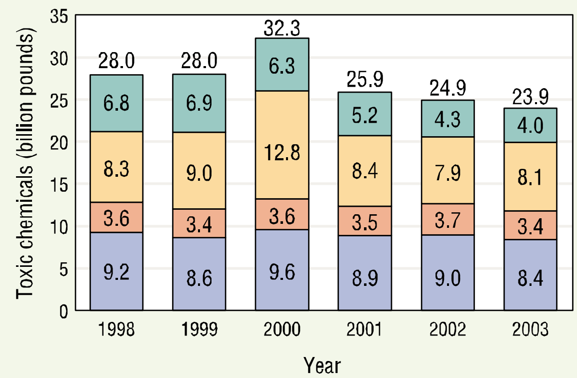
[25] The metal mining sector consists of facilities that fall within Standard Industrial Classification Code 10 and must report to the Toxics Release Inventory in accordance with Section 313 of the Emergency Planning and Community Right to Know Act.

reduction trends in 2001. The 2000 increase is attributed to a few facilities that reported large amounts of onsite treatment and onsite recycling (U.S. EPA, 2002a).

Excluding metal mining releases to land, approximately 3.1 billion pounds (13.4 percent) were released offsite or onsite to air, land, or water in 2003 (Exhibit 4-19). The remaining 20 billion pounds (86.6 percent) were managed (onsite or offsite) through treatment, recycling, and energy recovery processes (Exhibit 4-18). The 3.1 billion pounds of environmental releases and offsite releases in 2003 were 18.6 percent less than the amount reported in 1998 (Exhibit 4-19). The 20 billion pounds otherwise managed in 2003 represent a 5.7 percent decline from 1998 (Exhibit 4-18).

Between 1998 and 2003 there were also distinct trends in media-specific and offsite releases (Exhibit 4-19). Air releases declined steadily between 1998 and 2003 by 24.2 percent (504 million pounds). Releases to surface waters increased by 14.7 million pounds between 1998 and 1999, but between 1998 and 2003 dropped by a net total of 12.8 percent (32.6 million pounds). Excluding metal mining, land releases declined by 260 million pounds (24.5 percent) since 1998. Offsite releases, which cannot be apportioned by media in TRI, rose steadily by 22.5 percent (90.3 million pounds) over the 1998 to 2003 period.

Exhibit 4-18. Quantities of toxic chemicals released, recycled, recovered for energy, and treated in the U.S., as reported to EPA's Toxics Release Inventory, 1998-2003[a,b]

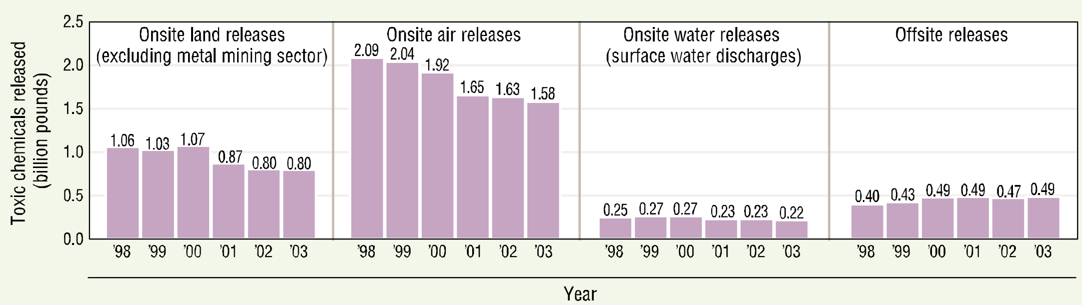


[a]**Coverage:** Production-related waste from facilities required to report to EPA's Toxics Release Inventory (TRI). More than 650 chemicals and chemical categories are reportable to TRI. This indicator does not cover TRI chemicals designated as PBTs (persistent, bioaccumulative, and toxic), as PBT reporting thresholds were changed midway through the period of record.

[b]Some waste quantities may be double-counted when waste has been transferred from one TRI facility (which has counted waste as offsite disposal or as other releases) to another TRI facility (which has counted transferred waste as onsite disposal or as releases to air, land, or water).

Data source: *U.S. EPA, 2005*

Exhibit 4-19. Quantities of toxic chemicals released in the U.S., by type of release, as reported to EPA's Toxics Release Inventory, 1998-2003[a,b]

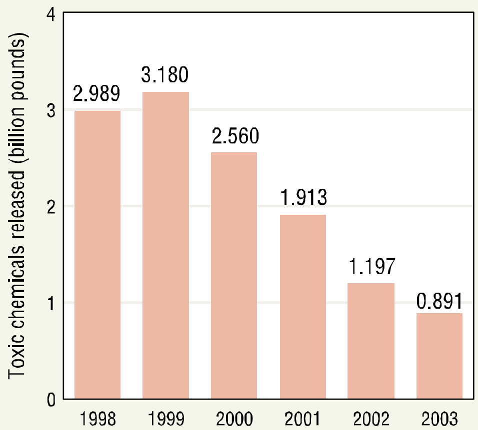


[a]**Coverage:** Production-related waste from facilities required to report to EPA's Toxics Release Inventory (TRI). More than 650 chemicals and chemical categories are reportable to TRI. This indicator does not cover TRI chemicals designated as PBTs (persistent, bioaccumulative, and toxic), as PBT reporting thresholds were changed midway through the period of record.

[b]Some waste quantities may be double-counted when waste has been transferred from one TRI facility (which has counted waste as offsite disposal or as other releases) to another TRI facility (which has counted transferred waste as onsite disposal or as releases to air, land, or water).

Data source: *U.S. EPA, 2005*

Exhibit 4-20. Quantities of toxic chemicals released by the metal mining sector, as reported to EPA's Toxics Release Inventory, 1998-2003[a,b]



	1998	1999	2000	2001	2002	2003
Offsite releases	0.001	0.002	0.001	0.001	0.001	0.001
Onsite air releases	0.004	0.005	0.003	0.003	0.003	0.003
Onsite land releases	2.983	3.172	2.556	1.910	1.192	0.887
Onsite water releases (surface water discharge)	0.001	0.000	0.000	0.000	0.001	0.001
Total	**2.989**	**3.180**	**2.560**	**1.913**	**1.197**	**0.891**

[a]**Coverage:** Production-related waste from facilities in the metal mining sector that are required to report to EPA's Toxics Release Inventory (TRI). More than 650 chemicals and chemical categories are reportable to TRI. This indicator does not cover TRI chemicals designated as PBTs (persistent, bioaccumulative, and toxic), as PBT reporting thresholds were changed midway through the period of record.

[b]Some waste quantities may be double-counted when waste has been transferred from one TRI facility (which has counted waste as offsite disposal or as other releases) to another TRI facility (which has counted transferred waste as onsite disposal or as releases to air, land, or water).

Data source: *U.S. EPA, 2005*

The metal mining sector accounted for 38 percent of the total production-related wastes released to the environment over the six-year period 1998-2003, releasing approximately 12.7 billion pounds of total production-related wastes (Exhibit 4-20), compared to 20.8 billion pounds reported by all other industry sectors (Exhibit 4-19). Nearly all of the production-related wastes managed by metal mining facilities were releases to land. There is a substantial downward trend for the quantities of total releases reported by the metal mining sector from 2001 to 2003 (Exhibit 4-20). In 2001, the metal mining industry reported nearly 2 billion pounds in total releases, and in 2003, only 0.89 billion pounds were reported, but part of this trend can be attributed to the court decision (*Barrick Goldstrike Mines, Inc. v. EPA)* in 2003 that excluded mine overburden as a reportable waste (U.S. EPA, 2004).

There are less dramatic trends among treatment, energy recovery, and recycling over the six-year period (Exhibit 4-18). The amount of TRI chemicals reported as treated declined by 185 million pounds (2.2 percent) from 1998 to 2003 (from 8.3 to 8.1 billion pounds). There were large variations in the amount treated during this period, from a high of 12.8 billion pounds in 2000 to a low of 7.9 billion pounds in 2002. The amount of TRI chemicals recycled declined by 844 million pounds (9.2 percent) from 1998 to 2003, varying from a high of 9.6 billion pounds in 2000 to a low of 8.4 billion pounds in 2003. TRI chemicals managed through energy recovery processes showed a decline of 179 million pounds (4.9 percent) in the six-year period, with less fluctuation, from a high of 3.7 billion pounds in 2002 to a low of 3.4 billion in 2003. Some of the year-to-year fluctuations may reflect changes in aggregate production levels in the national economy.

Indicator Limitations

- TRI data reflect only "reported" chemicals, and not all chemicals with the potential to affect human health and the environment. TRI does not cover all toxic chemicals or all industry sectors. The following are not included in this indicator: (1) toxic chemicals that are not on the list of approximately 650 toxic chemicals and toxic chemical categories, (2) wastes from facilities within industrial categories that are not required to report to TRI, and (3) releases from small facilities with fewer than ten employees or that manufactured or processed less than the threshold amounts of chemicals.

- TRI chemicals vary widely in toxicity, meaning that some low-volume releases of highly-toxic chemicals might actually pose higher risks than high-volume releases of less toxic chemicals. The release or disposal of chemicals also does not necessarily result in the exposure of people or ecosystems.
- Lead compounds are not included in the indicator because of a change in the reporting threshold in 2001. Vanadium releases were measured beginning in 2001; because the overall amounts were small relative to the other wastes, they are included in the 2001 to 2003 data.
- PBT chemicals are not included in this indicator because of a change in reporting thresholds during the period. They are of particular concern because they are toxic, they remain in the environment for long periods of time because they are not readily destroyed, and they build up or accumulate in body tissue.
- National trends in wastes released to the environment are frequently influenced by a dozen or so large facilities in any particular reporting category. These trends may not reflect the broader trends in the 2,500 smaller facilities that report to TRI each year.

Data Sources

This indicator is based on data from EPA's TRI Explorer database (U.S. EPA, 2005b), an online tool that allows users to generate customized reports on toxic releases reported to TRI.

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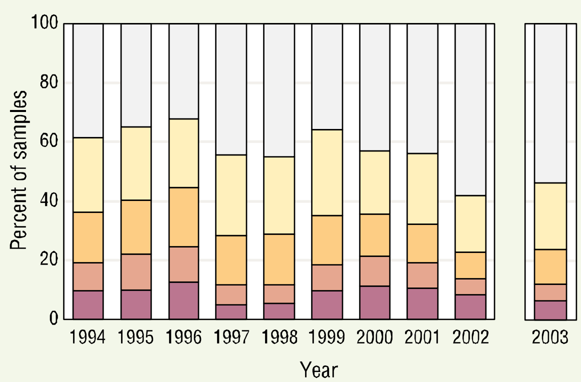
INDICATOR: Pesticide Residues in Food

Pesticides are substances or mixtures of substances intended for preventing, destroying, repelling, or mitigating plant or animal pests and may include herbicides, insecticides, fungicides, and rodenticides. More than one billion pounds of pesticides are used in the United States each year to control weeds, insects, and other organisms that threaten or undermine human activities (Aspelin, 2003). Some of these compounds can be harmful to humans if sufficient quantities are ingested, inhaled, or otherwise contacted (see the Urinary Pesticide indicator, p. 5-94). Potential health effects and primary exposure routes vary by chemical. The most common routes of exposure for the general population are ingestion of a treated food source and contact with applications in or near residential sites. Pesticides may also be harmful in the environment when non-target organisms are exposed (U.S. EPA, 2003).

This indicator represents data from the U.S. Department of Agriculture's Pesticide Data Program (PDP) which measures pesticide residue levels for more than 290 pesticides and their metabolites in fruits, vegetables, grains, meat, and dairy products from across the country, sampling different combinations of commodities each year. The analysis examines pesticides currently on the market and also includes continued testing for some persistent and bioaccumulative pesticides that have been banned since the 1970s, such as aldrin/dieldrin, heptachlors, and DDT and its metabolites. PDP data collection began in 1991 and includes both domestic and foreign-produced commodities. Results are published in annual reports, which include statistics on the number of pesticide residues detected, the number of residues exceeding the tolerance established by EPA for a given pesticide-commodity pair (Code of Federal Regulations, Title 40, Part 180), and the number of residues detected for which no tolerance has been established. This indicator depicts data from 1994 to 2003; data prior to 1994 are considered less reliable. Between 1994 and 2003, the number of food samples analyzed per year ranged from 5,771 (1996) to 12,899 (2002), with a general increase over time.

Exhibit 4-21. Pesticide detections in food in the U.S., 1994-2003[a,b]



Number of residues detected:[b]
- 0
- 1
- 2
- 3
- 4 or more

[a]**Coverage:** Based on a survey of fruits, vegetables, grains, meat, and dairy products across the U.S., with different combinations of commodities sampled in different years. Samples were analyzed for more than 290 pesticides and their metabolites.

[b]Data for 2003 are not comparable to prior years due to a difference in how detects were counted. Prior to 2003, each compound detected was counted as a separate "residue." Beginning in 2003, parent compounds and their metabolites were combined to report the number of "pesticides." For example, a sample with positive detections for endosulfan I, endosulfan II, and endosulfan sulfate would have been counted as three residues in 2002. In 2003, this sample would have been counted as one pesticide detection.

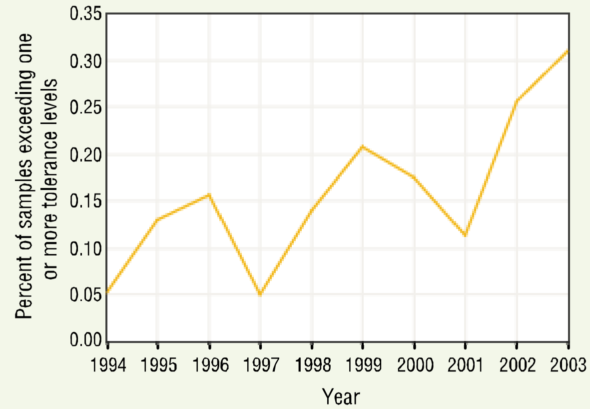
Data source: *USDA Pesticide Data Program*

What the Data Show

Overall, the percent of samples with no detectable pesticide residues increased during the period from 1994 to 2002 (Exhibit 4-21). Samples with no detects accounted for 38.5 percent of samples analyzed in 1994 and rose to 57.9 percent of samples in 2002. Data for 2003 cannot be compared directly to the previous years' data due to a change in the way that detects are counted. During the same period, each of the other categories (i.e., samples with one or more detected residues) remained steady or declined slightly. For example, in 1994, 9.8 percent of samples were found to contain four or more pesticide residues; this figure dropped to 8.2 percent in 2002. The stable or slightly declining trend in number of detections occurred at the same time that analytical limits of detection for these compounds have been decreasing, allowing the instruments to pick up ever smaller concentrations.

Exhibit 4-22 illustrates the percentage of samples in which at least one pesticide residue was detected at a concentration exceeding the tolerance established by EPA for a given pesticide-commodity pair. The percentage of samples exceeding EPA tolerance values increased from 0.05 percent in 1994 to 0.31 percent in 2003.

Exhibit 4-22. Pesticides exceeding EPA tolerance levels in food in the U.S., 1994-2003[a]



[a]**Coverage:** Based on a survey of fruits, vegetables, grains, meat, and dairy products across the U.S., with different combinations of commodities sampled in different years. Samples were analyzed for more than 290 pesticides and their metabolites.

Data source: *USDA Pesticide Data Program*

Indicator Limitations

- Among the data for number of residues detected (Exhibit 4-21), in 2003, measurement of a parent compound and/or any of its metabolites was counted as a single detect whereas in previous years, parent compounds and each of their metabolites were counted as separate detects. Therefore numbers from 2002 and earlier years cannot be compared directly with the data from 2003.
- The PDP does not sample all commodities over all years, so some gaps in coverage exist. Differences in the percent of detections for any given pesticide class might not be due to an increase (or decrease) in the predominance of detectable residues. Instead, these differences might simply reflect the changing nature and identity of the commodities selected for inclusion in any given time frame.
- The indicator measures pesticide residue related to dietary intake which does not directly correlate to toxicological effects in humans or effects on the environment.

Data Sources

Data for this indicator were obtained from a series of annual summary reports published by the U.S. Department of Agriculture's Pesticide Data Program (USDA, 1996 through 2005). These reports are all available from http://www.ams.usda.gov/science/pdp/. The Food and Drug Administration also collects data (not reported here) on pesticide residues in cooked food that may be a source of chemicals in human diets. These data are available at http://www.cfsan.fda.gov/~dms/pesrpts.html.

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INDICATOR: Reported Pesticide Incidents

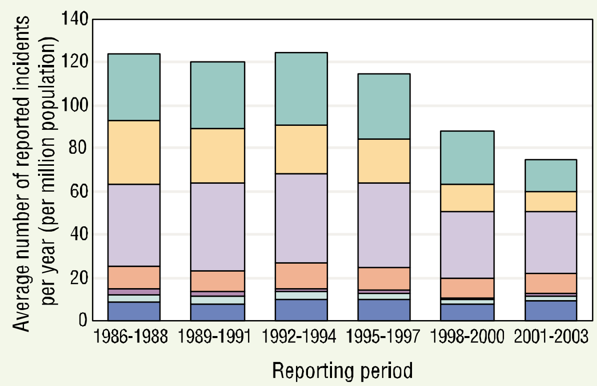
Even though pesticides play a role in protecting human health, food, and crops, they pose a risk of poisoning when not used and/or stored properly. The American Association of Poison Control Centers (AAPCC) collects statistics on poisonings and represents the single largest source of information on acute health effects of pesticides resulting in symptoms and requiring health care (Calvert et al., 2001). The data include incidents related to individual pesticides and to mixtures of products (about 8 percent of reports). The data also include intentional exposures (suicide attempts and malicious use) that account for less than 3 percent of reports. The AAPCC uses the Toxic Exposure Surveillance System (TESS) to collect information on all reported incidents.

This indicator is based on data from TESS published reports for the years 1986 through 2003. During this period, at least 50 percent of the U.S. population was covered by Poison Control Centers (PCCs) reporting to the national database. Annual reports of incidents were divided by the percent of U.S. population served to estimate the total incidents nationwide, and divided by the total U.S. population to develop the incidence rate. Only calls with known outcomes are reported here although this may introduce some bias because the percent of all reported pesticide incidents with a known outcome declined from 71 percent in 1986-1988 to just 42 percent in 2001-2003. Data are grouped into 3-year periods and presented as average annual rates to facilitate identification of trends.

What the Data Show

Between the periods 1986-1988 and 2001-2003, there was an overall 40 percent decline in reported pesticide incidents in the United States (Exhibit 4-23). The single largest decline occurred for the category of organophosphate (OP) insecticides, which saw a 71 percent drop in reported incidents. Part of the decline in reported OP-related incidents may be due to the substitution of other less toxic insecticides for some of the OPs over time. As reported OP-related incidents have dropped, there has not been a corresponding increase in incidents among the replacement products ("Other insecticides" category), which also declined 23 percent over the period. Only the "All other pesticides" category showed an overall increase in reports (8 percent increase).

Exhibit 4-23. Reported pesticide incidents per million U.S. population by type of pesticide, 1986-2003[a]



[a]This indicator tracks pesticide incidents reported to poison control centers (PCCs) that report to the AAPCC national database. The rate of reported incidents is calculated based on the population served by these PCCs—approximately 50% of the U.S. population.

Data source: *American Association of Poison Control Centers (AAPCC)*

Indicator Limitations

- Misclassification of incidents may occur when incidents reported over the phone are not verified by laboratory tests. For example, a child found holding a pesticide container may not have actually been exposed, but if a call was received by a PCC poison specialist who determined that the reported symptoms were consistent with the toxicology, dose, and timing of the incident, the call will be registered as an incident. About 13 percent of calls to PCCs arise from health care professionals, but the majority are calls made by victims or their relatives or caretakers. Although some misclassification can be expected to occur, it is assumed to be non-differential among the different types of pesticides.

- Only calls with known outcomes are reported in this indicator. This may introduce some bias because the percent of all reported pesticide incidents with a known outcome declined from 71 percent in 1986-1988 to just 42 percent in 2001-2003.
- The data collection process is standardized for PCCs, but is a passive system. Under-reporting of incidents is a serious shortcoming. Studies show that medical facilities generally report between 24 and 33 percent of incidents from all substances to Poison Control Centers (Chafee-Bahamon et al., 1983; Harchelroad et al., 1990; Veltri et al. 1987).
- Data are collected by multiple poison centers with follow-up likely performed in different ways.

Data Sources

This indicator is based on summary data from annual reports published by the American Association of Poison Control Centers, Toxic Exposure Surveillance System (Litovitz et al., 1987 through 2002; Watson et al., 2003 and 2004) (available from http://www.aapcc.org/poison1.htm). Annual data from these reports were grouped into three-year periods, and incidence rates were calculated from the population served by participating poison control centers; population figures can also be found in the annual reports. Only summary data are publicly available; raw data from individual cases are considered confidential.

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4.5.3 Discussion

What These Indicators Say about Trends in Chemicals Used on the Land and Their Effects on Human Health and the Environment

These indicators provide information on aspects of chemical use and effects. Data are presented on the amounts and types of chemical usage for two large sectors of the U.S. economy–agriculture and manufacturing. The disposition of pesticides in food and the number of reported pesticide incidents are examined. Two indicators describe stressors to the environment from chemical usage.

The amount of chemicals deliberately applied to agricultural land as commercial fertilizer has increased steadily over the last 40 years (Agricultural Fertilizer indicator, p. 4-50). Per acre total fertilizer use has nearly tripled since 1960 with peak usage occurring in 1994. Nitrogen use per acre has more than quadrupled over the same period. While fertilizers themselves are not inherently harmful, when applied improperly or in quantities above the level taken up by crops, streamside vegetation, or soil biota, they have the potential to contaminate groundwater and surface water in agricultural watersheds and estuaries. Fertilizer usage in 2000, for major crops, appears concentrated in the states surrounding the Mississippi River.

The Toxic Release Inventory (TRI) data (Toxic Chemicals in Wastes indicator, p. 4-54) show a small but steady decline in the quantities of TRI chemicals released to all media between 1998 and 2003, with the exception of offsite releases, which increased slightly. For purposes of this indicator, TRI chemicals represent the most toxic chemicals associated with production-related wastes.

Residues of potentially harmful substances used in food production, such as some pesticides, are assessed under food protection programs. While national-level indicators on the use and application of pesticides and pesticide loads in soil are lacking, the Pesticide Residues in Food indicator (p. 4-58) is an indirect measure of ambient conditions, providing insight into potential exposures from the most widely used pesticide products on the market. The indicator shows that in the time period where data are comparable, between 40 and 60 percent of the food commodities tested had one or more pesticide residues detected. It is important to note that current available technology used in the U.S. Department of Agriculture Pesticide Data Program (PDP) sampling provides the ability to detect pesticide residues at concentrations that are orders of magnitude lower that those determined to potentially have human health effects. Therefore, the number of pesticide detections that exceed federally established tolerance levels is perhaps more relevant. Results over the years suggest less than 1 percent of commodities tested were above tolerance levels.

Similarly, the Pesticide Incidents indicator (p. 4-61) provides information on the potential for human exposure to toxic substances through misuse. Reported incidents of pesticide exposure, which represent accidental exposure to a pesticide that is readily available to the public, declined between 1986 and 2003. The largest decline has occurred in organophosphate compounds, a group of insecticides that are acutely toxic to humans (and other vertebrates), but do not accumulate in the environment, unlike other toxic materials or compounds containing chromium, arsenic, heavy metals, etc.

Limitations, Gaps, and Challenges

While chemicals in soil or on plants may be an initial pathway into the environment, it is the movement and concentration of chemicals through the food chain that are often of greatest concern, as well as exposures from other media such as contaminated water or air. The indicators provide information on a relatively small universe of toxic chemicals and only limited information on the potential exposures humans may experience as a consequence of chemical use.

Fertilizer use in agriculture has been identified as one of the principal uses of chemicals responsible for nutrient loading into non-targeted water bodies and for nonpoint source loading of nutrients within agricultural watersheds.[26] Actual fertilizer use data are not available nationally. The Agricultural Fertilizer indicator (p. 4-50) is supported by sales data that do not consider mitigating factors (e.g., slow-release formulations) or agricultural practices that reduce runoff. The cost of fertilizer accounts for a relatively high percentage of agricultural costs, so it is generally assumed that purchased products eventually are applied in agricultural operations. Agricultural sources of fertilizer, however, are only estimated to be 85 percent of all sources, with the remaining being primarily professional lawn care, consumer retail, and golf courses. The usage patterns associated with these nonagricultural sources are unknown. Additionally, the urban and suburban watersheds, where these non-tracked uses occur are also locations where nutrient runoff may result from other sources such as turf runoff, septic systems, and sewage treatment plants.

The indicators do not provide information related to the land application of sludges[27] that may contain toxic metals and other persistent bioaccumulative substances. Sludges may be applied as fertilizer on agricultural or forest land in accordance with EPA requirements, but the implications for wildlife, aquatic organisms, and movement through the food chain are unknown. Additionally, the indicators reported provide only limited information on the potential exposures that target organisms other than humans may experience as a consequence of chemical use.

TRI data include information on a range of chemical categories such as arsenic, cyanide, dioxin, lead, mercury, and nitrate compounds, but do not reflect a comprehensive total of toxic releases nationwide. They do not include all toxic chemicals with the potential to affect human health and the environment, nor do they include all sources of potential releases. Facilities report release and other waste management data using various techniques which include estimations based on emission factors, mass balancing approaches, engineering calculations, and actual monitoring. Estimation techniques and factors considered may vary widely, making it difficult to ensure the accuracy of reporting. TRI data only represent a portion of the chemical life cycle (e.g., wastes as a result of production) and do not take into account amounts of chemicals incorporated into industrial and/or consumer products which also have the potential to affect the environment and human health when they are used, discarded, or recycled.

There is no existing reporting system that provides information on the volume, distribution, and extent of pesticide use in the United States. Estimates are developed based on information available through a variety of reports from multiple governmental and non-governmental entities on pesticide sales, crop profiles, and expert surveys. The Pesticide Residues in Food indicator (p. 4-58) provides information on one aspect of the potential for human exposure from pesticides (dietary intake from the commercial food supply), but does not provide a complete picture of all the ways in which humans can be exposed to pesticides, which include contaminated drinking water, pesticide drift, and dermal contact.

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[26] Howarth, R.W., D. Walker, and A. Sharpley. 2002. Sources of nitrogen pollution to coastal waters of the United States. Estuaries 25:656-676.

[27] Sludges are the nutrient-rich organic materials resulting from sewage and wastewater treatment processes. Sludges contain many of the nutrients required for improved plant growth (N, P, and K) and other organic matter that can improve overall soil condition and increase productivity.

4.6 WHAT ARE THE TRENDS IN CONTAMINATED LAND AND THEIR EFFECTS ON HUMAN HEALTH AND THE ENVIRONMENT?

4.6.1 Introduction

There are many settings for contaminated lands, ranging from abandoned buildings in inner cities to large areas contaminated with toxics from past industrial or mining activities. Contaminated lands include sites contaminated by improper handling or disposal of toxic and hazardous materials and wastes, sites where toxic materials may have been deposited as a result of wind or flood, and sites where improper handling or accidents resulted in release of toxic or hazardous materials that are not wastes.

Land contamination can result from a variety of intended, accidental, or naturally occurring activities and events such as manufacturing, mineral extraction, abandonment of mines, national defense, waste disposal, accidental spills, illegal dumping, leaking underground storage tanks, hurricanes, or floods. Sites are categorized in a variety of ways, often based on the level and type of contamination and the regulations under which they are monitored and cleaned up. Text Box 4.1 provides an overview of the common types of contaminated sites. With the exception of accidental spills and contamination that result from naturally occurring and other unanticipated events, most land contamination is the result of historical activities that are no longer practiced. Hazardous material and waste management and disposal are now highly regulated.

Contaminated soils can leach toxic chemicals into nearby ground or surface waters, where these materials can be taken up by plants and animals, contaminate a human drinking water supply, or volatize and contaminate the indoor air in overlying buildings. In dry areas, contamination in soil can be further distributed through wind-borne dusts. Once soil contamination migrates to waterways, it may also accumulate in sediments, which can be very difficult to remediate and may affect local ecosystems and human health. Humans can be harmed by contact with toxic and hazardous materials on a contaminated site via contact with land, air, water, and groundwater. When contaminated lands are not properly managed, humans and wildlife can come into contact with contaminants through inhalation, ingestion, or direct contact. The risks of human exposure are site-specific and difficult to generalize at the national level. Potential effects may be acute or chronic.

Some contaminated sites pose little risk to human health and the environment, because the level of contamination is low and the chance of exposure to toxic or hazardous contaminants is also low. Other contaminated sites are of greater concern because of the chemicals that may be present and their propensity to persist in or move through the environment, exposing humans or the environment to hazards. These sites must be carefully managed through containment or cleanup to prevent hazardous materials from causing harm to humans, wildlife, or ecological systems, both on- and off-site.

Text Box 4.1: Categorizing Contaminated Lands

Superfund National Priority List (NPL) Sites - The Superfund NPL sites are seriously-contaminated and include industrial facilities, waste management sites, mining and sediment sites, and federal facilities such as abandoned mines; nuclear, biological, chemical, and traditional weapons productions plants; and military base industrial sites (e.g., used for aircraft and naval ship maintenance).

Resource Conservation and Recovery Act Cleanup Baseline Facilities - The RCRA Cleanup Baseline is a priority subset of a broader universe of facilities that are subject to cleanup under RCRA due to past or current treatment, storage, or disposal of hazardous wastes and have historical releases of contamination.

Underground Storage Tanks/ Leaking Underground Storage Tanks - Businesses, industrial operations, gas stations, and various institutions store petroleum and hazardous substances in large underground storage tanks that may fail due to faulty materials, installation, operating procedures, or maintenance systems causing contamination of soil and ground water,

Accidental Spill Sites - Each year, thousands of oil, gas, and chemical spills occur on land and in water from a variety of types of incidents, including transportation (e.g., rail, barges, tankers, pipeline) and facility releases.

Sites Contaminated by Natural Disasters or Terrorist Activities - Disasters of any sort, naturally occurring or caused by humans, have the potential to create contaminated lands and cause problems at existing contaminated sites.

Land Contaminated with Radioactive and Other Hazardous Materials - Many sites spanning a large area of land in the United States are contaminated with radioactive and other hazardous materials as a result of activities associated with nuclear weapons production, testing, and research.

Brownfields - Brownfields are real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. Brownfields are often found in and around economically depressed neighborhoods.

Military Bases and Defense Sites - Some of the millions of acres of land used by the Department of Defense are contaminated from releases of hazardous substances and pollutants; discarded munitions, munitions constituents, and unexploded ordnance; and building demolition and debris.

Low Level Area-wide Contamination - Some soil contamination problems involve low-to-moderate levels of contamination that encompass large geographic areas ranging in size from several hundred acres to many square miles. Low-level, area-wide contamination can occur from emissions related to past industrial operations (e.g., smelters), widespread agricultural pesticide applications, combustion of gasoline, and deterioration of lead-based paint.

Past Waste Management Sites and Illegal Dumping Sites - Prior to the 1970s, solid waste was typically placed in unlined landfills that were not adequately designed to prevent adverse environmental impacts to ground water or surface water. Separately, illegal dumping of materials such as construction waste, abandoned automobiles, appliances, household waste, and medical waste, has occurred for decades and still occurs because of convenience and the cost of legal disposal.

Abandoned and Inactive Mine Lands - Abandoned and inactive mines have not been properly cleaned up, and may have features ranging from exploration holes to full-blown, large-scale mine openings, pits, waste dumps, and processing facilities.

Nationally, there are thousands of contaminated sites of varying size and significance. Many sites, particularly the largest and most severely contaminated, are tracked at the national level, but many others are tracked only at state or local levels. The number and status of contaminated sites changes frequently as sites are newly contaminated (e.g., via spills or hurricanes), discovered, documented, and cleaned up.

4.6.2 ROE Indicators

The ROE indicators for this question focus on the trends in reducing potential threats to human health associated with site contamination at some lands contaminated by a variety of industrial and other activities and from current and past waste management activities (Table 4.6.1). The indicators address sites on the Superfund National Priorities List (NPL) and facilities on the Resource Conservation and

Recovery Act (RCRA) Cleanup Baseline where human contact with contamination and migration of contaminated groundwater has been documented to be within acceptable established health-based levels.

Trends in the spread of contaminated groundwater and potential human contact with contaminants in excess of health-based standards are assessed through site-specific monitoring and modeling data collected by site personnel. Site data and conditions are generally reviewed and confirmed by federal and/or state program managers annually or more frequently if site conditions warrant.

Table 4.6.1. ROE Indicators of Trends in Contaminated Land and Their Effects on Human Health and the Environment

NATIONAL INDICATORS	LOCATION
High-Priority Cleanup Sites with No Human Contact to Contamination in Excess of Health-Based Standards	4.5.2 – p. 4-70
High-Priority Cleanup Sites Where Contaminated Groundwater Is Not Continuing to Spread Above Levels of Concern	4.5.2 – p. 4-73

INDICATOR: High-Priority Cleanup Sites with No Human Contact to Contamination in Excess of Health-Based Standards

The EPA Superfund and Resource Conservation and Recovery Act (RCRA) Programs conduct a number of activities to address the nation's most severely-contaminated lands. The Programs investigate and collect data on potentially-contaminated sites to determine whether they are contaminated and require cleanup. When a potentially-hazardous waste site is reported to EPA, trained inspectors determine whether the site presents a hazard to human health and the environment. Sites that pose the greatest threat are placed on the Superfund National Priorities List (NPL) or RCRA Cleanup Baseline. For RCRA, "sites" are more commonly referred to as RCRA Corrective Action Facilities.

One of the priorities for both the NPL and RCRA Cleanup Baseline sites is safeguarding against human contact with site contamination. EPA and state officials determine whether humans are in contact with site contamination and if interim actions are needed to reduce or eliminate all current human contact in excess of health-based standards. Such activities may include removing and/or isolating contaminated media, providing alternative water supplies, and restricting access or other land use controls. Contact at levels below the standards is considered protective. Although these standards may vary from state to state, EPA believes that they fall within an acceptable range for gauging whether human health is protected (U.S. EPA, 2005c). Determinations of human contact at levels of concern are based on site-specific characterization information and monitoring data (usually many analytical samples) pertaining to relevant environmental media (e.g., soil, indoor air, outdoor air, groundwater, and surface water), current human activity patterns, and actions taken to prevent human contact. All potential contact routes are assessed, including inhalation, direct contact, or ingestion of the contaminated media or food affected by contaminated media (U.S. EPA, 1999, 2005c).

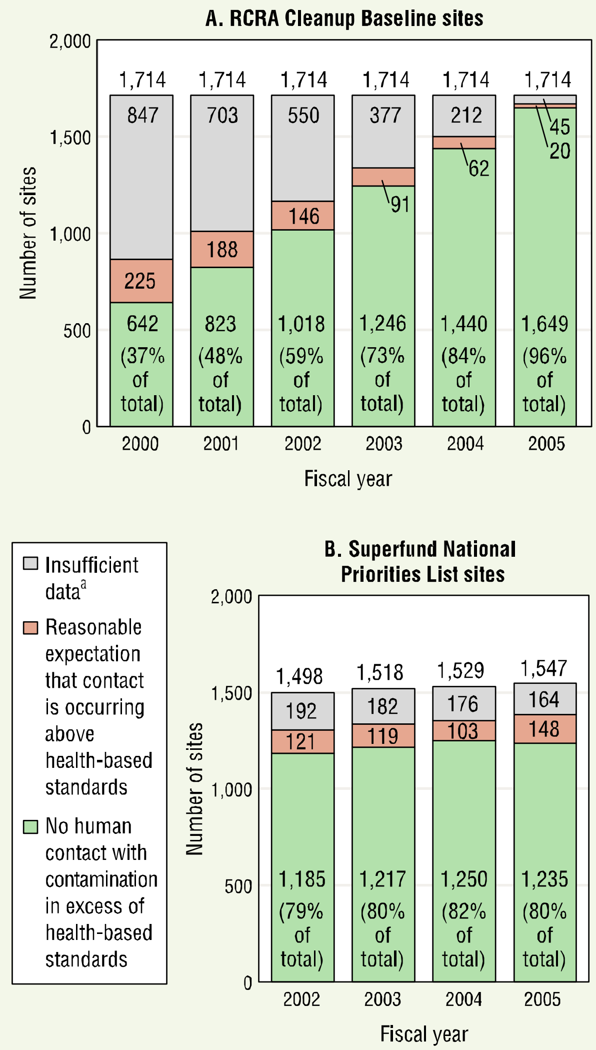
This indicator describes the numbers of NPL and RCRA Cleanup Baseline sites for which government officials have determined that humans are *not* in contact with contamination in excess of health-based standards, *are* reasonably expected to be in contact with contamination in excess of health-based standards, or *insufficient information exists* to make a finding of contact with contamination in excess of health-based standards. The intention of the indicator is not to capture an "action" or "administrative determination" on the part of EPA, but to characterize environmental conditions relevant to the risk to human health from contaminants at RCRA Cleanup Baseline and NPL sites.

What the Data Show

There are 1,714 sites on the RCRA Cleanup Baseline (U.S. EPA, 2005b). Of these, the percentage of sites where human contact to contamination in excess of health-based standards has been shown not to occur increased from 37 percent (642 sites) in fiscal year (FY) 2000 to 96 percent (1,649 sites) in FY 2005 (Exhibit 4-24, panel A). This increase represents a combination of sites where mitigation has prevented contact with contaminants and sites where the availability of sufficient data show that contact with contaminated media was not a problem, regardless of mitigation. The percentage of sites where officials had reasonable expectations that humans were in contact with contamination in excess of health-based standards has decreased from 13 percent (225 sites) in FY 2000 to just over 1 percent (20 sites) in FY 2005. These sites and the 45 remaining sites in 2005 for which there is insufficient information to make a determination include very complex sites where the appropriate data have yet to be collected due to high costs or technical difficulties.

As of October 2005, there were 1,547 sites on the NPL that were categorized as "Final" or "Deleted" (U.S. EPA, 2005d, 2005e). Given that the number of sites on the NPL changes each year, the percentages shown in this indicator are based on each year's total number of Final and Deleted NPL sites with determinations as to whether the site presents a hazard to human health and the environment. NPL sites where human contact to contamination in excess of health-based standards has been shown not to occur remained relatively constant as a percentage of the total: 79 percent (1,185 of 1,498 sites) in 2002 and 80 percent (1,235 of 1,547 sites) in 2005 (Exhibit 4-24, panel B). As of the end of FY 2005, officials determined that there are reasonable expectations that humans are in contact with contamination in excess of health-based standards at 9.6 percent (148 out of 1,547) of the NPL sites. This is an increase from 2002, when the percentage was 8.1 percent (121 out of 1,498). In 2005, there was insufficient information to confirm whether humans were in contact with contamination in excess of health-based standards at 10.6 percent (164) of the sites.

Exhibit 4-24. Status of human contact with contamination at high-priority cleanup sites in the U.S., fiscal years 2000-2005



[a]For RCRA Cleanup Baseline sites, "insufficient data" includes sites officially classified as "insufficient data" or "no status." For Superfund NPL sites, this category includes sites officially classified as "insufficient data" or "no data."

Data source: *U.S. EPA, Office of Solid Waste and Emergency Response (OSWER)*

Indicator Limitations

- The NPL does not represent all of the contaminated or potentially-contaminated sites listed in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) database that contains information on thousands of hazardous waste sites, potential hazardous waste sites, and remedial activities across the nation.
- The indicator results are presented for the 1,714 RCRA Cleanup Baseline sites, and not the entire group of approximately 6,500 hazardous waste management sites that fall under the federal RCRA Corrective Action Program.
- The indicator does not typically make measurements of exposure biomarkers among potentially-exposed individuals at the NPL or RCRA Cleanup Baseline sites, but relies on environmental measures at or near the point of exposure and activities that should prevent contact with contaminants.
- Concentrations of toxic and hazardous contaminants that must not be exceeded to designate a site as having/not having human contact to contamination in excess of health-based standards

vary from state to state but fall within a range determined to be acceptable to EPA (U.S. EPA, 2005a, 2005c).

- The indicator is based on certification by a responsible official that the criteria necessary to designate a site as having/not having human contact to contamination in excess of health-based standards have been met (U.S. EPA, 1999, 2005a, 2005c). The trend in the number of sites may be underestimated to the extent that certification lags behind the potential human contact with contamination or certification is delayed due to insufficient or outdated information.
- This approach may not take into account certain risks (e.g., endocrine disruptors) where specific risk-levels may not have been established. Some new sites (e.g., those created with the “reportable quantity” spill response program) as well as other known sites (e.g., spills) are not included in this indicator.

Data Sources

Data for this indicator were provided by EPA’s Office of Solid Waste and Emergency Response (OSWER). A list showing the current status of every RCRA baseline site is published online (U.S. EPA, 2005b). A summary of the status of Superfund NPL sites is available online for the most recent fiscal year (U.S. EPA, 2005d); information on the current status of any individual NPL site can be queried using EPA’s CERCLIS database (U.S. EPA, 2006) (http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm). Data for previous years are not publicly accessible, however, and must be requested from OSWER.

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INDICATOR: High-Priority Cleanup Sites Where Contaminated Groundwater Is Not Continuing to Spread Above Levels of Concern

The EPA Superfund and Resource Conservation and Recovery Act (RCRA) Programs conduct a number of activities to address the nation's most severely-contaminated lands. The Programs investigate and collect data on potentially-contaminated sites to determine whether they are contaminated and require cleanup. When a potentially-hazardous waste site is reported to EPA, trained inspectors determine whether the site presents a hazard to human health and the environment. Sites that pose the greatest threat are placed on the National Priorities List (NPL) or RCRA Cleanup Baseline.

One of the priorities for both the NPL and RCRA Cleanup Baseline sites is preventing the continued spread of contaminated groundwater, often referred to as "plumes" of contaminated groundwater. Protecting the groundwater is especially important in those areas where groundwater is the primary source for drinking water and irrigation, or a potential source for future water supplies.

EPA and state officials determine that the migration of contaminated groundwater is not continuing above levels of concern when ongoing monitoring shows that the contaminant plume is not expanding or negatively impacting surface waters (U.S. EPA, 1999). Preventing further migration of contaminated groundwater may result from an action taken, such as installation of a "pump and treat" or subsurface barrier system, or because of natural attenuation of the contaminants. A determination of whether migration has been prevented is based on monitoring data (usually hundreds of analytical samples) collected from groundwater wells located within and surrounding the spatial extent of the groundwater plume (U.S. EPA, 1999, 2005c).

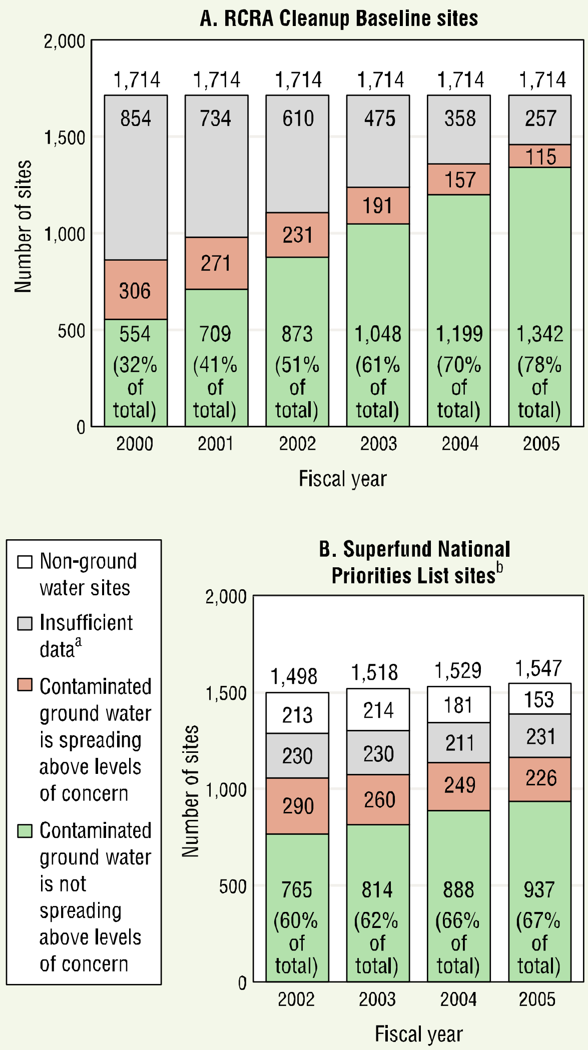
This indicator describes the percentage of NPL and RCRA Cleanup Baseline sites where government officials have determined that groundwater is not continuing to spread above levels of concern (e.g., that exceed the appropriate drinking water standards). This indicator covers both final and deleted NPL sites, and all 1,714 RCRA Cleanup Baseline sites. The percentage of sites where groundwater contamination continues to spread is also noted, as well as the number of sites where there are insufficient data to make a finding. The intention of the indicator is not to capture an "action" or "administrative determination" on the part of EPA, but to convey the underlying pressure on the environment and potential for human health effects resulting from contaminated groundwater.

What the Data Show

Of the 1,714 high-priority RCRA Cleanup Baseline sites, the percentage of sites where contaminated groundwater has been determined not to be spreading above levels of concern increased from 32 percent (554 sites) in FY 2000 to 78 percent (1,342 sites) in FY2005 (Exhibit 4-25, panel A). This increase represents a combination of sites where mitigation has halted the spread of contaminated groundwater, and sites where sufficient data have been collected to show that contaminated groundwater migration was not continuing, regardless of mitigation activities. The percentage of sites where officials have determined that contaminated groundwater was spreading above levels of concern decreased from 18 percent (306 sites) in FY 2000 to less than 7 percent (115 sites) in FY 2005. These sites, and the remaining 257 sites for which there are still insufficient data to make a determination at the end of FY 2005, tend to be very complex sites where the appropriate data have yet to be collected due to high costs or technical difficulties.

Groundwater has not been an issue at all Superfund NPL sites. Of those Final and Deleted NPL sites where groundwater contamination is present, the percentage where contaminated groundwater has been

Exhibit 4-25. Status of contaminated ground water spreading at high-priority cleanup sites in the U.S., fiscal years 2000-2005



[a]For RCRA Cleanup Baseline sites, "insufficient data" includes sites officially classified as "insufficient data" or "no status." For Superfund NPL sites, this category includes sites officially classified as "insufficient data" or "no data."

[b]For Superfund NPL sites, the percentage in the "not spreading" category is based on the total number of sites with contaminated ground water (does not include "non-ground water" sites).

Data source: *U.S. EPA, Office of Solid Waste and Emergency Response (OSWER)*

demonstrated not to be spreading above levels of concern increased from 60 percent (765 sites) in FY 2002 to 67 percent (937 sites) in FY 2005 (Exhibit 4-25, panel B). As of October 2005, contaminated groundwater was confirmed to be spreading above levels of concern at 16 percent (226) of these NPL sites, while the remaining 17 percent (231 sites) had insufficient data to confirm whether contaminated groundwater is spreading above levels of concern. These percentages do not include the 153 NPL sites classified as "non-groundwater" sites.

Indicator Limitations

- The NPL does not represent all of the contaminated or potentially contaminated sites listed in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) database that contains information on thousands of hazardous waste sites, potential hazardous waste sites, and remedial activities across the nation. Within the NPL sites, data are not available or insufficient to assess a number of sites.
- The indicator covers the 1,714 RCRA Cleanup Baseline sites, and not the entire group of 6,500 hazardous waste management sites that fall under the federal RCRA Corrective Action Program.
- The extent to which people have been affected, or could be affected, by the contaminated groundwater at NPL or RCRA Cleanup Baseline sites is not considered in this indicator, but is addressed in human-contamination contact indicator (High Priority Cleanup Sites with No Human Contact to Contamination in Excess of Health-Based Standards).
- The indicator does not address groundwater contaminated at other types of sites, such as sites with leaking underground storage tanks and other sites being addressed solely by state cleanup programs.

- Concentrations of toxic and hazardous contaminants in groundwater that must not be exceeded to designate a site as under control vary somewhat from state to state, but fall within a range determined to be acceptable to EPA (U.S. EPA 2005a, 2005c).
- This indicator is based on the certification by a responsible official that the criteria necessary to designate whether contaminated groundwater is continuing to spread above levels of concern have been met (U.S. EPA, 1999, 2005a, 2005c). Trends in the number of sites where the spread of contaminated groundwater has been shown to occur above levels of concern may be underestimated to the extent that certification lags behind the migration of contaminated groundwater or certification is delayed due to insufficient or outdated information.

Data Sources

Data for this indicator were provided by EPA's Office of Solid Waste and Emergency Response (OSWER). A list showing the current status of every RCRA baseline site is published online (U.S. EPA, 2005b). A summary of the status of Superfund NPL sites is available online for the most recent fiscal year (U.S. EPA, 2005d); information on the current status of any individual NPL site can be queried using EPA's CERCLIS database (U.S. EPA, 2006) (http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm). Data for previous years are not publicly accessible, however, and must be requested from OSWER.

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4.6.3 Discussion

What These Indicators Say About Trends in Contaminated Lands and Their Effects on Human Health and the Environment

The indicators provide insights into trends in protecting humans and groundwater from the nation's most contaminated lands. In 2005, almost all (more than 95 percent) of the RCRA facilities showed that human contact to contamination in excess of health-based standards was being prevented, while groundwater was not spreading above levels of concern at slightly more than 75 percent of the facilities. Similarly in 2005, the Superfund NPL sites showed that contact of humans to contamination in excess of health-based standards has been prevented at more than 80 percent of the sites, and groundwater has been prevented from spreading above levels of concern at more than 60 percent of the sites with groundwater contamination.

Limitations, Gaps, and Challenges

The two ROE indicators are limited in their ability to address the question. Currently, there is no single information source that tracks the extent of contaminated land nationwide. A substantial amount is known about thousands of the most contaminated sites on the Superfund National Priorities List (NPL) and facilities on the RCRA Cleanup Baseline, which have been the focus of in-depth studies and resource-intensive cleanup operations. Although these facilities represent some of the most seriously contaminated sites in the country, they do not reflect the full universe of contaminated sites or even the full universe of seriously contaminated sites. EPA would like to have information on other sites that require extensive cleanup including those contaminated with radioactive materials from historical nuclear weapons production; sites with leaking underground storage tanks; smaller accidental spill sites; and other cleanup sites managed by a variety of local, state, and federal authorities. Collectively, these contaminated sites outnumber the NPL sites and RCRA Cleanup Baseline facilities.

The Agency would also like to have information on the actual acreage and types of contamination from all sources nationally. Even where national data on contaminated sites are available, the affected area and the types and severity of contamination vary widely from site to site, making accurate trend analysis, aggregation, and generalization difficult or impossible. There is no comprehensive data source to determine the extent of these lands, populations that may be affected, and the potential for contamination to have harmful human health or ecological effects. Furthermore, EPA is interested in knowing how much previously contaminated land has been returned to productive uses. Data associated with the use of previously contaminated land could contribute to addressing both the question of trends and effects of contaminated land and the question of trends and effects of land use.

Current data gaps around contaminated lands stem from a variety of factors and challenges, including the multi-jurisdictional responsibilities for identifying, managing, and cleaning up contaminated lands; a focus in most contaminated lands data sets on measures of regulatory compliance and associated activities; high costs to identify, inventory, study, and cleanup large complicated sites; and complexity in the effects of contaminated lands on human health and the environment, including unique site characteristics and inability to generalize information over large geographic areas.