5.3 What Is the Ecological Condition of Farmlands?

Agricultural practices using high-yielding crop varieties, fertilization, irrigation, and pesticides have contributed substantially to increased food production over the past 50 years (Matson, et al., 1997). These same practices also have altered the biotic interactions in farmlands, with local, regional, and global ecological consequences (Matson, et al., 1997). This report (following The Heinz Center, 2002) defines a farmland as consisting of not only of the lands used to grow crops, but also the field borders, windbreaks, small woodlots, grassland and shrubland areas, wetlands, farmsteads, small villages, and other built-up areas within or adjacent to croplands. These land covers/uses both support agricultural production and provide habitat for a variety of wildlife species. Farmlands include lands that grow perennial and annual crops as well as lands that are used to produce forage for livestock. This definition overlaps with other ecosystems; most notably, pastures are considered croplands, but are also considered part of grassland/shrubland ecosystems.

Among ecologists concerned with ecological condition, farmlands are often referred to as "agroecosystems." EPA is interested not only in the ecological condition of farmlands, but also in their effects on adjacent ecosystems. Developing and implementing agricultural practices that integrate crop and livestock production with ecologically

Exhibit 5-16: Farmland indicators

Essential Ecological Attribute	Indicators	Category 1	Category 2	Source
Landscape Condition		1	2	
Extent of Ecological System/Habitat Types	Extent of agricultural land uses	■		USDA
Landscape Composition	The farmland landscape	■		DOI
Landscape Structure/Pattern				
Biotic Condition				
Ecosystems and Communities				
Species and Populations				
Organism Condition				
Ecological Processes				
Energy Flow				
Material Flow				
Chemical and Physical Characteristics				
Nutrient Concentrations	Nitrate in farmland, forested, and urban streams and ground water		■	DOI
	Phosphorus in farmlands, forested and urban streams		■	DOI
Other Chemical Parameters				
Trace Organics and Inorganics	Pesticides in farmland streams and ground water		■	DOI
	Potential pesticide runoff from farm fields		■	USDA
	Pesticide leaching potential		■	USDA
	Soil quality index		■	EPA
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows				
Dynamic Structural Conditions				
Sediment and Material Transport	Soil erosion		■	EPA
	Sediment runoff potential from croplands and pasturelands		■	USDA
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

based management practices has become the key for sustainable agriculture (NRC, 1999).

Some of the data on farmlands are available through the National Agricultural Statistics Service (NASS). Over the past 80 years, NASS has administered the USDA's program of collecting and publishing national and state agricultural statistics. NASS currently publishes more than 400 reports a year covering virtually every facet of U.S. agriculture—production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, and farm aspects of the industry. These estimates are based on a statistical area sampling frame that represents the entire land mass of the U.S. The biological indicators currently measured by NASS are primarily related to crop or animal production. However, NASS does not report on indicators of ecological condition. Physical or chemical indicators usually provide information relevant for agronomic production, but also can provide limited information on potential stressors to adjacent terrestrial and aquatic ecosystems such as soil erosion; nitrogen, phosphorus and pesticide runoff; and phosphorus and nitrate concentrations in farmland streams.

In 1990, EPA and the USDA Agricultural Research Service (ARS) undertook an interagency effort to assess the ecological condition of agroecosystems as part of the Environmental Monitoring and Assessment Program (EMAP). In 1994 and 1995, EMAP piloted a regional-scale assessment in the mid-Atlantic region (Hellkamp, et al., 2000). Some of the resulting indicators used in that pilot are included as Category 2 indicators in this report. These indicators could be measured in other regions and eventually across the nation in conjunction with the NASS annual surveys.

The farmland indicators used in this report are displayed in Exhibit 5-16, grouped according to the essential ecological attributes (EEAs). Some indicators relating to the EEAs of farmland landscape condition, the chemical and physical attributes of farmland streams, and the hydrology of farmland watersheds have been presented in the previous chapters on Better Protected Land and Purer Water, because these indicators also relate to questions about those media. Below, this section briefly summarizes the data for these indicators as they relate to the ecological condition of farmlands. The section then introduces additional indicators that relate to the EEAs of physical and chemical properties of farmland soils and the hydrology and geomorphology contributing to loss of soil from farmlands. Data are insufficient for national reporting on indicators in three of the six categories of EEAs: biotic condition, ecological processes, and natural disturbance regimes (The Heinz Center, 2002).

The following indicators presented in previous chapters relate to the ecological condition of farmlands:

- According to the indicator *Extent of Agricultural Land Uses* (Chapter 3, Better Protected Land), croplands total 377 million acres. As of 1997, Conservation Reserve Program (CRP) lands totaled 32 million acres, excluding Alaska (USDA, NRCS, 2000). Between 1982 and 1997, cropland decreased 10.4 percent, from about 421 million acres to nearly 377 million acres. Of this 44-million acre decrease, however, 32.7 million acres are now enrolled in the CRP, leaving an 11.3 million acre loss as a result of conversion of croplands to other land uses (USDA, NRCS, 2000).

  Unfortunately, there is no single, definitive, accurate estimate of the extent of cropland. Cropland is a flexible resource that is constantly being taken in and out of production. In addition, estimates of the amount of land devoted to farming differ because different programs use different methods to acquire, define, and analyze their data. For example, The Heinz Center report assesses total cropland (including pasture and hayland) as covering between 430 and 500 million acres in 1997, or about a quarter of the total land area in the U.S. (excluding Alaska). This report does not reconcile these differences, but does acknowledge that there are different estimates.

- The *Farmland Landscape* indicator (Chapter 3, Better Protected Land) describes the degree to which croplands dominate the landscape and the extent to which other land uses are intermingled (The Heinz Center, 2002). Croplands comprise about half of the larger farmland ecosystems in the East and Southeast and almost three-quarters of the farmland ecosystems in the Midwest (The Heinz Center, 2002). The remainder of the farmland ecosystems are forests in the East, wetlands in the Southeast, and both forests and wetlands in the Midwest. In the West, about 60 percent of farmland ecosystems are cropland, with grasslands and shrublands dominating the remainder in the western and northern Plains areas. Forests and grasslands/shrublands are about equal in the farmland landscape for the non-cropland area of the South Central region. In many areas of the U.S., other land cover types are almost as prevalent as croplands and can provide habitat for non-agronomic species.

- The indicator *Nitrate in Farmland, Forested, and Urban Streams and Ground Water* (Chapter 2, Purer Water) shows the loss of nitrate from agricultural watersheds, usually indicating the extent to which nitrogen fertilizer is lost or animal manure reaches streams via runoff or ground water. Sampling in areas where agriculture is the primary land use found that about 50 percent of the 52 stream sites sampled and 45 percent of the ground water wells sampled had nitrate concentrations greater than 2 ppm. About 20 percent of the ground water sites and 10 percent of the stream sites sampled had nitrate concentrations exceeding the drinking water nitrate standard of 10 ppm. These figures are much higher than the nitrate concentrations in forest streams (The Heinz Center, 2002).

- The indicator *Phosphorus in Farmland, Forested, and Urban Streams* (Chapter 2, Purer Water), shows the loss of phosphorus from agricultural watersheds, again usually indicating losses from fertilizer and animal manures. Total phosphorus concentrations in farmland streams were reported in four classes in the Heinz report: < 0.1 ppm, 0.1-0.3 ppm, 0.3-0.5 ppm, and > 0.5 ppm (The Heinz Center, 2002). EPA has set new regional criteria for phosphorous concentration, ranging from 0.023 to 0.076 ppm, to protect streams in agricultural ecosystems from eutrophication. The criteria vary according to differences in ecoregions, soil types, climate, and land use. The Heinz Center (2002) reports that about 75 percent of farmland streams had phosphorous concentrations greater than 0.1 ppm, thus exceeding any of EPA's criteria for eutrophication. Fifteen percent had phosphorous concentrations equal to or exceeding 0.5 ppm (The Heinz Center, 2002). Average phosphorous concentrations in farmland streams were similar to phosphorous concentrations measured in urban streams. As with nitrate concentrations, forest streams had lower phosphorous concentrations than farmland or urban streams.

- The indicator *Pesticides in Farmland Streams and Ground Water* (Chapter 2, Purer Water), captures the extent to which chemical conditions in streams may exceed the tolerance limits for aquatic communities. All streams monitored by the National Water Quality Assessment (NAWQA) program in farmland areas had at least one pesticide at detectable levels throughout the year (The Heinz Center, 2002). About 75 percent of these streams had an average of five or more pesticides at detectable levels, and more than 80 percent of the streams had at least one pesticide whose concentration exceeded the applicable aquatic life guideline. About 60 percent of ground water wells sampled in agricultural areas had at least one pesticide at detectable levels. A relatively small number of these chemicals—specifically the herbicides atrazine (and its breakdown product desethylatrazine), metalachlor, cyanazine, and alachlor—accounted for most detections.
- The *Potential Pesticide Runoff from Farm Fields* indicator (Chapter 3, Better Protected Land) identifies the potential for movement of agricultural pesticides by surface water runoff in watersheds nationwide, based on factors known to be important determinants of pesticide loss. These factors include: 1) soil characteristics, 2) historical pesticide use, 3) chemical properties of the pesticides used, 4) annual rainfall and its relationship to runoff, and 5) major field crops grown. The indicator uses 1992 as a baseline. Watersheds with high scores (i.e., the 4th quartile of runoff estimates) have a greater risk of pesticide contamination of surface water than do those with low scores (i.e., the 1st quartile of runoff estimates). The highest potential for pesticide runoff is projected for the central U.S., primarily in the upper and lower Mississippi River valley and the Ohio River valley. These areas are part of the "breadbasket" of the U.S., where pesticide application is highest. Many of the western watersheds have not been assessed.
- The hydrologic attribute indicator *Sediment Runoff Potential from Croplands and Pasturelands* (Chapter 3, Better Protected Land), captures the loss of valuable soil from the farmland, sediment impacts to the physical habitat of farmland streams, and transport of many pollutants to downstream lakes, reservoirs, and estuaries. This indicator combines land cover, weather patterns, and soils information in a process model that incorporates hydrologic cycling, weather, sedimentation, crop growth, and agricultural management to estimate the amount of sediment that could potentially be delivered to rivers and streams in each watershed. The highest potential for sediment runoff is concentrated in the central U.S., predominately associated with the upper Mississippi River valley and the Ohio River valley. Most of the western U.S. region is characterized by low runoff potential.

The other three indicators in Exhibit 5-16, described on the following pages, appear for the first time in this chapter.

Indicator Pesticide leaching potential - Category 2

Retention of pesticides in their target areas maximizes pesticide efficiency and minimizes off-site contamination (Hellkamp, et al., 2000). Pesticide leaching not only can contaminate surface and ground water, but also can have both chronic and acute toxic effects on non-target organisms, such as fish, birds, and other wildlife. This leaching potential is affected by soil properties, rainfall and runoff, pesticide chemistry, and other factors. The indicator was used as part of the NASS survey approach, so it has the potential for national application.

What the Data Show

During the 1994-1995 period, there were about 13.5 million acres of cropland in the MId-Atlantic region (Hellkamp et al, 2000). Although a large proportion of these 13.5 million acres had soils with properties conducive to pesticide leaching, the authors estimate that 50 percent (6.75 million acres) of the cropland received no pesticide application. Also, pesticides with moderately high to high leaching potentials were seldom applied to croplands with highly to very highly leachable soils. Consequently, only about 1 million acres (less than 10 percent of the total cropland acreage) was at moderately high to high risk for loss of pesticides from the on-farm target area (Hellkamp, et al., 2000).

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- The pesticide leaching potential indicator has only been applied in the mid-Atlantic region and has not been tested or applied in other regions. It has the potential to be applied in other areas, but it will have to be adjusted for regional differences.
- Data collection occurred only during 1994 and 1995.

Data Source

The data source for this indicator was the Mid-Atlantic Integrated Assessment Program, U.S. Environmental Protection Agency (1994-1995). (See Appendix B, page B-41, for more information.)

Indicator Soil quality index - Category 2

A Soil Quality Index (SQI) was developed and measured for agroecosystems in the mid-Atlantic region in 1994 and 1995 (Hess, et al., 2000; Hellkamp, et al., 2000). The SQI includes indicators of soil attributes, including physical (i.e., clay content, cation exchange capacity, base saturation), chemical (i.e., pH, sodium adsorption ratio, total nitrogen, total carbon, organic carbon/clay), and biological (i.e., microbial biomass). The SQI score is an average of eight numerical ratings (McQuaid and Olson, 1998) (Hellkamp, et al., 2000). The high soil quality range begins at SQI scores of 2.4, while the range of low SQI scores is from 0.0 to 1.6. While the SQI is an indicator of the capacity of the soil to support plant growth and is related primarily to agricultural productivity, it can also provide information on the capacity of the site to support non-agronomic plants.

This indicator was used as part of the NASS survey approach, so it has the potential for national application.

What the Data Show

SQI scores were obtained for the five-state mid-Atlantic region in 1994 and 1995 (Hellkamp, et al., 2000) (Exhibit 5-17). In 1994, the mean SQI score was 2.23 (CI[9] = 2.17 to 2.29); in 1995, the mean SQI was 1.98 (CI = 1.73 to 2.23). The difference in SQI scores between 1994 and 1995 was due to different index calculation procedures and sampling variability. SQI scores were lower in tilled soils compared with untilled soils, such as hay fields, in both 1994 and 1995. Untilled sites had higher microbial biomass values than conventional or reduced tillage sites in both years

Evaluation of the individual factors related to the moderate SQI scores indicated that cation exchange capacity (1994), carbon (total 1994, organic 1995), and microbial biomass (1995) had the lowest values (Hellkamp, et al., 2000).

Increasing the carbon content of soils might increase their capacity to support plant growth. Retaining or adding crop residues to the soils could increase both the carbon content and substrate for microbial activity. Crop residues can also reduce soil erosion and associated transport of nutrients and pesticides off the field. Nutrients and pesticides contribute to negative effects on aquatic receiving systems.

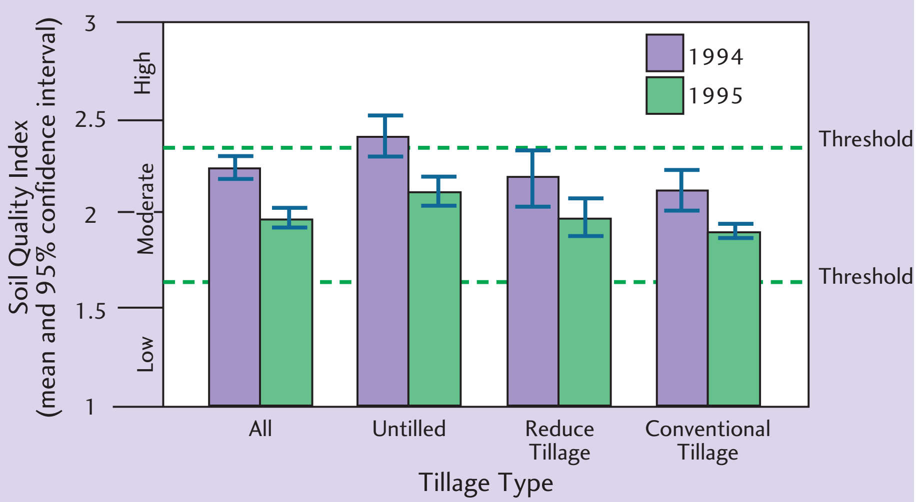
Indicator Gaps and Limitations

Data are available only for the mid-Atlantic region for 2 years. The indicator has the potential to be applied in other areas, but it will have to be adjusted for regional differences.

Data Source

The data source for this indicator was the Mid-Atlantic Integrated Assessment Program, U.S. Environmental Protection Agency (1994-1995). (See Appendix B, page B-41 for more information.)

Exhibit 5-17: Soil quality index for different tillage systems in the mid-Atlantic states, 1994 and 1995



Dashed lines represent thresholds between low, moderate, and high ranges in soil quality for supporting plant growth.

Coverage: Mid-Atlantic states.

Source: Hellkamp et al. *Assessment of the Condition of Agricultural Lands in Six Mid-Atlantic States. 2000.*

[9]The confidence interval (CI) of the mean is a range of values (interval) with a known probability (confidence, in this case 95 percent) of containing the true population mean. The 1994 measured SQI scores are only a sample of the entire population of SQI scores for the region. While the mean of the measured SQI scores was 2.23, there is a 95 percent probability that the mean for the entire population would be between 2.17 and 2.29.

Indicator Soil erosion - Category 2

Sediment resulting from soil erosion and transport is the greatest pollutant in aquatic ecosystems, both by mass and volume (EPA, OW, August 2002). Soil particles also can transport sorbed nutrients and pesticides and carry these into aquatic systems where these constituents contribute to water quality problems. Agricultural soil erosion decreases soil quality and can reduce soil fertility, and soil movement can make normal cropping practices difficult (The Heinz Center, 2002). Soil erosion and transport can occur both by wind and by water.

Soil erosion estimates were calculated using the U.S. Geological Survey hydrologic unit codes watersheds (8-digit HUCs), National Resources Inventory soils data, the Universal Soil Loss Equation (Renard, et al., 1997), and the Wind Erosion Equation (Bondy, et al., 1980; Skidmore and Woodruff, 1968). Soil parameters were obtained from the USDA Natural Resources Conservation Service database.

What the Data Show

The acreage of U.S. farmland with the greatest potential for wind erosion decreased by almost 33 percent to about 63 million acres from 1982 to 1997 (The Heinz Center, 2002) (Exhibit 5-18). This acreage represents about 15 percent of the total cropland in the U.S. The acreage with the greatest potential for water erosion also decreased by about 33 percent to 89 million acres, which represents about 22 percent of U.S. cropland (The Heinz Center, 2002). Reductions in erosion can occur through improved tilling or management practices, taking marginal land out of production, participation in the Conservation Reserve Program, or similar activities. These reductions not only can contribute to increased soil quality, but also improved water quality in adjacent and downstream aquatic ecosystems.

Indicator Gaps and Limitations

This indicator provides estimates for the initiation of soil movement, not sediment transport or delivery off farmlands, which would require additional measurements and calculations. The distance the soil particles are moved might be considerable or minimal and cannot be determined from soil erosion estimates.

Data Sources

The data sources for this indicator were the National Resources Inventory, U.S. Department of Agriculture (1982-1997); and the State Soil Geographic Database (STATSGO), U.S. Department of Agriculture (1982-1997). (See Appendix B, page B-42, for more information.)

Exhibit 5-18: Croplands most prone to erosion, 1997

Croplands most prone to wind erosion, 1997

Croplands most prone to water erosion, 1997

Coverage: lower 48 states.

Note: data cover cropland and Conservation Reserve Program lands, but not pasture.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the USDA, Natural Resources Conservation Service.

Summary: The Ecological Condition of Farmlands

Farmlands represent a significant portion of the landscape, but their ecological condition nationally, or even for most regions, is unknown. In a limited number of watersheds in which agricultural lands are the predominant land use, data indicate that concentrations of nitrate, phosphorus, and many contaminants are above levels of concern, but these data are not available for a representative sample of streams that could serve as a baseline for water quality management decisions for the entire U.S. No data for national indicators are available for three of the six essential ecological attributes, and many of the indicators for the other EEAs relate primarily to crop or livestock production. Habitat alteration and constituent loading from farmlands represent some of the major stressors on other ecosystems (see Chapter 2, Purer Water, and Chapter 3, Better Protected Land, for discussion of specific stressors.)

Landscape condition

While there is no single, definitive, accurate estimate of the extent of cropland, it has been estimated to have decreased by 10.4 percent between 1982 and 1997, from about 421 million acres to nearly 377 million acres. Of this 44-million acre decrease, 32.7 million acres are now enrolled in the CRP, leaving an 11.3 million acre loss as a result of conversion of croplands to other land uses. The Heinz report assesses total cropland (including pasture and hayland) as covering between 430 and 500 million acres in 1997, or about a quarter of the total land area in the U.S. (excluding Alaska). In many areas of the U.S., other land cover types within croplands are almost as prevalent as croplands themselves and can provide habitat for non-agronomic species. For example, croplands comprise only half of the larger farmland ecosystems in the East and Southeast and about three-quarters of the farmland ecosystems in the Midwest. This situation suggests that much of the farmland in the country supports more biodiversity and associated ecological processes than if it were more completely monoculture. Indicators for fragmentation of farmland landscapes by development and the shape of "natural" patches in farmland landscapes would be helpful additional indicators of landscape condition (The Heinz Center, 2002).

Chemical and physical characteristics

The physical and chemical characteristics of farmlands could provide information to measure national progress in controlling and managing non-point source pollutant transport to receiving waters under EPA's clean water Government Performance and Results Act (GPRA) goal. Unfortunately, many of the indicators for physical and chemical characteristics are estimated based on land use, rather than on measurements of water quality. The National Water Quality Assessment (NAWQA) program provides consistent and comparable information on nutrient and pesticide concentrations in streams in agricultural areas. The data show that nitrate and phosphorus concentrations in farmland streams are generally higher than in urban and suburban streams, and that more than 80 percent of the streams sampled had at least one pesticide whose concentration exceeded guidelines for protection of aquatic life. The sites sampled do not represent a probability sample and are too few to ensure that these data are representative of farmlands nationwide. Additional stream monitoring networks are required to assess the physical and chemical characteristics of streams in agricultural areas and the effectiveness of agricultural management practices for protecting or improving stream quality. A *pesticide leaching potential* indicator and a *soil quality index* indicate that only 10 percent of the soils in the mid-Atlantic region were highly leachable with respect to pesticides, and that soil quality was in the "moderate" range, but the indicator has not been widely applied elsewhere.

Hydrology and geomorphology

Sediment Runoff results in loss of valuable soil from the farmland, sediment impacts to the physical habitat of farmland streams, and transport of many pollutants to downstream lakes, reservoirs, and estuaries. The highest potential for sediment runoff is concentrated in upper Mississippi River valley and the Ohio River valley. Most of the western U.S. region is characterized by low runoff potential. Between 1982 and 1997, the acreage with the greatest potential for water erosion decreased by about 33 percent to 89 million acres, which represents about 22 percent of U.S. cropland. Wind can also erode soil. The acreage of U.S. farmland with the greatest potential for wind erosion decreased by almost 33 percent to about 63 million acres from 1982 to 1997, about 15 percent of the total cropland in the U.S. There were no indicators of hydrology available for either surface or ground water associated with agricultural ecosystems. Modification or elimination of wetlands and riparian areas contributes to hydrologic alteration of farmlands, as does agricultural irrigation, primarily in the western states. This consumption affects not only surface water through irrigation return flows, but also ground water through depletion of aquifers. Both water quantity and quality can be affected in farmlands. No national, representative monitoring programs exist for either the quantity or quality of water in farmlands.

No Category 1 or 2 indicators were available for this report for *biotic condition, ecological processes,* or *natural disturbance regimes.* The Heinz Center (2002) suggested that several indicators could be promising: soil biological condition, status of animal species in farmland areas, native vegetation in areas dominated by cropland, and stream habitat quality. An indicator of ant diversity and wildlife habitat also was developed and tested in the mid-Atlantic region by the Mid-Atlantic Integrated Assessment Program (MAIA). Data are insufficient, however, to report on agroecosystems nationally for any of these indicators (Hellkamp, et al., 2000; The Heinz Center, 2002). A particular problem in farmlands is establishing appropriate reference conditions for biological structure and ecosystem function measures (The Heinz Center, 2002). Agricultural systems are highly managed ecosystems, so no natural reference exists. It would be unrealistic to expect fish and invertebrate communities in farmlands to be comparable to relatively undisturbed forest or grassland ecosystems.