Indicator 4.19:

Area and percent of forest land with significant soil degradation

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What is the indicator and why is it important?

Forest productivity and health are directly controlled by underlying soil conditions. Changes in soil conditions as a result of disturbances or land use activities may adversely impact forest productivity and health. The goal of this indicator is to quantify changes in soil quality resulting from climate changes, disturbances, or land use activities.

What does the indicator show?

Reporting for this indicator relies on the Forest Inventory and Analysis (FIA) Program's Soil Quality Indicator, which was developed to assess the condition and trend of soil quality on all U.S. forest lands, directly addressing Indicator 4.19. The FIA Program samples forest plots across the country on a rolling basis, collecting data on various forest characteristics, including soils, for a selected subsample of plots. These plots have been visited twice since the institution of the Soil Quality Indicator in the early 2000s.

Estimates of bare soil on FIA sample plots provide an indirect measure of soil erosion potential, which is also related to precipitation amounts and distribution, slope steepness and length, soil texture, and types of disturbances (Elliot et al. 2000). Most FIA plots have at least some bare soil with means of less than 10 percent of plot area in all regions except the Interior West (fig. 19-1). Areas with mostly bare soil are at highest risk of accelerated soil erosion but cover only a very small fraction of all forested lands. The soil compaction indicator only estimates the areal extent of visual evidences of compaction and does not measure compaction intensity. The impact of soil compaction on forest productivity is complex and depends on numerous factors, including soil texture, moisture content, and vegetation (Powers et al. 2005). Most plots exhibit only small areas of compaction with means of less than 10 percent of plot area in all regions except the South (fig. 19-1). Soil compaction is not a large areal extent problem on forested lands and is largely confined to trails and forest harvest operations.

Soils develop in response to several interacting factors: parent material, topography (landscape position), organisms, climate, and time. Many highly weathered residual and glaciated soils, which develop in warmer areas with ample precipitation, are less productive and have lower levels of organic matter and nutrients. Forests

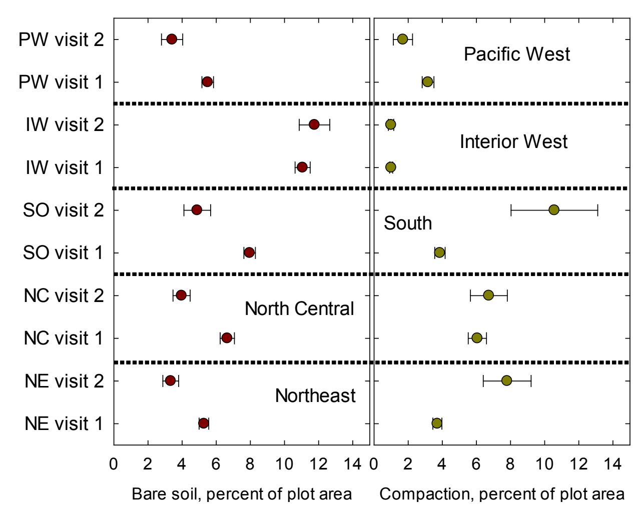

Figure 19-1—Mean ± standard error bare soil (left) and mean ± standard error compaction (right) as percent of FIA plot areas for major geographic regions and plot visit number. Data were collected in 2000–2012. Visits were conducted on a 5- or 10-year return interval depending on location (South, North Central, and Northeast = 5-year interval; Pacific West and Interior West = 10-year interval). IW = Interior West; NC = North Central; NE = Northeast; PW = Pacific West; SO = South.

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adapt to local soil conditions over time, but forests that develop on low-productivity soils may have a higher risk of soils-related forest health decline if subjected to additional environmental stressors and may be more prone to accelerated soil degradation if forest cover is lost.

The Soil Quality Index (SQI) in table 19-1 is an experimental index that integrates 19 separate measured physical and chemical properties into a single index number. It can be used to track soil quality spatial and temporal trends (Amacher et al. 2007). Soils with lower SQI levels (less than 50 percent) are at increased risk of soils-related forest health decline. These soils tend to be concentrated in the Northeast and South, where soils are more highly weathered and depleted of nutrients (fig. 19-2).

Nutrient-poor and acid forest soil conditions are found throughout the United States, but strongly acid soils with low calcium (Ca) and high aluminum (Al) levels are concentrated in the Northeast and South, primarily in the Appalachian regions (table 19-1). The most serious soils-related forest health threat is increasing soil acidity and associated decreasing soil Ca reserves, along with increasing potentially toxic levels of exchangeable Al. This soil condition is in part related to atmospheric acid deposition (Driscoll et al. 2001).

Critical loads have been calculated to identify the vulnerability of soils to atmospheric deposition. A critical load is a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge. Comparing these thresholds to current deposition rates of nitrogen and sulfur indicates that 21 percent of forested soils are exceeding their critical loads and are likely experiencing terrestrial acidification impacts (fig. 19-3). The locations of these critical load exceedances support the SQI results that suggest increased risks to forest health due to soil conditions in the Northeast and South regions.

Table 19-1—Percent of FIA Phase 3 plots (2000 – 2012) by region and plot visit number with less optimal soil conditions in the top 20-cm of soil and with increased risk of soils-related forest health decline. Visits were conducted on a 5- or 10-year return interval depending on location (South, North Central, and Northeast = 5-year interval; Pacific West and Interior West = 10-year interval).

	Northeast		North Central		South		Interior West		Pacific West	
	Visit 1	Visit 2	Visit 1	Visit 2	Visit 1	Visit 2	Visit 1	Visit 2	Visit 1	Visit 2
Soil Condition	Percent of plots									
SQI[2] < 50%	41.2	33.1	18.5	22.7	56.0	52.0	7.6	10.0	7.7	10.4
Organic C < 1 %	1.6	0.8	7.3	0.0	27.9	19.7	22.0	21.3	7.7	10.4
Total N < 0.1 %	10.4	21.2	23.9	37.8	62.6	62.4	38.8	41.0	27.3	37.4
Water pH < 4.0	15.8	22.0	1.6	2.5	4.0	4.6	0.0	0.2	1.9	2.5
Exch[1] K < 100 mg/kg	82.6	74.1	64.9	69.7	76.0	90.2	14.3	17.5	24.9	22.7
Exch Mg < 50 mg/kg	64.8	63.8	24.3	41.2	50.4	63.0	6.9	6.9	20.4	27.0
Exch Ca < 100 mg/kg	42.6	44.8	9.3	12.6	32.0	39.3	0.6	0.9	6.3	7.4
Exch Al > 100 mg/kg	75.2	81.9	26.5	26.1	31.0	23.7	6.6	4.7	23.5	22.1
Bray 1 P < 15 mg/kg	81.8	82.9	65.1	61.8	86.1	85.7	45.9	43.1	35.4	29.6
Olsen P < 10 mg/kg	54.8	60.0	35.9	42.9	90.9	88.9	54.2	52.8	36.5	33.1
% of plots resampled		11.5		14.7		9.9		36.2		23.4

[1]Exch = 1 M NH_4Cl exchangeable.
[2]SQI = soil quality index (< 50 % indicates increased risk of soils-related forest health decline).

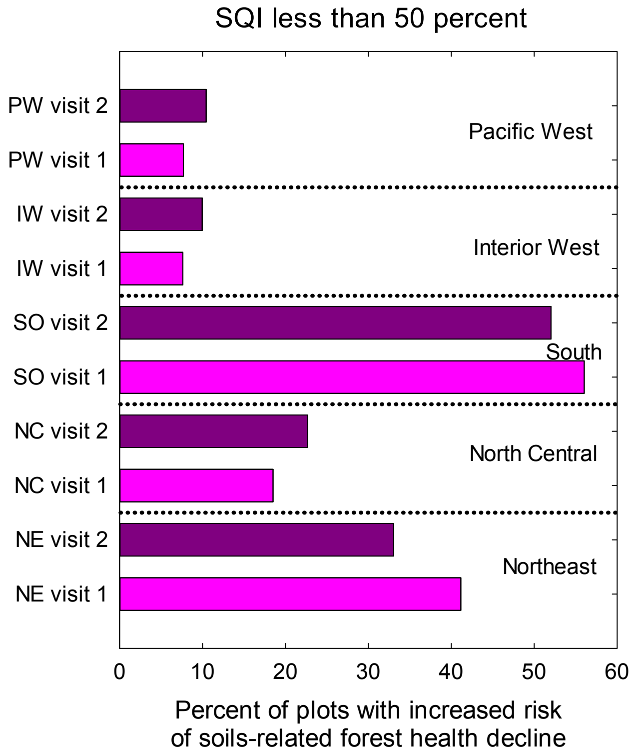

Figure 19-2—Percent of FIA plots with increased risk of soils-related forest health decline for major geographic regions and plot visit number. Data were collected in 2000–2012. Visits were conducted on a 5- or 10-year return interval depending on location (South, North Central, and Northeast = 5-year interval; Pacific West and Interior West = 10-year interval). IW = Interior West; NC = North Central; NE = Northeast; PW = Pacific West; SO = South; SQI = soil quality index.

What has changed since 2010?

About 10 to 36 percent of all plots sampled in visit 1 have been re-sampled for soil quality indictors since the previous report, depending on the region (table 19-1). Although re-sampling is still limited, less bare soil has been found in all regions except the Interior West (fig. 19-1). A slight increase in areal extent of compaction has been observed in the Northeast and South, but this is based on a limited number of re-measurements. In addition, there has been no decline in overall soil quality in all resampled areas in all regions, at least over the relatively short time period between samples (table 19-1 and fig. 19-2), however, more visits are required to establish a trend. The percentage of forested soils exceeding their critical load for terrestrial acidification has declined by 1.3 percent since 2010, and 7 percent since 2005, supporting the conclusion that there has been no significant decline in overall soil quality.

Are there important regional differences?

The Interior West tends to have more bare soil and less accumulated organic matter in forested areas than other regions, conditions that have been reinforced by the sustained drought occurring throughout much of the

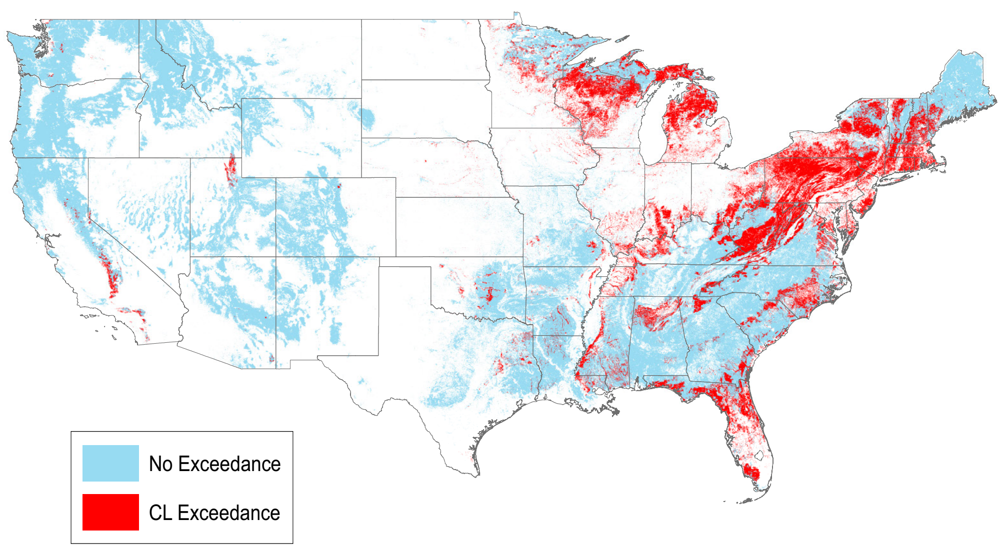

Figure 19-3—Locations of terrestrial acidification critical loads, with 2012 exceedances shown in red. Source: National Atmospheric Deposition Program, Critical Loads of Atmospheric Deposition Science Committee. CL = critical loads.

region in recent years (fig. 19-1). The extent of bare soil can fluctuate during a growing season and depends on physiographic location and plant communities and their condition. The Southern and Northeastern regions both showed an increase in soil compaction and, along with the North Central region, show more areas with evidence of soil compaction. The South has more highly weathered soils with lower organic matter and nutrients than other regions, and the South and Northeast have a large percentage of strongly acidic soils with low Ca and high Al levels. These conditions are clearly reflected in the relative SQI ratings and critical load exceedances for these regions. The Ca and Al data in table 19-1 indicate a developing soils-related forest health threat. Continued loss of Ca and increase in Al throughout the Northern and Southern Appalachians puts Ca-sensitive tree species at risk of decline and mortality. Even though southern forests are adapted to soil conditions in that region, the already low organic matter and nutrient status of these soils indicates that these forests may be more susceptible to impacts from additional stressors (e.g., industrial pollutants, drought, insects, and disease).

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