

Introduction

The soil quality indicator was initially developed as a tool for assessing (1) the current and future status of forest soil resources and (2) the contribution of forest soils to the global carbon cycle. The soil quality indicator, when combined with other data collected by the Forest Inventory and Analysis (FIA) program, can indicate the current rates of soil erosion, the extent and intensity of soil compaction, the thickness and properties of the forest floor, and the chemical composition and physical properties of the top 20 cm of soil. The data are collected using a variety of methods. Area of bare soil, useful in soil erosion potential prediction models, is estimated ocularly. Ocular estimates are also made of the area of compacted soil. Forest floor and soil samples are collected in the field and sent to regional laboratories for physical and chemical processing.

The national inventory for the soil quality indicator began in 1999, but the protocols were not finalized and formally implemented at a national scale until 2001 (U.S. Department of

Agriculture Forest Service 2002). The soil quality indicator is measured on a double-length phase 3 cycle. In any given State, soils are measured over a period of years, so that all phase 3 panels are measured. Over the next cycle of phase 3 measurements, soils are not measured in that State. This sampling schedule is designed to permit soil properties to respond to changing forest cover and climatic conditions before the soil profile is re-sampled. Since 2001, samples have been collected in most of the continental United States. The sample size will increase as inventories in these States are completed and additional States are inventoried. The changing sample size and refinement of the database management and estimation algorithms together suggest that the results presented here should be considered preliminary.

Why Are Physical Properties of the Soil Important?

The soil quality indicator, when combined with other data collected by the FIA program, can indicate the current rates of soil erosion, the extent and intensity of soil compaction,

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Chapter 8. Physical Properties of Forest Soils

CHARLES H. PERRY AND
MICHAEL C. AMACHER

and some basic physical properties of the forest floor and the top 20 cm of soil. In this report, two particular physical properties of the soil are presented: bare soil and soil compaction.

Soil erosion is the removal of soil from the land surface by agents such as wind and water. It is a natural process, and modest amounts of erosion may not affect forest health (Brady 1990, Liechty and others 2002). In contrast, accelerated erosion of mineral soil may be expected to reduce long-term forest productivity (Brady 1990, Merino and others 2004). Forest soils normally have adequate cover, such as forest floor and plant canopies, to protect them from erosion. The principal factors influencing soil erosion rates include climatic factors such as the amount and intensity of precipitation, the presence of bare soil, the soil texture, the slope of the soil surface, the length of the slope, and the occurrence of disturbances, such as fire and forest harvesting, that can alter soil properties. For this indicator, we are interested in assessing accelerated erosion due to disturbance events such as fire, forest harvesting, grazing, and recreational activities. Since the presence of bare soil can lead to accelerated soil erosion, it is the

key variable for assessing soil erosion potential and is an important input variable to soil erosion potential models such as the Watershed Erosion Prediction Project (U.S. Department of Agriculture Forest Service 2005).

Soil compaction is the crushing of soil aggregates leading to the reduction of pore space in the soil structure. As a consequence of soil compaction, soil aeration and water permeability are reduced, and roots have greater difficulty penetrating compacted layers to obtain the water, oxygen, and nutrients they need for optimal plant growth and vigor (Brady 1990).

Methods

Bare soil and soil compaction measurements were completed in the field according to well-documented ocular estimation procedures.¹ Soil field observation data from 2001 and 2002 were available for these analyses (fig. 8.1). The percent bare soil and percent compacted area were estimated on each of four subplots per plot. Additional details on field measurements, laboratory processing, and estimation procedures are available² (O'Neill and others 2005). The distribution of values of percent cover of

¹ U.S. Department of Agriculture, Forest Service. 2002. Forest inventory and analysis national core field guide: field data collection procedures for phase 3 plots, version 1.7. U.S. Department of Agriculture, Forest Service, Washington Office. Internal report. Vol. 2. On file with: U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis, Rosslyn Plaza, 1620 North Kent Street, Arlington, VA 22209.

² The current version of the *Forest Inventory and Analysis National Core Field Guide* is available online at <http://fia.fs.fed.us/library/field-guides-methods-proc/>.

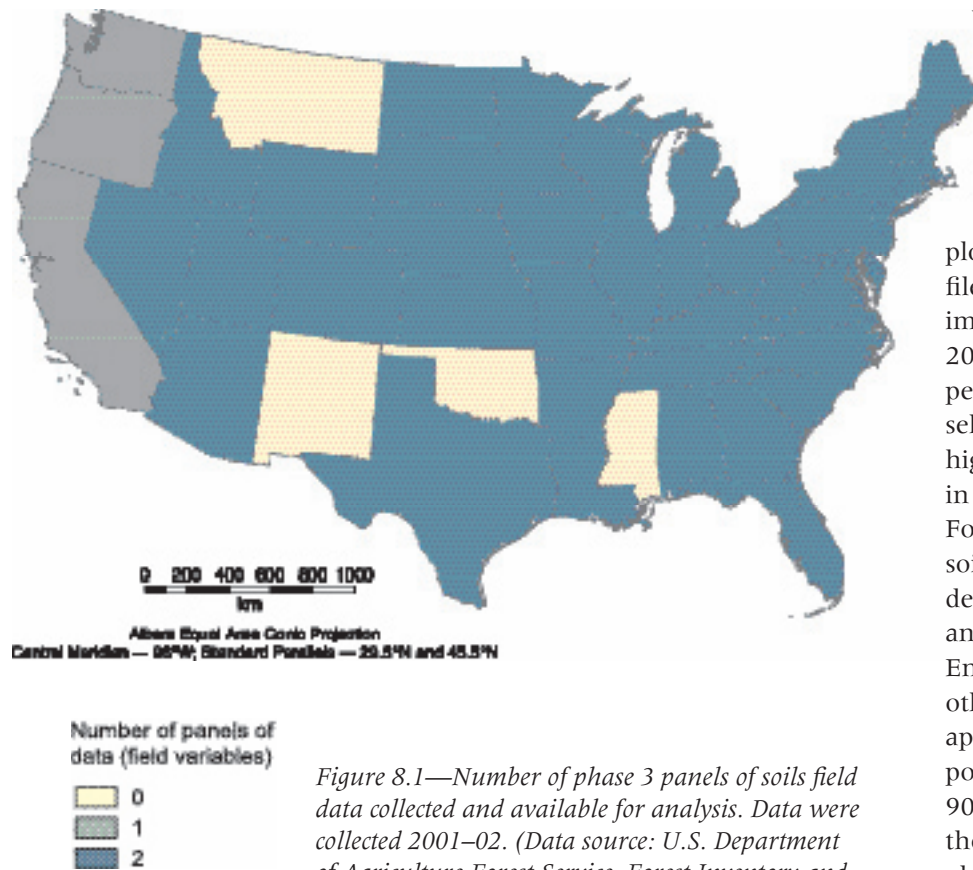


Figure 8.1—Number of phase 3 panels of soils field data collected and available for analysis. Data were collected 2001–02. (Data source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis program.)

bare soil and percent compacted area were analyzed considering each subplot estimate to be a single observation.

Numeric data were imported into R, a data analysis and graphics package (Venables and others 2005), for statistical analysis and plotting. Spatially explicit comma-delimited files were also exported from the database and imported into ArcMap (Harlow and others 2004). The maximum percent bare soil and percent compacted area on each plot were selected from the four subplot observations. The highest subplot value was reported for each plot in order to focus on areas of potential concern. For mapping purposes, the plot maxima for each soil property were then assigned to hexagons developed by the Environmental Monitoring and Assessment Program (EMAP) of the U.S. Environmental Protection Agency (White and others 1992). Each hexagon has an area of approximately 648 km², and hexagon center points are roughly 27 km apart. Approximately 90 percent of the hexagons had only one plot in them; the remaining 10 percent contained two observations, which were averaged.

What Do the Data Show?

Bare soil is not a common problem in the forests of the United States. The maximum observed bare soil fraction is 10 percent or less on half of the plots nationwide; the third quartile (75th percentile) is 25 percent bare soil (fig. 8.2). There are regional differences in the amount of exposed bare soil (fig. 8.3). The Northeastern United States and the Pacific Northwest (west of the Cascade Range) have little exposed soil. There are isolated pockets of bare soil in the Midwest, with a noticeable concentration in Wisconsin that requires further investigation. Bare soil is concentrated in the more arid Interior West, where lower precipitation levels lead to less plant canopy and forest floor cover.

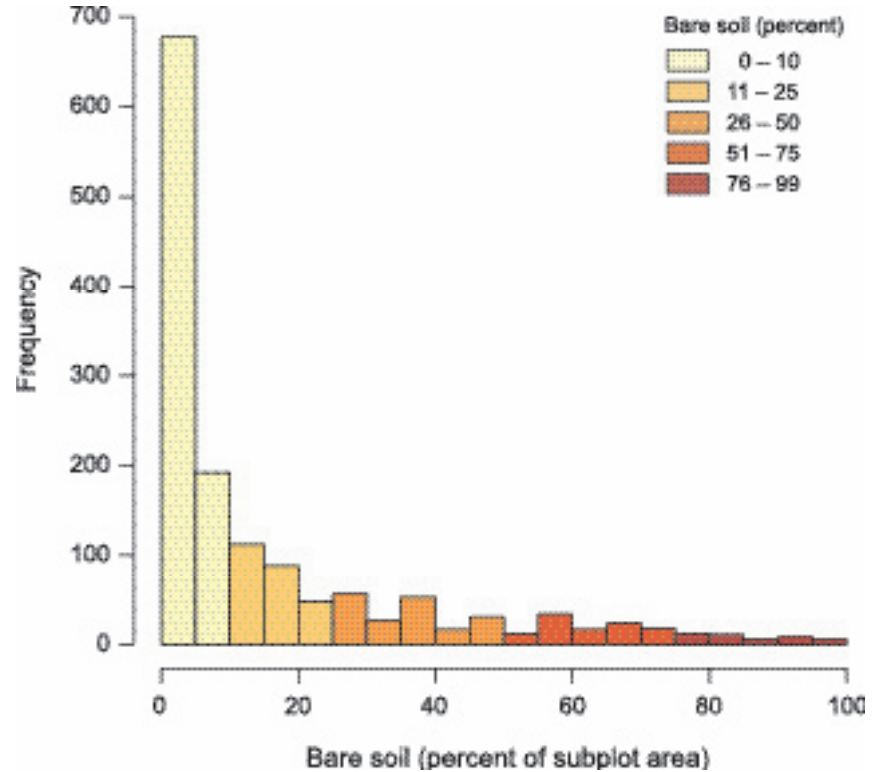


Figure 8.2—Distribution of bare soil observations (2001–02). Each observation represents the maximum percent bare soil recorded on any of four subplots on each plot. (75th percentile = 25 percent, mean = 17 percent, median = 10 percent, 25th percentile = 1 percent bare soil.) The colors represent the same bare soil percentages they represent in figure 8.3. (Data source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis program.)

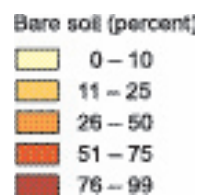
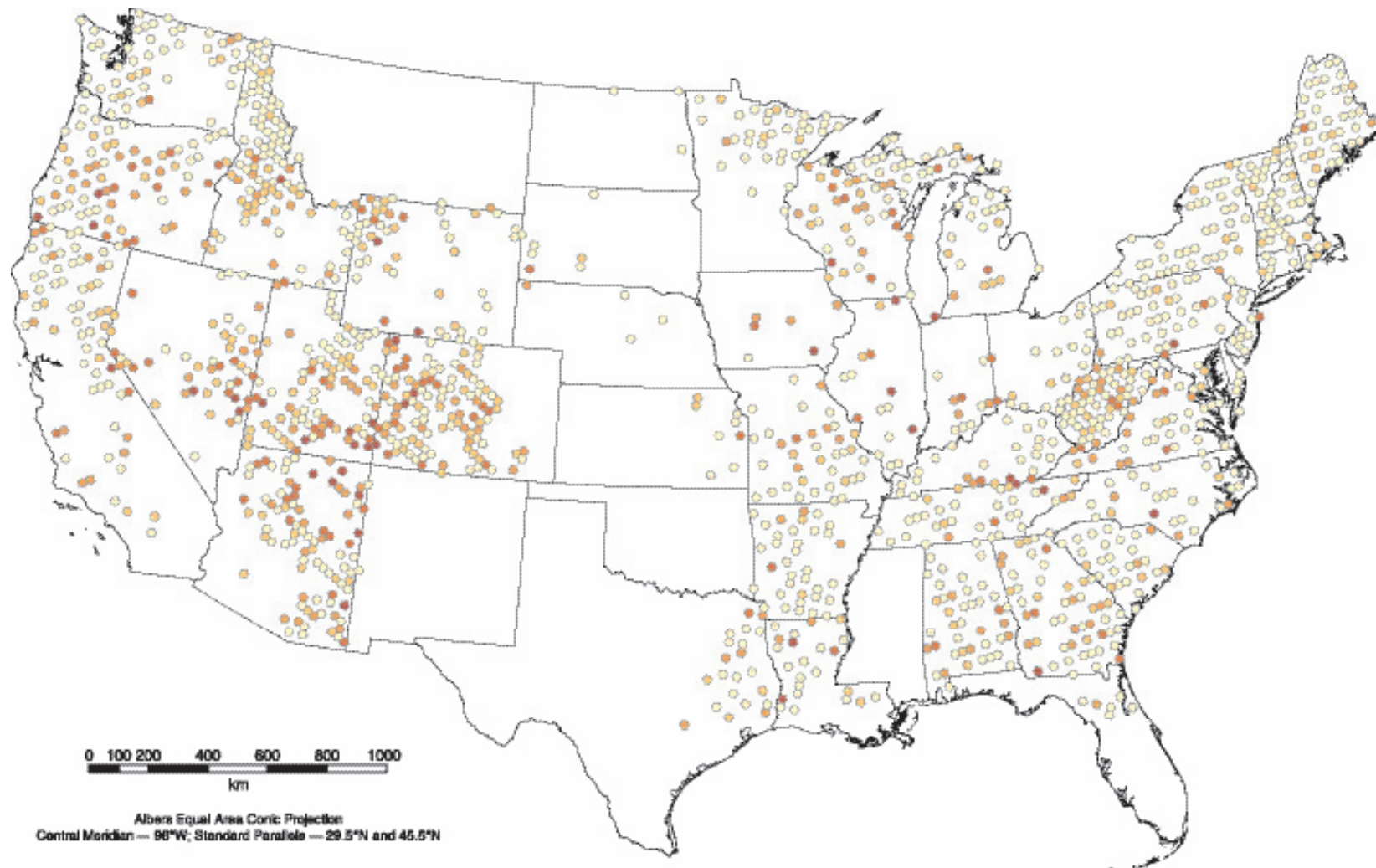


Figure 8.3—Bare soil observations (2001–02) by Environmental Monitoring and Assessment Program (EMAP) hexagon (White and others 1992). Values shown represent the average of the maximum percent bare soil observed on each plot in the EMAP hexagon. (Data source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis program.)

Like bare soil, soil compaction is not generally a problem in the forests of the United States. Half of the plots have no measurable areas of soil compaction (fig. 8.4). The 1,439 measurements are summarized into 387 EMAP hexagons for mapping purposes. Because only the maximum subplot values of percent compacted area for each plot are averaged for each EMAP hexagon, the values shown on the map (fig. 8.5) are skewed towards higher values of soil compaction. For this reason, the map identifies areas where soil compaction may be a problem rather than quantifying the extent of any such problem.

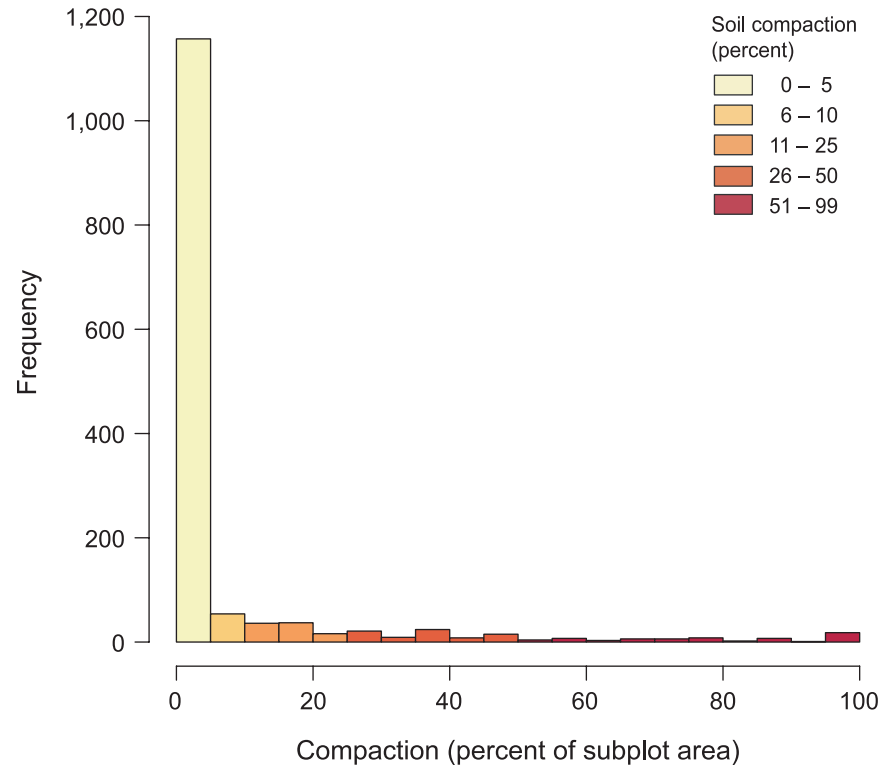


Figure 8.4—Distribution of soil compaction observations (2001–02). Each observation represents the maximum percentage of subplot area compacted recorded on any of four subplots on each plot. (75th percentile = 5 percent, mean = 7.4 percent, median = 0 percent, 25th percentile = 0 percent of area compacted.) The colors represent the same compaction percentages they represent in figure 8.5. (Data source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis program.)

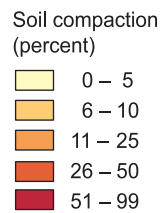
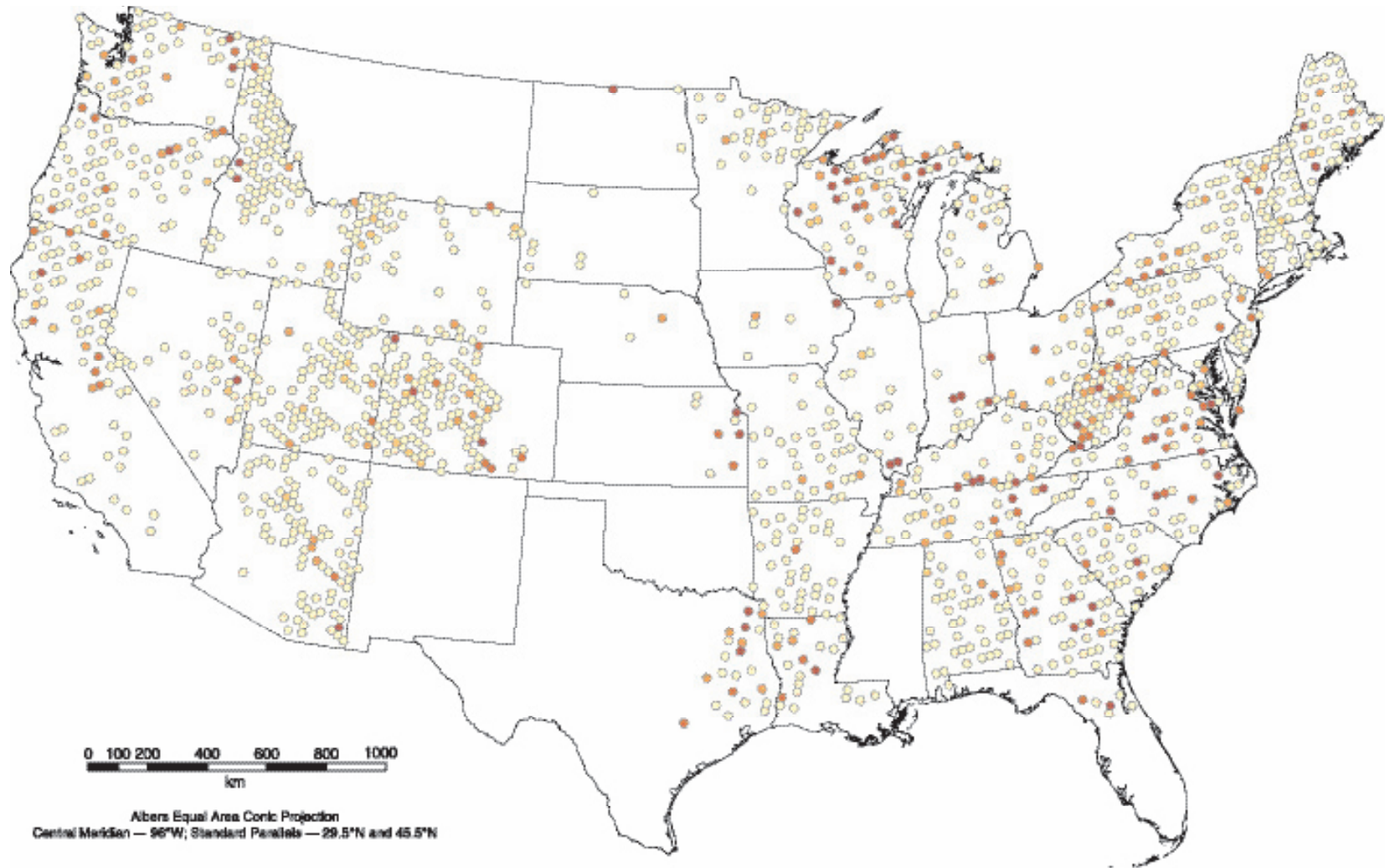


Figure 8.5—Soil compaction observations (2001–02) by Environmental Monitoring and Assessment Program (EMAP) hexagon (White and others 1992). Values shown represent the average of the maximum percent compaction observed on each plot in the EMAP hexagon. (Data source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis program.)

Literature Cited

- Brady, N.C. 1990. The nature and properties of soils. 10th ed. New York: Macmillan. 621 p.
- Harlow, M.; Pfaff, R.; Minami, M. [and others]. 2004. Using ArcMap: ArcGIS 9. Redlands, CA: ESRI Press. 598 p.
- Liechty H.O.; Shelton, M.G.; Luckow, K.R.; Turton, D.J. 2002. Impacts of shortleaf pine-hardwood forest management on soils in the Ouachita highlands: a review. *Southern Journal of Applied Forestry*. 26(1): 43-51.
- Merino, A.; Fernandez-Lopez, A.; Solla-Gullon, F.; Edeso, J.M. 2004. Soil changes and tree growth in intensively managed *Pinus radiata* in northern Spain. *Forest Ecology and Management*. 196(2-3): 393-404.
- O'Neill, K.P.; Amacher, M.C.; Perry, C.H. 2005. Soils as an indicator of forest health: a guide to the collection, analysis, and interpretation of soil indicator data in the Forest Inventory and Analysis program. Gen. Tech. Rep. NC-258. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 53 p.
- U.S. Department of Agriculture, Forest Service. 2002. Forest Inventory and Analysis fiscal year 2001 business report. FS-747. Washington, DC: U.S. Department of Agriculture, Forest Service. 31 p.
- U.S. Department of Agriculture, Forest Service. 2005. Forest Service WEPP. Available at: <http://forest.moscowfsl.wsu.edu/fswapp/> [Date accessed: June 21, 2005].
- Venables W.N.; Smith D.M.; the R Development Core Team. 2005. An introduction to R, notes on R: a programming environment for data analysis and graphics, Version 2.1.1 (2005-06-20). <http://www.r-project.org/> [Date accessed: June 21, 2005]. 90 p.
- White, D.; Kimerling, A.J.; Overton, W.S. 1992. Cartographic and geometric components of a global sampling design for environmental monitoring. *Cartography and Geographic Information Systems*. 19(1): 5-21.