Soil-Forming Factors

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Alfred E. Hartemink
University of Wisconsin–Madison

3 Soil-Forming Factors

3.1 Introduction

The expression of a soil results from five factors operating collectively: climate, organisms, relief, parent material, and time (Fig. 3.1). The factors are interacting over time and cause a range of soil processes (e.g., illuviation) that result in a diversity of soil properties (e.g., high clay content in the subsoil). Human activities that result in soil changes are often considered a sixth factor. Following the "Russian school of soil science," Kellogg (1930) illustrated the importance of geology, climate, and native vegetation on the distribution of soils in Wisconsin. Nygard et al. (1952) related the general distribution of soils in the northern Great Lakes region to climate, vegetation, and parent materials. The following is a review of the role of soil-forming factors in the development of Wisconsin soils.

3.2 Climate

3.2.1 Previous Work

Climate influences the soil development through differences in mean annual, seasonal, and extremes in temperature and moisture. Hole (1976) emphasized the importance of climate in the distribution of soils in Wisconsin: Spodosols are present in the north (Fig. 3.2); a transition zone with bisequal soils occurs in the central region, and Alfisols and Mollisols are predominant in the south (Fig. 3.3). The line separating soils in the frigid and mesic soil-temperature classes (8 °C mean annual soil temperature at the 50-cm depth) extends across what is known as the "Wisconsin Tension Zone" (Curtis 1959) (Fig. 3.4). The tension zone occupies an area of 18,500 km^2 and has a high biodiversity, with both northern and southern plants and animals occurring within it. The boundary between the mesic and frigid soil-temperature regimes roughly approximates the mean July temperature isotherm of 21 °C.

3.2.2 Current Climate

The Wisconsin State Climatology Office has a collection of data that extend back into the nineteenth century. There are presently nearly 200 stations that provide maximum and minimum temperature readings along with precipitation data on a daily basis.

Wisconsin lies in the temperate continental climatic zone. According to the Köppen–Geiger climate classification system, Wisconsin has a Dfa climate in the southern part of the state and a Dfb in the north. Southern Wisconsin has hot, wet summers and cool-to-cold, wet winters, whereas

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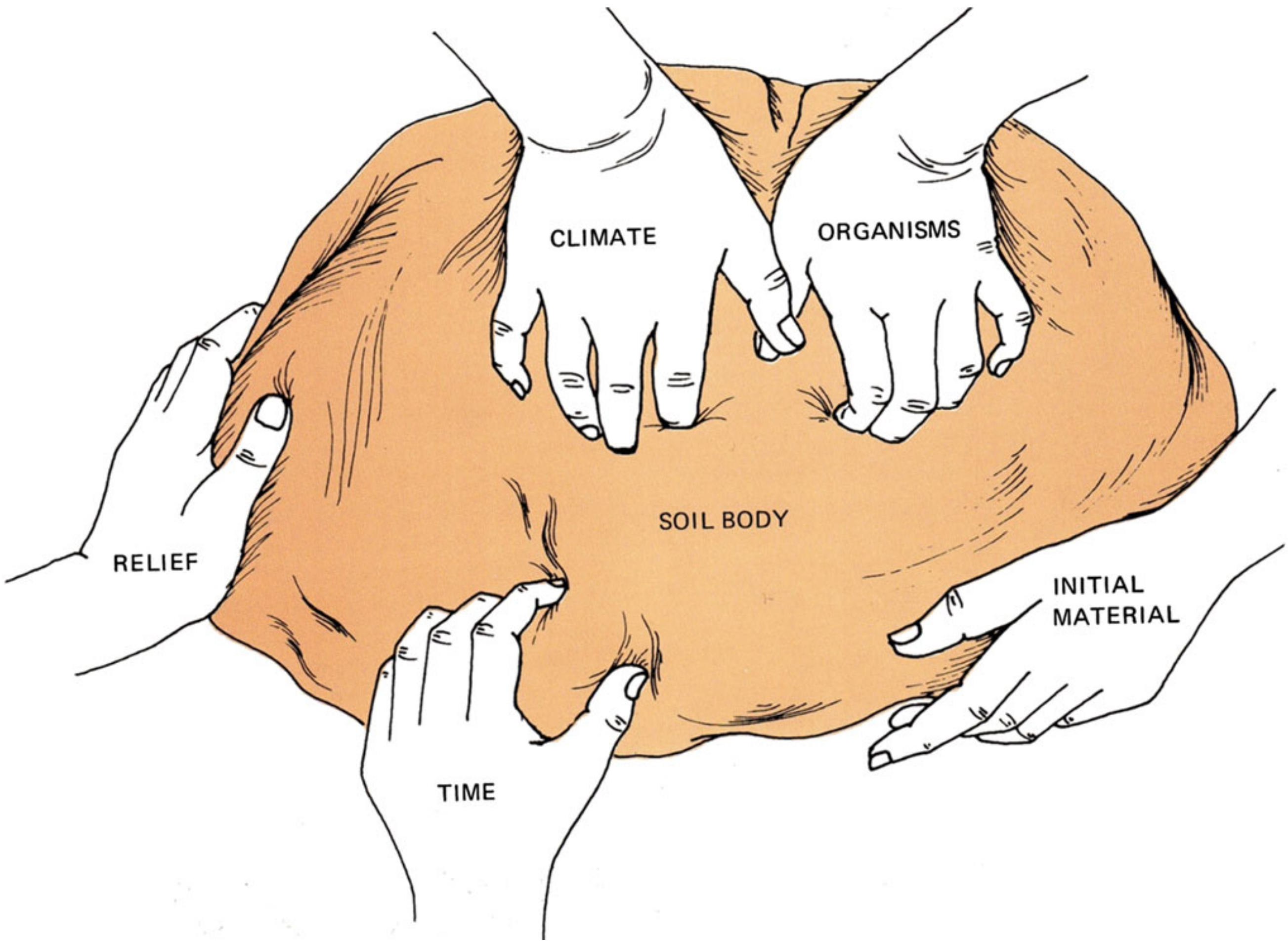

Fig. 3.1 The Five soil-forming factors (From Hole 1980). Climate and organisms are often considered active factors, whereas relief, time, and initial or parent material are considered more passive soil forming factors

northern Wisconsin has warm, wet summers and cold, wet winters. The mean annual temperature ranges from 4.0 °C in Ashland County in the far north to 9.4 °C in Grant County along the Mississippi River in southwestern Wisconsin (Fig. 3.5). Mean annual precipitation ranges from 740 mm in Florence County in the far northeast to 960 mm in Green County in southcentral Wisconsin (Fig. 3.6). Mean annual snowfall ranges from 81 cm in southern Rock County near the Illinois line to 425 cm in northern Iron County near the Upper Peninsula of Michigan (Fig. 3.7).

3.2.3 Past Climates

Wisconsin's climate has changed dramatically over the past 2.1 million years (Quaternary Period). A dozen or so glaciations covered most of the state, except for the Driftless Area in southwestern Wisconsin (see Sect. 3.5.3). The mean annual temperature was about 5.6 °C colder during the last glaciation, the Wisconsinan, approximately 14,000–20,000 years ago (Weaver et al. 1998). During the Holocene Climatic Optimum, approximately 9000–5000 years ago,

Fig. 3.2 Spodosol under Hemlock at Kemp station in Oneida County in North Wisconsin

Fig. 3.3 Alfisol developed in outwash (*top picture*) and Mollisol developed in loess (*bottom picture*)

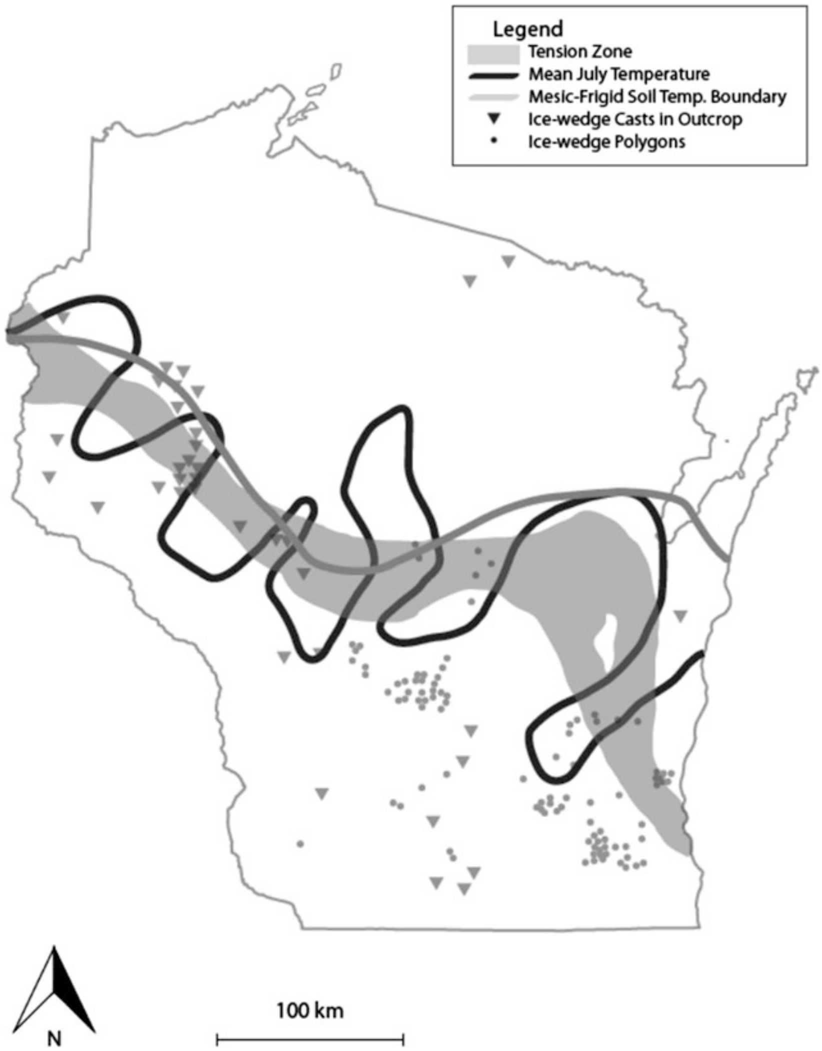

Fig. 3.4 Wisconsin's tension zone (from Bockheim and Schliemann 2013). The solid line is the 21 °C isotherm for July

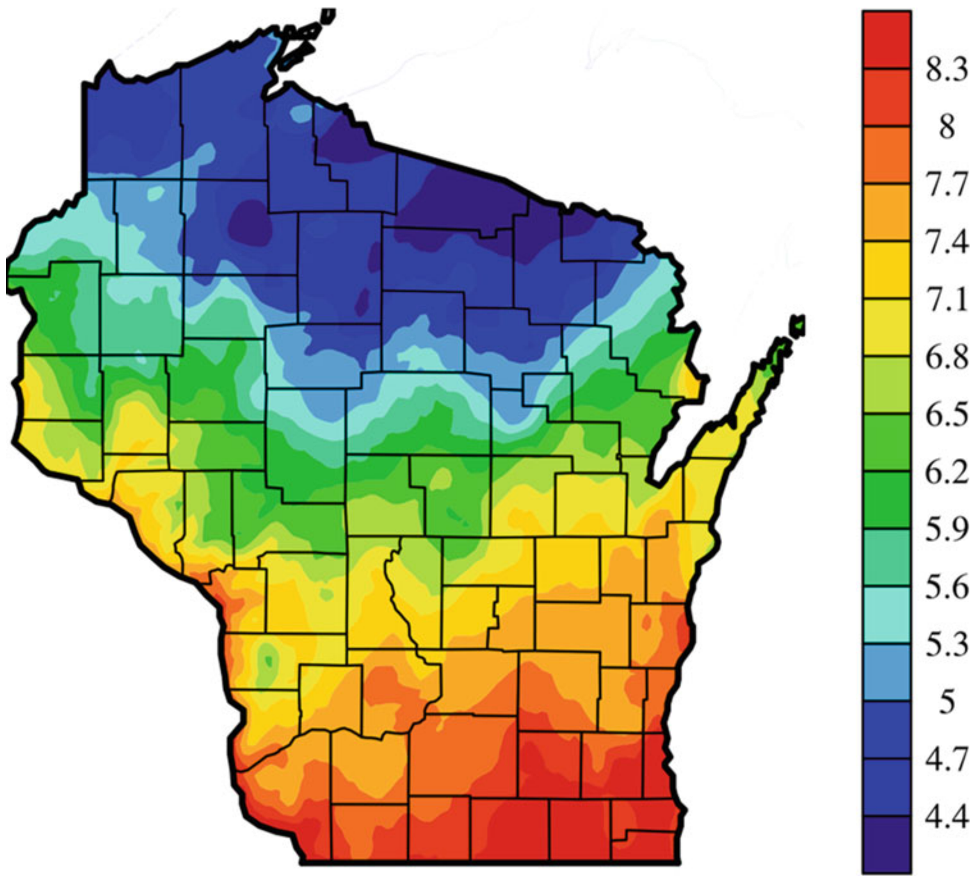

Fig. 3.5 Mean annual air temperature patterns (°C) in Wisconsin over the period 1950–2010. Data from the PRISM Climate Group (http://prism.oregonstate.edu)

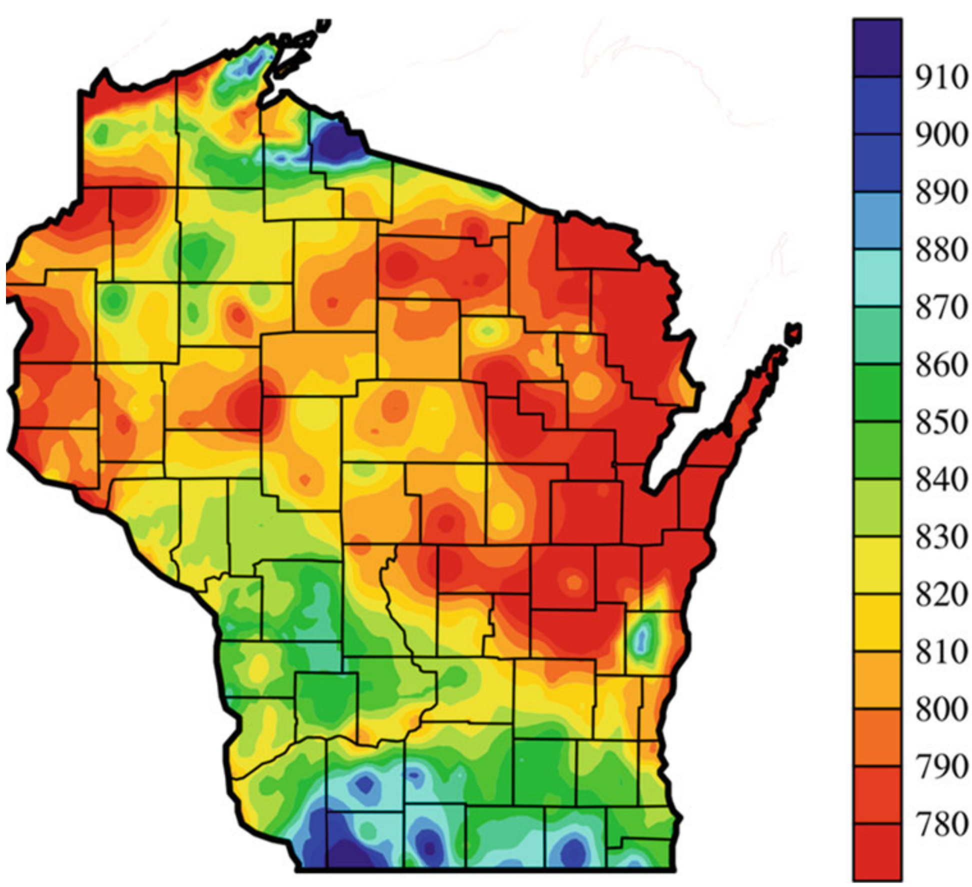

Fig. 3.6 Mean annual precipitation patterns (mm) in Wisconsin over the period 1950–2010. Data from the PRISM Climate Group (http://prism.oregonstate.edu)

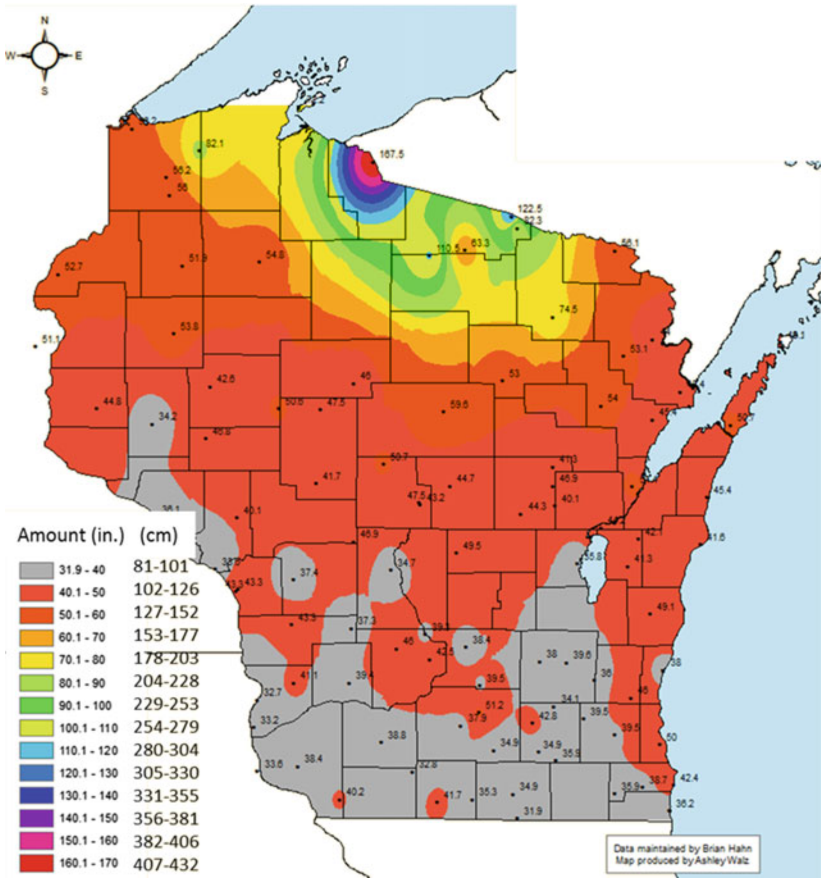

Fig. 3.7 Annual snowfall patterns (inch and cm) in Wisconsin over the interval 1981–2010. Values at specific points are reported in inches

the mean annual air temperature may have been 4 °C warmer than at present (Baker et al. 1992). These climate changes are evidenced in the fossil pollen record (Graumlich and Davis 1993), buried soils (paleosols) (see Chap. 14), and relict periglacial features such as patterned ground (Black 1964). The impact of the past climates is still present in the soils and includes, for example, sand-wedge casts in B and C horizons of some soils (Fig. 3.8), and the widespread presence of fragipans in northern Wisconsin that may have been formed partly under permafrost conditions (Hole 1976).

3.2.4 The Changing Climate

The Wisconsin Initiative on Climate Change Impacts (WICCI) Task Force prepared a comprehensive report in 2011, describing changes in Wisconsin's climate over the

Fig. 3.8 Sand-filled frost wedge in a Typic Argiaquolls, O'Briens farm, Dane County

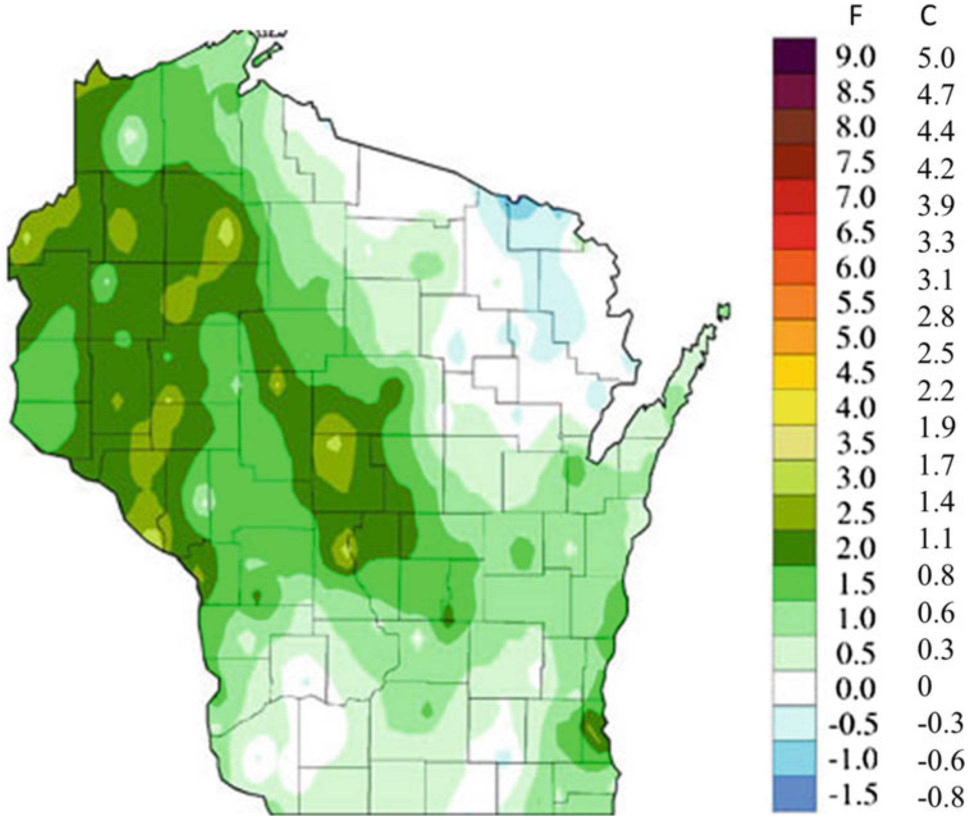

Fig. 3.9 Changes in mean annual air temperature (°F and °C) in Wisconsin over the period 1950–2006 (WICCI 2011)

period 1950–2006. During this period, the mean annual air temperature increased up to 1 °C in primarily the western part of the state (Fig. 3.9). Wisconsin winters have warmed more than any other season in recent decades, particularly in the northwestern part of the state. The length of the growing season has increased by as much as four weeks in parts of the state. The mean annual precipitation has increased by up to 178 mm over the past 56 years, especially in western and southcentral Wisconsin (Fig. 3.10).

Using climate simulation models, the task force projected up to a 4 °C increase in average annual temperature throughout the state by 2055 (Fig. 3.11). In view of the strong influence of climate on soils, we can expect changes in soil properties and distribution. It will also result in changing land use with increased areas under corn and soybeans in the northern part of the state. Such change in land use will also alter the soils. This is further discussed in Chap. 16.

3.3 Organisms

3.3.1 Past Work

Plants and animals influence soil development. Hole (1961) provided one of the first classifications of pedoturbations (soil mixing) from plants, animal, and humans. Nielsen and Hole (1963) compared the influence of prairie and forest vegetation on the distribution and cycling of organic matter on long-term plots in the University of Wisconsin Arboretum. Although the total amount of organic matter in the two ecosystems was similar, 54% was present in the

Fig. 3.10 Changes in mean annual precipitation (cm) in Wisconsin over the period 1950–2006 (WICCI 2011)

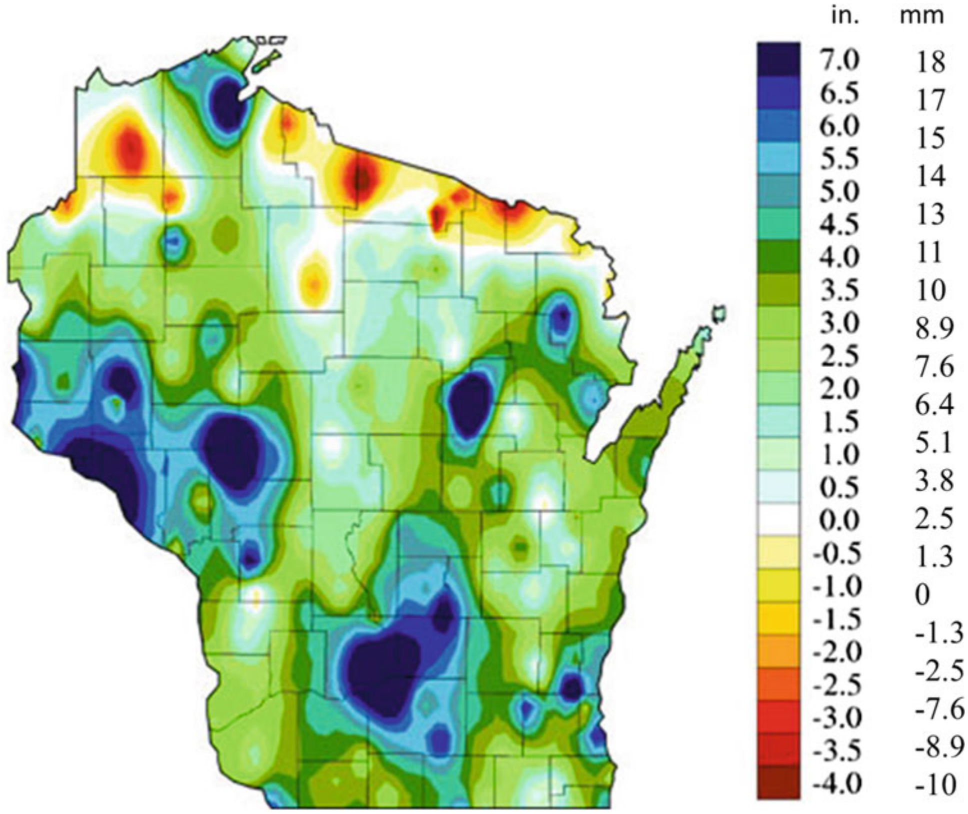

Fig. 3.11 Projected increase in mean annual air temperature in Wisconsin (°C) over the period 1980–2055 (WICCI 2011)

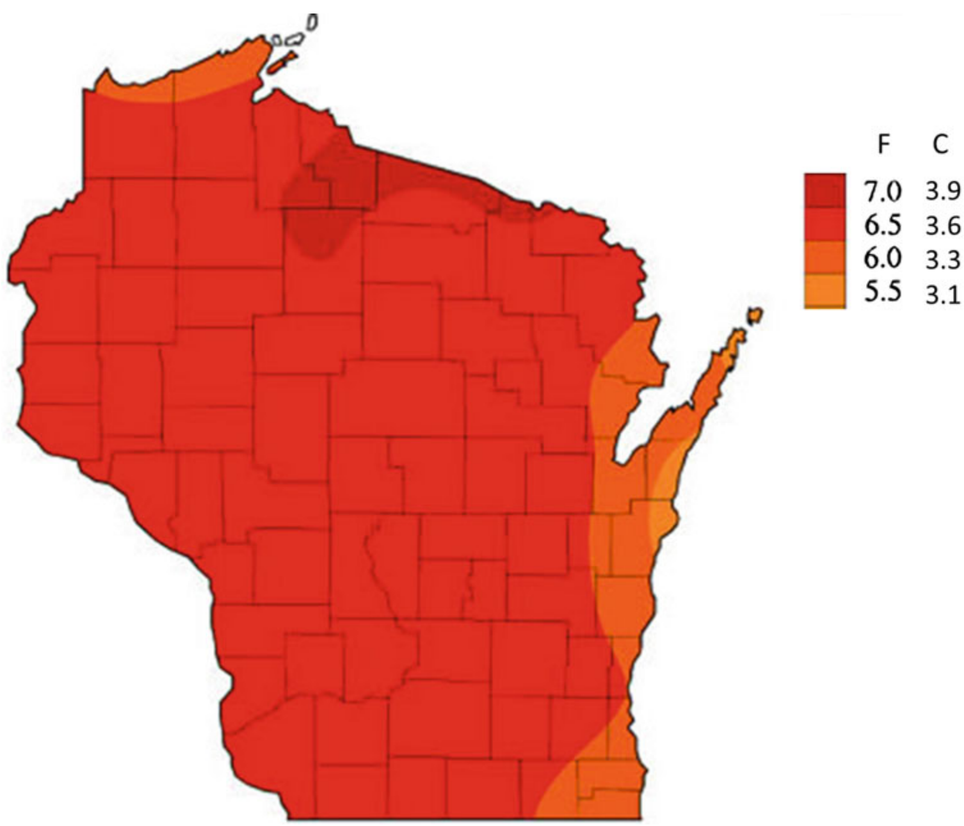

Table 3.1 Comparison of vegetation classification systems used in Wisconsin

Curtis (1959)[1]	% Area	Cottam and Loucks (1965)[2]	USFS (no date)	This study	% Area
Southern Mesic Forest	9.8	Southern Mesic Forest	Beech, sugar maple, basswood, red oak, white oak, black oak	Mixed hardwoods	7.1
			Sugar maple, basswood, red oak, white oak, black oak		
Southern Xeric Forest	4.0	Southern Oak Forest	Oak—white oak, black oak, bur oak	Mixed oaks	1.4
				Oak-hickory	11.4
Southern Lowland Forest	1.2	Lowland Hardwood	Lowland hardwoods—willow, soft maple, box elder, ash, elm, cottonwood, river birch	Wet hardwoods	3.2
Northern Mesic Forest	33.6	Northern Mesic Forest	Hemlock, sugar maple, yellow birch, white pine, red pine	Mixed forest	16.8
			Sugar maple, yellow birch, white pine, red pine	NHW (Northern Hardwoods)	18.4
			Aspen, white birch, pine	NHW-H (Northern Hardwoods-Hemlock)	9.8
Northern Xeric Forest	6.5	Pine Forest	White pine, red pine	Mixed pines	0.6
Northern Lowland Forest	6.4	Conifer Swamps	Swamp conifers—white cedar, black spruce, tamarack, hemlock	Wet conifers	2.3
				Wet mixed forest	6.1
Boreal Forest	1.9	Boreal Forest	White spruce, balsam fir, tamarack, white cedar, white birch, aspen	Boreal forest	1.6
Prairie	6.0	Prairie	Prairie	Prairie	5.8
Oak Savanna	20.7	Oak Savanna	Oak openings—bur oak, white oak, black	Oak savanna	3.5
Pine Barrens	6.7	Pine Barrens	Jack pine, scrub (hill's) oak forests and barrens	Oak-pine	6.8
Sedge Meadow	3.2	Sedge Meadows	Marsh and sedge meadow, wet prairie, lowland shrubs	Marsh	5.1

[1]Curtis (1959). The Vegetation of Wisconsin: an Ordination of Plant Communities. Univ. of Wisconsin Press, Madison, WI
[2]Cottam and Loucks (1965). Early Vegetation of Wisconsin. Univ. of Wisconsin-Extension, Geological and Natural History Survey
[3]US Forest Service. Wisconsin Original Vegetation. Great Lakes Ecological Assessment (http://www.ncrs.fs.fed.us/gla/histveg/wi-orveg.htm)

aboveground biomass of the mixed oak forest and 90% was present in the soil of the tallgrass prairie (Table 3.1).

Hole (1975) showed the effects of different forest vegetation on the development of B horizons in soils of the Menominee Tribal Lands, Wisconsin. Broad-leaved vegetation was important in the development of argillic (Bt) horizons, and coniferous vegetation was associated with the development of spodic (Bs) horizons. The complex mosaic of forest cover types results in striking differences in soils in the upper Great Lakes region (Bockheim 1997). Individual tree species influenced base cation distribution and cycling in Typic Haplorthods in the Upper Great Lakes region (Fujinuma et al. 2005). Pastor et al. (1982) illustrated the importance of vegetation on the distribution of soil taxa on a small (70 ha) island (Blackhawk Island) in the Wisconsin River (Fig. 3.12). Blackhawk Island is a wooded island in the Wisconsin River, which has cut deep narrow gorges in the Cambrian sandstone. The soils are dominated by sands and sandy loams of eleven different soil series. The island has several community types, all relatively undisturbed, with white oak, red oak, white pine, sugar maple, basswood, hemlock, white cedar, yellow birch, river birch, cottonwood,

Fig. 3.12 Trees on shallow soils over Cambrian sandstone and wind-thrown trees at Blackhawk island

and red maple, each found dominating in specific areas. Especially common are ferns; nearly one-third of the taxa of Wisconsin are present.

In a southern Wisconsin mixed oak forest, the giant earthworm (*Lumbricus terrestris*), an introduced species that has replaced the native earthworms, formed a coprogenic A horizon in as little as 30 to 40 years (Nielsen and Hole 1964). In a southern Wisconsin prairie, ants (*Formica cinerea*) play an important role in the soil development by constructing mounds, creating channels, and transporting materials (Baxter and Hole 1967) (Fig. 3.13).

3.3.2 Pre-settlement Vegetation

When the first French settlers arrived in 1634, most of the state was still covered with forest (Campbell 1906). At the beginning of the twentieth century, most of the natural forest had been logged (Whitson 1927). At the time of settlement by Europeans in the 1830s, Wisconsin was 63% forested, with 27% of the state land area in savanna and 10% in prairie and sedge meadow (Fig. 3.14). This map is based on the original land survey conducted around 1850 and systematic studies by Curtis (1959). The dominant forests were temperate mixed deciduous and conifers in northern Wisconsin that were comprised of eastern hemlock (*Tsuga canadensis*), sugar maple (*Acer saccharum*), yellow birch (*Betula alleghaniensis*), red pine (*Pinus resinosa*), and white pine (*Pinus strobus*) (40%). In southern and parts of western Wisconsin, the mesic forests were comprised of sugar maple, basswood (*Tilia americana*), red oak (*Quercus rubra*), white oak (*Quercus alba*), and black oak (*Quercus velutina*) (10%). Oak savannas or openings contained bur oak (*Quercus macrocarpa*), white oak, and black oak (21%). Pine-oak barrens composed of jack pine (*Pinus banksiana*), and Hill's oak (*Quercus ellipsoidalis*) occupied 7% of the land area.

3.3.3 Present Vegetation

At the present time, agricultural land occupies 46% of Wisconsin's total area, followed by forest (38%), wetlands (10%), with lesser areas in water (3%), urban and residential development (2%), and barrens (1%) (Figs. 3.15 and 3.16). The forest cover of the state has been reduced by 25%, native prairies by 6%, and oak savannas and pine-oak barrens by 25%. As of 2013, 77% of the land area of Wisconsin is privately owned, followed by the state (10%), county (7%), and federal government (5%) (Fig. 3.17). Forest land comprises 48% of the state, with 62% in private, non-industrial ownership, followed by county forests (14%), federal forests (10%), state forests (7%), private industrial forests (5%), and tribal lands (2%).

3.3.4 Vegetation and Soil Development

Vegetation is an important factor closely related to climate that is important in the development of Wisconsin soils: Alfisols occur under temperate deciduous forests; Spodosols are present under temperate mixed deciduous and conifer forests (especially where hemlock is a key component); Entisols are present under pine-oak barrens; Mollisols represent former prairies, and Histosols and wet mineral soils occur in stream bottoms and major wetlands (Fig. 3.18).

3.4 Relief

The influence of relief, or topography, includes elevation, aspect, and position on slope. The weathering of layer silicates was influenced by slope position in a catena of soils in southeastern Wisconsin (Borchardt et al. 1968). The more intensely leached upland soil had less amount of mica and greater amount of kaolinite than soils in the lower topographic position. To display landform elements of a valley in southwestern Wisconsin, Irvin and others (1997) showed the utility of "fuzzy set" ISODATA and a digital terrain model. Park et al. (2001) used a geographic-information system and a digital elevation model to provide a three-dimensional extension of a nine-unit soil landscape model for southern Wisconsin.

Dense, subsurface horizons similar to fragipans have formed in depressions in loess-covered till plains of southern Wisconsin (Park et al. 2006). Soils containing red clays (*Terra Rossa*) occur throughout the Driftless Area of Wisconsin, except in valley bottoms where loess deposition created a surface mantle in excess of 2 m (Evans and Hartemink 2014) (Fig. 3.19). One study suggested there were

Fig. 3.13 Ant hill in a restored prairie in southern Wisconsin, an earthworm in the glossic horizon of an Alfisol in central Wisconsin, and filled in earthworm tunnel with casts (scale in cm and inches)

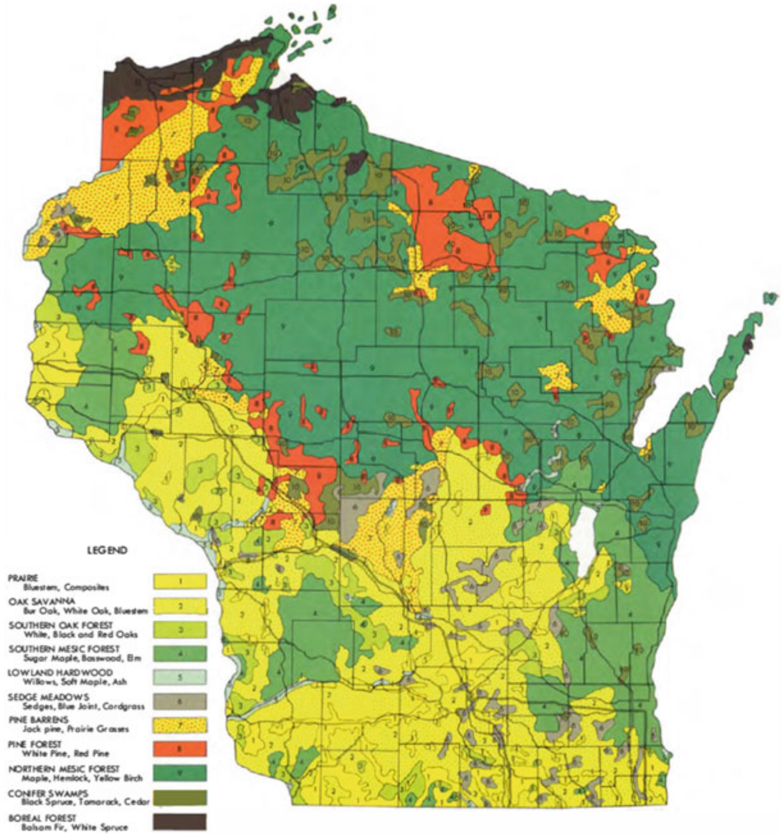

Fig. 3.14 Early vegetation of Wisconsin

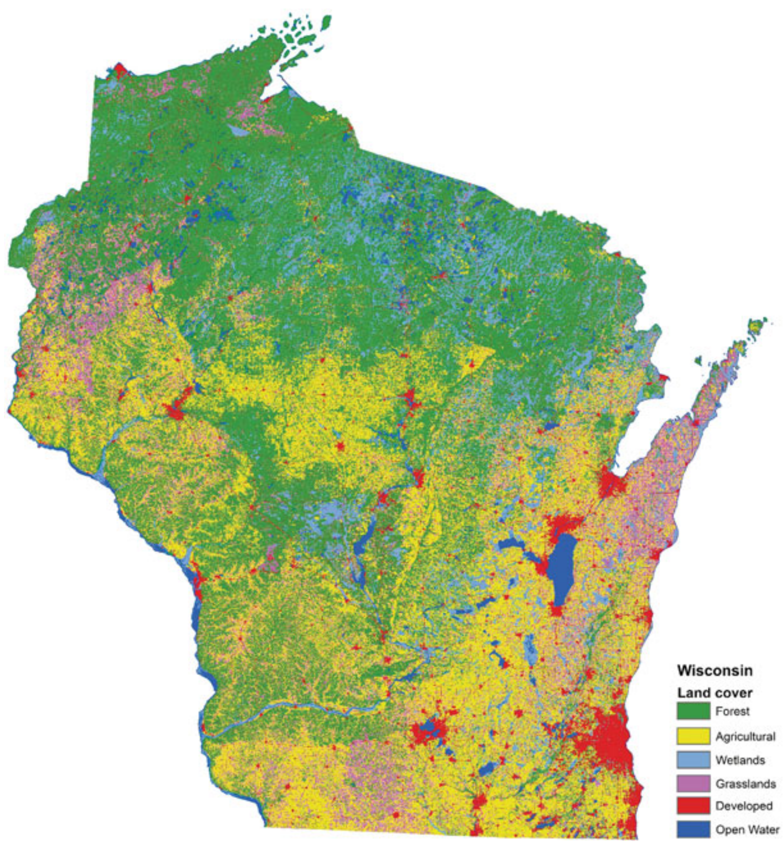

Fig. 3.15 Land cover in Wisconsin (compiled from National Land Cover Data 2006)

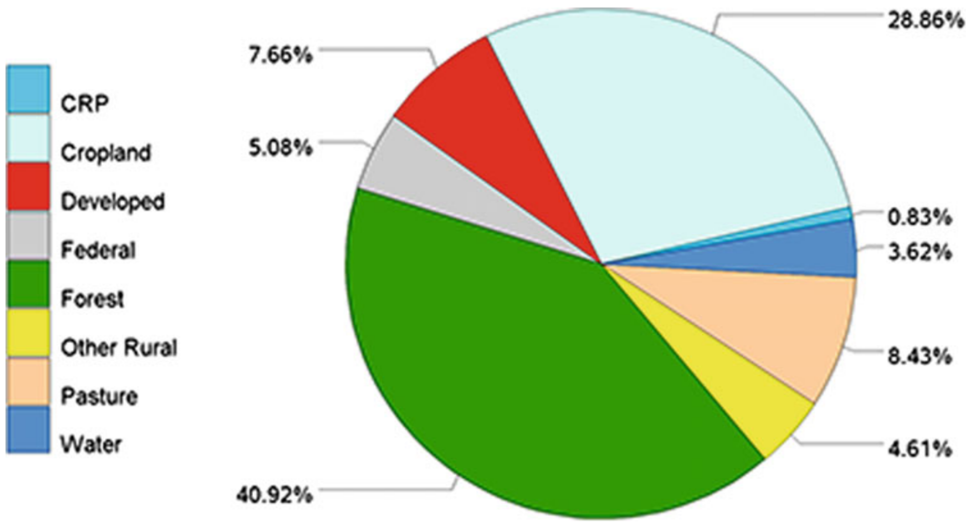

Fig. 3.16 Land cover in Wisconsin in 2014 (*Source* USDA Natural Resources Conservation Service). CRP is land in the Conservation Reserve Program—in exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality

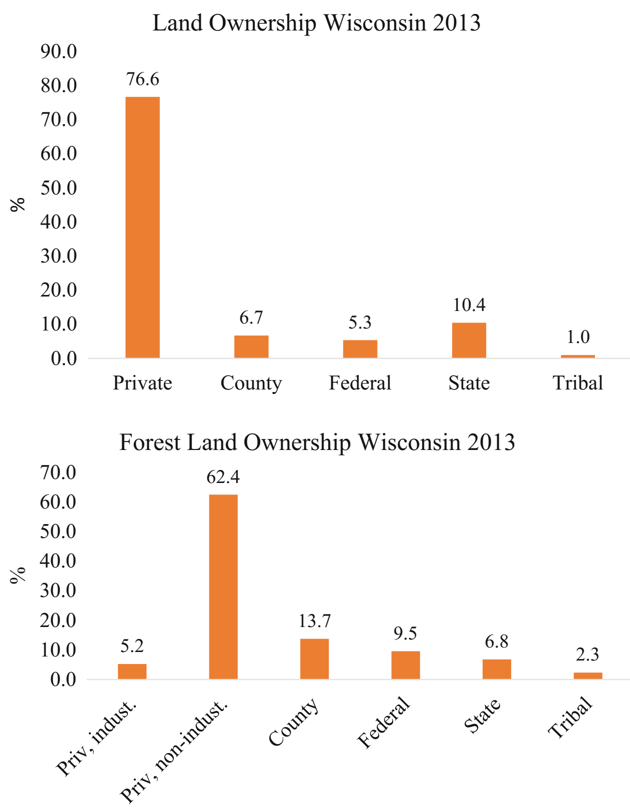

Fig. 3.17 Ownership of all land in Wisconsin (*top*) and forest land (*bottom graph*)

minimal differences in properties of the Fayette silt loam (Typic Hapludalfs), a forest soil common in the loess-mantled Driftless Area, as a function of slope (Frolking 1989). In contrast, Jacobs et al. (2012) showed considerable variation in soil horizonation and thickness in loess-mantled landscapes of southern Wisconsin.

Much of Wisconsin has a gently rolling topography. However, there is a considerable relief in the strongly dissected Driftless Area, and on the end moraines from the Green Bay, Lake Superior, and Chippewa Lobes (Fig. 3.20). The highest elevations are in the Northern Highlands Province (northcentral region), where elevations exceed 450 m a.s.l. The lowest elevations are adjacent to Lake Michigan (182 m).

3.5 Parent Materials

3.5.1 Previous Work

Parent materials are differentiated on the basis of chemical composition, particle size distribution, and their effects on susceptibility or resistance to breakdown by physical and chemical weathering (Wurman 1952). Madison and Lee (1965) delineated general areas of sandy soil in Wisconsin that are similar in mineralogy. Sandy soils derived from Cambrian or Ordivician sandstones contain primarily quartz, whereas sandy soils in northern Wisconsin have abundant feldspars, suggesting that they have not undergone substantial weathering. Lithologic discontinuities in soil parent materials were important in the occurrence of bisequal (Orthod sequum over an Udalf sequum) in northern

Fig. 3.18 Histosol augering and landscape in Jefferson County, Wisconsin

Wisconsin (Bockheim 2003). In his seminal paper "Wild soils of the Pine-Popple Rivers basin," Hole (1974) illustrated the effects of topography and parent material on the formation of "wild" (undisturbed) soils in northeastern Wisconsin through a series of block diagrams.

3.5.2 Geological Structure

Northeastern Wisconsin contains some of the oldest rocks in the world, including Lower Proterozoic and Upper Archean (Precambrian) granites and gneisses that are well over 1.5 billion years old (Fig. 3.21). These are overlain by Cambrian sandstones and Ordovian, Silurian, and Devonian formations of shale, dolomite, and other sedimentary rocks. In northern Wisconsin, the sedimentary rocks have been eroded following uplift and from repeated glaciations. In many parts of the state, glacial deposits (till, loess) cover the bedrock (Fig. 3.22). Most of the glacial deposits in Wisconsin are comprised of granites and gneisses from the Canadian Shield to the northeast.

3.5.3 Glacial Geology

Nearly 80% of the soils in Wisconsin are developed in glacial materials that largely differ in origin, composition, and thickness. The thickness of glacial cover is greater than 150 m on the Bayfield Peninsula (Fig. 3.22). In much of northern and eastern Wisconsin, the depth to bedrock ranges from 15 to 90 m. However, on the Door Peninsula, the thickness of drift cover is less than 15 m, whereas drift is lacking in the Driftless or nonglaciated area. The unconsolidated deposits overlying bedrock are comprised of two kinds of materials: glacial drift, including moraines and outwash; and post-glacial eolian materials, including silt (loess) and sand (Fig. 3.23). The loess thickness is about 0.5–5.0 m in southwestern Wisconsin but is largely absent in northeastern Wisconsin. About 10% of the soils have developed in glacial lake deposits.

Wisconsin has been subject to several glaciations for the past 2.1 million years. Glacial deposits fall into three age classes: early Holocene (ca. 9800 year BP), Late Wisconsinan 11,000–35,000 year BP), and pre-late Wisconsin (>35,000 year BP) (Attig et al. 2011) (Fig. 3.24). Glaciation in Wisconsin occurred during the advance of several lobes of ice that were part of the Laurentide Ice Sheet, including from west to east, the Des Moines Lobe, the Superior Lobe, the Chippewa Lobe, the Wisconsin Valley and Ontonagon Lobes, the Langlade Lobe, the Green Bay Lobe, and the Lake Michigan Lobe (Fig. 3.25). Whereas most of the glacial deposits are in the form of drift, including end moraines and ground moraine, there are areas of pitted outwash

Fig. 3.19 Freshly plowed fields in the Driftless Area, where *red* clay originating from the weathering of the underlying dolostone is brought to the surface

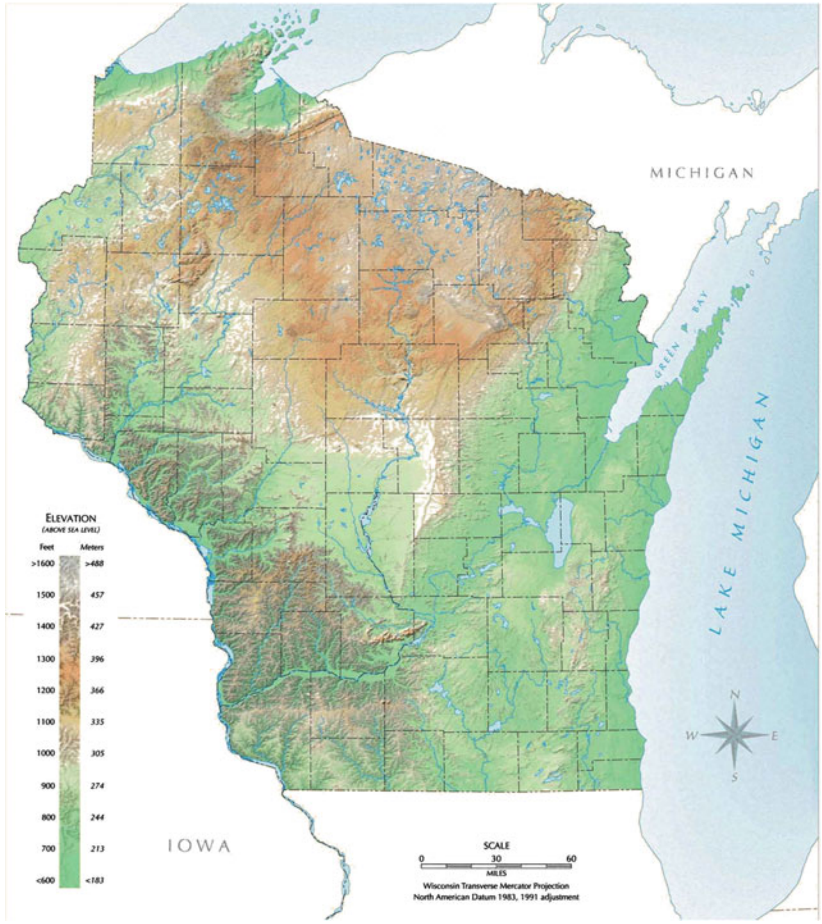

Fig. 3.20 Elevations of Wisconsin (m) (adapted from Wisconsin Geological and Natural History Survey 2004)

(northwestern and northeastern Wisconsin), unpitted outwash (central Wisconsin), and glacial lake basins (northwestern, central, and eastcentral Wisconsin) (Fig. 3.26). The Driftless Area covers about 35,700 km^2 in Wisconsin (25% of the state area) and has not been glaciated in the Quaternary. It is covered by a loess mantle, with outwash along the Wisconsin River.

Some of these features are evident in the relief map of Wisconsin, including the Driftless Area (A), Petenwill and Castle Rock Lakes in the former Glacial Lake Wisconsin basin (B), the Bariboo Hills to the south of the basin (C), the pronounced Almond Lateral Moraine (D) on the east side of the basin, and lakes in pitted outwash of northern Wisconsin (E) (Figs. 3.27 and 3.28). Figure 3.29 shows the Johnstown Moraine, which represents the southern limit of the Last Glacial Maximum. An aerial view, as shown in Fig. 3.30, shows the Johnstown Moraine and accompanying pitted outwash and kettle lakes along the distal margin. The Driftless Area is depicted in Fig. 3.31, an iconic image taken by the NRCS. Former Glacial Lake Wisconsin, which left 4700 km^2 of glaciolacustrine deposits in central Wisconsin approximately 19,000 to 15,000 years ago (Fig. 3.32). These deposits have been strongly reworked by wind.

Till in Wisconsin mostly has a sandy loam (40%) or loamy (38%) texture. However, clayey tills (10%) are present near Superior (Superior Lobe) and Michigan (Lake Michigan Lobe) lakes. Sandy tills (13%) occur in areas with abundant glaciolacustrine deposits or outwash. Tills from the Superior, Green Bay, and Lake Michigan Lobes are often calcareous. Pitted and unpitted outwash deposits are commonly sandy. The Driftless Area contains silty soils from loess deposition.

From descriptions and areas of the 740 soil series in Wisconsin, the primary parent material of the upper 1 m is loess (34%), or till (14%), alluvium (13%), outwash (12%), organic sediments (10%), glaciolacustrine (6%), and other materials such as colluvium, eolian, and glaciofluvial

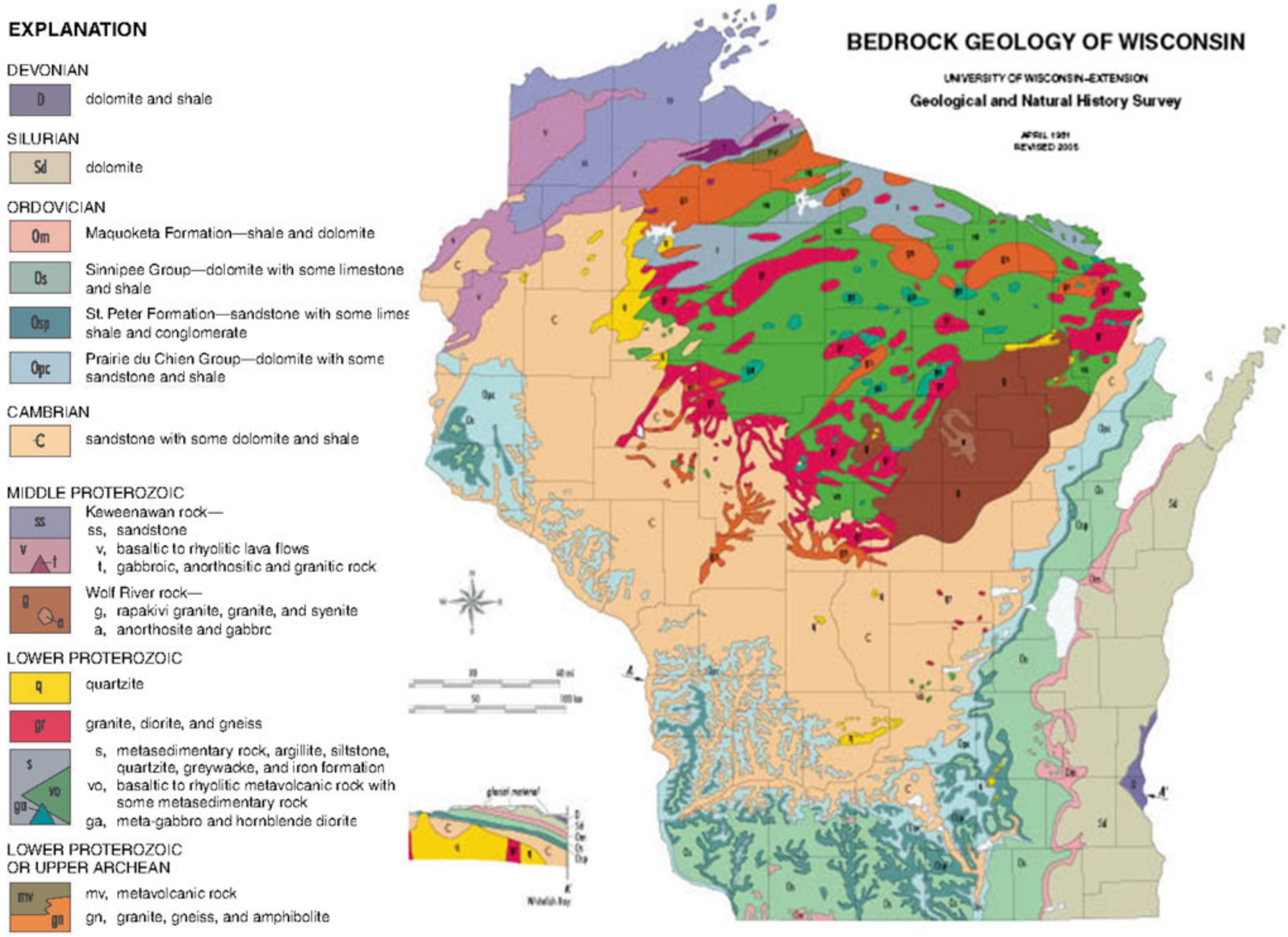

Fig. 3.21 Bedrock geology of Wisconsin (Wisconsin Geological and Natural History Survey 2005)

deposits (10%) (Fig. 3.33, upper). The second meter is mainly till (34%), or outwash (24%), residuum (13%), glaciolacustrine materials (8%), organic sediments and alluvium (7% each), and other materials such as colluvium, eolian, glaciofluvial, deep loess (7%) (Fig. 3.33, lower). Not many soils are derived solely from the weathering of the underlying bedrock.

3.6 Time

Time refers to stage of soil development and the susceptibility or resistance of different soil properties to change. Most of the soils of Wisconsin are derived from drift of Late Wisconsinan age (9500–30,000 year BP (Fig. 3.34). However, soils have been reported on pre-Late-Wisconsinan to

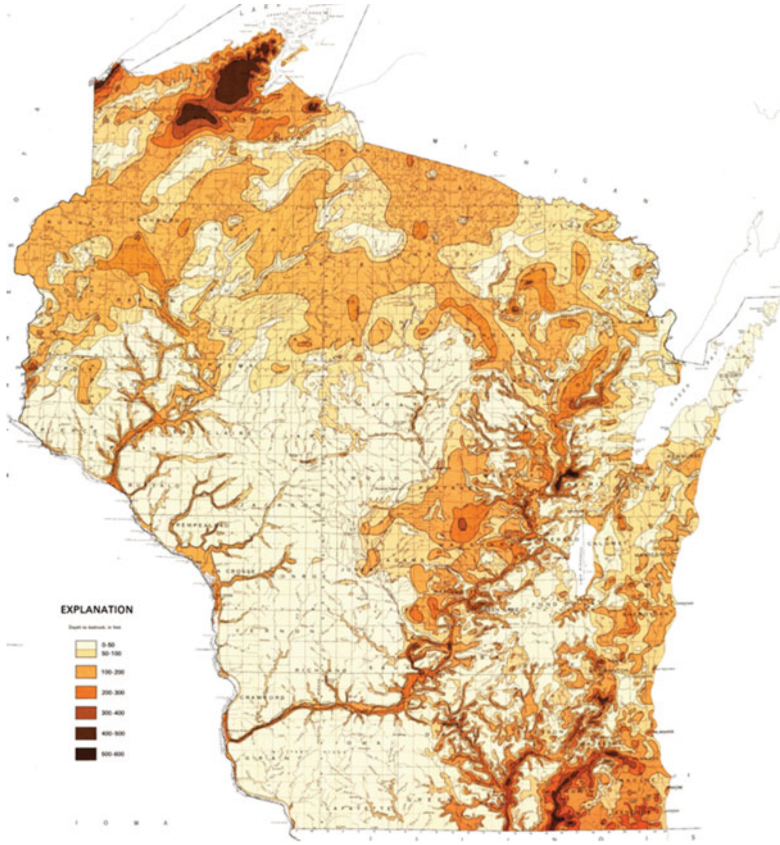

Fig. 3.22 Depth to bedrock in Wisconsin (Trotta and Cotter 1973)

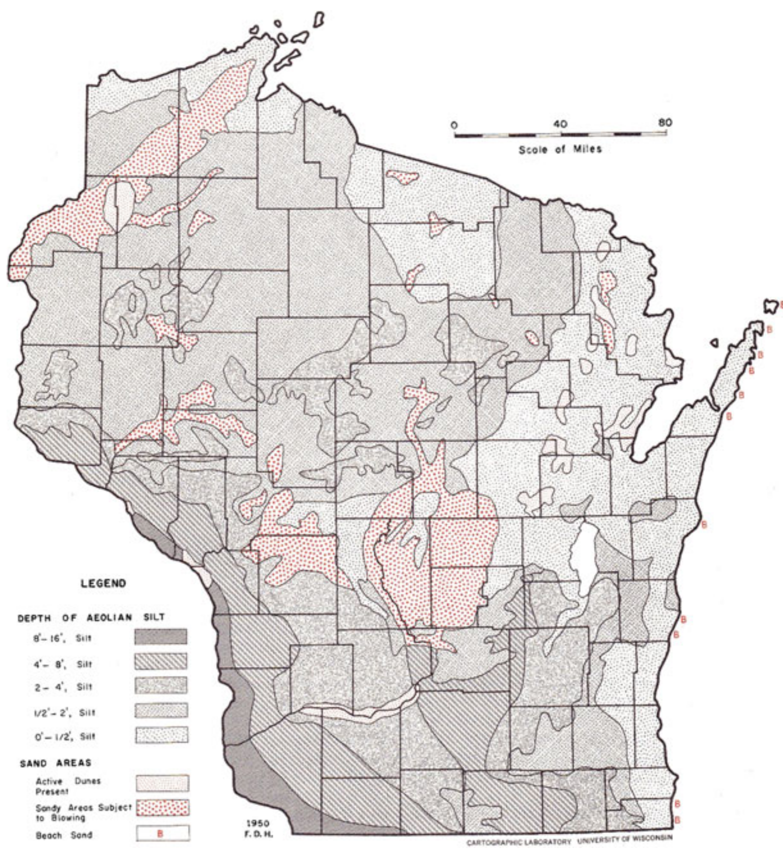

Fig. 3.23 Aolian silt and sand deposits in Wisconsin (Hole 1968)

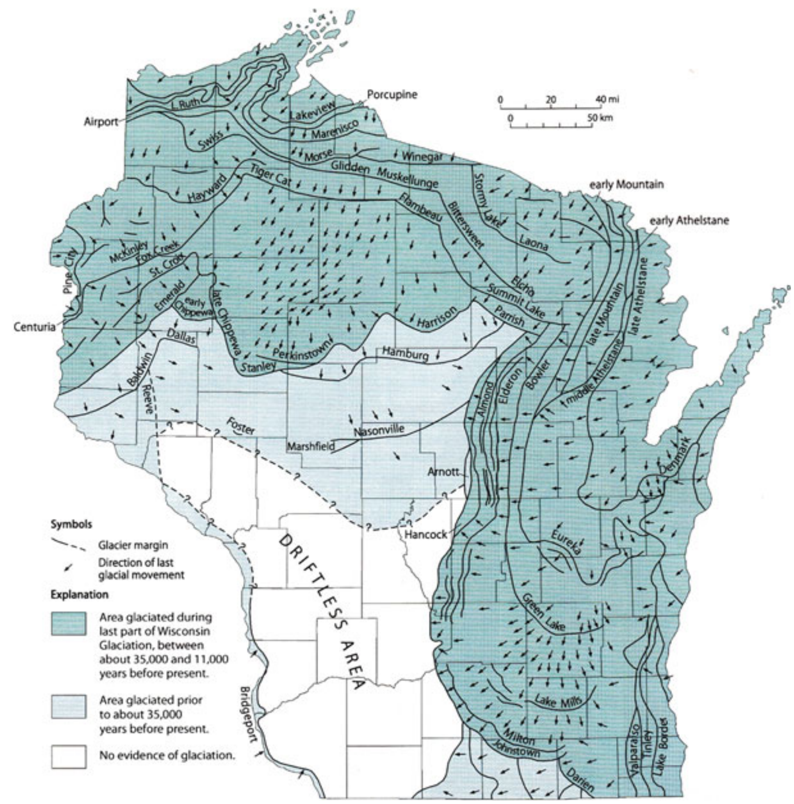

Fig. 3.24 Glacial deposits of Wisconsin (Attig et al. 2011)

Fig. 3.25 Lobes of the Laurentide Ice Sheet (Attig et al. 2011). Arrows indicate the direction of ice movement

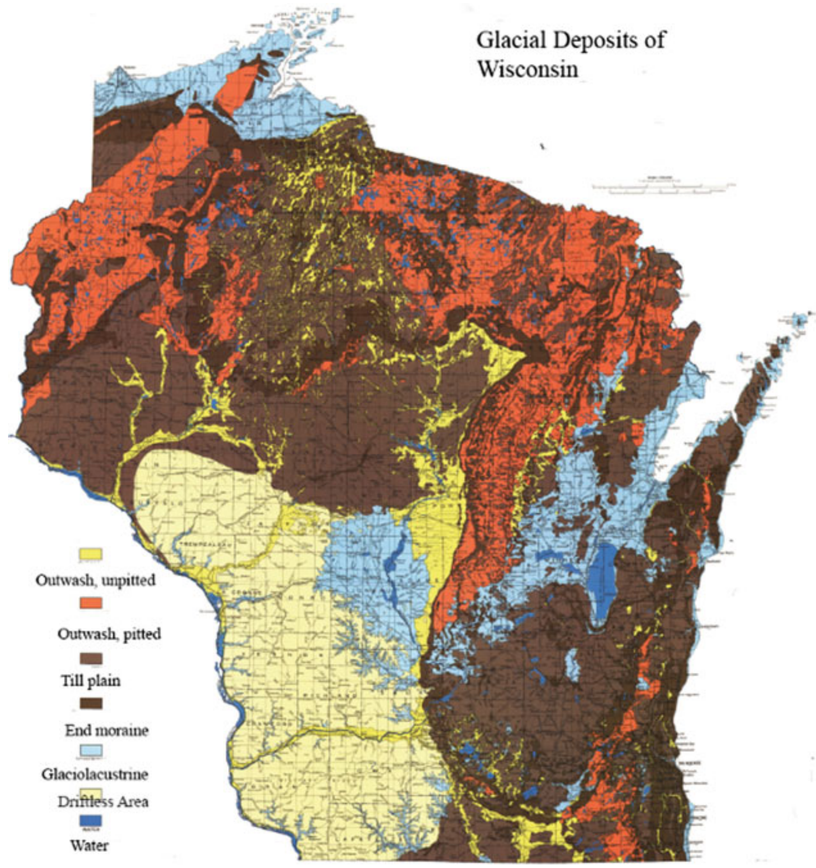

Fig. 3.26 Glacial deposits of Wisconsin (Wisconsin Geological and Natural History Survey 1976)

Illinoian drift (>30,000–300,000 year BP) and on pre-Illinoian drift between 780,000 and 2400,000 year BP (Syverson and Colgan 2011). The red clay pediment material in the Driftless Area is even older.

3.7 Humans

3.7.1 Previous Work

Humans have been in Wisconsin ever since the ice retreated about 13,500 years ago. They have altered the landscape by burning and changed the vegetation. Initially, this occurred at a slow pace but since the mid-1800s massive changes have occurred. All forests have been cleared, and agriculture has expanded. Below some examples are discussed how this has affected the soils.

Human cultivation erased the cradle-knoll micro-relief and replaced the forest floor and albic horizon with a plow layer, which resulted in slight reductions in nutrient contents of an Oxyaquic Haplorthods in northeastern Wisconsin (Gaikawad and Hole 1961). Grossman and Mladenoff (2008) concluded that agricultural cultivation results in more persistent changes than fire or clearcutting in forestry, particularly in the levels of P and Ca. Agriculturally induced erosion resulted in an “inverted horizon soilscape” in southcentral Wisconsin (Hartemink and Bockheim 2012).

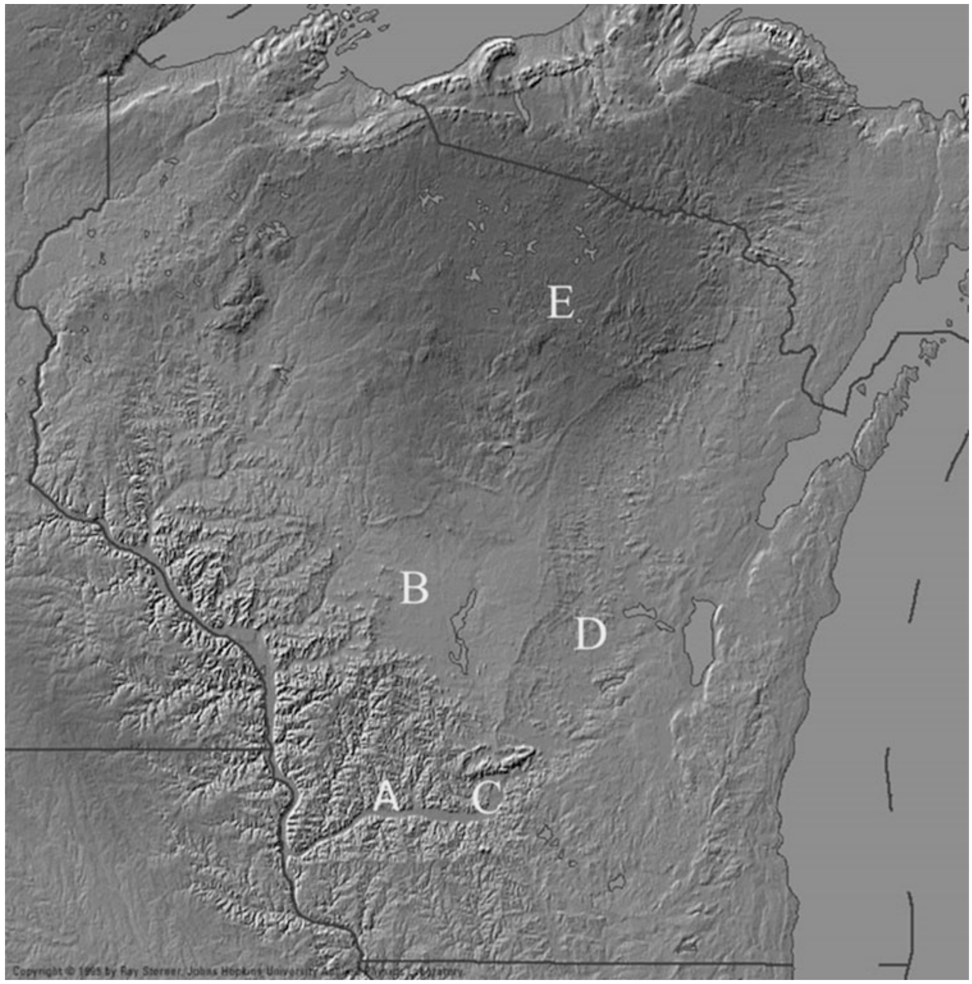

Fig. 3.27 Shaded relief map of Wisconsin, showing the Driftless Area (*A*), Petenwill and Castle Rock Lakes in the former Glacial Lake Wisconsin basin (*B*), the Bariboo Hills to the south of the basin (*C*), the pronounced Almond Lateral Moraine (*D*) on the east side of the basin, and lakes in pitted outwash of northern Wisconsin (*E*). Image by Ray Sterner, creator of the Color Landform Atlas of the United States

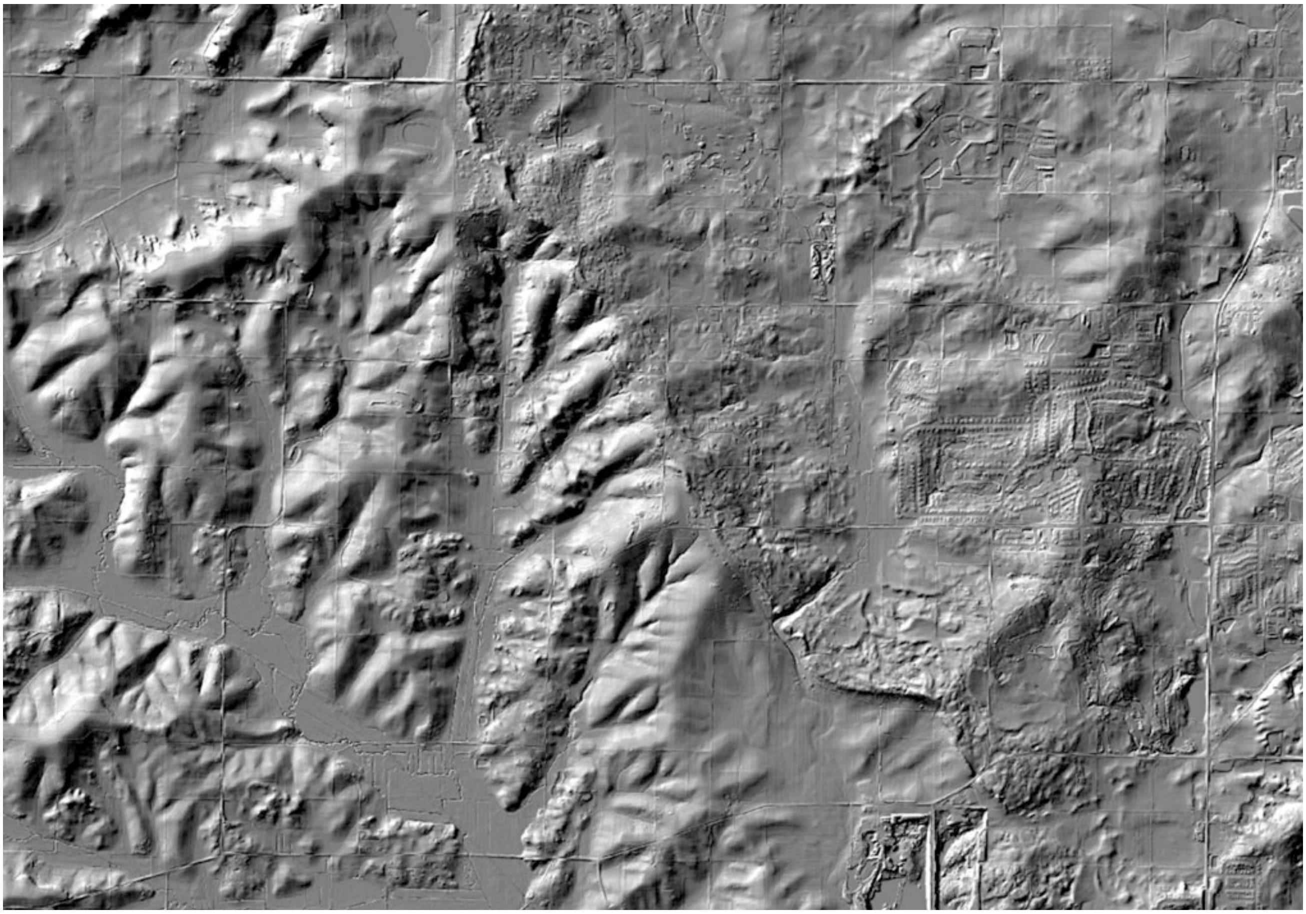

Fig. 3.28 Hillshade map of end moraine near Middleton with urban development on the pitted outwash. Sugar River and its tributaries in the left bottom part of the map

Fig. 3.29 Johnstown end moraine in southcentral Wisconsin

Fig. 3.30 Johnstown end moraine in southcentral Wisconsin with areas of pitted outwash and some kettle lakes (*lower picture*)

Fig. 3.31 Driftless Area (USDA Natural Resource Conservation Service (www.nrcs.usda.gov)

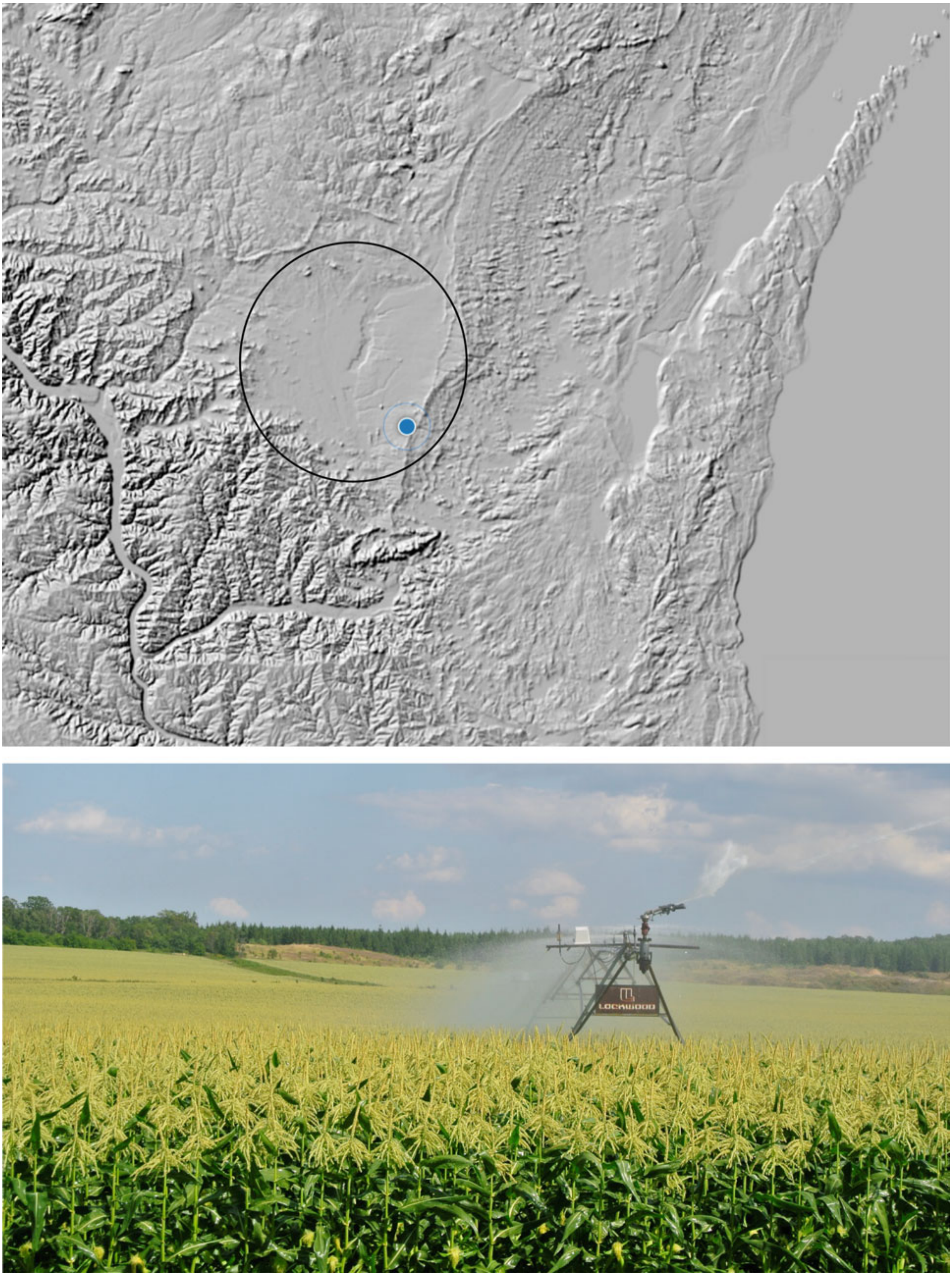

Fig. 3.32 Former Glacial Lake Wisconsin, which left 4700 km^2 of glaciolacustrine deposits in central Wisconsin approximately 19,000–15,000 years ago. Much of the former lake (also known as the central sands plains) is under irrigated agriculture (picture below with end moraine in the background)

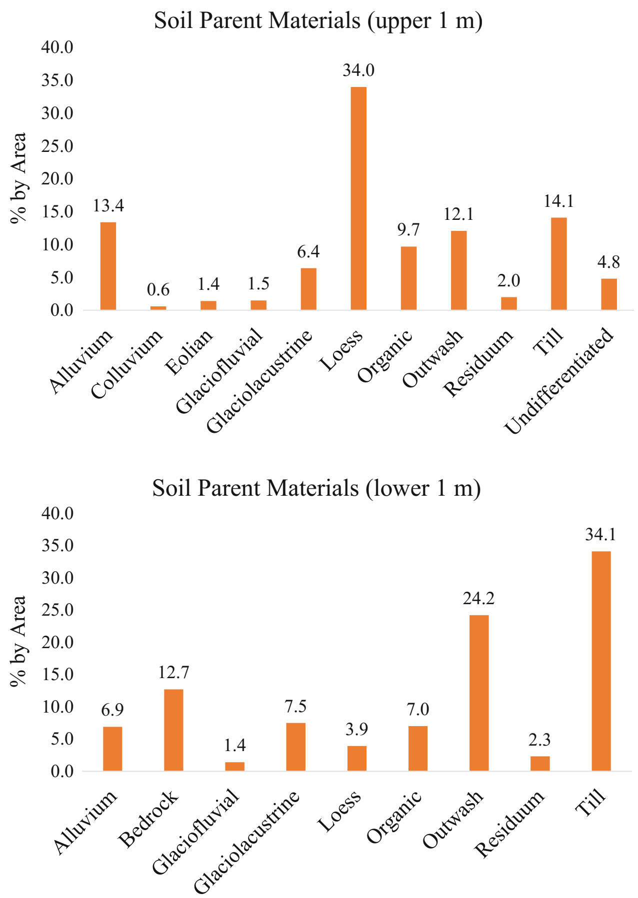

Fig. 3.33 Soil parent materials of the upper 1 m and lower 1 m from descriptions of 740 soil series

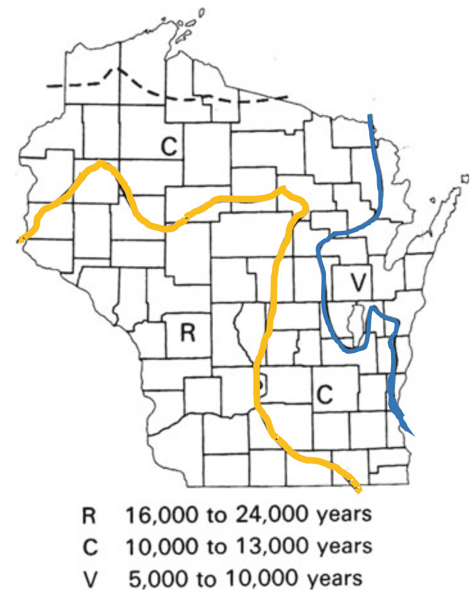

Fig. 3.34 Estimated age of the surface (after Hole 1976)

3.7.2 Paleo-Indians and Land Use

According to archeological studies, the earliest humans to enter Wisconsin were Paleo-Indians. One theory is that they crossed the Bering Land Bridge, a broad piece of land connecting the Eurasian and North American continents, during the waning stages of the Last Glacial Maximum approximately 13,500 years ago (Muñoz et al. 2010; Lambert and Loebel 2015). These early Americans hunted big game such as mastodon and gathered plants in what was then the southern Wisconsin tundra. Several mastodon butchering sites have been found in southern Wisconsin, the most famous one at Boaz.

During the Early Archaic or Late Paleo-Indian Tradition (11,250–8250 year BP), fishing and hunting of smaller mammals became more important as the glaciers retreated and the forest–tundra edge migrated northward. Forest fires increased, reflecting the shift toward a drier and warmer climate. During the Middle Archaic Tradition (8250–5250 year BP), the climate had warmed substantially and prairies became more evident. Ground stone tools and woodworking tools were developed during this time. During the Late Archaic Tradition (5250–3000 year BP), spear-throwing devices were developed. There was widespread trading of food and other resources among native peoples during this period. Copper trade items were introduced during this period.

Burial mounds were employed to interbodies and belongings during the Early Woodland Tradition (3000–2300 year BP. Cropping began during this period, especially the growing of corn, beans, and squash. Human-set forest fires became more common. Pottery was made from local clay deposits. These activities were expanded during the Middle Woodland Tradition (2300–1600 year BP), particularly by the Hopewell culture. Effigy mounds were constructed during the Late Woodland Tradition (1600–500 year BP). During the Mississippian Period (1100–400 year BP), stockade and permanent villages were established.

3.7.3 Modern Human Impacts

Soil erosion following clearing has been a problem throughout Wisconsin and has affected many of the soils. When the first settlers came in the Driftless Area in the 1850s, wheat was the primary crop grown and to lesser extent tobacco. Diseases and low wheat prices forced the settlers into dairy farming (Whitson 1927). As the land is sloping and much of the forest was logged, there was massive soil erosion in the Driftless Area and over 60% of the cropped land had lost 10–15 cm of its topsoil (Clark 1940).

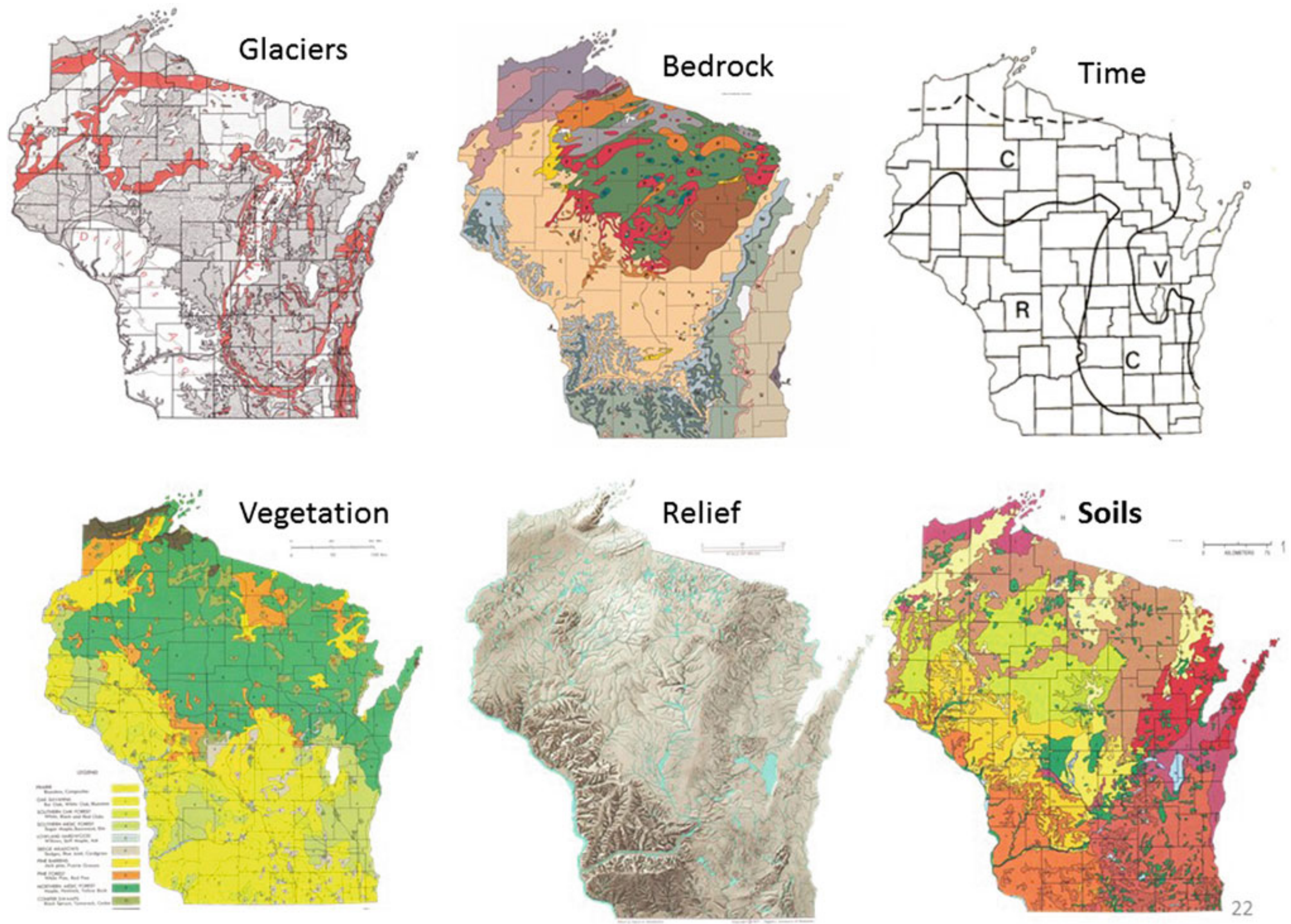

Fig. 3.35 Factors affecting the soil distribution in Wisconsin

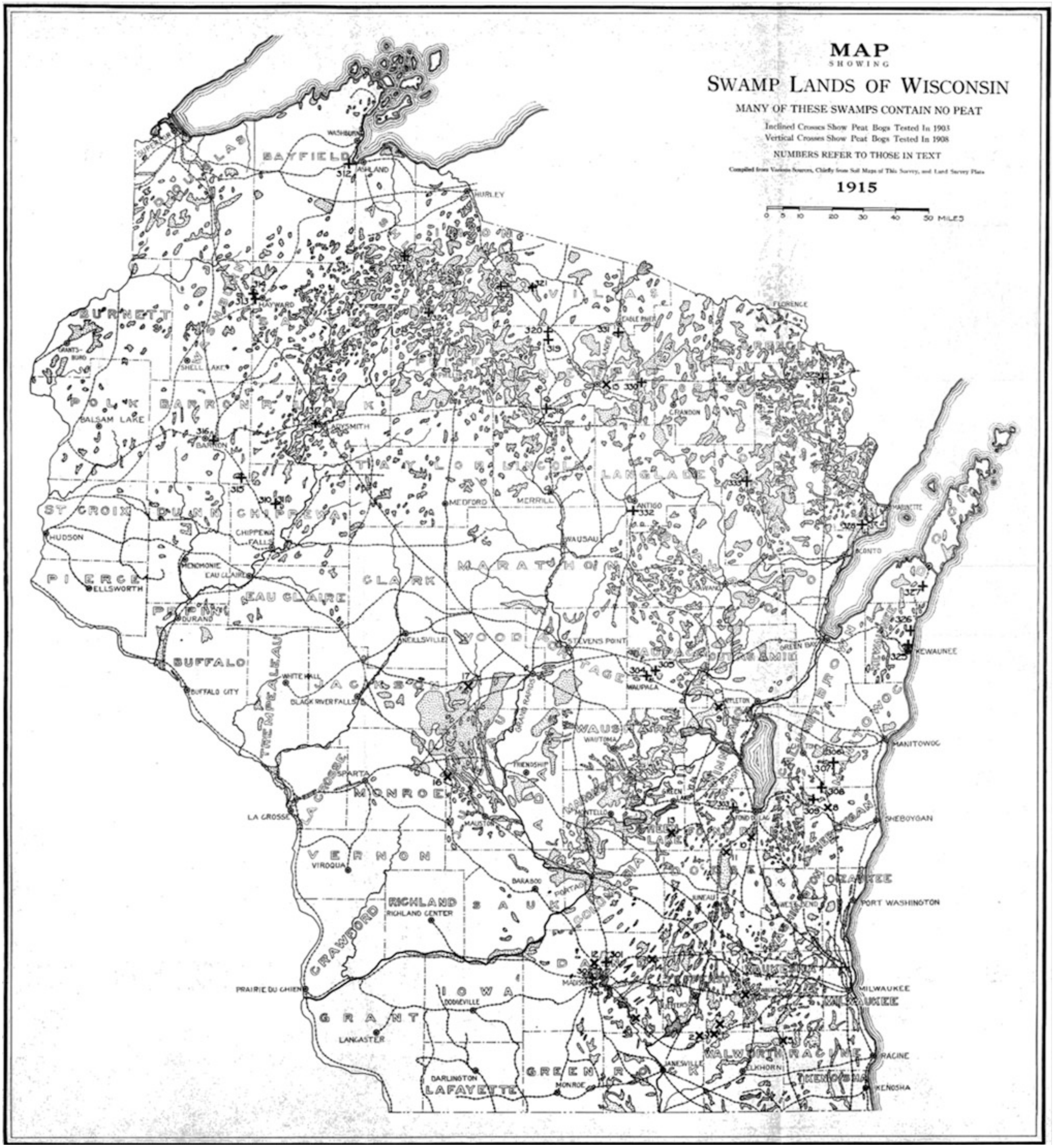

Fig. 3.36 Map of swamp lands in Wisconsin in 1915

According to Trimble and Lund (1982), average soil erosion rates in the 1930s were estimated to be about 34 Mg ha^{-1} year^{-1} but had decreased to about 8 Mg ha^{-1} year^{-1} in 1975. The reduction in erosion mainly resulted from improvements in land management and to a lesser degree by changes in land use; the total area under cropping had not changed much between the 1930s and 1975 but soil conservation management was greatly improved.

Other soil changes that were brought about by changes in land use include cultivation (mechanized, by hand), tillage, weeding, terracing, subsoiling, deep ploughing, manure, compost and fertilizer applications, liming, draining, and irrigation. Also the change in climate, hydrology, earth moving and paving has changed many of our soils.

3.8 Summary

The expression of a soil results from five factors operating collectively: climate, organisms, relief, parent material, and time; human activities are often considered a sixth factor (Fig. 3.35). The importance of climate as a soil-forming factor is evidenced by an ecotone, known as the "Wisconsin Tension Zone," that separates soils, dominantly Spodosols, with a frigid soil-temperature class (<8 °C at 50 cm) to the north and soils, dominantly Alfisols, with a mesic soil-temperature class (>8 °C at 50 cm) to the south. Vegetation is an important factor closely related to climate that is important in the development of Wisconsin soils: Alfisols occur under temperate deciduous forests; Spodosols are present under temperate mixed deciduous and conifer forests (especially where hemlock is a key component); Entisols are present under pine-oak barrens; Mollisols represent former prairies, and Histosols and wet mineral soils occur in stream bottoms and major wetlands (Fig. 3.36).

Topographic position along slopes exerts a strong control on soil development. About 80% of the soils are derived from glacial deposits. The Driftless Area in southwestern Wisconsin escaped the Quaternary glaciation. Most of the soils of Wisconsin are derived from drift of Late Wisconsinan age (9500–30,000 year BP). However, soils have been reported on pre-Late-Wisconsinan to Illinoian drift (>30,000–300,000 year BP) and on pre-Illinoian drift between 780,000 and 2,400,000 year BP. The red clay pediment material in the Driftless Area may be of Miocene (15 million year BP).

Although the Native Americans had an impact on soil formation through fires and occupation sites, European settlement in the mid-1850s caused the greatest change in soils. Clearing land for pastures, cultivation of land for agriculture, draining of wetlands, irrigation, and application of agrichemicals have altered the soils in the state.