CHAPTER 3.

Geographic Considerations for Fire Management in the Eastern United States: Geomorphology and Topography, Soils, and Climate

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Across the Eastern United States, there is on average an estimated 36 MT ha^{-1} (16 tons ac^{-1}) of dead woody fuel (Chojnacky and others 2004). Variations in fuel type, size, and flammability make the selection of treatment options critical for effective fuels management. The region is a complex landscape characterized by highly fragmented forests, large areas of wildland-urban interface, and vast differences in geomorphology, topography, soils, and climate. For example, the Coastal Plain is generally flat, has large areas of wetlands, and is derived from sedimentary parent material. By contrast, the Piedmont and Appalachian Mountains are derived primarily from igneous and metamorphosed igneous parent materials, have complex topography, and few or no wetlands. Understanding interactions among fuel management treatments and geographic areas, and matching treatment prescriptions with physical conditions is critical.

Fire and fuel management options are constrained by complex interactions among physical, biological, and social parameters. Biological and social parameters can be altered somewhat by management activities, new technologies, and policies; whereas physical parameters are generally not easily altered. Except where major changes have been possible (such as drainage of hydric ecosystems in the Coastal Plain), variation in physical parameters constrains fuel and fire management options among and within geographic areas.

The purpose of this chapter is to describe the geomorphology, topography, climate, and soils of major landscapes in the Eastern United States. The information is derived from several publications and provides the backdrop for understanding fire and fuel management options.

Although many levels of resolution in landscape variations have been described for the Eastern United States (Bailey 1995, Cleland and others 2007, Reed and Bush 2005), they can generally be characterized by eight major ecological divisions the basic geographic units described in this chapter; figure 1 shows the ecological provinces within each ecological division. Table 1 contains the geologic time scales for reference, and table 2 is a comparison of mean annual temperature, precipitation, and elevation among ecological divisions.

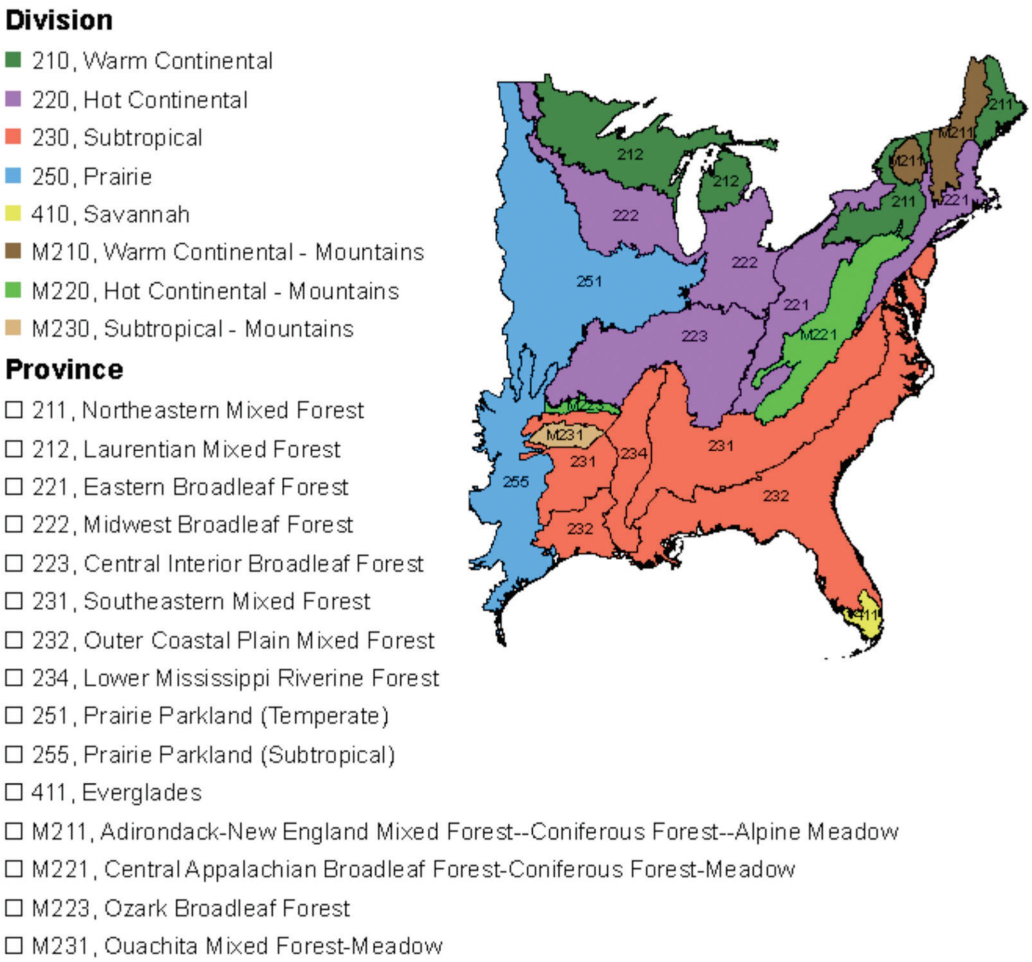

Figure 1. Ecological Divisions and Ecological Provinces in the Eastern United States, characterized by distinct biophysical features such as vegetation, topography, geology, soils, and climate (McNab and others 2005).

Geomorphology and Topography

A detailed description and comparative analysis of the temporal and spatial variations in topography and geology in the Eastern United States is beyond the scope of this chapter. In this section we describe topographic and geologic variation (figs. 2 and 3) within and among numbered ecological categories (fig. 1) described by McNab and others (2005), with specific attention given to the major landscapes within each (Fenneman and Johnson 1946); as an example, the Southern Appalachian Ridges and Valleys described below are classified as M221A, Northern Ridge and Valley (McNab and others 2005) and as the Tennessee Section of the Appalachian Highlands–Valley and Ridge (Fenneman and Johnson 1946).

Hot Continental Mountains Division

Blue Ridge

This area (M221D, Blue Ridge Mountains) consists of several distinct topographic features, including the Blue Ridge Escarpment to the east, the New River Plateau to the north, interior low and intermediate mountains throughout, intermountain basins between major mountains, and the high mountains making up the bulk of acreage. Elevations range from around 275 m (900 feet) at the southern and southwestern boundaries to more than 2010 m (6,600 feet) at the crest of the Great Smoky and Black Mountain ranges.

Table 1. Geologic time scales

		Years before present
		millions
Geologic era	Cenozoic	0 to 65
	Mesozoic	65 to 230
	Paleozoic	230 to 570
	Precambrian	570 to 4,500
Geologic period	Quaternary	0 to 2
	Tertiary	2 to 65
	Cretaceous	65 to 140
	Jurassic	140 to 190
	Triassic	190 to 230
	Permian	230 to 280
	Pennsylvanian	280 to 310
	Mississippian	310 to 345
	Devonian	345 to 405
	Silurian	405 to 425
	Ordovician	425 to 500
	Cambrian	500 to 570
Geologic epoch	Recent (Holocene)	0 to 0.010
	Pleistocene	0.01 to 2
	Pliocene	2 to 10
	Miocene	10 to 25
	Oligocene	25 to 40
	Eocene	40 to 55
	Paleocene	55 to 65

The bedrock geology in this area consists mostly of Precambrian metamorphic rock formations with a few small bodies and windows of igneous and sedimentary rocks. The degree of metamorphism varies but generally decreases westward. The higher grade metamorphic rocks include formations of gneiss, schist, and amphibolite. Low-grade metamorphic formations in the southwest include distinct and interbedded bodies of metasandstone, slate, phyllite, metasiltstone, and metaconglomerate. The northern Blue Ridge formed during a period of post-Cretaceous uplift along the eastern coast of North America, forming a sequence of resistant minerals primarily chlorite-actinolite, schist, schistose metabasalt, siliceous metabreccia, laminated metasedimentary gneiss, and quartzite. Surficial deposits in both the Northern and Southern Blue Ridge include colluvial material on fans and aprons along the ridges and alluvial material along the major streams.

Southern Appalachian Ridges and Valleys

Most of this area (M221A, Northern Ridge and Valley) is in the Tennessee Section of the Appalachian Highlands–Valley and Ridge. The thin stringers in the western part of the area are mostly in the Cumberland Plateau Section of the Appalachian Highlands–Appalachian Plateaus. A separate area in northern Alabama is in the Highland Rim Section of the Interior Plains–Interior Low Plateaus. The western side of the area is dominantly hilly to very steep and is rougher and much steeper than the eastern side, much of which is rolling and hilly. Elevation ranges from 200 m (660 feet) near the southern end of the area to more than 730 m (2,400 feet) in the part of the area in the

Table 2. Ranges in elevation, mean annual precipitation, and mean annual temperature within Ecological Divisions

Division		Elevation[a]	Mean annual precipitation	Mean annual temperature
		m	*mm*	*°C*
Hot Continental Mountains (M220)	Minimum	200 (SARV)	915 (BR)	8 (BR)
	Maximum	2010 (BR)	3000 (BR)	17 (SARV)
Warm Continental Mountains (M210)	Minimum	305 (NNU)	815 (AD)	1 (NNU)
	Maximum	1525 (NNU)	2665 (NNU)	8 (AD)
Prairie (250)	Minimum	200	485	4
	Maximum	300	1220	17
Sub-tropical (230)	Minimum	m.s.l. (LCP)	940 (SP)	12 (SP)
	Maximum	400 (SP)	1830 (UCP)	25 (SAV)
Sub-tropical Mountains (M230)	Minimum	200 (BM)	990 (AVR)	13 (BM)
	Maximum	840 (AVR)	1675 (OM)	17 (OM)
Hot Continental (220)	Minimum	160 (IPL)	485 (IPL)	4 (IPL)
	Maximum	505 (NP)	1320 (NP)	17 (IPL)
Warm Continental (210)	Minimum	275 (NGL)	660 (NGL)	4 (NGL)
	Maximum	1100 (APC)	1755 (NNC)	10 (APC)
Savanna (410)	Minimum	m.s.l.	1015	23
	Maximum	5	1575	25

Note: Abbreviations in parentheses represent physiographic provinces within each ecological division where the minimum or maximum values occur. BR = Blue Ridge, SARV = Southern Appalachian Ridge and Valley, NNU = Northern New England Uplands, AD = Adirondack Shield, SAV = Savannas, SP = Southern Piedmont, UCP = Upper Coastal Plain, LCP = Lower Coastal Plain, IPL = Interior Plains and Lowlands, NP = Northern Piedmont, NGL = Northern Great Lakes, APC = Allegheny Plateau and Catskills, AVR = Arkansas Valley and Ridges, BM = Boston Mountains, Ouachita Mountains.
[a] m.s.l. = mean sea level
Source: U.S. Department of Agriculture, Natural Resources Conservation Service (2006).

western tip of Virginia. Some isolated linear mountain ridges rise to nearly 1500 m (4,920 feet) above sea level. This area is highly diversified. It has many parallel ridges, narrow intervening valleys, and large areas of low, irregular hills. Many ridges and valleys have a difference in elevation of 200 m (660 feet).

The bedrock in this area consists of alternating beds of limestone, dolomite, shale, and sandstone of early Paleozoic age. Ridgetops are capped with more resistant carbonate and sandstone layers, and valleys have been eroded into the less resistant shale beds. These folded and faulted layers are at the southernmost extent of the Appalachian Mountains. The narrow river valleys are filled with unconsolidated deposits of clay, silt, sand, and gravel.

Cumberland Plateau

The northern third of this area (M221C, Northern Cumberland Mountains) is primarily in the Kanawha Section of the Appalachian Highlands–Appalachian Plateaus. The southern two-thirds is primarily in the Cumberland Plateau Section of the Appalachian Highlands–Appalachian Plateaus; a strip along the central part of the eastern edge of the area is in the Cumberland Mountain Section. Small areas along the southwestern edge are in the Highland Rim Section of the Interior Plains–Interior Low Plateaus.

This highly dissected portion occurs mainly as a series of long, steep side slopes between narrow ridgetops or crests and narrow stream flood plains. Elevation ranges from 200 m (650 feet) on the flood plain along the Ohio River to about 300 m (980 feet)

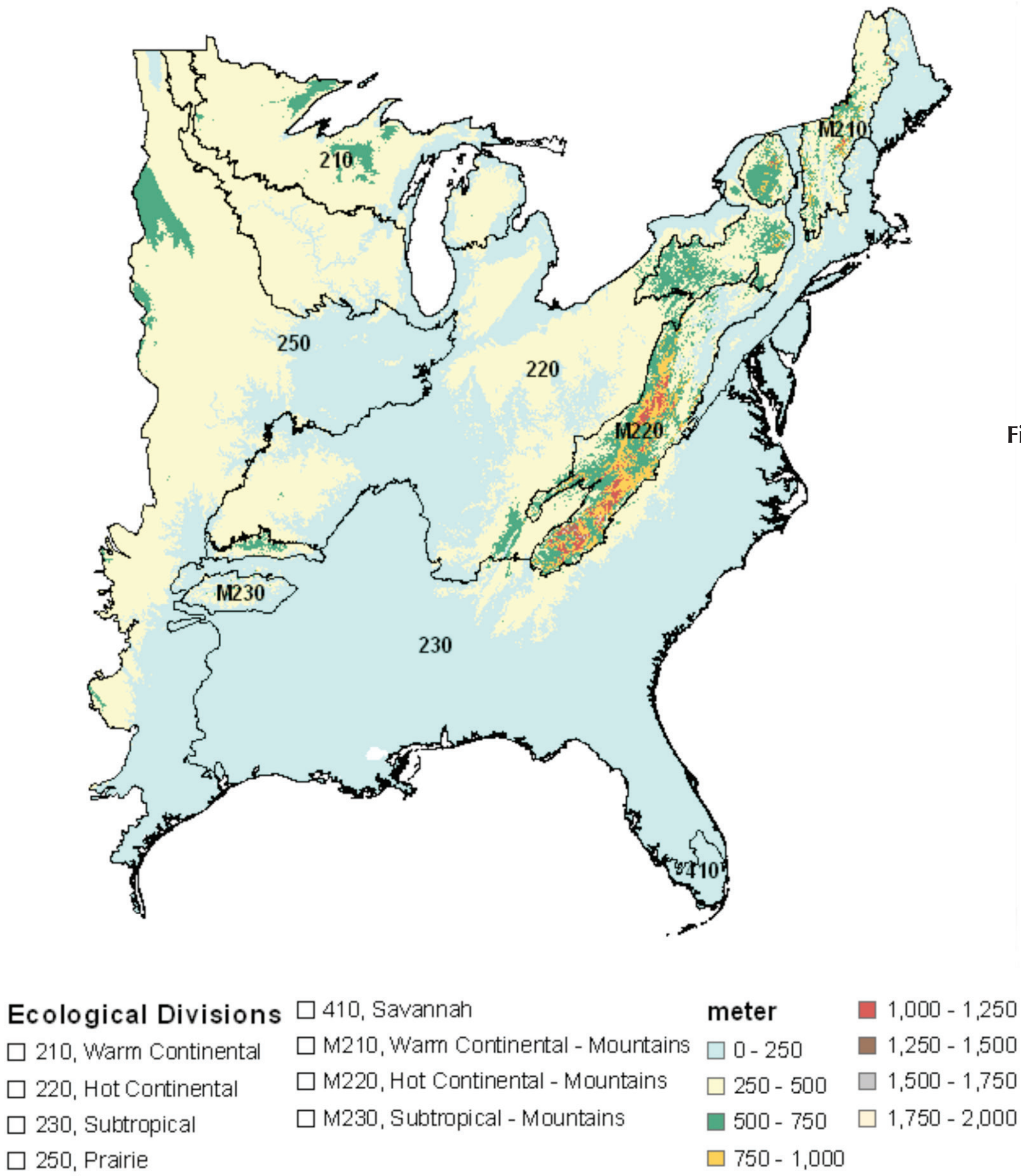

Figure 2. Elevations within Ecological Divisions in the Eastern United States (U.S. Geological Survey, Earth Resources Observation and Science Center 2007).

on nearby ridge tops. It gradually rises from these areas to areas near the Virginia–Kentucky border, where it is about 505 m (1,650 feet) on local flood plains and 1205 m (3,950 feet) on the higher mountains.

Cyclic beds of sandstone, siltstone, clay, shale, and coal of Pennsylvanian age form the bedrock in most of this area. Pennsylvanian limestone and dolomite bedrock is in the part of the area in Virginia and Alabama. Coal mining is the major industry. Unconsolidated deposits of silt, sand, and gravel are in the major river valleys and on terraces along these rivers. The lower parts of many hillslopes have a thin layer of colluvium.

Warm Continental Mountains Division

Adirondack Shield and Northern New England Uplands

Because of the similarities between these two areas (M211A, White Mountains; M211B, New England Piedmont; M211C, Green–Taconic–Berkshire Mountains;

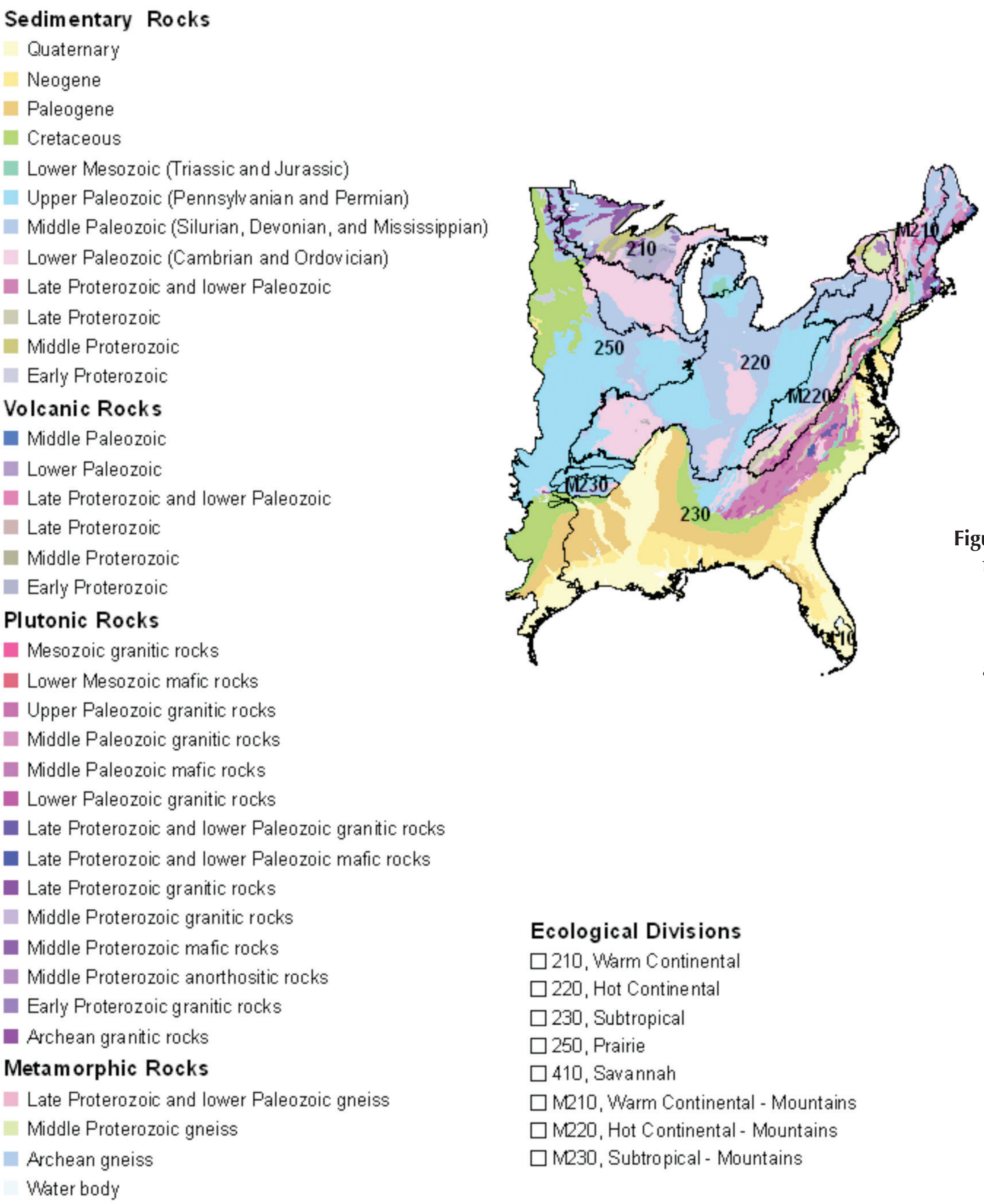

Figure 3. Geological formations within Ecological Divisions in the Eastern United States (Reed and Bush 2005).

M211D, Adirondack Highlands), we elected to treat this division as one unit. The westernmost part of this area is primarily in the Appalachian Highlands–Adirondack. A small area in the southern end of the western part is in the Mohawk Section of the Appalachian Highlands–Appalachian Plateaus. The easternmost part, primarily in northern Maine, is in the New England Upland Section of the Appalachian Highlands–New England, its southwestern half is in the White Mountain Section, and its middle part of this area is in the Green Mountain Section.

The mountains and foothills in the area are commonly rounded. They are underlain by bedrock and are typically covered with thin deposits of glacial till. The more rugged mountain areas are separated by high gradient streams coursing through steep areas of colluvium or talus-laden valleys. Many glacially broadened valleys are filled with glacial outwash and have numerous swamps and lakes. The mountains and foothills are moderately steep to very steep, and the valleys are nearly level to sloping. Elevation generally ranges from 305 to 1220 m (1,000 to 4,000 feet), but it is more than 1525 m (5,000 feet) on a few isolated peaks and is less than 305 m (1,000 feet) in some of the valleys, especially in northeastern Maine. Local relief ranges from moderate in some areas to high in ruggedly mountainous areas.

The entire portion of this division was glaciated by the last continental ice sheet. In addition, evidence on the more rugged mountain peaks indicates that alpine glaciation may have lingered after the retreat of Wisconsin ice. A thin mantle of till covers most of the bedrock. Sandy glacial outwash has been deposited in many stream valleys, and ice-contact, stratified drift (on kames and eskers) has been deposited on the walls of the valleys. When the European and African Continents were squeezed up against the North American Continent by plate tectonic activity, the mountains must have appeared to be similar to the present Himalaya Mountains. For the past 500 million years, as the Atlantic Ocean opened up and the European and African continental plates were pushed east, erosion has been the dominant process. Only the roots of those ancient mountains remain today. The bedrock consists primarily of igneous and metamorphic rocks. The metamorphic rocks (gneiss, schist, slate, metanorthosite, marble, and quartzite) are the oldest. The igneous rocks, primarily granite and granodiorite, were intruded into the metamorphic rocks during the Triassic and Cretaceous periods. The deformation history and the weathering of these rocks have left numerous fractures, joints, bedding plane partings, and cleavage partings that now contain freshwater.

Prairie Division

Almost all the eastern portion of the area (251C, Central Dissected Till Plains; 251D, Central Till Plains and Grand Prairies) is on the glaciated Bloomington Ridged Plain in the Till Plains Section of the Interior Plains–Central Lowland, and the northern tip is in the Eastern Lake Section. The western portion is on the eastern side of the Illinois River on the glaciated Springfield Plain. The extreme western part is dominantly on the Galesburg Plain. The northern part of this western area also encompasses the Green River Lowland and the Rock River Hill Country.

The entire area was glaciated and has deposits of loess of various thicknesses. The area is on a relatively young, moderately dissected to strongly dissected, rolling plain where stream terraces are adjacent to broad flood plains along the major streams and rivers. Slopes are generally less than 15 percent but are significantly steeper in some areas along the major streams. Elevation ranges from 200 m (660 feet) in the eastern and southern parts of the area to about 300 m (985 feet) in the western and northern parts. The maximum local relief is about 50 m (160 feet) along the major streams and along the dissected drainage-ways fingering into the uplands. Relief is considerably lower in much of the area. It typically is only 1 to 3 m (3 to 10 feet) on the broad, flat uplands. The eastern portion is a relatively young, moderately dissected, rolling plain with stream terraces adjacent to the broad flood plains along the major streams and rivers. Glacial moraines are numerous and tend to form elongated ridges tending from northwest to southeast. Slopes are generally less than 5 percent but are significantly steeper on the moraines and along the major streams. Elevation ranges from 200 m (660 feet) in the southern part of the area to about 300 m (985 feet) in the northern part. The maximum local relief is about 50 m (160 feet) along the major streams. Relief is considerably lower, however, in most of the area. It typically is only 1 to 3 m (3 to 10 feet) on the broad, flat uplands.

This area is underlain by Pennsylvanian shale, siltstone, and limestone in the southern part and Ordovician and Silurian limestone in the extreme northern part. Coal beds occur in the northern part and east of the Illinois River. Glacial drift covers all of the area, except for the bluffs along the major streams where the underlying bedrock is exposed. The glacial drift is Wisconsin in age to the east and Illinoian age to the west, and consists of distinct till units as well as sorted, stratified outwash. The entire area has been covered by a moderately thin or thick layer of loess. In a few areas the loess directly overlies the bedrock.

Subtropical Division

Southern Piedmont

The Southern Piedmont (231A, Southern Appalachian Piedmont; 231I Central Appalachian Piedmont) extends from Maryland southwest to Alabama and is bounded on the southeast by the Upper Coastal Plain and to the northwest by the Blue Ridge. Almost all of this area is in the Piedmont Upland Section of the Appalachian Highlands–Piedmont. A very small part in central North Carolina is in the Atlantic Plain–Coastal Plain. A very small part around Roanoke, VA, is on the eastern edge of the Appalachian Highlands–Blue Ridge.

It can be generally described as consisting of broad ridges separated by sometimes deeply incised stream channels. It is highly weathered in geologic time and highly eroded during the recent past (200 years) by intensive agricultural activities. Past land use practices have resulted in a piedmont landscape where agricultural and silvicultural activities in the red clay B horizon is a common practice, and a common feature of this landscape. The area is a rolling to hilly upland with a well defined drainage pattern. Streams have dissected the original plateau, leaving narrow to fairly broad upland ridgetops and short slopes adjacent to the major streams. The associated stream terraces are minor. Valley floors are generally narrow and make up less than 10 percent of the land area. Elevations range from 100 to 400 m (330 to 1,310 feet).

Precambrian and Paleozoic metamorphic and igneous rocks underlie most of this area. The dominant metamorphic rock types include biotite gneiss, schist, slate, quartzite, phyllite, and amphibolite. The dominant igneous rock types are granite and metamorphosed granite. Some gabbro and other mafic igneous rocks also occur, and diabase dikes are not uncommon. The Carolina Slate terrain occurs just east of an imaginary centerline in the area. It consists of metamorphic rocks with some metavolcanics and metasediments. Scattered graben basins, which are bounded by faults where the ground between the faults has dropped down, occur from South Carolina to south of Charlottesville and Richmond in Virginia. These basins have Triassic and Jurassic siltstone, shale, sandstone, and mudstone. River valleys have recent alluvium and few terraces.

Coastal Plain

This is an area of coastal lowlands, Coastal Plains, the Mississippi River Delta on the Gulf Coast, drowned estuaries, tidal marshes, islands, and beaches (231B, Coastal Plains–Middle; 232B, Gulf Coastal Plains and Flatwoods; 232E, Louisiana Coastal Prairie and Marshes: 232H, Middle Atlantic Coastal Plains and Flatwoods; 232H, Southern Atlantic Coastal Plains and Flatwoods). This area extends from Virginia to Louisiana and Mississippi, but it is almost entirely within three sections of the Atlantic Plain–Coastal Plain. The northern part is in the Embayed Section, the middle part is in the Sea Island Section, and the southern part is in the East Gulf Coastal Plain Section.

The area is mostly level to gently sloping and has low relief. It is strongly dissected into nearly level and gently undulating valleys and gently sloping to steep uplands. Stream valleys are generally narrow in their upper reaches but become broad and have widely meandering stream channels as they approach the coast. Elevations range from 25 to 200 m (80 to 655 feet), gradually increasing to the north. Local relief is mainly 3 to 6 m (10 to 20 feet) but is 25 to 50 m (80 to 165 feet) in some of the more deeply dissected areas.

This area is bounded on the west and north by the “fall line.” This physiographic feature marks the western and northern extent of the unconsolidated Coastal Plain sediments and is an erosional scarp formed when this area was the Atlantic Ocean shoreline during the Mesozoic period. The Southern Coastal Plain is underlain by eroded igneous and metamorphic bedrock. Rivers and streams draining the Appalachians deposited a thick wedge of silt, sand, and gravel east and south of the fall line as delta deposits in the Atlantic Ocean. These Jurassic and Cretaceous river sediments were eventually exposed as the Coastal Plain uplifted and the sea level changed. When the sea level rose again, the Coastal Plain was submerged and covered by a thin layer of Cretaceous sands in the east and limestone, dolomite, and calcareous sands in the west. This area has a "benched" appearance because of the cycles of erosion and deposition that occurred as the area was exposed and submerged numerous times in its geologic history.

Savanna Division

This area (411A, Everglades) is in the Floridian Section of the Atlantic Plain–Coastal Plain. It is on a level, low Coastal Plain that has large areas of swamps and marshes.

Poorly defined and broad streams, canals, and ditches drain the area to the ocean. Most of the area is flat, but in the interior, hummocks rise 1 to 2 m (3 to 6 feet) above the general level of the landscape and low beach ridges and dunes, mainly in the eastern part of the area, rise 3 to 5 m (10 to 15 feet) above the adjoining swamps and marshes. Elevation ranges from sea level to less than 25 m (80 feet).

This area is a young marine plain underlain by Tertiary-age rocks, including very fine-grained shale, mudstone, limestone, and dolomite beds. Limestone rock is the dominant subsurface material. A sandy marine deposit of Pleistocene age occurs at the surface in the northern part of the area.

Subtropical Mountains Division

Ouachita Mountains

This area (M231A, Ouachita Mountains; M231G, Arkansas Valley) is in the Ouachita Mountains Section of the Interior Highlands–Ouachita.

Most of the stream valleys are narrow and have steep gradients, but wide terraces and flood plains border the Ouachita River in western Arkansas. Elevation ranges from 100 m (330 feet) on the lowest valley floors to 800 m (2,625 feet) on the highest mountain peaks. Local relief is generally 30 to 60 m (100 to 200 feet), but can exceed 300 m (980 feet).

These steep mountains are underlain by folded and faulted sedimentary and metamorphic rock, dominantly shale and sandstone. Ordovician-age shale and sandstone are included in the Collier Shale, Crystal Mountain Sandstone, and Womble Shale. Mississippian-age shale, sandstone, novaculite, and chert are included in the Arkansas Novaculite and the Stanley Shale. Pennsylvanian-age shale, slate, quartzite, and sandstone are included in the Jackfork Sandstone, Johns Valley Shale, and upper Atoka Formations. Alluvial deposits of silt, sand, and gravel are on the wide terraces and flood plains that border the Ouachita River.

Ozark Highlands

This area (223A, Ozark Highlands) is in the Springfield–Salem Plateaus Section of the Interior Highlands–Ozark Plateaus. The landscape ranges from highly dissected, steeply sloping wooded hills and narrow, gravelly valleys in the central and southern parts of the area to gently rolling prairie-like uplands in the northern part. Soluble carbonate rocks are responsible for a well developed karst topography in the southern part of the area. This topography includes sinkholes, caves, dry valleys, box valleys, and large springs. Elevation ranges from about 90 m (300 feet) on the southeastern edge of the Ozark escarpment to about 490 m (1,600 feet) on the western side of the area. Relief is generally 60 to 245 m (200 to 800 feet). It is highest in the southwestern part of the area. The geologic strata generally are horizontally bedded, but with a slight dip to the west and south away from the apex of the Ozark Uplift in southeastern Missouri.

This area has a variety of geologic formations. Most of the bedrock consists of sedimentary rocks, including Ordovician-age dolostone and sandstone, Lower Mississippian-age limestone and dolostone, and Pennsylvanian-age sandstone and shale. Remnants of an ancient loess deposit ranging from a few inches to several feet in thickness are on the nearly level upland divides. The loess is thickest in the northern and eastern parts of the area. Most of the exposed bedrock consists of limestone and dolostone formations that have thick layers of chert bedrock or chert fragments. The chert generally occurs in long, wavy beds less than 1 foot thick. In some areas, however, it occurs in massive layers more than 2 meters (6 feet) thick. Several old and inactive geologic faults are in the area.

Eastern and Western Arkansas Valley and Ridges

Most of this area (M231A, Ouachita Mountains, 231G, Arkansas Valley) is in the Arkansas Valley Section of the Interior Highlands–Ouachita, and in the Osage Plains Section of the Interior Plains–Central Lowland. Elevation ranges from 90 m (300 feet) on the lowest valley floors to 840 m (2,750 feet) on the mountaintops. In the east, the topography consists of long, narrow ridges and high flat-topped mountains capped with sandstone that trend northeastward. Crests are narrow and rolling on ridges and broad and flat on mountaintops. The intervening valleys are broad and smooth. In the west, the topography of the area is characterized by long, narrow sandstone-capped ridges that trend northeastward. The ridges are dissected by valleys cut by streams at right angles to the ridges.

In the east, the ridges and valleys are underlain by slightly folded to level beds of sandstone and shale, respectively. The area principally consists of the Savanna group, McAlester group, Hartshorne sandstone group, and the upper and lower Atoka group. These are all of Pennsylvanian age. The terrace deposits along the Arkansas River include a complex sequence of unconsolidated gravel, sandy gravel, sands, silty sands, silts, clayey silts, and clays. The individual deposits commonly are lenticular and discontinuous. At least three terrace levels are recognized. The lowest is the youngest. In the west, the area principally consists of hard and soft sandstone, shale, siltstone, limestone, and some conglomerates of the Cabaniss, Krebs, and Marmaton groups. These are all of Pennsylvanian age. They may include economically viable coal deposits. The bedrock geology of the area is tilted 2 to 15 degrees from the horizontal and is gently folded in some areas. Unconsolidated clay, silt, sand, and gravel are deposited in the river valleys.

Boston Mountains

This area (M223A, Boston Mountains) is mostly in the Boston Mountains Section of the Interior Highlands' Ozark Plateaus. The northern half of the western tip of the area is in the Ozark Plateaus' Springfield–Salem Plateaus Section. The southern half of the western tip is in the Arkansas Valley Section of the Interior Highlands' Ouachita. This area marks the southern extent of the Ozarks. It is an old plateau that has been deeply eroded. Ridgetops are narrow and rolling. Valley walls are steep. Elevation ranges from 200 m (660 feet) on the lowest valley floors to 800 m (2,625 feet) on the highest ridge crests. Local relief commonly exceeds 30 m (100 feet).

Most of this area is underlain by level to slightly tilted shale, sandstone, and siltstone strata in the Pennsylvanian-age Atoka Formation and the Cane, Boyd Shale, and Prairie Grove members of the Hale Formation. Parts of the northern edge are underlain by the Mississippian-age Pitkin Limestone,

Fayetteville Shale, and Batesville Sandstone. Alluvium consisting of an unconsolidated mixture of clay, silt, sand, and gravel is deposited in river valleys.

Hot Continental Division

This ecological division is topographically quite diverse. It includes the Interior Plains and Lowlands of Indiana, Ohio, southern Illinois, and southern Michigan as well as most of Kentucky, eastern Tennessee, and portions of West Virginia and Pennsylvania. In addition, it includes the northern Piedmont of eastern Pennsylvania and northern Virginia, as well as the central New England coasts from New York to New Hampshire.

Interior Plains and Lowlands

This area (222H, Central Till Plains–Beech–Maple) is in the Till Plains Section of the Interior Plains–Central Lowland. It is dominated by broad, nearly level ground moraines that are broken in some areas by kames, outwash plains, and stream valleys along the leading edge of the moraines. Narrow, shallow valleys commonly are along the few large streams in the area. Elevation ranges from 160 to 425 m (530 to 1,400 feet), increasing gradually from west to east. Relief is mainly a few meters, but in some areas hills rise as much as 30 m (100 feet) above the adjoining plains.

This area is underlain by Pennsylvanian shale, siltstone, and limestone in the southern part and Ordovician and Silurian limestone in the extreme northern part. Glacial drift covers all of the area, except for some areas along the major streams where the underlying bedrock is exposed. The glacial drift is Wisconsin in age and consists of distinct till units as well as sorted, stratified outwash. The entire area has been covered by a moderately thin or thick layer of loess. In a few areas the loess directly overlies the bedrock.

Western and Central Allegheny Plateau

The physiography in the part of this area (221E, Southern Unglaciated Allegheny Plateau; 221H, Northern Cumberland Plateau) east of the Mississippi River is varied and consists of gently rolling terrain on level-bedded limestone in the Kentucky Bluegrass and Highland Rim areas. Moving eastward, the topography becomes progressively more dissected and hilly. The Appalachian Plateau, stretching from central Pennsylvania to northern Georgia, grades from a dissected plateau to a rugged band of mainly forested mountains and high hills underlain by shale, sandstone, coal, and some limestone. The Valley and Ridge features long, linear forested ridges and cropland in the valleys. The Central Allegheny Plateau is in the Kanawha Section of the Appalachian Highlands–Appalachian Plateaus. It is on a dissected plateau that is underlain mainly by horizontally bedded sedimentary rocks. The narrow, level valleys and narrow, sloping ridgetops are separated by long, steep and very steep side slopes. Elevation ranges from 200 m (650 feet) on the lowest valley floors to 400 m (1,310 feet) or more on the highest ridgetops. Local relief is about 100 meters (330 feet).

In the Western Alleghenies, cyclic beds of sandstone, siltstone, clay, shale, and coal of Pennsylvanian age form the bedrock. Similar rocks of Mississippian age occur along the southwestern edge of the area in Kentucky and southern Ohio. This area is on the eastern side of the Cincinnati Arch, so the bedrock is tilted to the east in Kentucky and Ohio. Old glacial drift deposits are in some of the major river valleys. Wisconsin-age glacial outwash deposits of unconsolidated sand and gravel are near the surface in river valleys in Pennsylvania and Ohio. Wisconsin-age glacial drift covers the surface in areas to the east and north of this area. In the Central Allegheny Plateau, the area is underlain mostly by horizontal layers of Pennsylvanian-age sandstone, siltstone, shale, coal, and some limestone. The valleys along the Ohio, Muskingum, and Kanawha Rivers have significant deposits of river alluvium (unconsolidated silt, sand, and gravel). The bedrock geology is faulted and folded shale, sandstone, and limestone.

Northern Piedmont

Most of this area (221D, Northern Appalachian Piedmont) is in the Piedmont Upland Section of the Appalachian Highlands–Piedmont. The southwestern end and the northwestern portion of the southwestern half of this area and the southeastern portion of the northeastern half are in the Piedmont Lowlands Section. The northwestern portion of the northeastern half of the area is in the New England Upland Section of the Appalachian Highlands–New England. Most of this area is an eroded part of the Piedmont Plateau. This area is mostly gently sloping or sloping. Intrusive dikes and sills form fairly sharp ridges that interrupt the less steep terrain. Differential erosion has created low areas where rocks are soft and high areas where rocks are resistant to erosion. The steeper slopes generally are on ridges at the higher elevations or on side slopes adjacent to drainages. Elevation is dominantly 100 to 300 m (330 to 985 feet) but ranges from 25 to 300 m (80 to 985 feet) in most areas. It is as much as 505 m (1,650 feet) or more on some ridges and isolated peaks.

Most of this area is above the "fall line" on the east coast. The fall line is the boundary between Coastal Plain sediments and the crystalline bedrock of the interior uplands. The eastern third of the area is underlain mainly by Lower Paleozoic to Precambrian sediments and igneous rocks that have been metamorphosed. The typical rock types in this part of the area are granite, gabbro, gneiss, serpentinite, marble, slate, and schist. The central part of the area is a crustal trough or basin that formed during the Triassic period. This basin represents the ancestral Atlantic Ocean that formed when the European–African continental plate began its movement westward from the North American plate. Many of the rocks in this part of the area are the same rocks as those in the western British Isles, since they were deposited at a time when the North American, European, and African plates were all one landmass. The rocks deposited in the basins include Triassic sandstone, shale, and conglomerate. These ancient basins have been uplifted and are now in the uplands. Numerous Jurassic diabase and basalt dikes and sills cut the sedimentary rocks in the basins. The far western part is underlain mostly by Cambrian to Silurian limestone. The northern boundary marks the southernmost extent of the Wisconsin glaciers. Earlier periods of glaciation extend farther south in north-central New Jersey and in eastern Pennsylvania. Unconsolidated stream alluvium (primarily sand and gravel) fills the major river valleys.

Warm Continental Division

Northern Great Lakes

This area (211M, Northern Minnesota and Ontario; 212N, Northern Minnesota Drift and Lake Plains) is in the Central Lowland areas south and west of the western Great Lakes. It is a glaciated area with numerous lakes and wetlands. Slopes are nearly level to gently undulating in areas of glacial lake deposits, gently undulating to rolling on till plains and ground moraines, and steep on end moraines, on valley sidewalls, and on escarpments along the margins of lakes. In the extreme northwestern portion, these glacial lake plains have remnants of gravelly beaches, strandlines, deltas, and sandbars. The mostly level or nearly level plains are bordered by some gently sloping strandlines and rolling dune land. In this northwestern section, elevation is 410 m (1,350 feet), decreasing gradually to 275 m (900 feet) in the north. Ditches have been used in an attempt to drain the many wetlands, but low gradients commonly prevent adequate removal of surface and subsurface water.

Precambrian-age bedrock underlies most of the glacial deposits. The bedrock is a complex of folded and faulted igneous and metamorphic rocks. The bedrock terrain has been modified by glaciation and is covered in most areas by Pleistocene deposits and windblown silts. The glacial deposits form an almost continuous cover in most areas. The drift is as much as several hundred feet thick in many areas. Loess covered the area shortly after the glacial ice melted. In the extreme northwestern portion, the surface is covered mostly by silty and clayey lacustrine sediments and lake-modified glacial till. Crystalline metamorphic rocks underlie the glacial deposits.

Glaciated Allegheny Plateau and Catskills

This area (211F, Northern Glaciated Allegheny Plateau; 211I, Catskill Mountains) is primarily in the southern New York section of the Appalachian Highlands–Appalachian Plateaus. The east-central part is in the Catskill Section. A small portion of the Allegheny Mountain Section is in the south-central part of this area, and the southwestern corner is in the Kanawha Section. The southeastern edge and a fingerlike area protruding into the southeastern corner are in the Middle Section of the Appalachian Highlands–Valley and Ridge. The top of the dissected plateau is broad and is nearly level to moderately sloping. The narrow valleys have steep walls and smooth floors. The Catskills in the east have steep slopes. Elevation is typically 200 to 305 m (650 to 1,000 feet) on valley floors; 505 to 610 m (1,650 to 2,000 feet) on the plateau surface; and 1100 m (3,600 feet) or more in parts of the Catskills.

The bedrock in this area includes alternating shale and sandstone beds of Devonian age. Some of the upper Devonian layers have been eroded away in the part of the area in New York. Glacial drift mantles the area. Significant deposits of glacial outwash, consisting of unconsolidated sand and gravel, fill most of the valley floors. Some glacial lake sediments and ice-contact and stratified drift deposits occur in most of the valleys. These deposits are the primary aquifers in this area. Younger stream deposits cover some of the glacial deposits on the valley floors.

Northern New England Coastal Area

This area (211C, Fundy Coastal and Interior; 211D, Central Maine Coastal and Embayment; 221A, Lower New England; M211A, White Mountains; M211B, New England Piedmont) is the Appalachian Highlands–New England. The separate western part is in the Taconic Section. The rest of the area is mostly in the New England Upland Section. The part in southeastern Maine is in the Seaboard Lowland Section. This area includes the entire coastal zone of Maine and extends inland along the major river valleys. Most of the area is characterized by rolling to hilly uplands. The area has some isolated mountain peaks. In the part of the area in southeastern Maine, gently sloping to level valleys terminate in coastal lowlands. Elevation ranges from sea level to 305 m (1,000 feet) in much of the area. It is 610 m (2,000 feet) on some hills and 900 m (2,950 feet) on a few isolated peaks. Local relief is mostly low or moderate. It generally is highest in the northern part of the area and decreases as sea level is approached. An exception is the Taconic Mountains along the New York–Massachusetts border, where relief is substantial. Relief is mostly about 2 to 20 m (5 to 65 feet) in the valleys and about 25 to 100 m (80 to 330 feet) in the uplands.

Most of this area is characterized by till-mantled, rolling to hilly uplands. The northern and eastern parts of the area are underlain mostly by granite, gneiss, and schist bedrock. Limestone, dolomite, and marble beds interspersed with basalt flows occur in the southern and western parts. Stratified drift deposits of unconsolidated sand and gravel, primarily glacial outwash, fill most of the narrow river valleys. Some marine sediments occur at the lower end of the valleys that terminate in the coastal lowlands in southeastern Maine. Some glacial lake sediments occur on valley floors behind glacial moraines.

Climate

Figures 4 and 5 show average annual precipitation and air temperature across the Eastern United States, where climate varies considerably in response to latitude, longitude, and elevation, and ranges from continental in the Interior Plains and Lowlands to marine along the coast (fig. 1). Average annual precipitation, for example, ranges from as little as 64 mm (26 inches) on the western shore of Lake Michigan to over 2500 mm (100 inches) at the highest peaks in the Southern Blue Ridge. Much of the variation in precipitation is driven by proximity and position around the Great Lakes, as well as topography. For example, although not as pronounced as in the Western United States, orographic effects can substantially influence precipitation patterns and distribution across eastern mountains, particularly in the southern Appalachians where elevational gradients are the strongest (Kittel and others 1997). For example, in the mountains of southwestern North Carolina, precipitation is approximately 30 percent greater at the high versus low elevation (a difference in elevation of approximately 700 m or 2,300 feet) (Swift and others 1988). Similarly, there is a wide range in average annual and minimum and maximum temperatures across ecological divisions. In

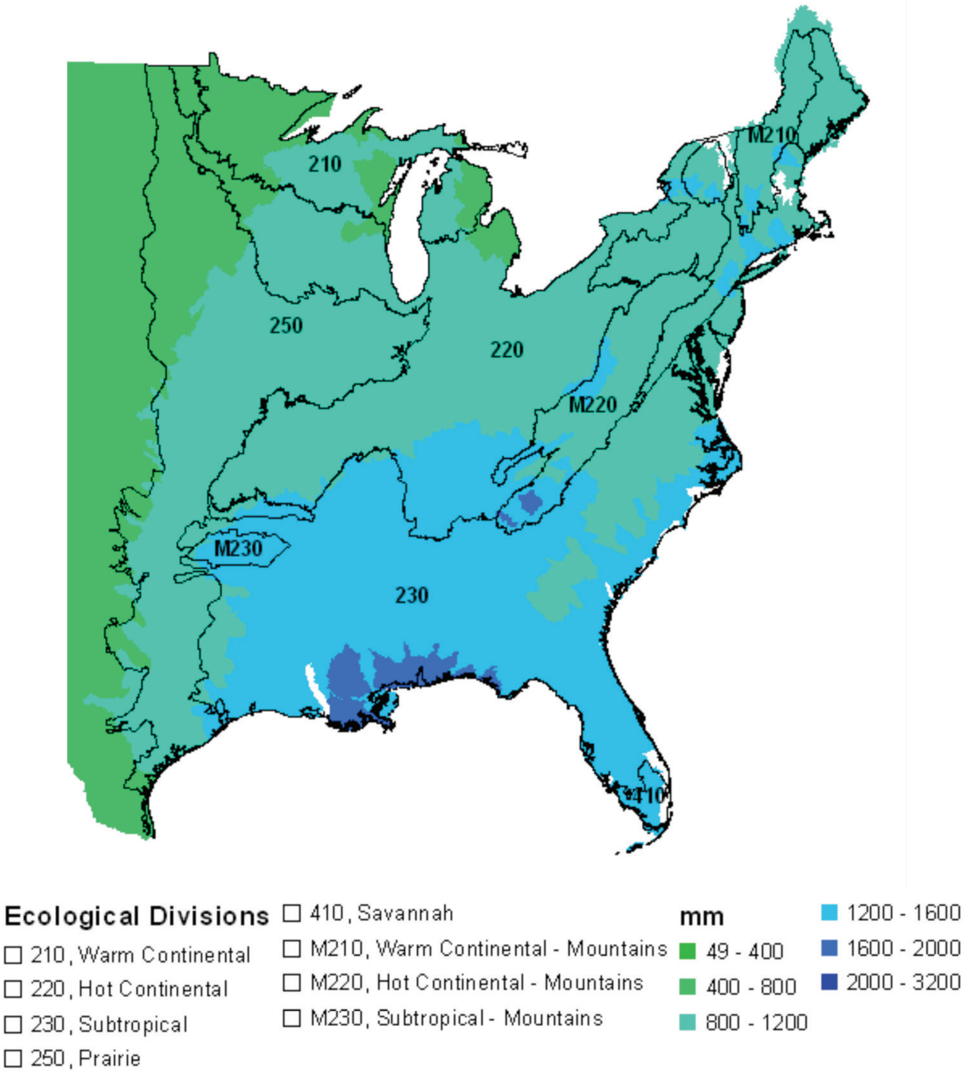

Figure 4. Average annual precipitation, 1963 to 1993, within Ecological Divisions in the Eastern United States (Kittel and others 1997).

the northern Great Lakes and northern Maine, average daily minimum temperature in January can reach –22 °C (–7 °F); whereas in the Savanna Division of southern Florida, average daily minimums rarely drop below 13 °C (55 °F) for the same time of year. Similarly, average daily maximum temperatures in July range from 25°C (77 °F) in northern areas of the Eastern United States and the highest elevations of the mountains to 36 °C (96 °F) in the Southern Coastal Plain.

Hot Continental Mountains Division

Blue Ridge

Average annual precipitation ranges from 915 to 1525 mm (36 to 60 inches), generally increasing with elevation and decreasing with latitude. Areas in southwestern North Carolina and northeastern Georgia rainfall amounts range from 1512 to 2300 mm (60 to 90 inches) per year and can reach totals of over 3000 mm (115 inches) on the higher peaks. Precipitation is generally lowest in October, but is well distributed throughout the year. Precipitation falls primarily as rain throughout most of the area except for the highest elevations. In the Northern Blue Ridge average annual precipitation is somewhat less than farther south and averages 915 to 1145 mm (36 to 45 inches) but can range as high as 1550 mm (61 inches) at high elevations. Unlike the Southern Blue Ridge, snow frequently covers the ground in winter and is a major contributor to total

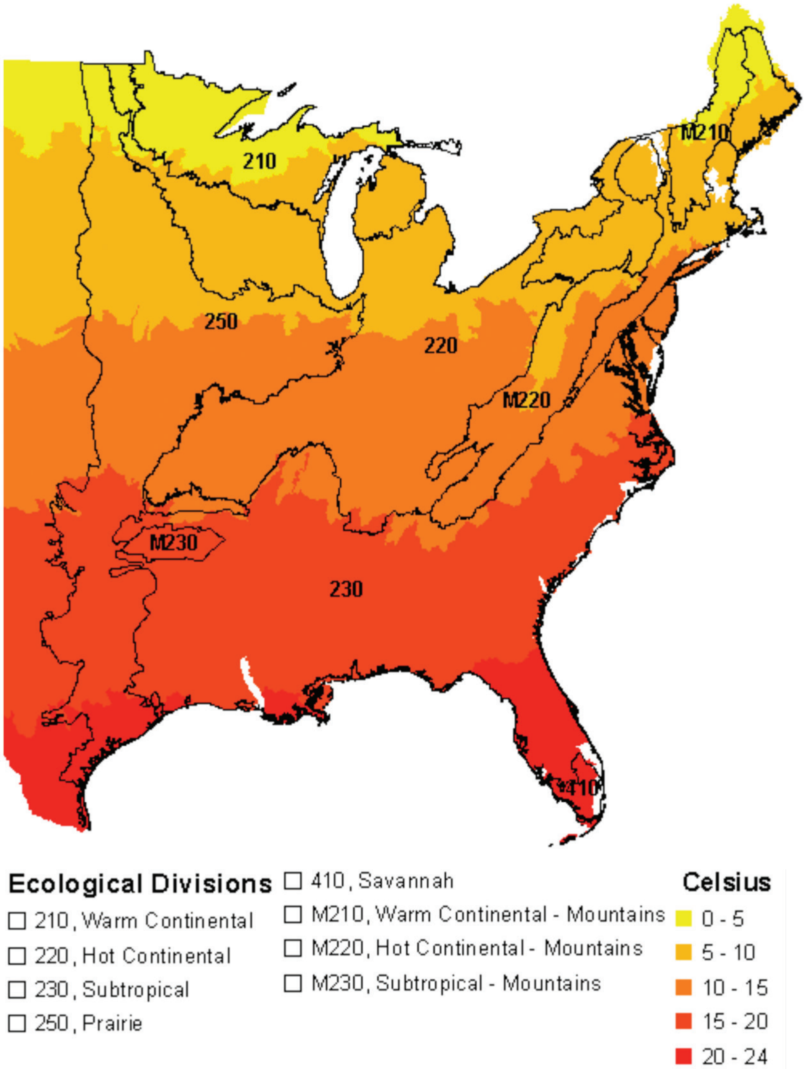

Figure 5. Average annual temperature, 1963 to 1993, within Ecological Divisions in the Eastern United States (Kittel and others 1997).

annual precipitation. In the Southern Blue Ridge average annual temperature ranges from 8 to 16 °C (46 to 60 °F), generally decreasing with elevation. The freeze-free period averages 185 days and ranges from 135 to 235 days. The length of this period decreases with increasing elevation, and with cold air drainage on valley floors. Strong aspect gradients exist and microclimatic differences resulting from aspect variation significantly affect the type and vigor of the plant communities in the area, driven primarily by differences in moisture and temperature regimes. South-facing and west-facing slopes, for example, are warmer and drier than north-facing and east-facing slopes and those shaded by the higher mountains. In the Northern Blue Ridge average annual temperature ranges from 9 to 14 °C (49 to 56 °F) and decreases with increasing elevation. The freeze-free period averages 195 days and ranges from 165 to 225 days, and shortens with increasing elevation.

Southern Appalachian Ridges and Valleys

The average annual precipitation in most of this area is 1040 to 1395 mm (41 to 55 inches). It increases to the south and is as much as 1675 mm (66 inches) at the highest elevations in eastern Tennessee and the northwestern corner of Georgia. The maximum precipitation occurs in midwinter and midsummer, and the minimum occurs in autumn. Most of the rainfall occurs as high-intensity, convective thunderstorms. Snowfall may occur in winter. The average annual temperature is 11 to 17 °C (52 to 63 °F), increasing to the south. The freeze-free period averages 205 days and ranges from 165 to 245 days. It is longest in the southern part of the area and shortest at high elevations and at the northern end.

Cumberland Plateau

Average annual precipitation ranges from 940 to 1145 mm (37 to 45 inches) in the northern third of this area and 1145 to 1525 mm (45 to 60 inches) in the southern two-thirds. It can reach 1525 mm (60 inches) at the higher elevations in the northern third of the area and can be as much as 1905 mm (75 inches) in the mountains in the southern two-thirds. Almost half of the annual precipitation falls during the growing season. Rainfall typically occurs during high-intensity, convective thunderstorms in summer. Snow may occur during winter in the northern part of the area and at the higher elevations. Average annual temperature is 10 to 15 °C (50 to 60 °F). The freeze-free period averages 200 days and ranges from 170 to 225 days. The shorter freeze-free periods are at the higher elevations and in the more northerly parts of the area.

Warm Continental Mountains Division

Adirondack Shield and Northern New England Uplands

Because of the similarities between the two areas, we elected to treat this division as one. The average annual precipitation in most of this area is 815 to 1145 mm (32 to 45 inches). It is typically 1145 to 1525 mm (45 to 60 inches) at the higher elevations in the mountains and is 1525 to 2665 mm (60 to 105 inches) on the highest peaks in the Green and White Mountains. More precipitation generally falls in summer than in winter. Most of the rainfall occurs as high-intensity, convective thunderstorms during the summer. Heavy snowfalls are common in winter. The average annual temperature is 1 to 8 °C (35 to 46 °F). The freeze-free period averages 145 days and ranges from 110 to 185 days, decreasing in length with elevation.

Prairie Division

Typically, the land surface is a nearly level to gently sloping, dissected glaciated plain. The average annual precipitation is typically 815 to 990 mm (32 to 39 inches), but ranges from 485 to 1220 mm (19 to 48 inches), increasing from north to south. Most of the precipitation occurs during the growing season. In most of the area, the average annual temperature is 8 to 12 °C (47 to 53 °F), but it ranges from 4 to 17 °C (38 to 62 °F), increasing from north to south. The freeze-free period generally is 170 to 210 days, and increases in length from north to south.

Subtropical Division

Southern Piedmont

Climatic regimes fall between warm, moist-temperate and subtropical (Bailey 1989). Much of the climate is dominated by frontal activity either from off shore or continental sources. Often, the convergence of warm moist air off the coast with cooler continental air masses produces severe thunderstorms in the piedmont. Average annual precipitation ranges from 940 to 1145 mm (37 to 45 inches) at the southern end, and is as much as 1905 mm (75 inches) in a small high elevation area of northeastern Georgia. Precipitation is generally evenly distributed throughout the year but is generally lowest during the autumn months. Most of the rainfall during the growing season occurs as high-intensity, convective thunderstorms, whereas during the dormant season weather patterns tend to be dominated by less intense and more persistent frontal weather systems. Significant moisture also comes from the movement of warm and cold fronts from November to April. High amounts of rainfall are associated with tropical weather systems such as hurricanes and other significant depressions. Snowfall is typically light.

Average annual temperature is 12 to 18 °C (53 to 64 °F). The freeze-free period averages 230 days and ranges from 185 to 275 days. Both temperature and length of freeze-free period decrease from south to north and with increasing elevation.

Upper Coastal Plain

Average annual precipitation ranges from 1040 to 1525 mm (41 to 60 inches), increasing from north to south. It is typically 1550 to 1830 mm (61 to 72 inches) in the extreme southwestern part of the area, inland along the Gulf Coast. The minimum precipitation occurs in autumn throughout the area. The maximum precipitation occurs during midsummer in the eastern part of the area and during winter and spring in the western part. Rainfall typically occurs as high-intensity, convective thunderstorms during the summer, but moderate-intensity tropical storms can produce large amounts of rainfall during winter in the eastern and southwestern parts of the area. Snowfall does not occur in the southern part of the area, but occasionally occurs in the northern part. The average annual temperature is 13 to 20 °C (55 to 68 °F), increasing from north to south. The freeze-free period averages 250 days and ranges from 200 to 305 days, increasing in length from north to south.

Lower Coastal Plain

This area includes the Atlantic Coast Flatwoods and Tidewater. The climate is mostly temperate to hot and humid. The average annual precipitation is 1065 to 1370 mm (42 to 54 inches). It commonly exceeds 1650 mm (65 inches) along the Louisiana, Mississippi, and Alabama coastlines. The area is generally driest at the northern end and wettest at the southern end. The amount of precipitation is slightly higher during the fall and winter than during the rest of the year. Snowfall occurs in the northern third. Average annual temperature ranges from 14 to 18 °C (58 to 65 °F). The freeze-free period ranges from 220 to 305 days, increasing in length to the south.

Savanna Division

This area includes the Everglades and associated areas where average annual precipitation is 1015 to 1575 mm (40 to 62 inches). About 60 percent of the precipitation occurs from June through September. The center of the area is the driest. Most of the rainfall occurs as moderate-intensity, tropical storms that produce large amounts of rain from late spring through early autumn. Late autumn and winter are relatively dry. The average annual temperature ranges from 23 to 25 °C (73 to 78 °F). The freeze-free period averages 355 days and ranges from 345 to 365 days.

Subtropical Mountains Division

Ouachita Mountains

Average annual precipitation in most of this area is 1270 to 1675 mm (50 to 66 inches). It decreases to 1040 to 1245 mm (41 to 49 inches) along the western edge of the area. The precipitation is fairly evenly distributed throughout the year. The maximum occurs in spring and early in autumn. Most of the rainfall occurs as high-intensity, convective thunderstorms. Snowfall is not common in winter. The average annual temperature is 14 to 17 °C (57 to 63 °F). The freeze-free period averages 230 days and ranges from 205 to 255 days. The shorter freeze-free periods occur at the higher elevations on the major ridges.

Ozark Highlands

Average annual precipitation in almost all of this area is 965 to 1145 mm (38 to 45 inches). It is as high as 1245 mm (49 inches) in some small areas along the extreme southeastern and southern edges of the area. About 57 percent of the annual precipitation falls during the six warmest months of the year. Snow falls nearly every winter, but the snow cover lasts for only a few days. The annual snowfall averages about 305 mm (12 inches). Average annual temperature is about 12 to 16 °C (53 to 60 °F). The lower temperatures occur at the higher elevations in the western part. The freeze-free period averages 210 days and ranges from 175 to 245 days. It is shortest at the higher elevations along the western edge. The longer freeze-free periods occur at the lower elevations.

Eastern and Western Arkansas Valley and Ridges

Average annual precipitation is 990 to 1170 mm (39 to 46 inches), with the western portion being the driest. Precipitation averages 1145 to 1550 mm (45 to 61 inches) in the eastern two thirds of the area. Most of the rainfall occurs as frontal storms in spring and early summer. Some high-intensity, convective thunderstorms occur in summer. Precipitation occurs as rain and snow in January and February. The average seasonal snowfall is 125 mm (5 inches). Most of the precipitation falls from April through September. The average annual temperature is 14 to 17 °C (58 to 62 °F). The freeze-free period averages 235 days and ranges from 220 to 260 days. The shorter freeze-free periods occur at the higher elevations on top of the major ridges.

Boston Mountains

Average annual precipitation is 1065 to 1395 mm (42 to 55 inches). The maximum precipitation occurs in spring and fall, and the minimum occurs in midsummer. Most of the rainfall occurs as high-intensity, convective thunderstorms. Snowfall is uncommon in winter. The average annual temperature is 13 to 16 °C (55 to 61 °F). The freeze-free period averages 225 days and ranges from 200 to 245 days.

Hot Continental Division

Interior Plains and Lowlands

The average annual precipitation is typically 815 to 990 mm (32 to 39 inches), but it ranges from 485 to 1220 mm (19 to 48 inches), increasing from north to south. Most of the precipitation occurs during the growing season. Rainfall decreases with distance from the ocean, hence, this area is subdivided into moist oceanic and dry continental zones. In most of the area, the average annual temperature is 8 to 12 °C (47 to 53 °F), but ranges from 4 to 17 °C (38 to 62 °F), increasing from north to south. The freeze-free period generally is 170 to 210 days and increases in length from north to south.

Northern Piedmont

Average annual precipitation is 940 to 1320 mm (37 to 52 inches). The maximum precipitation occurs as high-intensity, convective thunderstorms in spring and early in summer. Droughts of 10 to 14 days are common in summer. Snowfall occurs in winter. The average annual temperature ranges from 9 to 14 °C (48 to 57 °F). The freeze-free period averages 205 days and ranges from 170 to 240 days.

Southern New England Coasts

Along the coast including Long Island and Cape Cod, average annual precipitation is 1040 to 1220 mm (41 to 48 inches). The precipitation is fairly evenly distributed throughout the year. Rainfall occurs as high intensity, convective thunderstorms during the summer. The seasonal snowfall is moderate to low in winter, and extended periods of no snow cover can be expected in winter because of relatively moderate temperatures. The average annual temperature is 10 to 12 °C (49 to 54 °F). The freeze-free period averages 220 days and ranges from 195 to 240 days. Farther inland, the average annual precipitation is 890 to 1145 mm (35 to 45 inches) in the Hudson Valley, which is in the northern half of the western part of this area. It is 1145 to 1370 mm (45 to 54 inches) in the southern end of the western part of the area and in most of the eastern part of the area. Precipitation generally is evenly distributed throughout the year, but decreases during the summer as you near the coast. It is slightly higher in spring and fall in inland areas. Rainfall occurs as high-intensity, convective thunderstorms during the summer. During the winter, most of the precipitation occurs as moderate-intensity storms (northeasters) that produce large amounts of rain or snow. The average annual temperature is 6 to 12 °C (44 to 54 °F), increasing from north to south. The freeze-free period averages 190 days and ranges from 145 to 240 days, increasing in length to the south.

Warm Continental Division

Northern Great Lakes

Climate varies considerably in this area. In eastern Wisconsin and around Green Bay, average annual precipitation can be as low as 735 mm (29 inches), and in portions of the Upper Peninsula of Michigan can average as low as 660 mm (26 inches). Around 20 percent of total precipitation is snowfall. Whereas on the lee side of Lake Michigan in the northern half of Michigan's southern peninsula, precipitation amounts can average 1000 mm (40 inches), and snowfall amounts can reach 3800 mm (150 inches) annually. The average annual temperature ranges from 4 to 7 °C (39 to 44 °F). The freeze-free period ranges from 120 to 175 days, increasing in length from north to south.

Glaciated Allegheny Plateau and Catskill Mountains

Average annual precipitation in most of this area ranges from 760 to 1145 mm (30 to 45 inches). It is 1145 to 1625 mm (45 to 64 inches) in small pockets at high elevations in the eastern part. Rainfall occurs as high-intensity, convective thunderstorms during the summer, but most of the precipitation occurs as snow. Average annual temperature ranges from 4 to10 °C (40 to 50 °F). The freeze-free period averages 165 days and ranges from 130 to 200 days. The coldest temperatures and the shortest freeze-free periods are at high-elevations in the eastern part of Allegheny Plateau and Catskill Mountain portion of this area.

Northern New England Coasts

Average annual precipitation in most of the area is 840 to 1145 mm (33 to 45 inches) and can range from 1145 to 1755 mm (45 to 69 inches) in a few scattered, higher elevation areas and along the coast. Precipitation generally is evenly distributed throughout the year. Near the coast, however, it is slightly lower during the summer months. In inland areas, it is slightly higher in spring and fall. Rainfall occurs as high-intensity, convective thunderstorms during the summer. During the winter, most of the precipitation occurs as moderate-intensity storms (northeasters) that produce large amounts of rain or snow. Heavy snowfalls commonly occur late in winter. Average annual temperature is 4 to 9 °C (39 to 48 °F). The freeze-free period averages 160 days and ranges from 120 to 195 days. Temperatures and the length of the freeze-free period increase from north to south and closer to the coast.

Soils

The soils described in this section are classified and named in accordance with the U.S. Department of Agriculture system of classifying soils described in Soil Taxonomy (Soil Survey Staff 1999). The information and descriptions herein are derived primarily from the U.S. Department of Agriculture, Natural Resources Conservation Service (2006). Soils throughout the Eastern United States are extremely variable, ranging from glaciated tills and moraines in the north to subtropical mudflats in the south. The formation of these soils was strongly influenced by climate and mineralogy and in many areas; the surface soils are a reflection of past and present land use patterns. In the southern Piedmont, for example, past agricultural activities resulted in widespread erosion that left much of the area with surface B horizons and surface C horizons in extreme cases. The erosivity of soils when subjected to cultural activities such as farming and silviculture varies considerably, as well. For example, due primarily to mineralogy (relative proportions of clay, silt, and sand), erosivity of some soils is extreme and caution must be used when soil disturbance is planned in these areas. Steep landscapes are particularly vulnerable to erosive forces when disturbed. Hence, understanding the interactions between land management options and soil behavioral properties is critical for insuring long-term site productivity and minimal offsite impacts such as sedimentation of surface water.

Hot Continental Mountains Division

Blue Ridge

Dominant soil orders are Inceptisols and Ultisols. The soil moisture regime is udic and the soil temperature regime is mesic, but is frigid at elevations above 1280 m (4,200 feet). Soil depth ranges from shallow to very deep. The general textural class is loamy or clayey. At elevations less than 1065 m (3,500 feet), the soils on uplands generally are red, fine-loamy or fine Typic Hapludults (Evard, Junaluska, and Hayesville series). Humic Hapludults (Trimont and Snowbird series) are on northern and eastern aspects. Soils that formed in colluvium in coves are Typic Dystrudepts (Tate, Greenlee, and Northcove series), or Humic Hapludults (Saunook and Thunder series). At elevations between 1065 and 1280 m (3,500 and 4,200 feet) are generally brown, fine-loamy or coarse-loamy Dystrudepts. Humic Dystrudepts (Plott, Porters, Cheoah series) are common on northern and eastern aspects, and Typic Dystrudepts (Edneyville, Chestnut, Ditney, and Stecoah series) are common on southern and western aspects. Soils that formed in colluvium in coves are Humic Dystrudepts (Cullasaja, Spivey, Tuckasegee, and Santeetlah series) or Humic Hapludults (Saunook and Thunder series). The general soil texture class at this intermediate elevation is loamy or clayey. Soil depth ranges from shallow, mostly on the ridge tops, to very deep at the base of ridges formed by colluvium. Most soils are well drained and only in areas of alluvium near large streams do anaerobic conditions exist where drainage is poor. In areas at elevations above 1280 m (4,200 feet), the soils on uplands generally are brown, fine-loamy or coarse loamy Humic Dystrudepts with a frigid soil temperature regime (Burton, Oconaluftee, and Breakneck series). Soils that formed in colluvium also are Humic Dystrudepts (Balsam and Chiltoskie series). Soils that formed in alluvium vary with stream gradient, energy, and entrenchment into the valley floor. In the upper reaches of watersheds where flood plains are narrow, the soils are Oxyaquic and Fluvaquentic Dystrudepts (Dellwood, Reddies, and Cullowhee series). In the lower and broader river valleys, Udipsamments (Biltmore series) and coarse-loamy Dystrudepts (Rosman series) are in areas closest to rivers and streams on flood plains. Humaquepts (Ela, Nikwasi, and Toxaway series) are in low-lying, frequently flooded or ponded areas. Ultisols are most common on the more stable stream terraces. Fine-loamy Aquic and Typic Hapludults (Dillard and Statler series) are on low terraces, and fine Typic Hapludults (Braddock and Unison series) are on high terraces.

Southern Appalachian Ridges and Valleys

The soils are mainly Udults and, to a lesser extent, Udepts. They have a udic soil moisture regime and a thermic or mesic soil temperature regime; are dominantly well drained, strongly acid, and highly leached; and have a clayenriched subsoil. They range from shallow on sandstone and shale ridges to very deep in valleys and on large limestone formations. Paleudults (Decatur, Dewey, Frederick, Fullerton, and Pailo series, commonly cherty) are in the many extensive areas underlain by southwest-to-northeast traversing limestone. Hapludults (Townley and Armuchee series) are dominant in valleys underlain by acid shale. Steep, shallow or moderately deep, shaly and stony Dystrudepts (Weikert, Wallen, Montevallo, and Calvin series) are on the sides of steep ridges. Shallow, shaly Eutrudepts (Bays and Dandridge series) are in areas of the shale formation extending along the eastern side of the area. Eutrudepts (Hamblen, Sullivan, and Pettyjon series) are on narrow bottomland.

Cumberland Plateau

Most of the soils in the undulating to rolling areas on the Cumberland Plateau are Hapludults. Moderately deep or deep, well drained, loamy Hapludults (Lily, Lonewood, and Hartsells series) formed in sandstone residuum. Shallow, somewhat excessively drained, loamy Dystrudepts (Ramsey series) also formed in sandstone residuum. They are less extensive than the other soils in the undulating to rolling areas on the Cumberland Plateau. Most of the remaining soils in the undulating to rolling areas are deep or very deep, moderately well drained, loamy Hapludults (Clarkrange and Hendon series), which formed in a loamy mantle and sandstone residuum. The dominant soils in hilly to steep areas are Hapludults (Gilpin and Lily series) and Dystrudepts (Petros and Matewan series). They are shallow to moderately deep, well drained or somewhat excessively drained, and loamy and formed in sandstone or shale residuum. The remaining soils on steep slopes generally are deep or very deep, well drained, loamy Hapludults (Bouldin, Grimsley, Jefferson, Pineville, and Shelocta series) and Dystrudepts (Varilla, Highsplint, and Guyandotte series), which formed in gravelly or stony colluvium derived from sandstone or shale or both. Soils on flood plains are of small extent on the Cumberland Plateau and are slightly more extensive in the Cumberland Mountains. Most of these soils are well drained or moderately well drained Dystrudepts (Ealy, Pope, Philo, and Sewanee series) or Eutrudepts (Grigsby, Sensabaugh, and Chagrin series) or poorly drained Endoaquepts (Bonair and Atkins series). They are deep or very deep, are loamy, and formed in alluvium derived from sandstone and shale. Material derived from surface and deep mines is common. Udorthents (Bethesda, Cedarcreek, Fairpoint, and Kaymine series) formed in this material.

Warm Continental Mountains Division

Adirondack Shield and Northern New England Uplands

Because of the similarities between the two areas, we elected to treat this division as one. The dominant soil orders are Inceptisols and Spodosols. The soils dominantly have a frigid soil temperature regime, an aquic or udic soil moisture regime, and isotic or mixed mineralogy. At elevations above 915 m (3,000 feet) in the Adirondack Mountains, the soil temperature regime is cryic. The soils are shallow to very deep, generally somewhat excessively drained to poorly drained, and loamy. Humaquepts (Burnham series) and Epiaquepts (Monarda series) formed in dense till in depressions on till plains. Haplorthods formed in loamy till on hills, mountains, and plateaus (Berkshire, Lyman, Thorndike, and Tunbridge series) and in dense till on drumlins, hills, and ridges (Becket, Colonel, Dixfield, Howland, Marlow, Peru, and Plaisted series).

Prairie Division

The soils are dominantly Alfisols, Entisols, Inceptisols, or Mollisols. Some Histosols occur on flood plains and in wetlands. The dominant suborders are Udalfs, Aqualfs, and Aquolls. The sandy soils are typically Psamments. The soils dominantly have a mesic soil temperature regime, an aquic or udic soil moisture regime, and mixed or smectitic mineralogy. In central Illinois, the dominant soil orders are Mollisols and Alfisols. Most of the soils are Udolls or Aquolls. They have a mesic soil temperature regime, an aquic or udic soil moisture regime, and dominantly mixed mineralogy; and generally are moderately deep to very deep, poorly drained to moderately well drained, and silty or clayey. Nearly level Endoaquolls (Drummer series) and gently sloping to sloping Argiudolls (Saybrook and Catlin series) formed in loess over loamy till on uplands. Hapludalfs commonly occur along the major stream valleys. They are on the gently sloping to moderately sloping uplands (Birkbeck and Mayville series) or on the steep or very steep valley bluffs (Strawn series). Nearly level Endoaquolls (Ashkum, Bryce, and Drummer series) are on broad flats and in shallow depressions. Moderately well drained Argiudolls (Graymont and Varna series) formed in loess and loamy till on gently sloping to sloping uplands. In areas of the more clayey till, somewhat poorly drained Argiudolls (Clarence, Elliott, and Swygert series) are more prevalent. Hapludalfs (Kidami and Ozaukee series) commonly occur on gently sloping to moderately sloping uplands along major stream valleys. They also occur on many of the more sloping glacial moraines. Moderately well drained Eutrudepts (Chatsworth series) generally are in the steeper areas. Haplosaprists (Houghton and Lena series) are common in wet, closed depressions. Loamy, moderately well drained and well drained Argiudolls (Proctor and Warsaw series) and Hapludalfs (Camden and Fox series) are on outwash plains or broad stream terraces underlain by sand and gravel. Somewhat poorly drained Argiudolls (Martinton series) and poorly drained Endoaquolls (Milford series) commonly are on broad glacial lake plains. Cumulic Endoaquolls (Sawmill series) and Cumulic Hapludolls (Lawson and Huntsville series) formed in alluvium on nearly level, broad flood plains and in the smaller upland drainage ways.

Subtropical Division

Southern Piedmont

The dominant soil orders are Ultisols, Inceptisols, and Alfisols. The soils have a thermic soil temperature regime, a udic soil moisture regime, and kaolinitic or mixed mineralogy. They are shallow to very deep, generally well drained, and loamy or clayey in texture. Hapludalfs (Enon and Wilkes series), Hapludults (Badin, Nason, and Tatum series), and Kanhapludults (Appling, Cecil, Georgeville, Herndon, Madison, Pacolet, and Wedowee series) formed in residuum on hills and ridges. Dystrudepts (Chewacla series) formed in alluvium on flood plains. Udults in the Rhodic subgroup (Davidson, Hiwassee, and Lloyd series) formed in old alluvium on stream terraces or in residuum derived from mafic rocks.

Upper Coastal Plain

Dominant soil orders are Ultisols, Entisols, and Inceptisols. The soils dominantly have a thermic soil temperature regime, a udic or aquic soil moisture regime, and siliceous or kaolinitic mineralogy. They generally are very deep, somewhat excessively drained to poorly drained, and loamy. Hapludults formed in marine sediments (Luverne and Sweatman series) and mixed marine sediments and alluvium (Smithdale series) on hills and ridges. Kandiudults formed in marine sediments (Dothan, Fuquay, Norfolk, and Orangeburg series) and mixed marine and fluvial sediments (Troup series) on hills and ridges. Fragiudults (Ora and Savannah series) and aleudults (Ruston series) formed in mixed marine and fluvial sediments on uplands and stream terraces. Fluvaquents (Bibb series) and Endoaquepts (Mantachie series) formed in alluvium on flood plains. Quartzipsamments (Lakeland series) formed in sandy eolian or marine material on uplands. Paleaquults (Rains series) formed in marine and fluvial sediments on terraces.

Lower Coastal Plain

Soils are dominantly Alfisols, Entisols, and Ultisols, but Histosols and Spodosols are not uncommon. The soils typically formed in alluvium on flood plains, in depressions, and on terraces. They dominantly have a thermic soil temperature regime, an aquic or udic soil moisture regime, and siliceous, mixed, or smectitic mineralogy. The soils of the Lower Coastal Plain are made up predominantly of Spodisols (Harris 2001). Spodisols can develop under excessively to poorly drained conditions and are commonly associated with widely fluctuating water tables within 2 m (6.5 feet) of the soil surface. Although edaphic conditions associated with Spodisols are rather specific, vegetation is less definitive because a variety of plant species assemblages are found to occur over Spodisols. However, acidifiying trees and shrubs (heaths, conifers) are commonly associated with Spodisols (Dalsgaard 1990). Soil depth to the saturated zone varies seasonally throughout the Lower Coastal Plain, and particularly in shallow soils, can be underwater during certain times of the year.

Soil texture is predominately sandy-loamy to coarse-loamy materials under humid and perhumid climates. Soil depth can vary seasonally as water tables fluctuate but is generally around 2 m deep. However, during certain times of the year local flooding is common as the water table rises. Soils are excessively to poorly drained. Seasonal flooding occurs in depressions created as karst features of the landscape underlain by deep limestone substrate beneath the saturated (aquiclude) zone. These ephemeral ponds can serve as discharge zones during periods of low water table. Immediately along the coast (The Atlantic Coast Flatwoods), the dominant soil orders are Alfisols and Entisols. The soils are characterized by restricted drainage, a thermic soil temperature regime, and an aquic soil moisture regime. The soils in the northern part of the area dominantly have mixed mineralogy, and those in the southern part dominantly have mixed clay and siliceous sand mineralogy. Very deep, loamy to clayey Endoaquults (Tomotley, Yeopim, Yemassee, and Wahee series), Umbraquults (Cape Fear and Portsmouth series), Endoaqualfs (Argent and Yonges series), and Albaqualfs (Meggett series) are extensive. Hapludults (Bertie and Tetotum series) are in the higher areas where drainage is better but is somewhat restricted. Other important soils are Alaquods (Leon and Lynn Haven series) and Psamments (Wando, Newhan, Corolla, and Fripp series). Histosols (Pungo and Belhaven series) are in large areas in North Carolina and Virginia, in the Great Dismal Swamp and in broad upland wetlands known as poquosins. Aquents (Bohicket and Capers series) are extensive throughout the brackish tidal marshes protected by the barrier islands and sea islands.

Savanna Division

The dominant soil orders are Entisols and Histosols. The soils dominantly have a hyperthermic soil temperature regime, an aquic or udic soil moisture regime, and carbonatic mineralogy. They are very shallow to very deep, generally moderately well drained to very poorly drained, and loamy or sandy. Udorthents (Krome series) formed in residuum on flats. Fluvaquents (Biscayne and Perrine series) and Psammaquents (Hallandale series) formed in marine sediments on flats and in depressions and sloughs. Haplosaprists (Pahokee and Terra Ceia series) formed in organic deposits in marshes.

Subtropical Mountains Division

Ouachita Mountains

The dominant soil orders are Ultisols and Inceptisols. These soils dominantly have a thermic soil temperature regime, a udic soil moisture regime, and mixed or siliceous mineralogy. They are shallow to very deep, generally somewhat excessively drained to somewhat poorly drained, and loamy. Dystrudepts (Bismarck and Clebit series) and Hapludalfs (Clearview series) formed in residuum on hills and mountains. Hapludults formed in colluvium (Zafra series), colluvium over residuum (Bengal series), and residuum (Carnasaw, Pirum, Sherless, Sherwood, Stapp, and Townley series) on hills, mountains, and plateaus. Udifluvents (Ceda series) formed in alluvium on flood plains.

Ozark Highlands

Most of the soils in this area are Alfisols or Ultisols. They formed in material weathered from cherty limestone. Most areas in the northern and eastern parts are partly covered with a thin mantle of loess. Physical and chemical weathering has caused the cherty limestone to disintegrate into its least soluble components, which are chert and clay. The chert remains in the form of angular fragments or wavy horizon beds interstratified with layers of clay. Downslope movement by gravitational creep and overland waterflow has altered the cherty material in the upper part of some soils. In general, the soils are shallow to very deep, moderately well drained to excessively drained, and medium textured to fine textured. The soil temperature regime is mesic bordering on thermic, the soil moisture regime is udic, and mineralogy is mixed or siliceous. Many of the soils on nearly level to moderately sloping upland divides are Paleudalfs (Gravois, Gepp, and Peridge series), Fragiudalfs (Union, Viraton, and Wilderness series), or Fragiudults (Captina, Scholten, and Tonti series). Many of the soils on moderately sloping to steep side slopes in the uplands are Hapludalfs (Gatewood, Mano, Ocie, and Wrengart series), Hapludults (Bendavis, Bender, and Lily series), Paleudalfs (Alred, Goss, and Rueter series), or Paleudults (Clarksville, Coulstone, Noark, and Poynor series). Many of the soils in glades are Mollisols (Gasconade, Knobby, and Moko series). Many of the soils on terraces and the adjacent flood plains are Hapludalfs (Razort, Secesh, and Waben series), Hapludolls (Cedargap, Dameron, and Sturkie series), Paleudalfs (Britwater and Pomme series), Eutrudepts (Gladden and Jamesfin series), or Udifluvents (Midco and Relfe) series.

Eastern and Western Arkansas Valley and Ridges

In the eastern portion, the dominant soil orders are Ultisols. In the west, they are dominated by Udalfs or Udepts. Both areas have a thermic soil temperature regime, a udic soil moisture regime, and mixed or siliceous mineralogy. In the east, soils are stony or non-stony and are medium textured. Well drained, shallow and moderately deep Hapludults (Mountainburg and Linker series) formed on ridgetops, benches, and the upper slopes. Well drained, deep Hapludults (Enders series) and Paleudults (Nella series) formed on the middle and lower slopes and in concave areas between ledges. Fragiudults (Leadvale, Taft, and Cane series) formed in valleys. Udifluvents (Roxana series), Udipsamments (Crevasse series), Haplaquolls (Roellen series), and Hapludalfs (Gallion series) are minor soils along the Arkansas River, and Dystrochrepts (Barling series) and Hapludults (Spadra and Pickwick series) are minor soils on terraces along the smaller streams. In the west, moderately deep, gently sloping to steep Hapludalfs (Clearview series) formed on ridgetops, shoulder slopes, and side slopes. Very deep, gently sloping to sloping Paleudalfs (Stigler series) formed on the side slopes of valleys. Deep, gently sloping to steep Hapludalfs (Endsaw series) formed on side slopes and footslopes. Shallow, sloping to steep Dystrudepts (Clebit and Hector series) formed on narrow ridgetops and the upper shoulder slopes. Very deep, gently sloping to steep Paleudalfs (Larton and Porum series) and Hapludalfs (Karma series) are minor soils on terraces along streams. Nearly level to sloping Hapludolls (Verdigris series) and Udifluvents (Severn series) are minor soils along flood plains throughout the area.

Boston Mountains

The dominant soil orders are Ultisols and Inceptisols. These soils dominantly have a thermic soil temperature regime, a udic soil moisture regime, and mixed or siliceous mineralogy. They are shallow to very deep, generally well drained, and loamy. Hapludults (Enders, Linker, Mountainburg, and Steprock series) and Dystrudepts (Hector series) formed in residuum on hills, plateaus, and mountains. Paleudults formed in alluvium or colluvium over residuum (Allen and Nella series) and alluvium or colluvium (Leesburg series) on hills and terraces.

Hot Continental Division

Interior Plains and Lowlands

Soils are chiefly Inceptisols, Ultisols, and Alfisols, rich in humus and moderately leached, with a distinct light-colored leached zone under the dark upper layer. The Ultisols have a low supply of bases and a horizon in which clay has accumulated.

The soils typically have a frigid soil temperature regime, an aquic or udic soil moisture regime, and mixed mineralogy. They generally are very deep, well drained to very poorly drained, and loamy.

Southern New England Coasts

The soils are dominantly Entisols or Spodosols. They commonly have a fragipan. Alfisols are less extensive. They formed in limy parent material and have a fragipan. The dominant suborders are Ochrepts and Orthods at the higher elevations and Aqualfs, Aquepts, and Histosols on lowlands and in depressions. The soils on flood plains (Fluvents) are of small extent but are important for many uses. The soils dominantly have a frigid or mesic soil temperature regime, a udic soil moisture regime, and mixed mineralogy. The major soil resource concerns are water erosion, wetness, and maintenance of organic matter content and productivity of the soils. Wind erosion is a hazard in some of the northern parts where the lighter textured soils occur. Protecting wildlife habitat and preserving the quality of surface water and ground water are additional concerns in many parts of this area.

Northern Piedmont

The dominant soil orders are Alfisols, Inceptisols, and Ultisols. The soils dominantly have a mesic soil temperature regime, a udic soil moisture regime, and mixed, micaceous, or kaolinitic mineralogy. They are moderately deep to very deep, moderately well drained to somewhat excessively drained, and loamy or loamy-skeletal. Hapludalfs (Duffield, Neshaminy, and Penn series) and Dystrudepts (Manor, Parker, and Mt. Airy series) formed in residuum on hills. Fragiudalfs (Reedington series) formed in residuum on footslopes and in drainageways. Hapludults (Chester, Elioak, Gladstone, and Glenelg series) and Kanhapludults (Hayesville series) formed in residuum on hills, upland divides, and ridges. Fragiudults (Glenville series) formed in colluvium or residuum on hills. The far northeastern extent of the northern Piedmont was affected by early periods of glaciation, and many soils formed in very deep, highly weathered till; the dominant soils are Hapludalfs (Washington and Bartley series) and Fragiudults (Annandale and Califon series).

Warm Continental Division

Northern Great Lakes

The soils are primarily Histosols, Alfisols, Spodosols, and Entisols. Some areas also have a significant acreage of Mollisols or Inceptisols. Almost all of the soils have a frigid soil temperature regime, and all have an aquic or udic soil moisture regime. Soils with a mesic soil temperature regime are in many areas in the southern part. Mineralogy is dominantly mixed, but it is isotic in some areas.

Glaciated Allegheny Plateau and Catskill Mountains

The dominant soil order is Inceptisols. The soils dominantly have a mesic soil temperature regime, an aquic or udic soil moisture regime, and mixed mineralogy. They are shallow to very deep, well drained to very poorly drained, and loamy or loamy-skeletal. Dystrudepts (Arnot, Lordstown, and Oquaga series) formed in till on hills and dissected plateaus. Fragiudepts (Bath, Lackawanna, Mardin, Swartswood, Wellsboro, and Wurtsboro series) and Fragiaquepts (Chippewa, Morris, Norwich, and Volusia series) formed in till (dense till in some areas) on hills and till plains.

Northern New England Coasts

The dominant soil orders are Inceptisols and Spodosols. The soils dominantly have a frigid soil temperature regime, an aquic or udic soil moisture regime, and isotic, illitic, or mixed mineralogy. They are shallow to very deep, generally excessively drained to poorly drained, and loamy or sandy. Eutrudepts (Buxton series) and Epiaquepts (Scantic series) formed in glaciomarine or glaciolacustrine deposits on coastal lowlands and in valleys. Dystrudepts formed in till on till plains and moraines (Lanesboro, Shelburne, and Colrain series) and on hills and ridges (Taconic series). Haplorthods formed in glaciofluvial deposits on outwash plains and eskers (Adams and Colton series); in till on till plains, ridges, and moraines (Bangor, Berkshire, Dixmont, Hermon, Lyman, Monadnock, and Tunbridge series); and in dense till on drumlins and uplands (Marlow and Peru series).

Conclusions

The Eastern United States encompasses significant variation in biophysical features that constrain management practices available to reduce fuel loads. For example, in areas with generally flat topography (such as the Coastal Plain), mechanical techniques are easy to implement. By contrast, fuel management options are more limited in steeper terrain where mechanical techniques are difficult (or cost prohibitive) to implement. Variation in climate influences species composition and fuel load, and also determines site access (wetter areas may be less accessible for mechanical techniques) and unsuitable moisture levels (either too wet or too dry) for prescribed fire. Variation in soils and geology determine the sensitivity of soils to compaction or erosion after mechanical treatments, and sustainability of soil productivity after prescribed fire. In summary, variation in geomorphology, topography, soils, and climate in the Eastern United States requires understanding interactions among fuel management treatments and geographic landscapes, and matching treatment prescriptions with physical conditions.

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