

## **Chapter 3. Barton D. Clinton, James M. Vose, Erika C. Cohen**

### **Geographic Considerations for Fire Management: Geomorphology, Topography, Soils, and Climate of the Eastern U.S.**

#### **Introduction**

Across the eastern US, there is on average an estimated 36 Mg ha<sup>-1</sup> of dead woody fuel (Chojnacky et al. 2004). Variation in fuel type, size, and flammability across the region makes selection of treatment options critical for effective fuels management. The eastern U.S. 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 region is generally flat, has large areas of wetlands, and is derived from sedimentary parent material. By contrast, the Piedmont and Appalachian Mountain regions are derived primarily from igneous and metamorphosed igneous parent materials, have complex topography, and little or no wetlands. Thus, it is important to understand interactions among fuel management treatments and geographic regions, 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 to some degree by management activities, new technologies, and policies, whereas physical parameters are generally not easily altered. Except where major changes in physical parameters have been possible (e.g., drainage of hydric ecosystems in the coastal plain), variation in physical parameters across geographic regions constrains fuel and fire management options among and within regions.

The purpose of this chapter is to describe, compare, and contrast the geomorphology, climate, and soils of major physiographic regions in the eastern U.S. The information in this chapter is derived from several publications (Bailey 1995, Cleland et al. 2005, USDA NRCS 2006), and provides the backdrop for understanding fire and fuel management options in the eastern U.S. Although many levels of resolution in landscape variation have been described for the eastern U.S. (Bailey 1995, Cleland et al. 2005), it can generally be characterized by 8 major Ecological Divisions (Cleland 2005; Plates 1 and 2; Table 1), the basic geographic units described in this volume. Plate 1 shows the Ecological Provinces as defined by Cleland (2005) within each Ecological Division. On each plate, boundaries of each ecological division is superimposed and outlined in white with each division numbered and named in the legend. Table 2 contains the Geologic Time Scales for reference, and Table 3 is a comparison of mean annual temperature, precipitation, and elevation among ecological divisions.

Table 1. Ecological Divisions and Ecological Provinces contained within (Cleland 2005; see Plate 1).

<b>Ecological Division</b>	<b>Ecological Provinces</b>
<b>Warm Continental (210)</b>	
	Laurentian Mixed Forest
	Northeastern Mixed Forest
<b>Warm Continental Mountains (M210)</b>	
	Adirondack
	New England Mixed Forest
	Coniferous Forest
	Alpine Meadow
<b>Hot Continental (220)</b>	
	Eastern Broadleaf Forest
	Midwest Broadleaf Forest
	Central Interior Broadleaf Forest
<b>Hot Continental Mountains (M220)</b>	
	Central Appalachian Broadleaf Forest
	Coniferous Forest
	Meadow
	Ozark Broadleaf Forest
<b>Subtropical (230)</b>	
	Southeastern Mixed Forest
	Outer Coastal Plain Mixed Forest
	Lower Mississippi Riverine Forest
<b>Subtropical Mountains (M230)</b>	
	Ouachita Mixed Forest
	Meadow
<b>Prairie (250)</b>	
	Prairie Parkland (Temperate)
	Prairie Parkland (Subtropical)
<b>Savanna (410)</b>	
	Everglades

These ecological divisions are characterized by distinct biophysical features such as vegetation, topography, geology, soils, and climate and provide the backdrop for natural resource management planning recognizing the substantial differences that exist among provinces with respect to responses to management activities. For purposes of reference, each Ecological Division is discussed in the context of major geographic regions contained within.

# Geomorphology

## (Plates 3 and 4)

A detailed description and comparative analysis of the temporal and spatial variation in topography and geology in the Eastern U.S. is beyond the scope of this volume. In this section we describe, in general terms, topographic and geologic variation within and among Ecological Divisions, with specific attention given to major geographic regions within each Division. Included is a table (Table 2) of the Geologic Time Scale for reference.

### ***Hot Continental Mountains Division (Blue Ridge, Southern Appalachian Ridges and Valleys, Cumberland Plateau) –***

#### **Blue Ridge**

Topography – The region consists of several distinct topographic areas, including the Blue Ridge Escarpment to the east, the New River Plateau to the north, interior low and intermediate mountains throughout, intermountain basins between the major mountains, and the high mountains making up the bulk of the region. Elevations range from around 275 m (900 ft) at the south and southwest boundaries to more than 2,010 m (6,600 ft) at the crest of the Great Smoky and Black Mountain ranges.

Bedrock – 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 southwestern part of this region include distinct and interbedded bodies of metasandstone, slate, phyllite, metasilstone, and metaconglomerate. The northern Blue Ridge formed during a period of post-Cretaceous uplift along the east 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**

Topography – Most of this area is in the Tennessee Section of the Valley and Ridge Province of the Appalachian Highlands. The thin stringers in the western part of the area are mostly in the Cumberland Plateau Section of the Appalachian Plateaus Province of the Appalachian Highlands. A separate area of the region in

northern Alabama is in the Highland Rim Section of the Interior Low Plateaus Province of the Interior Plains. 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 ft) near the southern end of the area to more than 730 m (2,400 ft) in the part of the area in the western tip of Virginia. Some isolated linear mountain ridges rise to nearly 1,500 m (4,920 ft) 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 ft).

*Bedrock* – 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**

*Topography* – The northern third of this area is primarily in the Kanawha Section of the Appalachian Plateaus Province of the Appalachian Highlands. The southern two-thirds is primarily in the Cumberland Plateau Section of the same province and division. A strip along the central part of the east edge of the area is in the Cumberland Mountain Section of the same province and division, and small areas of the region along the southwestern edge are in the Highland Rim Section of the Interior Low Plateaus Province of the Interior Plains. This highly dissected portion of this division 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 ft) on the flood plain along the Ohio River to about 300 m (980 ft) on nearby ridgetops. It gradually rises from these areas to areas near the Virginia-Kentucky border, where it is about 505 m (1,650 ft) on local flood plains and 1,205 m (3,950 ft) on the higher mountains.

*Bedrock* – 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 in this region. 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, Northern New England Uplands)***

#### **Adirondack Shield and Northern New England Uplands**

**Topography** – **Because of the similarities between the two provinces within this division, we elected to treat this division as one.** The westernmost part of this area is primarily in the Adirondack Province of the Appalachian Highlands. A small area in the southern end of the western part is in the Mohawk Section of the Appalachian Plateaus Province of the same division. The easternmost part of this division, primarily in northern Maine, is in the New England Upland Section of the New England Province of the Appalachian Highlands. The southwestern half of this part is in the White Mountain Section of the New England Province of the Appalachian Highlands, and the middle part of this region is in the Green Mountain Section of the same province and division. The mountains and foothills in the region 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 1,220 m (1,000 to 4,000 ft), but it is more than 1,525 m (5,000 ft) on a few isolated peaks and is less than 305 m (1,000 ft) in some of the valleys, especially in northeastern Maine. Local relief ranges from moderate in some areas to high in ruggedly mountainous areas.

**Bedrock** – 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 in this region 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 in the area 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***

**Topography** – Almost all the eastern portion of the area is on the glaciated Bloomington Ridged Plain in the Till Plains Section of the Central Lowland

Province of the Interior Plains. The northern tip is in the Eastern Lake Section of the same province and division. The western portion of the area is on the east 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 region was glaciated and has deposits of loess of various thickness. 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 ft) in the eastern and southern parts of the area to about 300 m (985 ft) in the western and northern parts. The maximum local relief is about 50 m (160 ft) 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 ft) 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 in the area 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 ft) in the southern part of the area to about 300 m (985 ft) in the northern part. The maximum local relief is about 50 m (160 ft) 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 ft) on the broad, flat uplands.

***Bedrock*** – 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, Upper and Lower Coastal Plains, Savannas)***

#### **Southern Piedmont**

***Topography*** – The Southern Piedmont extends from Maryland southwest to Alabama and is bounded on the SE by the Upper Coastal Plain and to the NW by the 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) due to

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. Almost all of this area is in the Piedmont Upland Section of the Piedmont Province of the Appalachian Highlands. A very small part of the region in central North Carolina, is in the Atlantic Plain Division. A very small part in the Roanoke, Virginia, area is on the eastern edge of the Blue Ridge Province of the Appalachian Highlands. The region 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% of the land area. Elevations range from 100 to 400 m (330 to 1,310 ft).

Bedrock – Precambrian and Paleozoic metamorphic and igneous rocks underlie most of this region. 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 region. 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, Virginia. These basins have Triassic and Jurassic siltstone, shale, sandstone, and mudstone. River valleys have recent alluvium and few terraces.

## **Coastal Plain**

Topography – This is a region of coastal lowlands, coastal plains, the Mississippi River Delta on the Gulf Coast, drowned estuaries, tidal marshes, islands, and beaches. The region is mostly level to gently sloping and has low relief. This area extends from Virginia to Louisiana and Mississippi, but it is almost entirely within three sections of the Coastal Plain Province of the Atlantic 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 Coastal Plain 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 ft), gradually increasing to the north. Local relief is mainly 3 to 6 m (10 to 20 ft) but is 25 to 50 m (80 to 165 ft) in some of the more deeply dissected areas.

Bedrock – This region 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 region 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.

## **Savannas**

Topography – This area is in the Floridian Section of the Coastal Plain Province of the Atlantic 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 ft) 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 ft) above the adjoining swamps and marshes. Elevation ranges from sea level to less than 25 m (80 ft).

Bedrock – 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 in this division. A sandy marine deposit of Pleistocene age occurs at the surface in the northern part of the area.

## **Subtropical Mountains Division (Ouachita Mountains, Ozark Highlands, Eastern and Western Arkansas Valley and Ridges, Boston Mountains)**

### **Ouachita Mountains**

Topography – This area is in the Ouachita Mountains Section of the Ouachita Province of the Interior Highlands. 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 ft) on the highest mountain peaks. Local relief is generally 30 to 60 m (100 to 200 ft), but can exceed 300 m (980 ft).

Bedrock – 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 in this area.

## **Ozark Highlands**

Topography – This area is in the Springfield-Salem Plateaus Section of the Ozark Plateaus Province of the Interior Highlands. 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 ft) on the southeast edge of the Ozark escarpment to about 490 m (1,600 ft) on the western side of the area. Relief is generally 60 to 245 m (200 to 800 ft). 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 southeast Missouri.

Bedrock – 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 6 feet (2 meters) thick. Several old and inactive geologic faults are in the area.

## **Eastern and Western Arkansas Valley and Ridges**

Topography – Most of this area is in the Arkansas Valley Section of the Ouachita Province of the Interior Highlands, and in the Osage Plains Section of the Central Lowland Province of the Interior Plains. Elevation ranges from 90 m (300 ft) on the lowest valley floors to 840 m (2,750 ft) 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.

Bedrock – In the east, the ridges and valleys in this area 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**

Topography – This area is mostly in the Boston “Mountains” Section of the Ozark Plateaus Province of the Interior Highlands. The northern half of the western tip of the area is in the Springfield-Salem Plateaus Section of the same province and division. The southern half of the western tip is in the Arkansas Valley Section of the Ouachita Province of the Interior Highlands. This region 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 ft) on the lowest valley floors to 800 m (2,625 ft) on the highest ridge crests. Local relief commonly exceeds 30 m (100 ft).

Bedrock – 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 (Interior Plains and Lowlands, Western and Central Allegheny Plateau, Northern Piedmont, Central New England Coastal Regions)***

This Ecological Division is topographically quite diverse. It includes the Interior Plains and Lowlands of Indiana, Ohio, southern Illinois, and southern Michigan, but also includes most of Kentucky, east 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 coastal regions from New York to New Hampshire.

## **Interior Plains and Lowlands**

Topography– This area is in the Till Plains Section of the Central Lowland Province of the Interior Plains. 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 ft), increasing gradually from west to east. Relief is mainly a few meters, but in some areas hills rise as much as 30 m (100 ft) above the adjoining plains.

Bedrock– 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 region, 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**

Topography– The physiography in the part of this region 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 Plateaus Province of the Appalachian Highlands. 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 ft) on the lowest valley floors to 400 m (1,310 ft) or more on the highest ridgetops. Local relief is about 100 meters (330 ft).

Bedrock– In the Western Alleghenys, cyclic beds of sandstone, siltstone, clay, shale, and coal of Pennsylvanian age form the bedrock in this area. Similar rocks of Mississippian age occur along the southwest edge of the area in Kentucky and southern Ohio. This region is on the east 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 region. In the Central Allegheny Plateau, the region 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**

Topography – Most of this area is in the Piedmont Upland Section of the Piedmont Province of the Appalachian Highlands. The southwest end and the northwest portion of the southwest half of this region and the southeast portion of the northeast half are in the Piedmont Lowlands Section of the same province and division. The northwest portion of the northeast half of the area is in the New England Upland Section of the New England Province of the Appalachian Highlands. Most of this area is an eroded part of the Piedmont Plateau. This region 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 ft) but ranges from 25 to 300 m (80 to 985 ft) in most areas. It is as much as 505 m (1,650 ft) or more on some ridges and isolated peaks.

Bedrock – 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 region 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 region 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 of the region. Numerous Jurassic diabase and basalt dikes and sills cut the sedimentary rocks in the basins. The far western part of this region 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 Region, Glaciated Allegheny Plateau and Catskills, Northern New England Coastal Regions) –***

### **Northern Great Lakes Region**

*Topography* - This region is in the Central Lowland areas south and west of the western Great Lakes. It is a glaciated region 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 NW portion of the region, 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 NW section, elevation is 410 m (1,350 ft), decreasing gradually to 275 m (900 ft) in the north. Ditches have been used in an attempt to drain the many wet areas in the region, but low gradients commonly prevent adequate removal of surface and subsurface water.

*Bedrock* - Precambrian-age bedrock underlies most of the glacial deposits in this region. 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 NW portion of the region, 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**

*Topography* - This area is primarily in the Southern New York Section of the Appalachian Plateaus Province of the Appalachian Highlands. The east-central part is in the Catskill Section of the same province and division. A small portion of the Allegheny Mountain Section is in the south-central part of this region, and the southwest corner of the region is in the Kanawha Section. These two sections are in the Appalachian Plateaus Province of the Appalachian Highlands. The southeast edge and a fingerlike area protruding into the southeast corner of the area are in the Middle Section of the Valley and Ridge Province of the Appalachian Highlands. The top of the dissected plateau in this area 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 ft) on valley floors; 505 to 610 m (1,650 to 2,000 ft) on the plateau surface; and 1,100 m (3,600 ft) or more in parts of the Catskills.

**Bedrock** - 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 Regions**

**Topography** – This area is the New England Province of the Appalachian Highlands. The separate western part of the area is in the Taconic Section of the province. 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 region 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 ft) in much of the area. It is 610 m (2,000 ft) on some hills and 900 m (2,950 ft) 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 ft) in the valleys and about 25 to 100 m (80 to 330 ft) in the uplands.

**Bedrock** - Most of this region 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.

Table 2. Geologic time scales.

<b>Geologic Era</b>	<b>Years before present (BP) (in millions of years)</b>
Cenozoic	Present to 65
Mesozoic	65 to 230
Paleozoic	230 to 570

Precambrian	570 to 4 500
<b>Geologic Period</b>	
Quaternary	Present 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
<b>Geologic Epoch</b>	
Recent (Holocene)	Present 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

## Climate

### Introduction – (Plates 5 and 6)

Climate varies considerably in the eastern U.S. driven by latitude, longitude, and elevation, and ranges from continental in the Interior Plains and Lowlands to marine along the coast (Plate 1). Average annual precipitation, for example, ranges from as little as 64 mm (26 inches) on the western shore of Lake Michigan to over 2,500 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 regions of the U.S., orographic effects can substantially influence precipitation patterns and distribution across the mountainous regions of the east, particularly in the southern Appalachians where elevational gradients are the strongest. For example, in the mountains of southwestern North Carolina, precipitation is approximately 30% greater at the high vs. low elevation (a difference in elevation of approximately 700 m) (Swift et al. 1988). Similarly, there is a wide range in average annual and minimum and maximum temperatures across Ecological Divisions. In 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 south 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 regions of the eastern U.S. and the highest elevations of the mountainous regions to 36 °C (96 °F) in the Southern Coastal Plain.

The following are brief descriptions of current climate patterns for each of the eight Ecological Divisions.

### ***Hot Continental Mountains Division (Blue Ridge, Southern Appalachian Ridges and Valleys, Cumberland Plateau) –***

#### **Blue Ridge**

In this region, average annual precipitation ranges from 915 to 1,525 mm (36 to 60 inches), generally increasing with elevation and decreasing with latitude. Areas in southwest North Carolina and northeastern Georgia rainfall amounts range from 1,512 to 2300 mm (60 to 90 inches) per year and can reach totals of over 3,000 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 region except for the highest elevations. In the Northern Blue Ridge average annual precipitation is somewhat less than farther south and averages 915 – 1,145 mm (36 – 45 inches) but can range as high as 1,550 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 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 on valley floors due to cold air drainage. 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- and west-facing slopes, for example, are warmer and drier than north- 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 1,040 to 1,395 mm (41 to 55 inches). It increases to the south and is as much as 1,675 mm (66 inches) at the highest elevations in east Tennessee and the northwest 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**

In this region, average annual precipitation ranges from 940 to 1,145 mm (37 to 45 inches) in the northern third of this area and 1,145 to 1,525 mm (45 to 60 inches) in the southern two-thirds. It can reach 1,525 mm (60 inches) at the higher elevations in the northern third of the area and can be as much as 75 inches (1,905 millimeters) 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, Northern New England Uplands)***

#### **Adirondack Shield and Northern New England Uplands**

**Because of the similarities between the two provinces within this division, we elected to treat this division as one.** The average annual precipitation in most of this area is 815 to 1,145 mm (32 to 45 inches). It is typically 1,145 to 1,525 mm (45 to 60 inches) at the higher elevations in the mountains and is 1,525 to 2,665 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 1,220 mm (19 to 48 inches), increasing from north to south. Most of the precipitation occurs during the growing season. In most of the region, 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, Upper and Lower Coastal Plains, Savannas)***

#### **Southern Piedmont**

Climatic regimes fall between warm, moist-temperate and subtropical (Post et al., 1985; Bailey, 1989). Much of the climate in this region is dominated by frontal activity either from off shore or continental sources. Often, severe thunderstorms develop in the piedmont due to the convergence of warm moist air off the coast with cooler continental air masses. Average annual precipitation ranges from 940 to 1,145 mm (37 to 45 inches) at the southern end, and is as much as 1,905 mm (75 inches) in a small high elevation area of northeast 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 across the region 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 1,040 to 1,525 mm (41 to 60 inches), increasing from north to south. It is typically 1,550 to 1,830 mm (61 to 72 inches) in the extreme southwest 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 region includes the Atlantic Coast Flatwoods and Tidewater. The climate is mostly temperate to hot and humid. The average annual precipitation is 1,065 to 1,370 mm (42 to 54 inches). It commonly exceeds 1,650 mm (65 inches) along the Louisiana, Mississippi, and Alabama coastlines. The region 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 of the region. 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.

## **Savannas**

This area includes the Everglades and associated areas where average annual precipitation is 1,015 to 1,575 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, Ozark Highlands, Eastern and Western Arkansas Valley and Ridges, Boston Mountains)**

### **Ouachita Mountains**

The average annual precipitation in most of this area is 1,270 to 1,675 mm (50 to 66 inches). It decreases to 1,040 to 1,245 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**

The average annual precipitation in almost all of this area is 965 to 1,145 mm (38 to 45 inches). It is as high as 1,245 mm (49 inches) in some small areas along the extreme southeast and south edges of the area. About 57 percent of the annual precipitation falls during the 6 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 of the region. 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 of the region. The longer freeze-free periods occur at the lower elevations.

### **Eastern and Western Arkansas Valley and Ridges**

The average annual precipitation in this area is 990 to 1,170 mm (39 to 46 inches), with the western portion being the driest. Precipitation averages 1,145 to 1,550 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**

The average annual precipitation in this area is 1,065 to 1,395 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, Northern Piedmont, Southern New England Coastal Regions)***

#### **Interior Plains and Lowlands**

The average annual precipitation is typically 815 to 990 millimeters (32 to 39 inches), but it ranges from 485 to 1,220 millimeters (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 region is subdivided into moist oceanic and dry continental provinces. In most of the region, 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**

The average annual precipitation in this area is 940 to 1,320 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 Coastal Regions**

Along the coast including Long Island and Cape Cod, the average annual precipitation in this area is 1,040 to 1,220 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 1,145 mm (35 to 45 inches) in the Hudson Valley, which is in the northern half of the western part of this area. It is 1,145 to 1,370 mm (45 to 54 inches) in the south 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 Region, Glaciated Allegheny Plateau and Catskills, Northern New England Coastal Regions)**

#### **Northern Great Lakes**

Climate varies considerably in this region. 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). Snowfall comprises around 20% of total precipitation. 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 1,145 mm (30 to 45 inches). It is 1,145 to 1,625 mm (45 to 64 inches) in small areas at high

elevations in the eastern part of the region. Rainfall occurs as high-intensity, convective thunderstorms during the summer, but most of the precipitation occurs as snow. Average annual temperature ranges from 4 to 10 °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 in the high-elevation areas in the eastern part of Allegheny Plateau and Catskill Mountain portion of this area.

## **Northern New England Coastal Regions**

Average annual precipitation in most of the area is 840 to 1,145 mm (33 to 45 inches) and can range from 1,145 to 1,755 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**

### **Introduction**

The soils described in this section are classified and named in accordance with the USDA system of classifying soils described in *Soil Taxonomy* (Soil Survey Staff, 1999). The information and descriptions herein are derived primarily from USDA Agricultural Handbook No. 296 (USDA NRCS 2006). Soils throughout the eastern U.S. 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 which 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 (i.e., 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 off-site impacts such as sedimentation of surface water.

The following are brief descriptions of the soils in each of the eight ecological divisions discussed in this volume.

### ***Hot Continental Mountains Division (Blue Ridge, Southern Appalachian Ridges and Valleys, Cumberland Plateau)***

#### **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 (4200 ft). Soil depth ranges from shallow to very deep. The general textural class is loamy or clayey. At elevations less than 1,065 m (3,500 ft), 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 north and east 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 ft) are generally brown, fine-loamy or coarse-loamy Dystrudepts. Humic Dystrudepts (Plott, Porters, Cheoah series) are common on north and east aspects, and Typic Dystrudepts (Edneyville, Chestnut, Ditney, and Stecoah series) are common on south and west 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 for this mid-elevation region 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 1,280 m (4,200 ft), 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 Fluvaquent 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 in this area 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 limestone that traverse the region from southwest to northeast. 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 region. Eutrudepts (Hamblen, Sullivan, and Pettyjon series) are on narrow bottom land.

## **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 and/or shale. 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 in this area. Udorthents (Bethesda, Cedar creek, Fairpoint, and Kaymine series) formed in this material.

## ***Warm Continental Mountains Division (Adirondack Shield, Northern New England Uplands)***

### **Adirondack Shield and Northern New England Uplands**

**Because of the similarities between the two provinces within this division, we elected to treat this division as one.** The dominant soil orders in this region 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 Ft) 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 in this region 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 Psammets. The soils in the region 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. The soils in the area have a mesic soil temperature regime, an aquic or udic soil moisture regime, and dominantly mixed mineralogy. They 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, Upper and Lower Coastal Plains, Savannas)***

#### **Southern Piedmont**

In this region, 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 in this region are Ultisols, Entisols, and Inceptisols. The soils in the area 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. Kandiodults 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 in the region 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 Spodosols (Harris 2001). Spodosols can develop under excessively to poorly drained conditions and are commonly associated with widely fluctuating water tables within 2 m of the soil surface. Although edaphic conditions associated with Spodosols are rather specific, vegetation is less definitive because a variety of plant species assemblages are found to occur over Spodosols. However, acidifying trees and shrubs (heaths, conifers) are commonly associated with Spodosols (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 in this region is predominately sandy- to coarse-loamy materials under humid and perhumid climates. Soil depth can vary seasonally as water tables fluctuate but are 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.

## **Savannas**

The dominant soil orders in this portion of this division 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, Ozark Highlands, Eastern and Western Arkansas Valley and Ridges, Boston Mountains)**

#### **Ouachita Mountains**

The dominant soil orders in this area 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 of the region 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 of this region, 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 Dystrubrepts (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 Dystrubrepts (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 in this area 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 Dystrubrepts (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, Northern Piedmont, Southern New England Coastal Regions)***

#### **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 Coastal Regions**

The soils in this region 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 in the region 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 of the region 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 region.

## **Northern Piedmont**

The dominant soil orders in this portion of this division are Alfisols, Inceptisols, and Ultisols. The soils in the area 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 in this part of the division are Hapludalfs (Washington and Bartley series) and Fragiudults (Annandale and Califon series).

## ***Warm Continental Division (Northern Great Lakes Region, Glaciated Allegheny Plateau and Catskills, Northern New England Coastal Regions) –***

### **Northern Great Lakes**

The soils in this portion of this division are primarily Histosols, Alfisols, Spodosols, and Entisols. Some areas also have a significant acreage of Mollisols or Inceptisols. Almost all of the soils in the region 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 of the region. Mineralogy is dominantly mixed, but it is isotic in some areas.

## **Glaciated Allegheny Plateau and Catskill Mountains**

The dominant soil order in this region 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 Coastal Region**

The dominant soil orders in this region are Inceptisols and Spodosols. The soils in the area 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).

## **Summary**

The eastern U.S. encompasses significant variation in biophysical features that constrain management practices available to reduce fuel loads. For example, in areas with generally flat topography (e.g., 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 (i.e., wetter areas may be less accessible for mechanical techniques) and suitable conditions (i.e., 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 U.S. requires understanding interactions among fuel management treatments and geographic regions, and matching treatment prescriptions with physical conditions.

Table 3. Ranges in elevation, mean annual precipitation, and mean annual temperature within ecological divisions (Plate 1). 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, m.s.l.=mean sea level.

<b>Ecological Division</b>	<b>Elevation (m)</b>	<b>Mean Annual Precip. (mm)</b>	<b>Mean Annual Temp. °C</b>
<i>Hot Continental Mountains (M220)</i>			
min	200 (SARV)	915 (BR)	8 (BR)
max	2 010 (BR)	3 000 (BR)	17 (SARV)
<i>Warm Continental Mountains (M210)</i>			
min	305 (NNU)	815 (AD)	1 (NNU)
max	1 525 (NNU)	2 665 (NNU)	8 (AD)
<i>Prairie (250)</i>			
min	200	485	4
max	300	1 220	17
<i>Sub-tropical (230)</i>			
min	m.s.l. (LCP)	940 (SP)	12 (SP)
max	400 (SP)	1 830 UCP)	25 (SAV)
<i>Sub-tropical Mountains (M230)</i>			
min	200 (BM)	990 (AVR)	13 (BM)
max	840 (AVR)	1 675 (OM)	17 (OM)
<i>Hot Continental (220)</i>			
min	160 (IPL)	485 (IPL)	4 (IPL)
max	505 (NP)	1 320 (NP)	17 (IPL)
<i>Warm Continental (210)</i>			
min	275 (NGL)	660 (NGL)	4 (NGL)
max	1 100 (APC)	1 755 (NNC)	10 (APC)
<i>Savanna (410)</i>			
min	m.s.l.	1 015	23
max	5	1 575	25

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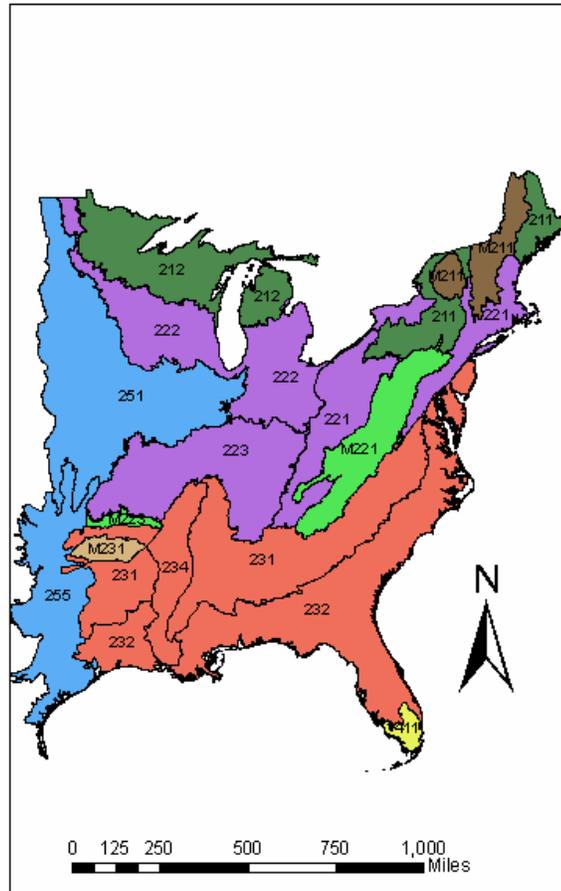
## Cleland Ecological Divisions and Provinces in the Eastern United States

**Division**

- 210, Warm Continental
- 220, Hot Continental
- 230, Subtropical
- 250, Prairie
- 410, Savannah
- M210, Warm Continental - Mountains
- M220, Hot Continental - Mountains
- M230, Subtropical - Mountains

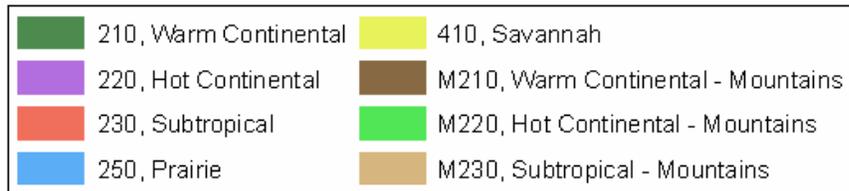
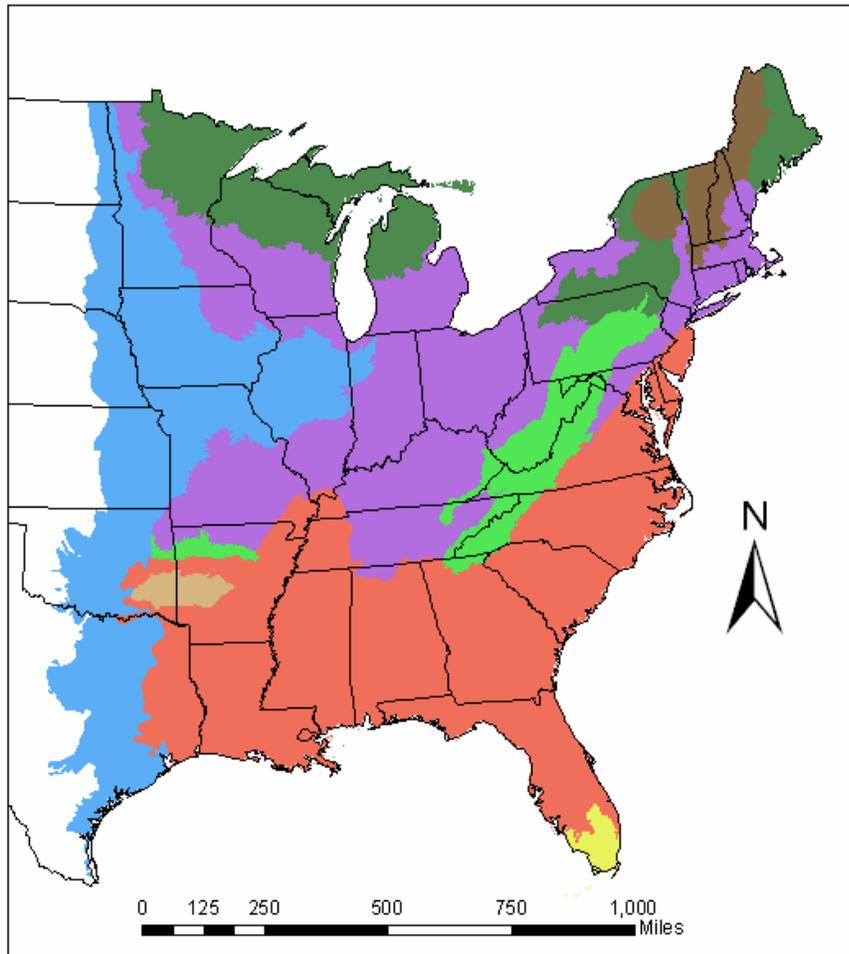
**Province**

- 211, Northeastern Mixed Forest
- 212, Laurentian Mixed Forest
- 221, Eastern Broadleaf Forest
- 222, Midwest Broadleaf Forest
- 223, Central Interior Broadleaf Forest
- 231, Southeastern Mixed Forest
- 232, Outer Coastal Plain Mixed Forest
- 234, Lower Mississippi Riverine Forest
- 251, Prairie Parkland (Temperate)
- 255, Prairie Parkland (Subtropical)
- 411, Everglades
- M211, Adirondack-New England Mixed Forest--Coniferous Forest--Alpine Meadow
- M221, Central Appalachian Broadleaf Forest-Coniferous Forest-Meadow
- M223, Ozark Broadleaf Forest
- M231, Ouachita Mixed Forest-Meadow



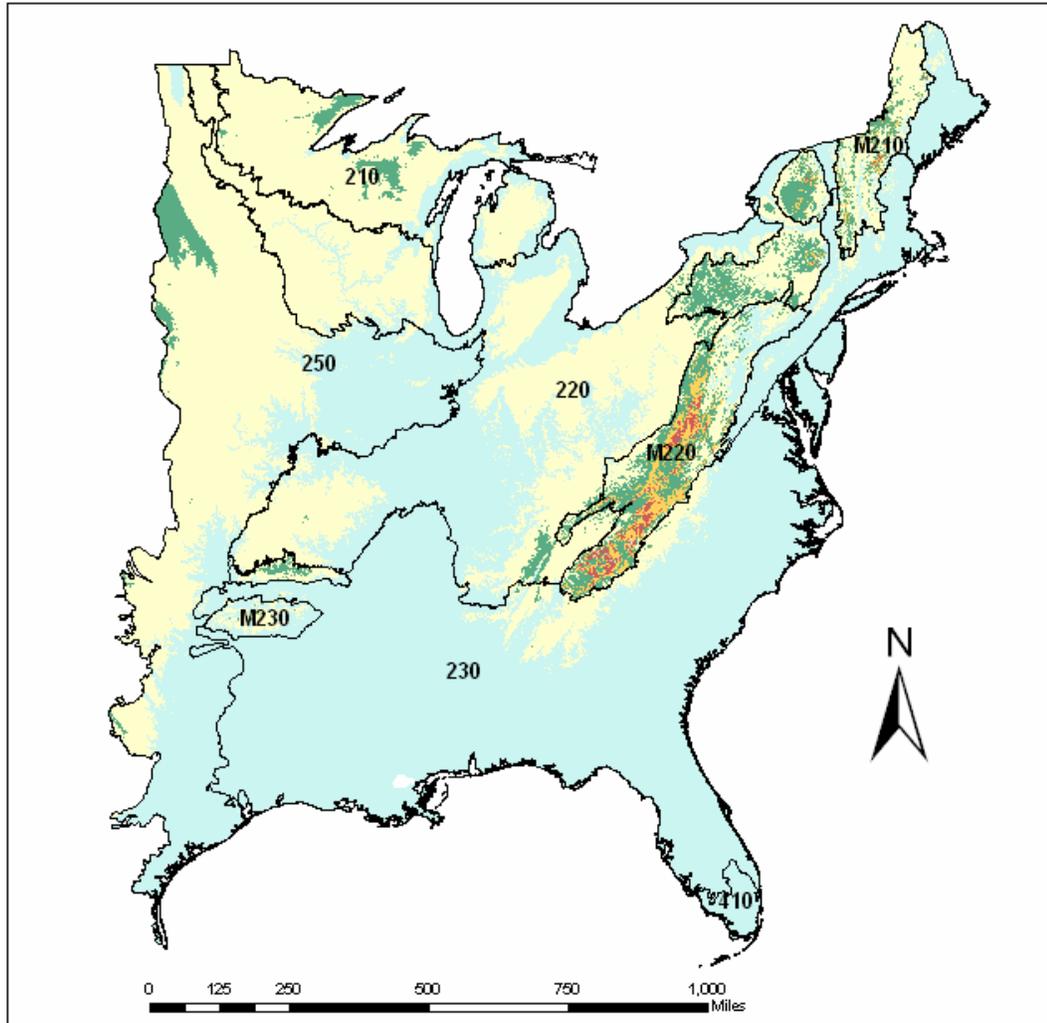
Data Source: Cleland et al., 2005

## Cleland Ecological Divisions in the Eastern United States



Data Source: Cleland et al., 2005

# Elevation in the Eastern United States



Ecological Divisions		meter	
□ 210, Warm Continental	□ M210, Warm Continental - Mountains	□ 0 - 250	■ 1,000 - 1,250
□ 220, Hot Continental	□ M220, Hot Continental - Mountains	■ 250 - 500	■ 1,250 - 1,500
□ 230, Subtropical	□ M230, Subtropical - Mountains	■ 500 - 750	■ 1,500 - 1,750
□ 250, Prairie		■ 750 - 1,000	■ 1,750 - 2,000
□ 410, Savannah			

Data Source: USGS EROS, 2007

# Geology of the Eastern United States

## Sedimentary Rocks

- Quaternary
- Neogene
- Paleogene
- Cretaceous
- Lower Mesozoic (Triassic and Jurassic)
- Upper Paleozoic (Pennsylvanian and Permian)
- Middle Paleozoic (Silurian, Devonian, and Mississippian)
- Lower Paleozoic (Cambrian and Ordovician)
- Late Proterozoic and lower Paleozoic
- Late Proterozoic
- Middle Proterozoic
- Early Proterozoic

## Volcanic Rocks

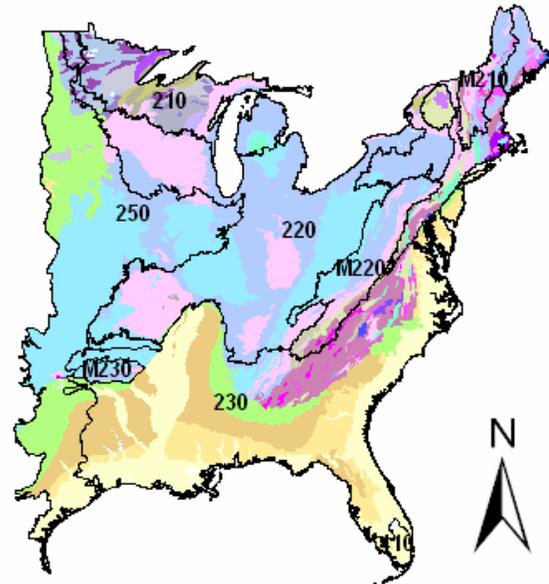
- Middle Paleozoic
- Lower Paleozoic
- Late Proterozoic and lower Paleozoic
- Late Proterozoic
- Middle Proterozoic
- Early Proterozoic

## Plutonic Rocks

- Mesozoic granitic rocks
- Lower Mesozoic mafic rocks
- Upper Paleozoic granitic rocks
- Middle Paleozoic granitic rocks
- Middle Paleozoic mafic rocks
- Lower Paleozoic granitic rocks
- Late Proterozoic and lower Paleozoic granitic rocks
- Late Proterozoic and lower Paleozoic mafic rocks
- Late Proterozoic granitic rocks
- Middle Proterozoic granitic rocks
- Middle Proterozoic mafic rocks
- Middle Proterozoic anorthositic rocks
- Early Proterozoic granitic rocks
- Archean granitic rocks

## Metamorphic Rocks

- Late Proterozoic and lower Paleozoic gneiss
- Middle Proterozoic gneiss
- Archean gneiss
- Water body



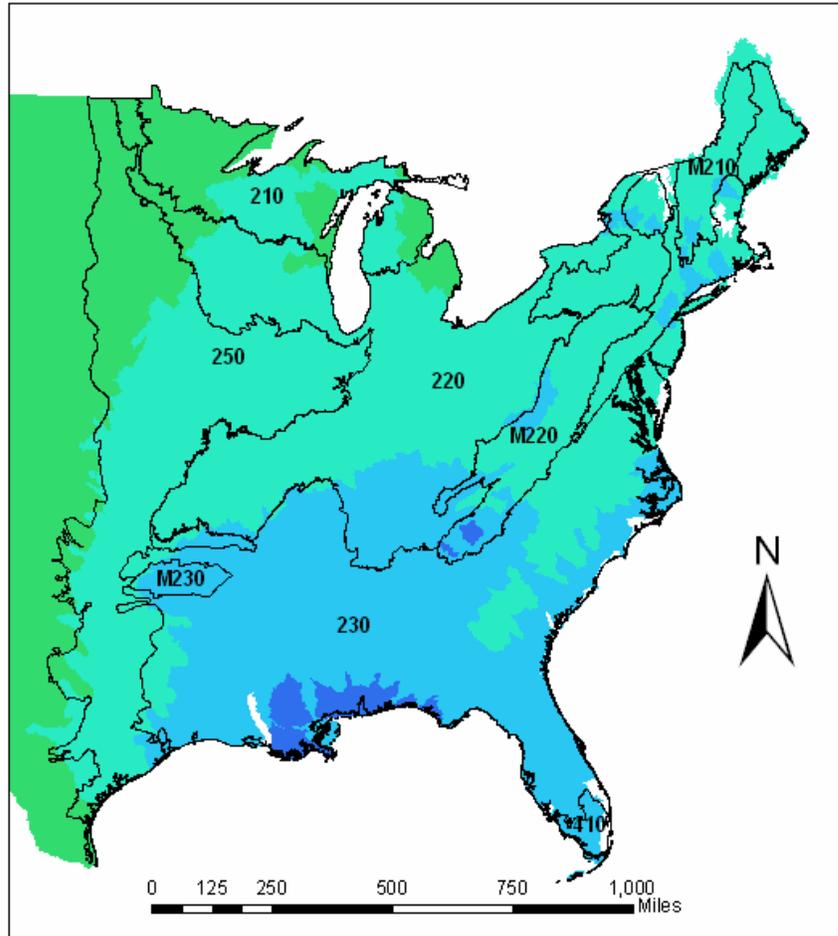
0 155 310 620 930 1,240 Miles

## Ecological Divisions

- 210, Warm Continental
- 220, Hot Continental
- 230, Subtropical
- 250, Prairie
- 410, Savannah
- M210, Warm Continental - Mountains
- M220, Hot Continental - Mountains
- M230, Subtropical - Mountains

Data Source: Reed, Jr. and Bush, 2005

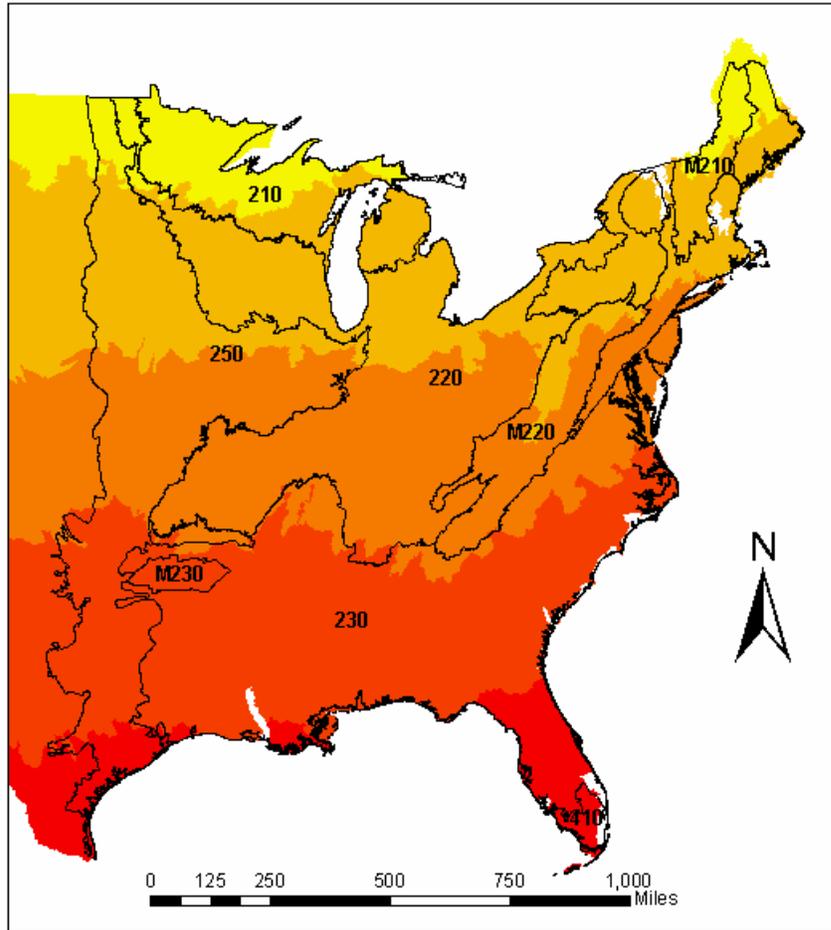
## Average Annual Precipitation 1963-1993



Ecological Divisions		mm	
<input type="checkbox"/> 410, Savannah	<input type="checkbox"/> M210, Warm Continental - Mountains	<input type="checkbox"/> 49 - 400	<input type="checkbox"/> 1200 - 1600
<input type="checkbox"/> 210, Warm Continental	<input type="checkbox"/> M220, Hot Continental - Mountains	<input type="checkbox"/> 400 - 800	<input type="checkbox"/> 1600 - 2000
<input type="checkbox"/> 220, Hot Continental	<input type="checkbox"/> M230, Subtropical - Mountains	<input type="checkbox"/> 800 - 1200	<input type="checkbox"/> 2000 - 3200
<input type="checkbox"/> 230, Subtropical			
<input type="checkbox"/> 250, Prairie			

Data Source: Kittel et al., 1997

## Average Annual Temperature 1963-1993



Ecological Divisions		Celsius
□ 210, Warm Continental	□ M210, Warm Continental - Mountains	0 - 5
□ 220, Hot Continental	□ M220, Hot Continental - Mountains	5 - 10
□ 230, Subtropical	□ M230, Subtropical - Mountains	10 - 15
□ 250, Prairie		15 - 20
		20 - 24

Data Source: Kittel et al., 1997