Chapter 2
Subregional Variation in Upland Hardwood Forest Composition and Disturbance Regimes of the Central Hardwood Region

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Abstract Oaks and hickories characterize the Central Hardwood Region, with its temperate, humid climate and deep soils. Several xerophytic species characterize stands on xeric sites; mesic sites usually have greater diversity of oaks and hickories and include maple, ash, beech, and yellow-poplar. Ice and wind storms are common disturbances across the region; wildland fires ignited by lightning are uncommon and generally confined to small, stand-size areas. Variable environmental conditions, topography, and forest species compositions from the eastern Appalachians to the western Ozarks can require different silvicultural prescriptions to create early successional habitats, even in stands of similar appearance.

2.1 Introduction

Extensive temperate deciduous broadleaf forests are present in only three areas on earth: central Europe, eastern Asia, and the eastern USA (Rohrig and Ulrich 1991). These areas have a moderately humid, continental climate with ample summer rainfall and severe winters (Whittaker 1975). In the USA, deciduous forests dominated primarily by upland hardwoods (with minor amounts of coniferous species) occur mainly from latitudes 35° to 40°, between grasslands on the west and forests with a higher proportion of conifers on the north and south (USDA Forest Service 1967). Historically referred to as the Central Hardwood Region, these forests are among the most compositionally and structurally complex vegetative assemblages in eastern North America (Braun 1950; Barbour and Billings 2000). Embedded within this region are equally complex bottomland deciduous forests associated with some of the largest river systems in the

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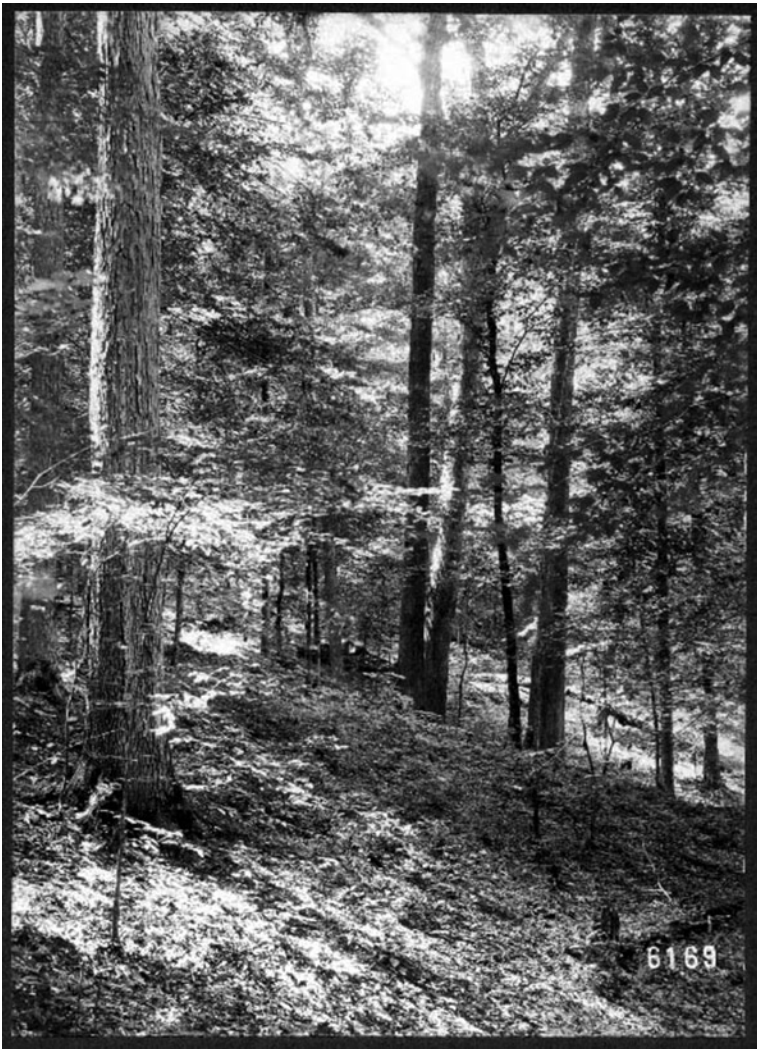

Plate 2.1 Oaks and hickories typically dominate the canopy of mature forests on middle and upper slopes in the Central Hardwood Region, such as this stand on the Cumberland Plateau, in Scott County, Tennessee (US Forest Service photo by F.E. Olmsted, 1901. Source: US Forest Service Photograph Collection, #P9801, D.H. Ramsey Special Collections, UNC-Asheville)

USA, including the Ohio, Wabash, Cumberland, and Tennessee Rivers (Braun 1950). The Central Hardwood Region covers over 40 million ha of the central USA.

Two general associations of canopy species are apparent in upland forests of the Central Hardwood Region: xerophytic associations of dry sites and mesophytic associations of moist sites. Stands on dry sites (ridges, upper and middle slopes) are characterized by a high proportion of oaks (*Quercus*) and hickories (*Carya*) in the canopy (Plate 2.1). On moist sites (coves and lower slopes), however, oaks and

Plate 2.2 A 55-year old stand of almost pure yellow-poplar that regenerated on an old-field site in a mesic cove of the Southern Appalachian Mountains, in Union County of northeastern Georgia (US Forest Service photo by C.A. Abell, 1930. Source: US Forest Service Photograph Collection, #P9876, D.H. Ramsey Library Special Collections, UNC-Asheville)

hickories are less abundant and the canopy may be shared with red maple (*Acer rubrum)*, white ash (*Fraxinus pennsylvanicum*), beech (*Fagus grandifolia*), sugar maple (*A. saccharum*) or occasionally dominated by few mesophytic species after severe disturbance (Plate 2.2) (Schnur 1937; Braun 1950). Although the region is dominated by upland hardwoods several species of conifers, such as red cedar (*Juniperus virginiana*) and Virginia pine (*Pinus virginiana*), may be present as minor components in stands on dry sites, particularly after disturbance. Many stands have three or more vertical strata: the overstory canopy, usually 24 m or more in height; a midstory of shade tolerant species; and a low shrub layer that usually includes advance regeneration of overstory species (Braun 1950). Abundance of advance regeneration and new seedlings depends strongly on the severity and timing of natural disturbances, which vary on a gradient of intensity from relatively frequent mortality of single canopy trees to infrequent catastrophic stand replacing events (White et al., Chap. 3). Considerable knowledge is available on the ecology, regeneration, and response of upland hardwood stands to silvicultural manipulations (Barrett 1980; Hicks 1998; Loftis et al., Chap. 5).

In this chapter, I describe the extent of the Central Hardwood Region and composition of arborescent vegetation in relation to environmental gradients, and briefly review the major types of disturbance across the region. Although I use canopy tree composition and its association with soil moisture availability to subdivide the region, other authors have chosen to use equally appropriate methods of stratification, such as ecoregions, as a basis of analysis for their chapters. This chapter provides an overview of the Central Hardwood Region that will supplement and link material presented throughout the book.

2.1.1 Distribution of Upland Hardwood Forests

The Central Hardwood Region has been delineated with general agreement (Schnur 1937; Braun 1950; USDA Forest Service 1967; Hicks 1998; Barbour and Billings 2000; Fralish 2003) (Fig. 1.1). This region is bordered on the north by forests with fewer oaks and more northern hardwoods (e.g. beech, sugar maple) and conifers (e.g. eastern white pine [*P. strobus*], eastern hemlock [*Tsuga canadensis*]) that transition to the Northern Hardwood Region (Braun 1950). To the south, southern yellow pines such as loblolly (*P. taeda*) Virginia, and shortleaf (*P. echinata*) increase in importance and oaks decrease as forests transition to the Southern Pine Region in the Piedmont (Eyre 1980; USDA Forest Service 1967). Conifers or hardwood-conifer mixtures may occur because of local conditions. For example, stands of red spruce (*Picea rubens*) occupy small areas of high mountain tops in West Virginia (>1,000 m) North Carolina (>1,400 m), where altitude presents environmental conditions similar to boreal conditions of southern Canada. As with other major forest regions in the eastern USA, (e.g. Southern Pine, Hemlock-Northern Hardwood) the Central Hardwood Region may be defined by its canopy composition of deciduous upland hardwoods (Braun 1950; Eyre 1980), and particularly by the predominant oak-hickory forest cover type (Barrett 1980; Hicks 1998; Fralish 2003).

The Central Hardwood Region also can be described by its climate. Whittaker (1975) reported an association of temperate deciduous forests with average temperature range between 3°C and 20°C and annual precipitation from about 1,125 to 1,225 mm. Stephenson (1998) explained the distribution of deciduous hardwood forests by actual evapotranspiration and water supply: "(1) annual precipitation (water supply) must be greater than 600 mm, (2) annual potential evapotranspiration (energy supply) must be greater than 600 mm, and (3) the seasonal timing of available water and potential evapotranspiration must be such that at least 600 mm of both occur simultaneously." In general, the Central Hardwood Region is associated with a climate in which precipitation is about equivalent to potential evapotranspiration and deficiencies of precipitation are offset by stored soil water during the mid to late frost-free season of most years.

2.1.2 Environment of the Central Hardwood Region

The continental climate of the Central Hardwood Region is classified as humid-temperate (Bailey 1995), with long hot summers and cold winters. Mean annual temperature in most of the region ranges from 11°C to 16°C. The frost-free season ranges from about 120 days in the north to almost 200 days in the south.

Annual precipitation ranges from less than 750 mm near the Great Plains to more than 1,100 mm in mountainous areas, with more than half falling in the growing season. Throughout this region, potential evapotranspiration during the early to middle growing season is about equal to the precipitation

West of the Mississippi River, elevations in the Central Hardwood Region range from about 100 m in major river valleys to over 800 m in the Ouachita Mountains, which are part of the Ozark Plateau, an extensive area in Arkansas and Missouri underlain by limestone, sandstone, and shale bedrock. East of the Mississippi River, elevation ranges from 100 m in the northeastern part of the Central Hardwood Region to over 2,000 m in the Southern Appalachian Mountains of North Carolina. Topography on level-bedded limestone and sandstone formations in central Kentucky and the Highland Rim of Tennessee ranges from gently rolling to dissected and hilly. The Appalachian Plateau, from central Pennsylvania to northern Alabama, grades from a dissected plateau to high hills and subdued mountains underlain by shale, sandstone, coal, and some limestone. Eastward, the folded and faulted shale, sandstone, and limestone bedrock of the Ridge and Valley province form long sandstone capped ridges separated by valleys underlain by limestone. East of that province are the highly weathered, steep Blue Ridge Mountains and the hilly Piedmont, both of which are underlain by igneous and metamorphic rocks. Overall, the highly variable topography and geologic substrate of the Central Hardwood Region have a greater effect on the distribution of species at smaller, landscape scales than on limiting the broader regional extent of the oak-hickory cover type throughout the central USA.

Soils of the Central Hardwood Region are varied and include four orders with extensive distributions. Ultisols are present across about half the region, from Arkansas and southern Missouri, central Tennessee, and Kentucky southeastward to the Piedmont and north into Pennsylvania. These soils are acidic, generally low in fertility, have high clay content in the subsoil and low amount of moisture storage capacity, and often are eroded as a result of past land use. Inceptisols are young soils that are present on steep terrain of the Appalachian and Cumberland Mountains, West Virginia, Pennsylvania, and southwestern Indiana. Alfisols usually form over calcareous rock formations and are present in northern Missouri, northwestern and central Kentucky and much of Indiana, Ohio, and southern Michigan. With sufficient soil moisture, Alfisols can be highly productive. Mollisols are the principal soil order in northern Missouri and much of Illinois, where the “Prairie Peninsula” extends eastward from the Great Plains into the Central Hardwood Region. Although soil orders are variable across the region, properties such as solum thickness of the A and B horizons and texture are among the most important factors affecting species composition and productivity of stands on both dry and moist sites.

Much of the central part of the region north of the Ohio River, including most of Illinois, has been influenced by one or more periods of glaciation, the most recent being the Wisconsin, which reached its peak about 20,000 years before present. Forward movement of the ice sheet created a smoothed landscape while its retreat left a layer of till of varying thickness and local variation caused by end moraines. Soils are generally deep and fertile in the northern part of the glaciated area.

Soils on flat terrain in the southern parts of Ohio, Indiana, and Illinois generally have poor internal drainage, resulting in wet conditions in winter and dry conditions in summer. An indirect effect of glaciations in the northern part of the region was deposition of wind-blown loess, which ranges in thickness from less than 0.5 to over 5 m.

Major, landscape-scale, natural disturbances throughout the Central Hardwood Region are associated mostly with wind (Everham and Brokaw 1996) and ice storms (Lemon 1961), and somewhat less by fire. Wind storms, mainly tornados, are more likely to occur in the western parts of the region (Fig. 3.3). Ice storms tend to be more common in the Appalachian Mountains and in the north (Fig. 3.3). Drought is a subtle form of natural disturbance that affects species composition of stands, particularly on moist sites, in the low-elevation parts of the Central Hardwood Region. Although wildland fires ignited by lightning occur throughout the region, the humid climate and highly urban and agricultural landscape limit their numbers to fewer than 300 annually and total area burned of about 4,500 ha (www.nifc.gov/fire_info/lightning_human_fires, accessed 12 Jan 2011). However, anthropogenic fires, set by Native Americans and later European settlers, were common throughout much of the region until the past several decades (Spetich et al., Chap. 4). Two historic sources of natural disturbances to forests in the eastern part of the Central Hardwood Region include elimination of American chestnut (*Castanea dentata*) as a canopy species during the 1920s and the differential effects among species from defoliation by gypsy moth (*Lymantria dispar*). White et al. (Chap. 3) provide more detailed information on the type and extent of disturbances.

2.1.3 Subregions of the Central Hardwood Region

Several species of oaks are in the canopy of most upland stands in the Central Hardwood Region, particularly on sites that are drier than average; mesophytic species increase on upland sites that are wetter than average (Braun 1950). The east–west precipitation gradient, variable bedrock formations with differing geologies and associated soils, and variable topography combine to form four smaller subregions of more uniform vegetation composition within upland forests: (1) Western Dry Subregion, (2) Transition Dry-Mesic Subregion, (3) Central Mesic Subregion, and (4) Eastern Mesic Subregion (Fig. 2.1). These subregions are similar to geographical areas delineated by Braun (1950), as oak-hickory, western mesophytic, mixed mesophytic, and oak-chestnut, respectively. Although forests are generally dominated by oaks, species composition varies in relation to moisture gradients at the subregion and stand scales.

Much of the information in the following paragraphs was extracted with little change from descriptions of large ecosystems termed major land resource areas (Natural Resources Conservation Service 2006); arborescent species composition was condensed from Braun (1950). The climatic regime of each subregion is presented as a water balance diagram for a representative location that combines annual variation in temperature and precipitation (Stephenson 1998). Potential evapotranspiration and actual evapotranspiration were estimated using the function developed by the US Geological Survey. Thirty year normal temperature and

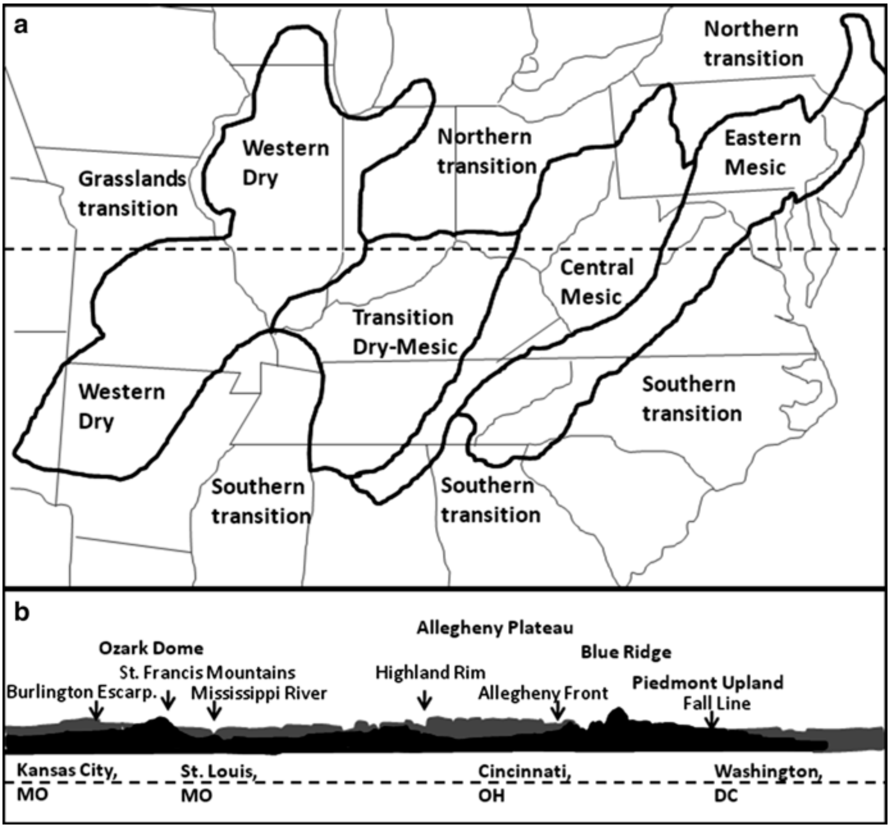

Fig. 2.1 (**a**) The Central Hardwood Region, its subregions, and transitions to adjoining subregions (From Braun 1950), and (**b**) profile of physiography along a transect (*dashed line*) from Kansas City, Missouri to Washington, DC and corresponding with the dashed transect line in (**a**) (from Lobeck 1957)

precipitation (1961–1990) were obtained from www.worldclimate.com. Soil field capacity of 200 mm was used for all locations.

2.1.3.1 Western Dry Subregion

This subregion extends in a broad diagonal band from northwestern Arkansas through south-central Missouri, and includes much of Illinois, which was about 60% prairie and oak savannah at the beginning of European settlement (Anderson 1970). The average annual temperature ranges from about 11.6°C to 15.5°C; the frost free season ranges from 175 to 245 days. Average annual precipitation ranges from about 1,000 to 1,150 mm, almost 60% falls during the growing season. Most of this subregion is a nearly smooth peneplain that was glaciated in the northern part (in Illinois) but not in the south, where it is slightly dissected by small streams.

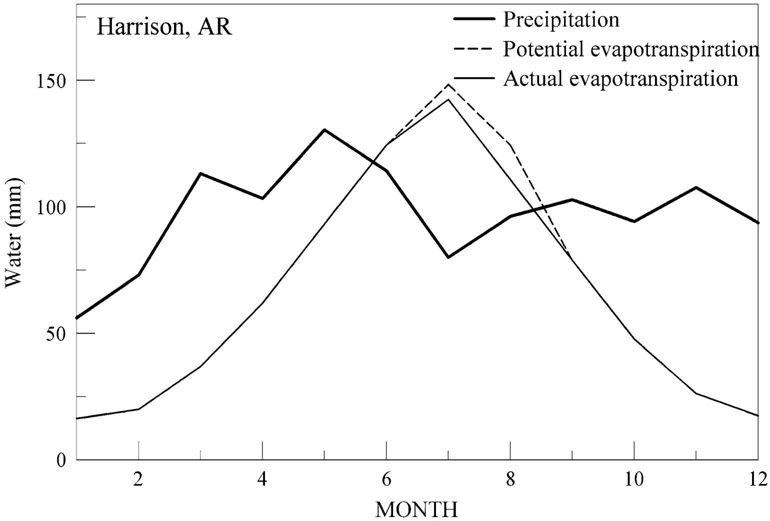

Fig. 2.2 A soil moisture deficit begins to develop in parts of the Western Dry Subregion during June in response to decreased summer precipitation as shown by a water balance diagram for Harrison, Arkansas

Elevation ranges from about 180 to 510 m. The Burlington Escarpment (Fig. 2.1) rises nearly 100 m above the peneplain and separates the Salem and Springfield Plateaus in southwestern Missouri. Bedrock geology is mostly sedimentary formations although intrusive granites are present in the St. Francis Mountains area of the Ozark Dome (Fig. 2.1), a large Precambrian uplifted and eroded region. Loess deposits range from several centimeters to almost a meter in thickness, with the greatest depth in the northern and eastern parts of the subregion. Soils are primarily Alfisols or Ultisols that have formed in material weathered from cherty limestone.

Tree species found in mesic ravines and gorges of this region include beech, northern red oak (*Q. rubra*), white oak (*Q. alba*), chinkapin oak (*Q. muehlenbergii*), sweetgum (*Liquidambar styraciflua*), winged elm (*Ulmus alata*), American elm (*U. Americana*), white ash, sugar maple, bitternut hickory (*C. cordiformis*), and basswood (*Tilia americana*). Dry site species on ridges and slopes include black oak (*Q. velutina*), white oak, shortleaf pine, scarlet oak (*Q. coccinea*), shagbark hickory (*C. ovata*), and in southern areas of the subregion, post oak (*Q. stellata*), blackjack oak (*Q. marilandica*), and southern red oak (*Q. falcata*). Before European settlement, much of this subregion in Illinois was a mosaic of open woodlands and tall-grass prairie maintained by frequent fire (Spetich et al., Chap. 4).

A water balance diagram for Harrison, Arkansas, in the northwest corner of the state near Missouri and the transition to the Great Plains, shows precipitation does not meet evapotranspiration requirements beginning in June and continuing during the growing season through October (Fig. 2.2). Water required for evapotranspiration, but not supplied by precipitation, is obtained from stored soil moisture. In a normal year, about 35% of available soil moisture remains at the end of the growing season. The steep decline in summer precipitation, particularly for July, is typical of climates associated with grasslands (Vankat 1979). Windstorms, particularly tornados, and drought are the main types of natural disturbance. Fire set by humans was also an important disturbance prior to the early 1900s (Spetich et al., Chap. 4).

2.1.3.2 Transition Dry-Mesic Subregion

This subregion includes much of the western and central parts of Kentucky and central Tennessee, and is a transition between the drier subregion to the west and mesic area to the east. The landscape is a plateau with low, rolling hills, upland flats, and narrow valleys. Steep slopes are present in the Nashville Basin and bordering the Coastal Plain on the west. Limestone is present in many areas, particularly the fertile Bluegrass Region of Kentucky (Fig. 2.1), which was an oak savannah before European settlement. The average annual temperature ranges from about 11.1°C to 15.5°C; the frost free season ranges from 185 to 235 days. Average annual precipitation ranges from about 1,100 to 1,600 mm. Precipitation is generally well distributed annually, but the monthly maximum occurs during late winter and early spring; the minimum occurs in fall. Bedrock geology is mostly Ordovician to Mississippian age limestone and dolomite. Thick clay covers much of the bedrock and areas of karst occur where clay is not present. Loess deposits of varying thickness cover much of the bedrock on uplands and ridges. Soils are mostly Alfisols, Inceptisols, and Ultisols that are deep to very deep, generally well drained, and loamy or clayey texture.

Some of the more important tree species of mesic sites in this subregion include beech, yellow-poplar (*Liriodendron tulipifera*), northern red oak, sugar maple, black walnut (*Juglans nigra*), and slippery elm (*U. rubra*); dry site species are white oak, northern red oak, shagbark hickory, black oak, pignut hickory (*C. glabra*), sassafras (*Sassafras albidum*) and, on basic soils, chinkapin oak. A water balance diagram for Columbia, Tennessee, shows a small deficit of precipitation developing in early summer that remains about constant until fall (Fig. 2.3). July precipitation increases sharply from the amount received in June, a trend which differs markedly from that of the adjoining Western Dry Subregion. Fire was less common here compared to neighboring subregions (Fig. 3.3). Drought is a recurring natural disturbance throughout this subregion; wind storms are more common in the north.

2.1.3.3 Central Mesic Subregion

This subregion extends from central Pennsylvania to northern Alabama (Fig. 2.1) and includes much of the Appalachian Plateau, which consists of the Allegheny Plateau and Mountains in the north and the Cumberland Plateau and Mountains in the south (Fenneman 1938; Bailey 1995). Its eastern and western boundaries are marked by abrupt changes in topography identified as the Allegheny Front and Highland Rim, respectively (Fig. 2.1). Elevations range from about 300 m along the western edge to over 1,200 m in the Allegheny Mountains. Topography in much of this subregion is

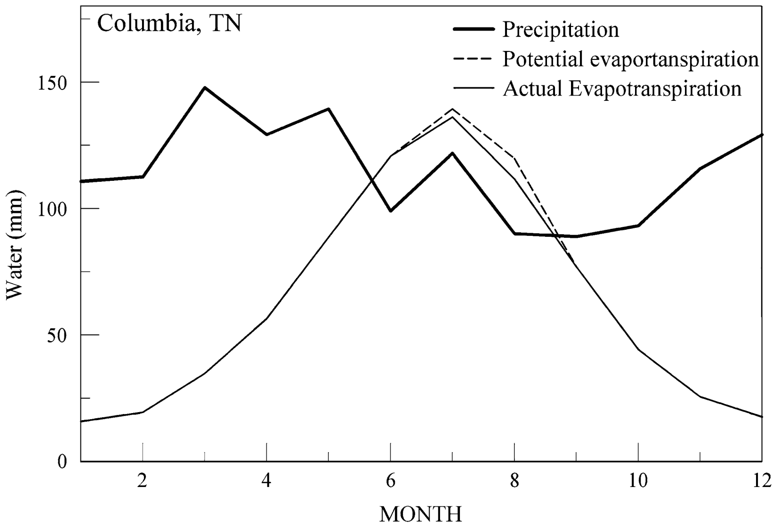

Fig. 2.3 As illustrated in a water balance diagram for Columbia, Tennessee, increased precipitation during July is the primary reason that soil moisture deficits are small in the Transition Dry-Mesic Subregion of the Central Hardwood Region

highly dissected plateau with steep side slopes between narrow ridge tops and mountains of moderate to high relief. The average annual temperature ranges from about 7.2°C to 15.6°C; the frost free season is variable depending on elevation and latitude, and ranges from 120 to 225 days. Average annual precipitation ranges from about 900 to 1,500 mm, and may exceed 1,900 mm in the mountains; about half occurs during the early growing season. Bedrock geology is mostly sedimentary formations of sandstone and shale, with small areas of limestone and coal in Virginia and Alabama. Ultisols form most of the soils in the undulating to rolling landscape of the Cumberland Plateau; shallow to deep and well drained to excessively drained Inceptisols are typical in areas of steep sandstone or shale residuum.

Canopy species composition is more varied here than in the other subregions and on mesic sites includes white oak, northern red oak, yellow-poplar, beech, sugar maple, buckeye (*Aesculus* spp.), black walnut, slippery elm, bitternut hickory and white ash; species on dry sites usually include white oak, chestnut oak (*Q. prinus*), black oak, shagbark hickory, pignut hickory, and redbud (*Cercis canadensis*). Stands of red spruce are present on the highest mountains in central West Virginia. A water balance diagram for Farmers, Kentucky, on the western edge of the subregion, shows a trend of actual evapotranspiration similar to the adjacent transition dry-mesic subregion to the west, but with very slight deficit of soil moisture as a result of the high July precipitation (Fig. 2.4). Ice storms are the most important type of natural disturbance, especially in the northern part of the subregion. Spetich et al. (Chap. 4) suggest that Native American use of fire was a common type of disturbance in this subregion that likely affected the regeneration dynamics of American chestnut, which was a component of many upland hardwood stands on non-calcareous soils,

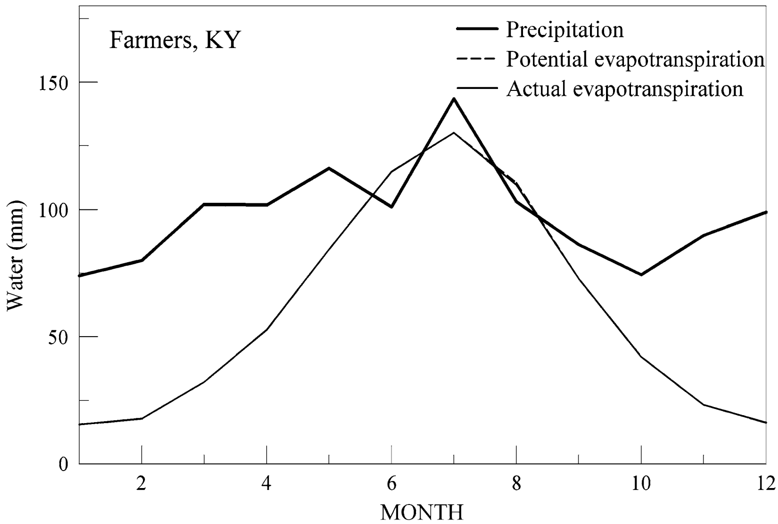

Fig. 2.4 Potential and actual evapotranspiration are almost equal in many parts of the Central Mesic Subregion, as shown by this water balance diagram for Farmers, Kentucky

before it was eliminated as a canopy species by the chestnut blight (*Cryphonectria parasitica*) in the early 1900s.

2.1.3.4 Eastern Mesic Subregion

Two large areas of differing physiology are included in this subregion: the low topography of the Ridge and Valley and higher peaks of the Blue Ridge Mountains (Fig. 2.1). Both of these areas extend from eastern Tennessee and western North Carolina through western Virginia into eastern Pennsylvania. Elevation ranges from about 30 m in the north to over 2,000 m in the southern mountains. Average annual temperature ranges from about 7.8°C to 15.6°C; the frost free season averages about 180 days, but is variable depending on elevation and latitude and ranges from 135 to 235 days. Average annual precipitation ranges from about 1,000 to 1,500 mm, and exceeds 2,500 mm along parts of the southern Blue Ridge escarpment in western North Carolina. Precipitation is generally evenly distributed annually with slightly reduced amounts in the fall. Ridge and valley bedrock geology consists of alternating beds of limestone, dolomite, shale, and sandstone; ridge tops are topped with resistant sandstone and the valleys have been eroded into less resistant shale and limestone. Southern Appalachian Mountain bedrocks consist mainly of Precambrian metamorphic formations of gneiss, schist, and small areas of amphibolites. The dominant soil orders are Inceptisols, Ultisols, and Alfisols, which are shallow to very deep, moderately well-drained to excessively drained and loamy or clayey.

Composition of the canopy in this subregion is almost as varied as in the central mesic subregion. Common mesophytic species of low to middle elevation stands are

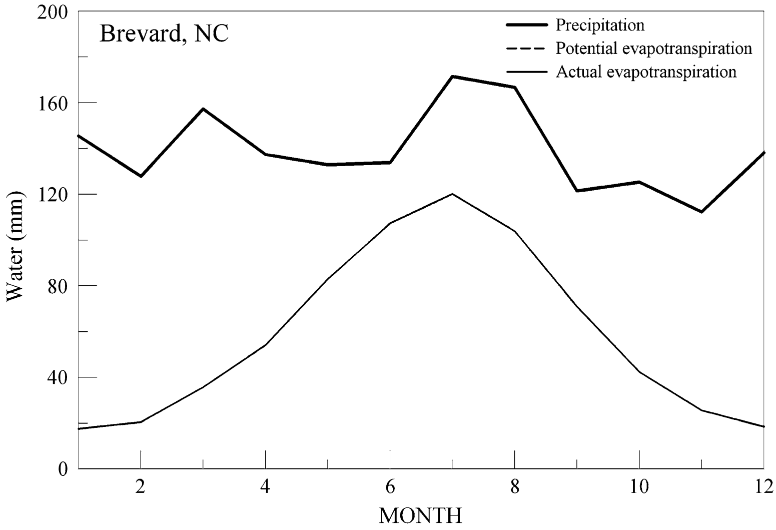

Fig. 2.5 Brevard, North Carolina, is in a high rainfall zone of the Eastern Mesic Subregion, where soil moisture deficits are rare

yellow-poplar, northern red oak, sweet birch (*Betula lenta*), white oak, red maple, white ash, silverbell (*Halesia carolina*), beech, and cucumber magnolia (*Magnolia acuminata*); xerophytic species include chestnut oak, scarlet oak, black oak, white oak, sourwood (*Oxydendrum arboreum*), pignut hickory, and mockernut hickory (*C. alba*). High elevation forests (above 1,300 m) are dominated by northern red oak on exposed slopes and ridges, and northern hardwoods (buckeye, sugar maple, yellow birch, and basswood) on protected slopes. Red spruce and Fraser fir (*Abies fraseri*) are extensive at still higher elevations (above 1,600 m). A water balance diagram for Brevard, North Carolina, indicates precipitation exceeds potential evapotranspiration throughout the growing season (Fig. 2.5). Ice storms are the major recurring type of natural disturbance although periodic drought (Hursh and Haasis 1931), the southern pine beetle (*Dendroctonus frontalis*) (Thatcher et al. 1981), and wind from remnants of hurricanes (Greenberg and McNab 1998) may also be important. Lightning caused fires are uncommon in the humid climate of this subregion, but human-caused fires were an important type of disturbance associated with American Indian and European settlement (Spetich et al., Chap. 4).

2.1.4 Subregional Comparisons and Subdividing the Region by Other Criteria

The four subregions of the Central Hardwood Region share a similar canopy composition dominated by upland oaks, and similar climates where rainfall is well distributed throughout the year and adequate to maintain soil moisture near field

Table 2.1 Composition by subregion of selected hardwood species on timberland of the Central Hardwood Region (Smith et al. 2004)[a]

Species or species group	Subregion			
	Western dry	Transition dry-mesic	Central mesic	Eastern mesic
Percent[b]				
All oaks	64	41	38	37
All hickory	12	11	7	4
White ash	3	4	2	3
Basswood	<1	1	3	1
Am. beech	<1	3	5	3
Yellow-poplar	<1	13	16	12
Sugar maple	1	5	6	4
Red maple	3	5	8	13
Others	16	17	15	23

[a]Timberland is forest land that is producing or is capable of producing crops of industrial wood in excess of 1.4 m^3/ha per year of industrial wood in natural stands
[b]Percent of total volume of hardwood growing stock >12.7 cm diameter breast height

capacity during much of the growing season. However, they differ in two respects: the relative proportions of mesophytic species and predominant types of natural disturbance. For example, yellow-poplar, an aggressive, shade intolerant mesophytic species that can hinder development of oak regeneration, is a minor component of stands in the Western Dry Subregion (Table 2.1). Ice storms are more likely to occur in the northern part of the Region (Fig. 3.3), and can cause almost continuous canopy disturbance across large areas. In contrast, early successional habitats resulting from wind-caused disturbances are more common in the western subregions and often result in small, discontinuous areas of tree blowdowns. Although the macro-climate may be similar throughout the Central Hardwood Region, differences in site quality, species composition, and natural disturbances among subregions should be considered by managers when planning silvicultural prescriptions to meet goals for creating and maintaining early successional habitats (Loftis et al., Chap. 5; Greenberg et al., Chap. 8). Potential climate change induced shifts in forest composition (Wear and Huggett, Chap. 16) and the frequency and intensity of natural disturbances (White et al., Chap. 3) will also require careful consideration in land management planning for early successional habitats at the local and regional level.

In addition, subregions delineated using Braun's (1950) major subdivisions as a basis may not be suitable for some purposes. Other methods and criteria for subdividing the Central Hardwood Region include physiographic provinces (Fenneman 1938), potential natural vegetation (Kuchler 1964), and large nested ecosystems of regional extent called ecoregions (Bailey 1983). Two widely used ecoregion maps have been developed by the USDA Forest Service (Cleland et al. 2007) and the US Environmental Protection Agency (2009) (Table 2.2). The versatility of these ecological maps is demonstrated by their use for purposes unintended in their development, such as delineation of bird conservation regions in the Central Hardwood Region used by some authors in this volume (Franzreb et al., Chap. 9; Warburton et al., Chap. 13) (US North American Bird Conservation Initiative 2000).

Table 2.2 Approximate correspondence among vegetation and ecological classifications of the Central Hardwood Region used by authors in this book

Subregions of Central Hardwood Region[a]	Divisions of the deciduous forest formation[b]	Ecoregions			
		USDA-FS[c]	USEPA[d]	BCR[e]	SFFP[f]
Western Dry	3a, 3d	M231, 231G, 223A, 251D, M223, 223G	36, 37, 38 39, 72, 54	24 (west half) 22 (west half) 25 (north half)	Midsouth in Arkansas
Transition Dry-Mesic	2a, 2b, 2c, 2e, 2d	223D, 223E, 223F, 223B	55, 70, 71	24 (east half) 22 (east half)	Western part of App-Cumb.
Central Mesic	1a, 1b, 1c	221H. 221J, M221B, 221E M221C	68, 69, 70	28 (west half)	Central part of App-Cumb.
Eastern Mesic	4a, 4b, 4d, 4e	M221D, 231A, 221D, M221A 231I	66, 45	28 (east half) 29	Eastern part of App-Cumb. SA Piedmont

Note: Text in each column refers to units displayed on each map
Ecoregion assessment areas are abbreviated as: *App-Cumb* Appalachian-Cumberland, *SA Piedmont* Southern Appalachian Piedmont
[a]Chapter 2 of this book (Braun 1950)
[b]Braun (1950)
[c]Cleland et al. (2007)
[d]US Environmental Protection Agency (2009)
[e]US North American Bird Conservation Initiative (2000)
[f]Southern Forest Futures Project (Wear et al. 2009)

Authors of other chapters (Wear and Huggett, Chap. 16) have used a combination of ecoregions and administrative boundaries to define large areas of the Central Hardwood Region as a basis for forecasting of future forest conditions.

2.2 Conclusions

The Central Hardwood Region extends east from the Great Plains almost to the Atlantic Ocean and south from Lake Erie to the Piedmont Fall Line. The temperate, humid climate, well-distributed annual rainfall, and deep soils of the region form environmental conditions where moisture is usually available to vegetation throughout the frost-free season. At the regional scale, upland forests are characterized by oaks and hickories in the canopy. Species composition can be variable at the landscape scale, however, where topography and soil variation create moisture gradients occupied by a suite of vegetative species ranging from xerophytes (oaks and hickories) to mesophytes (maples and yellow-poplar). The relative abundance of some species, particularly yellow-poplar, varies considerable among subregions and should be taken into account when planning silvicultural activities to achieve resource management goals related to creating and maintaining suitable quantities and qualities of early successional habitats.

Literature Cited

Anderson RC (1970) Prairies in the prairie state. Trans Ill State Acad Sci 63:214–221

Bailey RG (1983) Delineation of ecosystem regions. Environ Manage 7:365–373

Bailey RG (1995) Description of the ecoregions of the United States. Misc Publ 1391, USDA Forest Service, Washington, DC, 108 p

Barbour MG, Billings WD (2000) North American terrestrial vegetation. Cambridge University Press, New York, p 708

Barrett JW (1980) Regional silviculture of the United States. Wiley, New York, 551 p

Braun EL (1950) Deciduous forests of eastern North America. Blackburn Press, Caldwell, 596 p

Cleland DT, Freeouf JA, Keys JE Jr, Nowacki GJ, Carpenter CA, McNab WH (2007) Ecological subregions: sections and subsections of the conterminous United States. [Map on CD-ROM] (AM Sloan, cartographer), USDA Forest Service, Washington, DC, Map scale 1:3,500,000

Everham EM III, Brokaw NVL (1996) Forest damage and recovery from catastrophic wind. Bot Rev 62:113–185

Eyre EH (ed) (1980) Forest cover types of the United States and Canada. Society of American Foresters, Bethesda, 148 p (with 1 map)

Fenneman NM (1938) Physiography of eastern United States. McGraw-Hill, New York, 714 p

Fralish JS (2003) The central hardwood forest: its boundaries and physiographic provinces. In: Van Sambeek JW, Dawson JO, Ponder F Jr, Loewenstein EF, Fralish JS (eds) Proceedings of the 13th central hardwood Forest conference, Gen Tech Rep NC-23, USDA Forest Service North Central Research Station, St. Paul, pp 1–20

Greenberg CH, McNab WH (1998) Forest disturbance in hurricane-related downbursts in the Appalachian mountains of North Carolina. For Ecol Manage 104:179–191

Hicks RR Jr (1998) Ecology and management of central hardwood forests. Wiley, New York, 412 p

Hursh CR, Haasis FW (1931) Effects of 1925 summer drought on southern Appalachian hardwoods. Ecology 12:380–386

Kuchler AW (1964) Potential natural vegetation of the conterminous United States. Special Publ 36, American Geographical Society. New York

Lemon PC (1961) Forest ecology of ice storms. Bull Torrey Bot Club 88:21–29

Lobeck AK (1957) Physiographic diagram of the United States. Geographical Press, Maplewood, 8 p

Natural Resources Conservation Service (2006) Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. Agri Handbook 296, USDA Natural Resources Conservation Service, 669 p

Rohrig E, Ulrich B (1991) Temperate deciduous forests – ecosystems of the world – 7. Elsevier, Amsterdam, p 635

Schnur GL (1937) Yield, stand, and volume tables for even-aged upland oak forests. Tech Bull 560. USDA Forest Service, Washington, DC, 87 p

Smith WB, Miles PD, Vissage JS, Pugh SA (2004) Forest resources of the United States, 2002. Gen Tech Rep NC-241, USDA Forest Service North Central Research Station, St. Paul, 137 p

Stephenson NL (1998) Actual evapotranspiration and deficit: biologically meaningful correlates of vegetation distribution across spatial scales. J Biogeogr 25:855–870

Thatcher RC, Searcy JL, Coster JE, Hertel GD (eds) (1981) The southern pine beetle. Tech Bull 1631, USDA Forest Service, Washington, DC, 267 p

US North American Bird Conservation Initiative (2000) Bird conservation region descriptions; a supplement to the North American bird conservation initiative. In: Bird conservation regions map. USDI Fish and Wildlife Service, Arlington, 38 p

USDA Forest Service (1967) Major forest types (map), the national atlas of the United States of America. Map scale 1:7,500,000. USDA Forest Service, Washington, DC

US Environmental Protection Agency (2009) Level III and IV ecoregions of the coterminous United States (map). Western Ecology Division. US Environmental Protection Agency, Corvalis. Map scale 1:7,500,000

Vankat JL (1979) The Natural Vegetation of North America: An Introduction. Wiley, New York, p 261

Wear DN, Greis JG, Walters N (2009) The southern forest futures project: using public input to define the issues. Gen Tech Rep SRS-115, USDA Forest Service Southeastern Research Station, Asheville, 17 p

Whittaker RH (1975) Communities and Ecosystems. Macmillan, New York, p 385