Ecological Regions and Soil Conditions in the Hoosier-Shawnee Ecological Assessment Area

Felix Ponder, Jr.

ABSTRACT

I present information on the ecological sections, subsections, and soils within the Hoosier-Shawnee Ecological Assessment Area. The assessment area falls within the Ozark Highlands Section, the Upper Golf Coastal Plain Section, and the Shawnee Hills and Highland Rim Sections of the Interior Low Plateau. I reviewed physical, chemical, and biological soil properties; soil loss; compaction; and productivity. Management practices such as logging, fire or its exclusion, water drainage, and conversion to agricultural uses have led to much change in soil productivity and forest cover type since presettlement times. Although fire appears to have had little or no direct long-term impacts on soils in these forests, its use can significantly impact vegetation growth and composition. Private landowners within the Shawnee and Hoosier National Forest Purchase Areas are taking advantage of State and Federal programs to improve their land; their goals are similar to the goals of the two national forests, which include enhancing timber production, watershed protection, and wildlife habitat.

About the Author:

Felix Ponder, Jr.
Research Soil Scientist,
U.S. Department of
Agriculture, Forest Service,
North Central Research
Station, 208 Foster Hall,
Lincoln University,
Jefferson City, MO 65102.
Phone: 573-681-5575;
e-mail: fponder@fs.fed.us

The assessment area is located in the unglaciated southern one-third of Illinois and Indiana and a small part of western Kentucky and is in the Ozark Highlands Section, the Upper Gulf Coastal Plain Section, and the Shawnee Hills and Highland Rim Sections of the Interior Low Plateau. Landscapes range from xeric to mesic. Water drains from the Shawnee National Forest to the Mississippi and Ohio Rivers and from the Hoosier National Forest to the Wabash and Ohio Rivers. Soils within these forests have a wide range of moisture levels, depths, internal physical characteristics, and fertility levels. Both national forests have many acres of private land within their purchase boundaries. These lands have been subjected to some of the same natural occurrences and poor management activities that previously occurred on lands now in national forest ownership.

ECOLOGICAL SECTIONS AND SOIL CONDITIONS

The information I present on the ecological sections, and subsections, and soils within the Hoosier-Shawnee Ecological Assessment Area is based on McNab and Avers (1994) and Keys et al. 1995.

Ozark Highlands Section

The portion of the assessment area in the Ozark Highlands Section includes the Illinois Ozarks

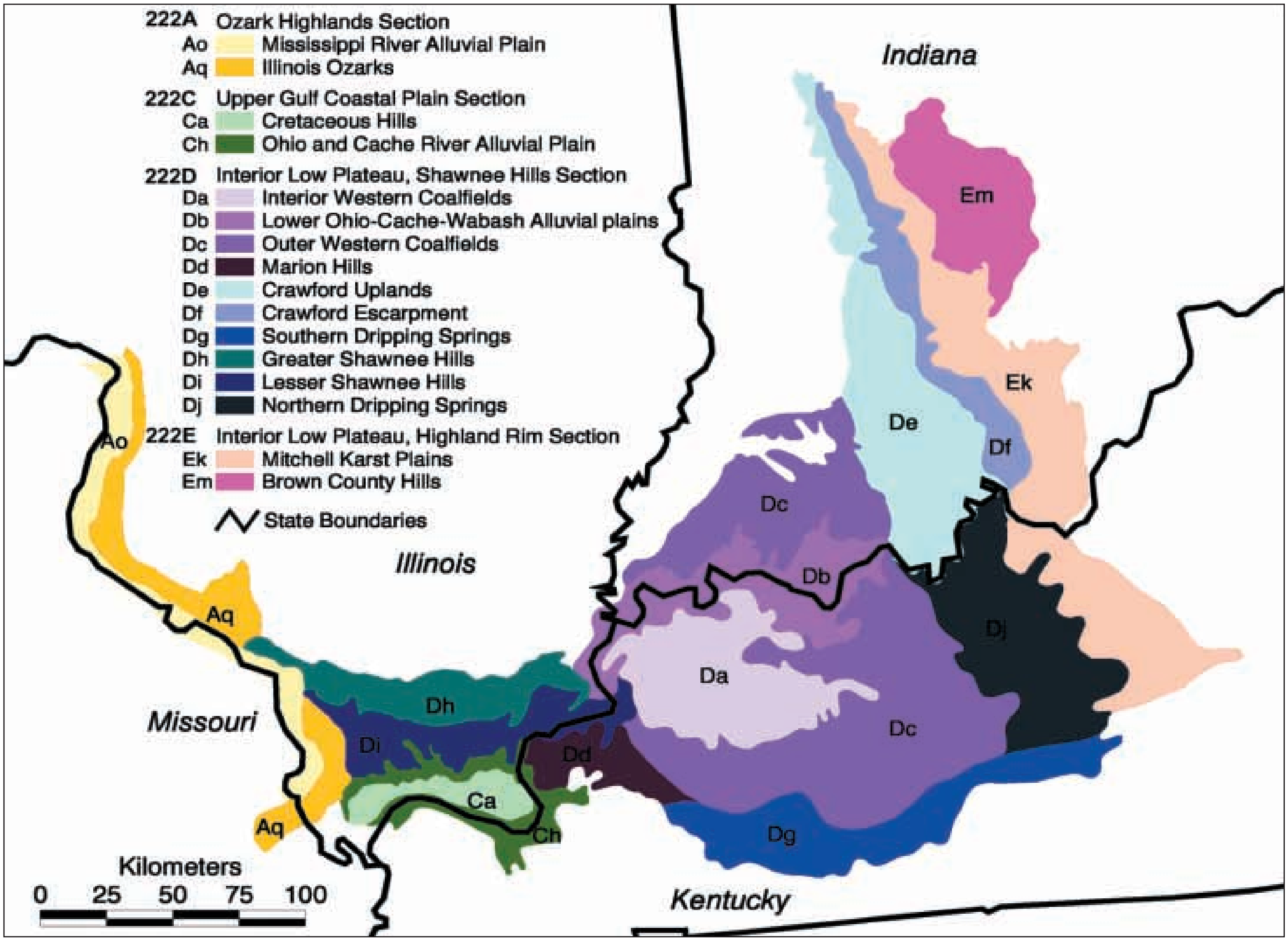

Figure 1. Ecological sections and subsections within the Hoosier-Shawnee Ecological Assessment Area (Adapted from Keys et al. 1995). Alpha-numeric designations of subsections refer to names and descriptions in table 1 and the Map Unit Tables in Keys et al. (1995).

(222Aq, fig. 1) and Mississippi River Alluvial Plain (222Ao, fig. 1) Subsections. These are very ancient landscapes, much older than the Rockies. The bedrock is Devonian and Silurian in age. Over the years, weathering has reduced their height by many hundreds of feet. The mean annual precipitation varies from 40 to 48 inches from northwest to southeast. Snow averages about 10 inches. Mean annual temperature is 55 to 60ºF. The growing season lasts 180 to 200 days.

The soils in this section are primarily Alfisols, Entisols, Inceptisols, Mollisols, and Ultisols with mesic temperature regime. The soils are mostly cherty, developed in loess mantle. Most ridgetops with gentle slopes (3 to 8 percent) have about 2 feet of loess or loess-like silty mantle compared to ridgetops with moderate slopes (8 to 15 percent), which have soils with gravelly subsoils. The Illinois Ozarks Subsection has a thicker loess mantle due to its proximity to the Mississippi River. The Mississippi River Valley was a historic source for loess during the Pleistocene age. Mineralogy is siliceous or mixed, generally fine loamy, fine silty, loamy-skeletal, or clayey-skeletal in texture. Soils are of variable depth to bedrock, but are generally shallow, stony, and acidic, except on broad ridges and bottomlands.

Upper Gulf Coastal Plain Section

This section includes the Cretaceous Hills (222Ca, fig. 1) and the Ohio and Cache River Alluvial Plain (222Ch, fig. 1) subsections. Soils in these subsections developed from Mississipian limestone with considerable alluviation along the Cache River. Soils in the Upper Gulf Coastal Plain are mostly Alfisols (Menfro, Hosmer), Inceptisols (Belknap, Burnside) with some Entisols, Mollisols, and Ultisols (Anonymous

1982, Keys et al. 1995). Uplands are dominated by well-drained and moderately well drained soils on side slopes and ridgetops. Alluvial soils are present on floodplains of the Ohio River and Cache Rivers and their tributaries. These alluvial soils are generally deep and medium textured, and they have adequate moisture during the growing season. Well-drained Haymond and Sharon series and the somewhat poorly drained Belknap and Wakeland series occupy relatively narrow floodplains. High bedrock summits occur in northeast Johnson, Pope, and Hardin Counties. The annual precipitation averages 48 to 52 inches. Average temperature ranges from 61 to 68ºF. The growing season lasts 190 to 220 days.

Interior Low Plateau, Shawnee Hills Section

This is the largest portion of the assessment area and includes the following subsections: Interior Western Coalfields (222Da), Lower Ohio-Wabash Alluvial Plains (222Db), Outer Western Coal Fields (222Dc), Marion Hills (222Dd), Crawford Uplands (222De), Crawford Escarpment (222Df), Southern Dripping Springs (222Dg), Greater Shawnee Hills (222Dh), Lesser Shawnee Hills (222Di), and Northern Dripping Springs (222Dj) (fig. 1). Soils in the Greater Shawnee Hills Subsection were derived from Pennsylvanian sandstone and shale with some Mississippian limestone, while soils in the Lesser Shawnee Hills were derived from Mississippian sandstone, shale, and limestone. Soils in the Lower Ohio-Wabash Alluvial Plains Subsection were derived from Pleistocene outwash of the late Paleozoic shale-sandstone.

The Crawford Escarpment Subsection is characterized by limestone of the middle Mississippian age overlain by regolith and colluvium as thick as 5 feet, with areas where bedrock is commonly exposed and massive limestone cliffs. Sandstone, shale, and limestone of late Mississippian and early Pennsylvanian age composed most of the surface bedrock in the Crawford Upland Subsection. Bedrock is exposed in many places or is very near the surface except in stream valleys.

The mean annual precipitation averages 44 inches. The average annual temperature is about 55ºF in southern Indiana. The growing season is approximately 195 days.

Major soils include Alfisols, Entisols, Inceptisols, Mollisols and Ultisols. These soils were formed under deciduous forests from loess, residuum, and alluvium. Alfisols (Zanesville, Grantsburg, Elkinsville, Wellston, and Bartle series) dominate the section with inclusions of Inceptisols (Haymond, Belknap, and Huntington series). Soils are generally well drained to moderately well drained, and many have silt loam or loam textures. On steep slopes, soils are typically thin with gravelly or channery textures. Subsoil permeability for upland soils is generally slow to very slow while floodplain soils typically have slow to moderately slow permeability. The soils occur on gently sloping to very steep topography, often on narrow ridges bordered by steep slopes and bedrock outcrops. Zaneville, Wellston, and Muskingum series also occur in association with other soils on the steep side slopes. Moderately well drained Grantsburg and the somewhat poorly drained Robbs series are the main soils occupying ridgetops. Permeability is slow to very slow because of a moderately to strongly developed fragipan in the lower subsoil. Many rock outcrops also are present on the steeper slopes. Some wetlands occur throughout this section mainly on floodplains.

Also, some parts of this section contain soluble bedrock strata composed primarily of limestone, made of calcium carbonate. Because limestone is somewhat more soluble than dolomite (calcium-magnesium carbonate), sinkholes and other karst landforms are common.

(See a description of karst in the paragraph just before the section on soil productivity limitations.) Because recharge to the water table is rapid, it can carry contaminants from the surface. Contaminants may include effluent from private septic systems, agricultural chemicals, animal and livestock wastes, motor oil, industrial waste, and garbage. Consequently, in karst landscapes, the risk of groundwater contamination from residential, agricultural, or industrial development is very high.

Both the Ozark Highlands and the Shawnee Hills Sections contain areas of thin, very droughty soils over bedrock that is often exposed in places. Because these soils contain little moisture or plant nutrients, many of the trees growing on them are stunted or gnarled. Further, the plant communities supported on these xeric forest soils have been characterized as "barren or transitional vegetation," usually having no more than 50 percent woody cover and a codominant understory of grasses or other plants. Barren or transitional land areas occur mostly along ridgetops and south and southwest facing slopes. Acreages of these lands are present in the Greater Shawnee Hills, Lesser Shawnee Hills, Illinois Ozarks, and the Cretaceous Hills subsections on the Shawnee and in the Crawford Escarpment and the Crawford Uplands subsections on the Hoosier.

Interior Low Plateau, Highland Rim Section

The eastern portion of the assessment area is in the Interior Low Plateau, Highland Rim Section and includes the Brown County Hills (222Em, fig. 1) and Mitchell Karst Plain (222Ek, fig. 1) Subsections. The sandstone-shale region occurs as two main bodies in southern Indiana. The eastern portion is separated by deep stream valleys, and it is mostly wooded hillside land, with little suitable cropland, which occurs in small stream bottoms. The western area has stony hillside land with rock bluffs, but more areas of productive land. A large percentage of the land has been worked as strip mines and is now in forest. The Brown County Hills Subsection is composed of siltstone and shale of early to middle Mississippian age. This subsection is very rugged, with deep entrenchments by streams that drain into the Wabash River basin. The area has had long-term fluvial erosion, resulting in a noticeable dendritic drainage pattern. Fluvial erosion, transport, and deposition are the predominant geomorphic processes in the subsection. Derived from middle Mississippian age carbonate bedrock, regolith as much as 30 feet thick over limestone is the predominant surface material in the Mitchell Karst Plain Subsection. Stream entrenchment has, in some places, produced limestone outcrops. Terra rossa, a red clayey regolith from 5 to 50 feet thick, is a distinctive feature of this subsection.

Annual precipitation in the Highland Rim Section averages 44 to 54 inches. Temperature averages 55 to 61°F. The growing season lasts 180 to 200 days.

The Brown County Hills Subsection is dominated by well-developed udic Ultisols, udic Alfisols, and acidic, udic Inceptisols. Other Alfisols have both aquic and udic soil moistures, and some have fragipans. Along streams, Entisols dominate and have both udic and aquic moisture regimes. There are also some sandy Entisols near the West Fork of the White River. In addition, udic Entisols may occur on steeper slopes and on recently exposed loess. Although acidic Inceptisols are more common, basic Inceptisols are also present. Also occurring are aquic Inceptisols. Mollisols are common in some areas having both aquic and udic soil moisture regimes.

The Mitchell Karst Plain Subsection is characterized as a region of irregular topography. Soils were formed in a thin layer of discontinuous loess and silty clayey residuum-colluvium. Well-developed udic Alfisols on stable surfaces is the dominant soil type in this region. Fragipans have developed in some areas. Other common well-developed soils are the udic Ultisols, some with fragipans. The Alfisols in this region can also have aquic soil moisture, and some have a fragipan. Inceptisols with an udic moisture regime appear with both acidic and basic characteristics. Udic Mollisols are common. Paleudults (Frederick series), Fragiuldults (Zaneville series), Hapludalfs (Wellston series), and Dystrochrepts (Berks series) are representative soils in these two subsections.

The term “karst” refers to a landscape that typically is marked with sinkholes, that may be underlain by caves, and that has many large springs that discharge into stream valleys. Once these underground drainage pathways become established in bedrock, surface-water drainage is diverted underground. As a result, karst areas, such as the Mitchell Karst Plain, generally lack the network of surface streams seen in most other areas. It is generally a rolling plain pocked with sinkholes, but in areas of stream entrenchment, steep hillsides and cliffs occur. Streams, however, are uncommon because of the sinkholes. Drainage, which is commonly subterranean, flows into the Wabash or Ohio River basins. Most of the surface landscape consists of regolith. Bedrock outcrops, mostly limestone, occur on steep slopes bordering streams and at the crests of some hills. The breakdown of limestone beds (to form sinkholes) is important in shaping the landscape.

SOIL PRODUCTIVITY LIMITATIONS

Soil Loss

Considerable soil loss had occurred over the landscapes in both national forests before Forest Service ownership. Estimates of surface horizon loss range from 25 percent to over 75 percent for some areas. Timber cutting and farming had peaked and begun to decline by 1900 and had caused widespread soil erosion. Soils erode when soil porosity is reduced, especially when there is a lack of good vegetative cover. Preserving topsoil is important because deep surface layers generally translate into higher productivity. Topsoil material is usually enriched with organic matter. Organic matter provides soil with large pores, thus reducing soil density and enhancing water infiltration. Thin topsoil usually means lower organic matter content, because this is where nearly all soil organic matter is located, except for roots and other buried biomass. Soil organic matter increases soil water storage. In addition, approximately 50 percent of the plant available phosphorus (P) and potassium (K) reside in the topsoil. Thin topsoil means less rooting depth and plant available water capacity. Losing topsoil, therefore, contributes to a loss of nitrogen (N), P, and K and subsequent decline in productivity.

Growing trees increase soil porosity by providing litter in the form of leaves and other plant materials used by burrowing soil organisms that feed on dead organic matter. Thus, the potential for soil erosion lies with activities associated with tree removal rather than just with the temporary absence of tree cover.

Erosion is also affected by the steepness and length of the slope. Greater slope lengths increase the runoff velocity and the movement of sediments carried in runoff. In many areas, severe and prolonged erosion contributed significantly to reduced soil productivity on the Hoosier and Shawnee.

Wells and Jorgensen (1979) concluded that biomass-harvesting practices that removed more than tree boles could be selected from rotation to rotation without serious risk of decline in soil productivity in forests where the only concern for productivity loss was associated with nutrients removed in harvested biomass, because soil nutrient supply and productivity in forests change relatively slowly. However, an increase in harvest intensity could be expected to increase soluble nutrient losses and increase transport of particulate matter. Increasing the amount of biomass removal reduces the quantity of organic residue that would ordinarily be subjected to decomposition and nutrient release. If forest floor temperature and moisture are increased by biomass removals, there could be a nutrient flush from accelerated forest floor decomposition.

The addition of soil amendments such as animal manure and fertilizers can supply needed nutrients for tree growth and help offset losses in soil fertility caused by soil loss. However, productivity lost by excessive soil erosion cannot be restored through additional nutrient inputs for soils with subsoil material that has unfavorable properties (shallow to bedrock or restrictive layer, poor drainage, and so on) for tree growth.

The conversion of forested land in southern Illinois and southern Indiana to agriculture increased the opportunity for soil erosion, and soon forests and soils were nearing exhaustion. The most important factors in rehabilitating these soils on the national forests were the planting of trees and good forest management.

Alluviation

The most productive sites on both forests are alluvial land areas in floodplains along rivers such as the Mississippi, Wabash, and Cache, and some of the larger streams. Alluvium is made up of eroded rock particles from hillsides that are ground into finer and finer grains of soil material each time they move downstream. Soil texture and depth for these soils are variable because of the alluvial nature of the materials. These sites are usually readily accessible, so most of them have been heavily cut over and/or farmed. Areas vary in size and shape and are scattered over the landscape.

The bottomlands along the Mississippi River were formed by glacial floodwaters. The floodplain is quite large and reflects the meandering history of the river, which has left many oxbow lakes and sloughs. The soils vary in that some are sandy and well drained while others are clay and poorly drained. Almost all bottomland forests along the Mississippi River floodplain were cleared for agriculture in the past (Groninger and Zaczek 1999). Although much fewer in number compared to less productive soils in national forest ownership, many of these bottomland soils are well drained and fertile. More recent floods (1993 and 1996), especially in areas influenced by the Mississippi River and large streams, caused the abandonment of additional acres within the forest purchase boundary that had been cleared of trees for farming. Efforts are being made to regenerate some of these recently purchased lands to trees (Inahgeh Project: History and Status of the Inahgeh Project, copy in the files at the Forest Service office in Jefferson City, MO).

A large acreage of these floodplain soils also occurs in the southernmost section of Illinois and includes the bottomlands of the Cache River. The area has swampy forest bottomland and is the northernmost extension of the Gulf Coastal Plain Province. Bald cypress-tupelo swamps are unique to this division. Although never glaciated, this area has been affected by glacial floodwaters. Sediments of sands, gravel, and clay in older terraces, as well as more recent alluvium, are quite deep, burying the bedrock. Before the intervention of humans, rivers and streams flooded regularly, increasing productivity and enriching floodplains with sediments and nutrients. Changes in rivers, such as levees, locks, and dams, have diminished the natural flooding cycles and reduced the productivity of alluvial systems.

Soil Compaction

Compaction, the moving of soil particles closer together by external forces such as falling rain or traffic, can affect forest soil productivity. It can restrict soil drainage and increases the bulk density of soil and its resistance to penetration. Compaction reduces air exchange in the rooting area. All of these can hinder plant growth and yield. Today, more and more land managers are seeing the adverse effects of compaction over the entire range of soil types—from sands to heavy clays. However, more and more compaction problems are showing up in medium-textured soils, such as silt loam—a texture found throughout both forests. The worst compaction occurs on somewhat poorly drained soils and soils having low shrink-swell properties; compaction is often worse there than on poorly drained depressional soils.

Soil compaction can contribute to poor root health and reduce the response time of roots to localized nutrient concentrations (Chaudhary and Prihar 1974, Shierlaw and Alston 1984). It has been shown to reduce soil volume, soil porosity, aeration, water infiltration, and saturated hydraulic conductivity (Greacen and Sands 1980) or to limit bulk density for root growth (Daddow and Warrington 1983).

Sandy soils also compact. Sandy soils tend to remain compacted because the natural processes of shrink-swell and free-thaw have little effect on them. Gomez et al. (2002) indicated that for some coarse-textured soils, seedling performance may be better in compacted soil than in soil not compacted. Early results show that both height growth and diameter at breast height (d.b.h.) were better for shortleaf pine planted in compacted forest plots containing Clarksville cherty silt loam than in plots where the soil was not compacted (Ponder 2004). The reverse was true for northern red oak and white oak planted on the same Missouri site.

Although timber harvesting equipment is getting larger, equipment manufacturers and land managers are becoming more aware of the potential soil damage that can occur during the harvesting process. To reduce soil compaction on highly susceptible soil, timber harvesting is restricted when soil is wet. There is some concern that residual compaction during thinning could, after several entries into the same stand, reduce productivity. Although there are data to show that soils in skid trails and roads are compacted compared to other soil in the stand, controlling traffic during the harvest and reusing major skid trails and roads restrict compaction to the same areas. The natural recovery of compacted soil often takes many years.

All of the answers on how to deal with soil compaction are not yet available. It is hard to rehabilitate compacted forested soil. Conifer species, because of their shallower root systems compared to hardwoods, are more adapted to growing on compacted and shallow soils, and on some sites they should be the species of choice for regeneration. Bedding the planting rows before planting conifers has become the method of choice for private and Federal lands in some locations. However, soil bedding before planting is not widespread in the central hardwood forests.

Some soils in the region have a very slowly permeable fragipan. However, these soils are suitable for trees. Fragipans tend to affect the growth of some trees more than others; thus, selecting the proper species for a site can enhance productivity.

Other Factors

In general, these forests have been highly disturbed (soil loss, alluvium, and compaction) by fire, grazing, and cutting that occurred in the early decades of the 1900s and consequently lost some productivity because of these activities (Sutherland 1997). Environmental factors constitute the majority of factors used to determine a soil's overall productivity. The relative importance of each factor is interwoven into the influence of the others. None are dominant in all circumstances, although one may have a greater influence. For example, although

Table 1. Ecological sections, subsections, and potential vegetation in the Hoosier-Shawnee Ecological Assessment Area. Adapted from Keys et al. (1995)

Ecological section	Subsection	Potential vegetation
Ozark Highlands	Mississippi River Alluvial Plain (222Ao)	Cottonwood-willow forest, green ash-elm-hackberry forest, pin oak-swamp white oak forest
Ozark Highlands	Illinois Ozarks (222Aq)	White oak-black oak forest, shortleaf pine-oak forest, little bluestem-sideoats gramma glade, beech-sugar maple forest
Interior Low Plateau, Highland Rim	Mitchell Karst Plain (222Ek)	White oak-red oak forest, little bluestem-sideoats gramma glade, beech-maple forest
Interior Low Plateau, Highland Rim	Brown County Hills (222Em)	Upland oak-hickory forest, beech-maple forest, chestnut oak-mixed oak forest
Upper Gulf Coastal Plain	Cretaceous Hills (222Ca)	White oak-red-oak forest, southern red oak-mixed oak forest, post oak-mixed oak woodland-barrens
Upper Gulf Coastal Plain	Ohio and Cache River Alluvial Plain (222Ch)	Cypress-tupelo swamps, pin-oak-swamp white oak flatwoods, watercup oak-sweet gum forest
Interior Low Plateau, Shawnee Hills	Interior Western Coalfields (222Da)	Southern red oak-white oak-hickory forest, oak forest
Interior Low Plateau, Shawnee Hills	Lower Ohio-Wabash Alluvial Plains (222Db)	Oak-sweetgum bottomland forest, cypress-tupelo swamps, bulrush-cattail marsh
Interior Low Plateau, Shawnee Hills	Outer Western Coal Fields (222Dc)	Southern red oak-white oak-hickory forest, beech-maple forest
Interior Low Plateau, Shawnee Hills	Marion Hills (222Dd)	Chestnut-oak-oak-hickory forest, southern red-oak-white oak-hickory forest
Interior Low Plateau, Shawnee Hills	Crawford Uplands (222De)	White oak-red oak forest, beech-maple forest
Interior Low Plateau, Shawnee Hills	Crawford Escarpment (222Df)	White oak-red oak forest, beech-maple forest
Interior Low Plateau, Shawnee Hills	Southern Dripping Springs (222Dg)	Southern red oak-white oak-hickory forest, American beech-sugar maple-yellow poplar forest
Interior Low Plateau, Shawnee Hills	Greater Shawnee Hills (222Dh)	White oak-red oak forest, post oak-blackjack oak forest, blackjack oak-cedar glades
Interior Low Plateau, Shawnee Hills	Lesser Shawnee Hills (222Di)	White oak-red oak forest, post oak-blackjack oak forest, blackjack oak-cedar glades
Interior Low Plateau, Shawnee Hills	Northern Dripping Springs (222Dj)	Southern red oak-white oak-hickory forest, sugar maple-yellow poplar forest

approximately 760 mm of precipitation falls in the Shawnee and Hoosier National Forests during the growing season, summer droughts of up to 4 weeks during July and August are not uncommon. Also, because most of the soils in these two forests, excluding alluvial soil, were formed under forest, they have inherent low organic matter content compared with soils formed under grass. Thus, the combination of soil, climatic, and topography has created a variety of physiographic soil types and has a profound influence on the distribution of forest species and communities (table 1). While the aforementioned factors play an important role in determining inherent soil productivity, litter fall is an important internal nutrient cycling mechanism that helps regulate productivity in forest communities. Nutrient inputs from litter fall, dead wood, and reproductive litter in central hardwood forests are generally in the order of calcium (Ca) > N > K > magnesium (Mg) > P (Peterson and Rolfe 1980).

Effective soil depth and available water holding capacity (AWC) are recognized as major factors regulating site productivity and plant community composition (Fralish 1976, George and Fisher 1989). Available water holding capacity integrates effective soil depth with texture, percent stone, and bulk density changes through a particular depth. These variables have a strong effect on soil water, which ultimately determines site potential and tree growth. However, data for estimating AWC are not easily obtained, and thus, for predicting growth on disturbed sites such as forests where productivity may be below potential levels, it is necessary to use other site factors that can be rapidly observed in the field.

Redcedar (*Juniperus* spp.) occurs on the most xeric sites. Such sites have small amount of soil and limited water availability. Redcedar stands are located in a variety of slope positions that range from exposed bluff edges facing a variety of directions. On sites where the soil is somewhat deeper and covers the entire bedrock surface, the forest stands are generally dominated by post oak (*Quercus* spp.) with blackjack oak (*Quercus* spp.), hickory (*Carya* spp.), and white oak (*Quercus* spp.) (table 1). Stands of white oak tend to dominate middle slope positions, on more gently sloping land surfaces near ridgetop sites or on south, southwest, and west slopes. Occurring with white oak are post oak, black oak (*Quercus* spp.), and several species of hickory. Soils are deeper and the available water storage capacity is 5 cm more than for post oak sites. Northern red oak (*Quercus* spp.) stands are found in middle slope positions but on sites that have northwest, north, and northeast aspects. Soils average about 13 cm deeper than for white oak with similar available water storage capacity. Other relatively important species include pignut hickory (*Carya* spp.), shagbark hickory (*C. ovata* (Mill.) K. Koch), white ash (*Fraxinus americana* L.), and sugar maple (*Acer saccharum* Marsh.). These communities rapidly grade into sugar maple communities in lower slope positions. Soils averaging over 100 cm deep to bedrock, usually without a fragipan, and high available water storage capacity (>20 cm) in the profile have a mixture of relatively mesophytic hardwood species (Braun 1964). These hardwoods are designated as mixed hardwoods to distinguish them from the sugar maple community. Fisher and Kershaw (1985) concluded that while site characteristics do influence species composition, net basal area growth as a measure of productivity depends more on average tree size and stocking.

EFFECTS OF CURRENT AND PAST LAND USE PRACTICES

Deforestation and Conversion to Agriculture

Practices such as logging, water drainage, and conversion to agricultural uses have led to considerable change since presettlement times. Settlement of much of the land began in the early 1800s, some areas as early as 1763. At the close of the Revolutionary War, the American government encouraged immigration by offering homesteads at small cost, and settlers began to come down the Ohio River or up the Mississippi into southern Illinois where the population remained concentrated until the 1830s. The agricultural economy developed primarily in bottomlands, where people cleared forest for field crops and pastures by tree-girdling and burning. Many people migrated into the area in the 1850s with the development of the charcoal pig iron industry. The demand for this high-quality iron caused rapid deforestation of the area around the smelters. Pig iron production peaked in the 1880s and then declined with the loss of the timber resource for charcoal. Most of the smelters were closed by the turn of the century. The communities that surrounded the smelters were abandoned and the forests regrew. In other areas, the forest was removed because of surface mining for minerals. Over time, these mines closed or were abandoned and the forest regrew. However, from the time these forests were cleared until they redeveloped, many tons of soil were carried from the sites by water in tributary streams of rivers such as the Cache and Mississippi where the soil was deposited.

The area now occupied by the Oakwood Bottoms Greentree Reservoir was intensively farmed before its acquisition by the Federal government between 1933 and 1938. These flatwoods occur on nearly level lacustrine sediments. The soils are Inceptisols that formed in lacustrine sediments with high shrink-swell capability. Clay contents exceed 60 percent leading to vertic characteristics due to montmorillonitic mineralogy. These areas are often wet during the spring and fall. Since its acquisition, the Oakwood Bottoms Greentree Reservoir has been left to reforest itself naturally or through replanting. No tree harvest is planned on Oakwood Bottoms for timber management purposes. However, harvest may be used to regenerate oaks at 60- to 80-year intervals to improve and maintain wildlife habitat. Pin oak (*Quercus* spp.) grows rapidly on these lacustrine soils (McIlwain 1967). Very little of the wetlands and floodplain forests remain in presettlement condition. These physical changes to the landscape, including the mixture of agricultural and forest lands, have had a profound ecological effect.

Agricultural and Silvicultural Management

Before European settlement, vegetation in the Shawnee and Hoosier National Forests was mainly deciduous forest. In general, deep, well-drained upland soils supported sugar maple, oaks, hickories, beech (*Fagus* spp.), poplar (*Populus* spp.), and oaks. Shallow, well-drained upland soils were covered with scrub oak (*Quercus* spp.) (including blackjack and scarlet), while pin oak grew mostly on poorly drained soils. Farming eliminated forest from relatively level land areas and land surfaces on broad ridges and hills. More forested acres were decreased by mining. Many of these once abandoned fields and mining areas are now in some stage of forest stand development or other successional vegetation. During the 1930s through the 1950s, private agricultural lands that were purchased and put into the National Forest System on the Shawnee and Hoosier National Forest were reforested or maintained as wildlife openings. Much of the abandoned crop fields in the uplands were planted to non-native pine plantations while floodplain fields were primarily planted to tulip-poplar. These plantations helped control further erosion for watershed protection. Through reforestation and rehabilitation, hardwoods have made a comeback and occupy many acres in the Shawnee and Hoosier National Forests. Most of the once eroded forest soils planted to trees are in better condition now than they have been in decades, and many support native tree species such as oak, ash, and black cherry.

Private forests are expected to play an important role in meeting future timber needs. Both the Hoosier and Shawnee have large acreages of private timberland within their purchase boundaries. Private landowners own 85 percent of the forested land in Indiana. Each private landholder owns timberland for a unique reason, which makes it difficult to explain and predict how landowners will manage their forest resources. Public policymakers and industrial planners are concerned that these lands may not meet their potential in fulfilling future needs for timber. Continued division of the forest into smaller parcels and increased development may make harvesting uneconomical. For example, from 1978 to 1996, in just 18 years, the number of Indiana's private timberland owners tripled; however, the amount of private timberland increased by only 30,000 acres.

Planting trees prevents soil erosion and provides habitat for wildlife and recreation. Historical data and the presence of fire-resistant characteristics support the role of fire in the establishment and maintenance of mixed-oak forests in the Central Hardwoods Region. Following the clearcutting of the forests in the 1800s, fire suppression became a dominant forest management technique. Age and species diversity declined and forest stand composition shifted, allowing more vigorous and shade-tolerant species to dominate. As a result, seedlings in oak-dominated forests have become suppressed by vegetative competition, resulting in a decrease in oaks in the midstory. Adams and Rieske-Kinney (1999) concluded that this shift in species composition has resulted in the economic loss of an extremely valuable hardwood group and may also impact forest succession rate, wildlife composition and distribution, and watershed characteristics.

Fire can be a useful way to rejuvenate forested areas. Not only do fires replenish the soil with nutrients vital to plant growth by quickly breaking down dead plant materials, and allowing more sunlight to reach the forest floor to increase plant and animal diversity, but they also cut out disease from plant populations and often facilitate plant production. Rapid plant regrowth is essential to the rehabilitation of a burned area, for plants greatly influence the hydrology of a soil. For plants to grow back on a burned area, they require several nutrients whose concentrations are modified by fires. The degree of modification is determined by a fire's temperature, but there are a few general trends. Levels of P and pH (Kutiel and Shaviv 1993, Marion et al. 1991) both increase during a fire. Conversely, N decreases during a fire (Kutiel and Shaviv 1993, Marion et al. 1991).

Chemical concentrations in burned soils are greatly affected by a fire's intensity. Several studies show how minerals essential for plant growth in the soil are affected by fire intensity. Low-intensity fires (100-250°C) tend to increase levels of ammonium (Kutiel and Shaviv 1989, 1993), Ca (Weaver and Jones 1987), and Ca, Mg, and K (Kutiel and Shaviv 1989, Marion et al. 1991), while high-intensity fires (>500°C) tend to decrease them. Kutiel and Shiviv also noted in their study that pH increased with fire intensity and that the highest concentrations of sodium, K, and Mg occurred at a fire temperature of 250°C.

The highest concentration of essential minerals for plants occurs during low-intensity fires. Low-intensity fires also tend to create patchy burn mosaics on the landscape. These are desirable because N, which is essential to plant growth and is decreased by fires, can easily diffuse from the unburned areas into the burned areas in the form of NO3-N. Nitrogen can also be replaced through the migration of nitrifying plants from the unburned areas to the burned areas (Kutiel and Shaviv 1993). Patchy burning (low-intensity fire) is often a direct function of soil moisture. Therefore, prescribed burns are most effective (i.e., rejuvenating the vegetation and not degrading the soil) during the wetter months of the year.

Fire also has a tendency to change the texture of a soil by aggregating the clays into sand-sized particles (Ulery and Graham 1993). Dobrowolski et al. (1992) showed from their study of fire's effect on sandy soils that a high percent of sand in the top layer of soil and a low depth of clay rich horizons tend to increase the infiltration capacity of a soil. However, the effect is short lived, and in most cases the effect of fires on soils is to increase the erodibility of soils due to a lack of vegetation (Scott and Van Wyk 1990).

Increases in soil nutrient availability following fire have been found in some systems and fire regimes and not in others. So far, what we know about possible detrimental effects of fire on site chemistry suggests that these effects are minimal and of short duration. Intense fires of logging slash in the southern Appalachians have combusted some of the organic layer without significant loss of carbon (C) or N from the O-horizon (Vose and Swank 1993) and have increased available soil N (Austin and Baisinger 1955, Knoepp and Swank 1993). Fire is being reintroduced in the restoration and maintenance of a complex mosaic of woodlands, forests, barrens, and savannas using landscape-scale prescribed fire and other techniques. It will likely require multiple fires to restore the desired oak structure.

Acid deposition from sulfate and nitrate ions over the area included in these two forests diminishes southward and westward from north and northeastern sources (National Atmospheric deposition Program/National Trends Network- http://nadp.sws.uiuc.edu). The most noted effect associated with acid deposition has been a decrease in pH. Hydrogen ion concentration as pH in 1999 was 4.4 in central Indiana compared to 4.5 in southern Indiana and 4.6 in southern Illinois. With few exceptions, sulfate ion deposition followed the same pattern. Nitrate ion deposition as NO_3-, however, was higher (15 kg/ha) for the Hoosier than for the Shawnee (13 kg/ha). The region contains four of the Nation's top seven

NO_x emitters and three of the top five SO_2-emitters.

Acidification effects on soil have been postulated, but direct causal relationships on the ecosystem are far from clear. All soils are not equally susceptible to acidification. The buffering capacity of soil depends on mineral content, texture, structure, pH, base saturation, salt content, and soil permeability. Studies indicate that increases in acidification due to precipitation lead to a loss of cation exchange capacity and increased rates of mineral loss. Although the potential effects of acidic precipitation on soil could be long lasting, researchers note that many counteracting forces could mitigate the overall final effects, including the release of new cations to exchange sites by weathering or through nutrient recycling by vegetation. Trees appear to be slightly stimulated by acid precipitation, although this effect would be expected to be shortlived because of increased leaching of cationic nutrients and the buildup of toxic concentration of metals in soil water (Bittenbender et al. 2001). Hornbeck (1987) concluded that there were no obvious impacts of atmospheric deposition for red oaks and sugar maple from a 10-year inventory of forest resources in six New England States where acid deposition was high. Therefore, any changes in soil chemistry associated with acid deposition were minimal on tree growth.

Hardwood Restoration Programs

To aid private landowners in timber management and to demonstrate the importance of private forests in providing wood products, wildlife habitat, and soil and water protection, both Federal and State assistance is available for all phases of timber management from site preparation to harvesting. Although the major incentive for these programs is the protection of the soil and water resources by planting trees or grasses, they encourage farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover including filter strips or riparian buffers. With new and potential markets for timber, owners of mined land are keenly interested in reforestation with commercially valuable hardwoods.

Both the Conservation Reserve Program and the Wetlands Reserve Program provide assistance to landowners to apply conservation practices to their land through cost-sharing agreements. The inherent value of functional wetlands resides in the benefits provided to society through floodwater mitigation, water quality enhancement, groundwater recharge, habitat for rare and endangered species, forest production, game and nongame species production, and aesthetics. Recent studies have shown that 46 percent of all threatened and endangered U.S. plant and animal species are associated with wetland habitats. Predicting the effectiveness of wetland restoration efforts is difficult due to the longevity of forested systems. For restoration to be considered effective, important wetland functions need to be restored or at least on a path where restoration of those functions is probable and predictable. Functional linkages of restoration success must be designed to allow comparisons of parameters, such as soil organic matter development and characterization, and comparison of C and nutrient fluxes and nutrient pools at different successional stages during system recovery at various stages.

Private landowners' requests for enrollment in the programs greatly exceed allotted funding. When practices under these forest restoration programs are adequately administered, they enhance our ability to produce food and fiber, reduce sedimentation in streams and rivers, improve water quality, establish wildlife habitat, and enhance forest and wetland resources.

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