SHIFTS AND FUTURE TRENDS IN THE FOREST RESOURCES OF THE CENTRAL HARDWOOD REGION

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ABSTRACT.—Forests in the Central Hardwood region are undergoing change in terms of area, volume, species composition, and forest structure. These forests are dominated by deciduous species; are increasing their average stand size, volume, and age; and, are experiencing woody plant species replacement as shade intolerant species are being replaced by more shade tolerant species. As changes progress, concerns are being raised regarding the potential for these lands to produce the wide array of benefits associated with timberland. Changes in the forest resource as well as changes in land ownership and management objectives have repercussions for wildlife species, timber industries, recreational interests, and the wide array of other benefits reaped from this invaluable resource.

The Central Hardwood region, well known for its high quality hardwoods, has a wide variety of forest resources that make significant environmental and economic contributions. These forest resources play an important role with impacts ranging from employment and other value-added economic contributions to improving and protecting soil and water resources to providing wildlife habitat.

Central Hardwood forests are constantly undergoing change due to both natural processes and human impacts. As these changes progress, concerns related to forest fragmentation, species composition, ownership and resulting management objectives, and future sustainability are being raised. The area of forest land throughout the Central Hardwood region is increasing. Total area of forest land in this region steadily decreased from the time of European settlement until the late 1970s and early 1980s primarily due to conversion to agriculture. Since then, the area of forest land has been increasing at a steady rate as reversions from agriculture outweigh forest loss. However, sites where expansion is occurring are different from sites where forests have been lost. As a consequence, the potential for these sites to produce the wide array of benefits associated with forest land is different from what has historically been produced.

With the control of wildfires and selective harvesting methods, these forests are undergoing natural succession and maturing. Successional processes are moving the forest species composition from a mix of early successional species to domination by more shade-tolerant species. Changes in land ownership, management patterns, and harvesting techniques have crucial impacts on the composition and structure of Central Hardwood forests. Because changes dictate the quality and quantity of the future resource, it is important to document these changes.

METHODS

The Central Hardwood study region in this report is defined as the states of Illinois, Indiana, Iowa, Missouri, and Ohio (fig. 1). This region encompasses most of the mid-continental region of the USA. Although other states fall in the Central Hardwood region, a lack of data and the authors' sense that trends occurring in the above states represent trends across the region, and so additional states are not included in this study. Data for this study are from the USDA

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Figure 1.—*Central Hardwood five-state study area.*

Forest Service, Forest Inventory and Analysis (FIA) Database (Miles and others 2001), and are based on the previous and most recent complete statewide forest inventories for these five states. The dates of the FIA inventories are Illinois 1985 and 1998, Indiana 1986 and 1999, Iowa 1990 and 1999, Missouri 1989 and 1999, and Ohio 1979 and 1993. Although data pertain only to timberland, more than 95 percent of the forest land in the Central Hardwood region is classified as timberland (Powell and others 1993). Timberland is forest land capable of producing more than 20 cubic feet per acre per year of industrial wood crops under natural conditions and not withdrawn from timber utilization.

There are other classifications of land with trees, including reserved forest land, narrow planted and natural wooded strips, and pasture land with trees that do not meet the timberland definition. These other forest land categories make important contributions to the many forest related resources and their use, but until recently, FIA did not install field plots on these other lands. As a result, data are very limited for forest land classifications other than timberland.

For stand-size class determinations, deciduous sawtimber-sized stands are stands with half or more of the total live tree stocking in trees that are at least 11.0 inches in diameter at breast height (d.b.h.). Stand age is based on the average age of the dominant and co-dominant trees in the stand. Volume is the net volume of trees at least 5.0 inches d.b.h. and over, from 1-foot above the ground (stump) to a minimum 4-inch top diameter outside bark or to the point where the central stem breaks into limbs. Live volume is used in this study, which represents the volume in live trees that include non-commercial trees, rough trees, and rotten trees on timberlands.

FIA uses a systematic sampling design with land-use of plots determined via remotely sensed data. A subset of these plots is selected for field measurement where plot level and individual tree measurements are made. All data for this study originated as field measures through the FIA program.

RESULTS

Area

Within the 5-state (Ohio, Indiana, Illinois, Missouri, and Iowa) study area, representative of the Central Hardwood region, there are currently 165.4 million acres of land, of which 32.9 million acres (20 percent) are classified as timberland (table 1). This compares to 30.6 million acres of timberland in the previous inventories and represents an 8 percent increase over the past 13+ years. While the percentage of land in trees across the Central Hardwood region is relatively small compared to other land uses such as agriculture, the impact on the landscape and the contributions from this resource are significant.

The majority of the timberland is dominated by deciduous species. Except for a few sites, conifers play a minor role in this region. Of the total area of timberland, 60 percent is currently classified as oak-hickory (*Quercus-Carya*), 19 percent as maple-basswood (*Acer-Tilia*), 13 percent as bottomland hardwoods, and 7 percent as conifers (table 1). Other forest types, such as aspen-birch (*Populus-Betula*), contribute less than 1 percent to the total area of timberland in the Central Hardwood study region. In the previous inventories, oak-hickory represented 65 percent of the total area of timberland with maple-basswood being second at 16 percent. Bottomland hardwoods represented 11 percent and conifers 7 percent in the previous inventories. Depending on the site, oak-hickory and maple-basswood forest types are considered to be self-replacing with regeneration species composition similar to their overstory. These plant communities are replacing early successional forest types such as cottonwood (*Populus deltoides* Bartr.).

The only forest type to experience a decrease in its total area between inventories is the oak-hickory forest type. All others increased with the greatest increase occurring in the

maple-basswood forest type (an increase of more than 26 percent). Bottomland hardwoods increased by 20 percent in this same time period. The increase in the maple-basswood forest type is probably due partially to newly forested acres but also to the successional change from other forest types.

More than 90 percent of all oak-hickory and maple-basswood sites in the Central Hardwood region are classified as being mesic (table 2). Timberland in the very wet (hydric) or very dry (xeric) physiographic classes is relatively rare. Less than 4 percent of the total timberland area in this region is classified as bottomlands, primarily due to the bottomland hardwood classified forest types usually being classified as either mesic or hydric (13 percent of all timberland from a forest type classification but only 4 percent of all physiographic sites).

Bottomland hardwoods are a crucial component for timber industries, recreational uses, and wildlife in the Central Hardwood region. Over time, this forestland classification has received the most pressure for conversion to agriculture and pastureland due to the productive soils associated with bottomland hardwoods. In

Table 1.—*Central Hardwood area of timberland by forest type and stand-size class**

CURRENT INVENTORIES	Stand-size class				
Forest type	Total	Large diameter	Medium diameter	Small diameter	Nonstocked
	(Thousand acres)				
Conifers	2,153.4	876.6	773.3	503.6	0.0
Oak-hickory	19,851.7	11,849.3	6,243.5	1,758.9	0.0
Bottomland hardwoods	4,135.0	2,309.2	1,046.4	779.4	0.0
Maple-basswood	6,349.2	3,266.8	1,770.1	1,312.3	0.0
Aspen-birch	124.8	14.8	73.5	36.6	0.0
Nonstocked	251.9	0.0	0.0	0.0	251.9
Total	32,866.0	18,316.7	9,906.7	4,390.7	251.9

PREVIOUS INVENTORIES	Stand-size class				
Forest type	Total	Large diameter	Medium diameter	Small diameter	Nonstocked
	(Thousand acres)				
Conifers	2,009.6	804.7	609.6	572.9	22.4
Oak-hickory	19,901.3	10,757.3	4,940.8	4,047.9	155.3
Bottomland hardwoods	3,434.1	2,068.0	682.3	659.3	24.5
Maple-basswood	5,022.8	2,496.8	998.6	1,513.5	13.9
Aspen-birch	84.4	6.9	18.1	59.4	0.0
Nonstocked	104.9	0.0	0.0	0.0	104.9
Total	30,557.1	16,133.7	7,249.4	6,853.0	321.0

* Study area of Ohio, Indiana, Illinois, Missouri, and Iowa.

Table 2.—*Central Hardwood area of timberland by forest type and physiographic class**

CURRENT INVENTORIES	Physiographic class				
Forest type	Total	Xeric	Mesic	Bottomland	Hydric
	(Thousand acres)				
Conifers	2,153.4	43.3	2,110.2	0.0	0.0
Oak-hickory	19,851.7	155.7	19,479.3	156.1	59.8
Bottomland hardwoods	4,135.0	0.0	2,949.5	858.5	326.7
Maple-basswood	6,349.2	0.0	6,264.5	67.4	17.2
Aspen-birch	124.8	0.0	124.8	0.0	0.0
Nonstocked	251.9	0.0	216.1	27.1	8.7
Total	32,866.0	198.9	31,144.4	1,109.1	412.4

* Study area of Ohio, Indiana, Illinois, Missouri, and Iowa.

general, the majority of the bottomland hardwood sites that had the potential for conversion to these land uses have been converted. However, the current pressures on forest land for conversion to other land uses derive from the demand for additional urban/suburban space, second homes, and recreational facilities. These pressures exist for both bottomland and upland hardwoods. Fortunately, we have recently seen an increase in the percentage of forest land found on bottomland sites.

Land Use Changes

When forest land is developed for other land uses its composition, structure, and function change. Natural regeneration is often curtailed; stocking is usually lowered; snags, dead trees, and hollow/rotten trees that provide excellent wildlife habitat are often removed (usually justified as a safety perspective); and other changes occur with development.

There has been a net increase in the total area of timberland since the late 1970s to early 1980s, due primarily to increases in the width of existing narrow wooded strips and the conversion of cropland and pasture to timberland. These increases are greater than losses by development of timberland for agriculture, urban/suburban expansion, and other uses. For example, in Indiana timberland increased from 3.9 million acres in 1967, to 4.2 million acres in 1986, to 4.3 million acres in 1998 (fig. 2). Between 1986 and 1998 in Indiana, 382 thousand acres of timberland were converted to nonforest land uses and 421 thousand acres of nonforest land converted to timberland. This resulted in the net increase in the total area of timberland in Indiana. The new timberland areas, however, occupy different kinds of sites than those timberland areas lost to other land uses. Historically, in the Central Hardwood region, new timberland areas have established on upland mesic sites while timberland losses have occurred on bottomlands but as noted earlier this trend may be changing.

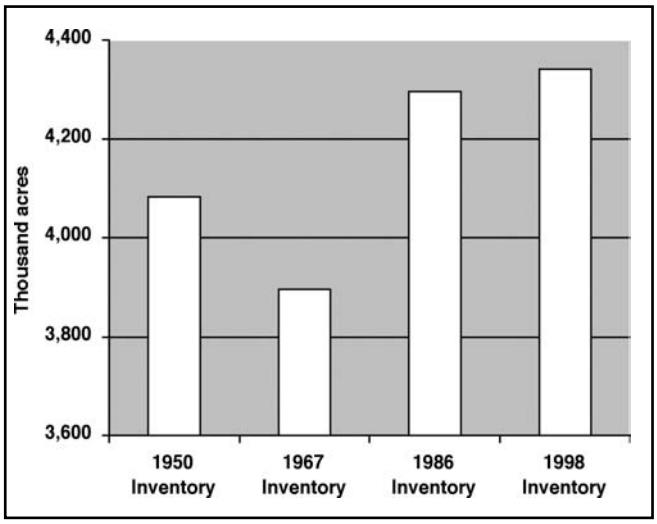

Figure 2.—*Area of timberland in Indiana by inventory time period.*

In addition to the changes in land use, changes occur in lands that remain timberland. Changes in species composition occur if the forest matures, through natural succession processes or if natural disturbances such as wind storms and floods transpire. Also, human-induced activities such as harvesting, timber stand improvement (TSI), and tree planting can change species composition. These events often result in a change in forest type classification.

Ownership

In the Central Hardwood region, 88 percent of the timberland area is privately owned (table 3). Public ownership is comprised of 8 percent in Federal, and 4 percent in State and local government ownership. Ownership by forest type generally follows the overall regional patterns for forest type. The distribution of forest land by ownership has remained relatively static over time. Although areas in public ownership have increased, the overall area of forest land has increased as well. The future of the forest resource in this region is almost totally dependent on the management objectives and intentions of private landowners.

Stand-Size Class

Larger-sized trees dominate the Central Hardwood timberland resource with 56 percent being classified in the large diameter stand-size class, or stands with dominant trees greater than or equal to 11.0 inches d.b.h. (generally referred to as sawtimber) (table 1). Medium diameter stands (poletimber) currently account for 30 percent of all timberland in the region (dominant trees between 5.0 inches and 11.0 inches d.b.h.). Small diameter (sapling-seedling) stands (dominant trees less than 5.0 inches d.b.h.) currently account for about 13 percent of the timberland area. In previous inventories, 53 percent of all timberland was classified as large diameter stands, 24 percent as medium diameter stands, and 23 percent as small diameter stands. Thus, the important change over time has been the dramatic decrease in the area of small diameter stands, a loss of more than one-third in roughly 13 years.

Table 3.—*Central Hardwood area of timberland by forest type and ownership class**

CURRENT INVENTORIES	Ownership class				
Forest type	Total	National Forest	Other federal	State and local	Private
	- - - - - - - - - - - - - - - - (Thousand acres) -				
Conifers	2,153.4	316.2	62.6	130.1	1,644.6
Oak-hickory	19,851.7	1,344.2	385.2	1,083.2	17,039.1
Bottomland hardwoods	4,135.0	29.2	73.9	136.5	3,895.5
Maple-basswood	6,349.2	246.7	77.4	124.9	5,900.0
Aspen-birch	124.8	4.8	0.0	4.1	115.9
Nonstocked	251.9	28.2	0.4	1.2	222.2
Total	32,866.0	1,969.3	599.4	1,479.9	28,817.4

* Study area of Ohio, Indiana, Illinois, Missouri, and Iowa.

Average stand-size class is increasing, an indication of a lack of significant disturbance through either natural occurrences or harvesting. For example, the area of oak-hickory in the large diameter class increased by 10 percent and the area of oak-hickory in the medium diameter class increased by 26 percent between inventories. The area of oak-hickory classified as small diameter decreased by more than 57 percent during this same time period. The only forest type to increase in area of small diameter stands between inventories was the bottomland hardwoods type, showing an 18 percent increase.

Selective harvesting methods used in hardwood stands throughout the Central Hardwood region do not cause the large-scale disturbances that move larger-sized stands to smaller-sized stands. In addition, high-grading of hardwood stands tends to leave the "economically less desirable" species (such as maple, beech, and birch) and lower quality cull trees which could hasten the transition to a later successional stage.

Stocking Changes

Stocking is a measure of the degree to which land is occupied by trees. Stocking is an important concept because it influences successional processes such as the type of regeneration, individual tree growth habit, and forest structure. The goal of most forest managers is to maintain the forests in a fully stocked condition since this condition provides for full utilization of the site. However, management can be directed to obtain different stocking levels. In the Central Hardwood region, 65 percent of the timberland is currently medium to fully stocked and 9 percent is overstocked (table 4). More than 70 percent of the oak-hickory forests, compared to less than 50 percent of the bottomland hardwood forests, is currently medium to fully stocked.

Individual tree growth habitat is a reflection of stocking. Open grown trees, often referred to as "wolf" trees, generally have large well-developed crowns with larger than average branches. For the same species, open-grown trees provide considerably different resource use potential and wildlife habitat than trees grown in an overstocked condition. Depending on the species, stocking can be one of the most important criteria for determining quality of the resource from a timber management and wildlife habitat perspective.

Stand Ages

Stand age is another important characteristic describing the forest resource. Across the Central Hardwood region, 27 percent of all forest land have average stand ages of more than 80 years, considered the threshold for entering economic maturity (fig. 3). As a comparison, across the Lake States region, only 16 percent of all forest land have an average stand age of more than 80 years (Schmidt and others 1996). In the eastern United States, the Central Hardwood region has an above average amount of timberland in the older age classes, primarily due to the lack of disturbance. Mature and overmature forests provide important wildlife habitat not typical of younger-aged stands. Overstory structure, down and dead woody material, snags, and other components enable mature and overmature stands to function in a vital manner for selected wildlife species. These older forests are a source for forest products including wood fiber and fuelwood, and provide unique recreational experiences as well as soil and watershed protection.

Only 12 percent of the timberland in the Central Hardwood region has an average stand age of less than 20 years. Young stands (typically sapling-seedling stands) provide crucial habitat

Table 4.—*Central Hardwood area of timberland by forest type and stocking class**

CURRENT INVENTORIES	Stocking class					
Forest type	**Total**	**Over**	**Full**	**Medium**	**Poor**	**Nonstocked**
			(Thousand acres)			
Conifers	2,153.4	165.5	544.3	771.2	567.5	104.9
Oak-hickory	19,851.7	1,672.7	6,275.8	7,869.2	3,551.2	482.8
Bottomland hardwoods	4,135.0	340.6	751.4	1,269.6	1,264.4	509.0
Maple-basswood	6,349.2	604.0	1,459.7	2,258.1	1,635.5	391.8
Aspen-birch	124.8	20.9	26.6	25.6	51.7	0.0
Nonstocked	251.9	0.0	0.0	0.0	106.8	145.1
Total	32,866.0	2,803.7	9,057.7	12,193.8	7,177.2	1,633.6
PREVIOUS INVENTORIES						
Total	30,557.1	2,040.2	8,379.2	13,431.5	6,422.7	283.5

*Study area of Ohio, Indiana, Illinois, Missouri, and Iowa.

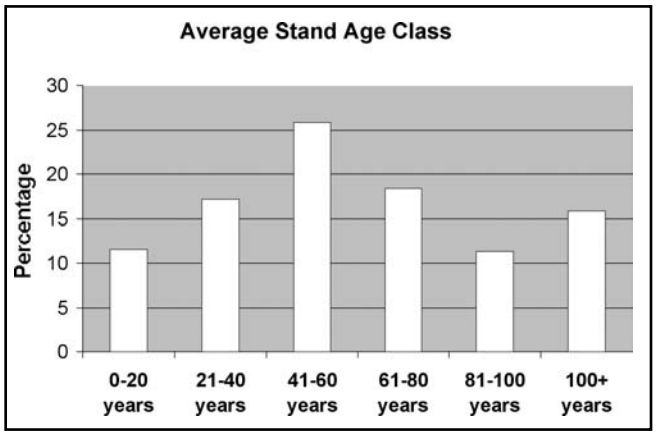

Figure 3.—*Average stand age of timberland in the Central Hardwood region.*

for many wildlife species such as white-tailed deer (*Odocoileus virginianus*) and ruffed grouse (*Bonasa umbellus*). Many wildlife species rely heavily on the seedlings, shrubs, and understory "brush" associated with these younger-aged stands. These younger stands are also a primary source of future forests; their current composition will have an important influence on the future of our forests.

Species Composition

Species composition is an important descriptor of the economic importance of timberland and its contribution to arboreal diversity and successional stage. Two states, Indiana and Missouri, are selected to quantify species composition. In the most recent inventories, a total of 92 different tree species are found on FIA plots in Indiana and 90 in Missouri. While the total number of species is similar, there are differences in the species composition. There are nine species found in Missouri but not in Indiana while, Indiana has 11 species that are not found in Missouri.

Generally, climatic changes across the Central Hardwood region result in different woody plant species compositions. As climatic factors such as precipitation, temperature, and average windspeed change, species change. The eastern portions of the Central Hardwood region typically have more species, whereas in the west where precipitation becomes more limited some species such as beech (*Fagus grandifolia* Ehrh.) and yellow-poplar (*Liriodendron tulipifera* L.) disappear from the landscape. As the species lists become smaller, the importance of the remaining species increases. On the western fringe of the Central Hardwood region in eastern Kansas and Nebraska, the oak resource is limited from the perspective of number of species and is represented by only bur oak (*Quercus macrocarpa* Michx.). The importance of bur oak in this portion of the region is of greater significance than in more easterly portions of the Central Hardwood region where more than 18 different oak species can be found.

In total, there currently are more than 17.5 billion trees in the five-state study area (table 5). Oak species are the most common, representing almost 21 percent of all live trees. The other most common species groups are maple with 11 percent, hickories with 10 percent, conifers with 5 percent, and ash (*Fraxinus* spp.) with just less than 5 percent. Black walnut (*Juglans nigra* L.) is one of the most recognized and valued species across the Central Hardwood region but only represents 1 percent of all live trees.

Less than 1 percent of the total live trees in the Central Hardwood region are at least 19.0 inches d.b.h. but these represent more than 125

Table 5.— *Number of live trees by species group and diameter class in the Central Hardwood region**

CURRENT INVENTORIES		Diameter class (in inches)			
Species group	**Total**	**1.0-4.9**	**5.0-10.9**	**11.0-18.9**	**19.0+**
		(Million trees)			
Conifers	887.4	610.0	238.4	38.3	0.7
Oak	3,662.9	2,227.8	972.3	399.1	63.7
Hickory	1,678.7	1,269.7	323.0	80.7	5.2
Hard maple	1,082.8	905.7	132.8	38.4	5.8
Soft maple	897.2	695.4	147.1	45.4	9.3
Ash	804.0	606.2	147.9	44.2	5.7
Black walnut	205.2	105.8	69.3	28.2	1.8
Other hardwoods	8,287.5	7,148.9	903.6	201.6	33.4
Total	17,505.7	13,569.6	2,934.5	876.0	125.5

*Study area of Ohio, Indiana, Illinois, Missouri, and Iowa

million trees. The oak species group represents 50 percent of all live trees in the region with diameters more than 19.0 inches d.b.h. Oak dominates this region, however when regeneration is considered, the continued future dominance by this species is of concern. Oaks are long-lived and, once established, not as susceptible to environmental influences such as windthrow and wildfires when compared to other species native to the study area. However, the oak resource is also threatened by oak wilt (*Ceratocystis fagacearum* (Bretz) Hunt), oak decline, and gypsy moth (*Lymantria dispar* L.) (Juzwik and Schmidt 2000). If oaks succumb to these factors, short-term wildlife habitat could be improved due to an increase in standing dead trees but long-term wildlife habitat quality could be negatively impacted if the trees are not replaced by similar species, as oaks are a critical food source for many wildlife species.

More than three-fourths of all trees are less than 5.0 inches d.b.h. The dominance of smaller sapling/seedling-sized trees could lead to the conclusion that the timberland is dominated by sapling/seedling-sized stands. However, as noted, timberland in the study area is predominately sawtimber size. The reason is that while there might be seedlings in a stand, if larger trees are present they dominate the stand and the size classification. In most timberland, the number of smaller-sized woody plants exceeds the number of larger-sized trees. The growing space needed by a seedling is dramatically different from that needed by a large dominant tree. The crucial point is that the combination of overstory and understory woody species, their interspersion, and their species composition dictate the structure and function of the forest.

The relative proportion of smaller-sized trees varies by species group. “Other hardwoods” has the greatest proportion of small trees. Currently, 86 percent of the trees in this group are less than 5.0 inches d.b.h. This group contains all of the species not associated with the other named species groups. The hard and soft maples, hickories, and ash species groups have more than 75 percent of their trees in the less than 5.0 inch size class.

The oak species group is different than any other in terms of number of smaller-sized trees. Only 60 percent of all oak trees are considered regeneration or sapling-seedlings (less than 5.0 inches d.b.h.). Oaks are of special interest due to their economic and environmental benefits. In addition, their importance as a source of food and habitat for a wide variety of wildlife species cannot be understated. For example, acorns are one of the primary plant foods for white-tailed deer (*Odocoileus virginianus*), blue jays (*Cyanocitta cristata*), and Eastern gray squirrel (*Sciurus carolinensis*). The future of oak species in the Central Hardwood region could have a direct tie to the future populations of many timber production facilities and wildlife species.

Because of the maturing of the region’s forests, and the limited ability of white and red oak to regenerate under shade, the regeneration of these species is of concern. In most states, the number of oak seedlings is remaining static at best. For the near future, there should be sufficient oak regeneration to replace the existing older, mature oak following harvest or mortality of canopy trees. Nevertheless, even though oak seedlings can survive in shade for several years, they must have adequate sunlight to successfully develop. As the timberlands in the Central

Hardwood region continue to mature, future regeneration of oaks could become even more limited.

Volume

Volume has been increasing over time throughout the region. There are currently more than 44.1 billion ft^3 on the 32.9 million acres of timberland in the study region equating to almost 1,340 ft^3 per acre of timberland across the entire region (table 6). In previous inventories, total volume was 34.1 billion ft^3, an average of 1,116 ft^3 per acre throughout the Central Hardwood region. In the 13 years between inventories, total volume increased by 29 percent, continuing the trend established since the 1930s of increasing volume on the timberland in the Central Hardwood region. To provide a comparison on a local level, average volume per acre in Indiana increased from about 680 ft^3 per acre in 1950 to 1,589 ft^3 per acre in 1998.

With high volumes, concerns regarding fuel hazard, growth being suppressed due to competition, and other forest health issues increase. Greater volume levels can have either a positive or negative impact, depending on the perspective. For example, growing-stock volume in Indiana increased from 5.2 billion ft^3 in 1986 to 6.9 billion ft^3 in 1998, reflecting the increase in both area and stocking during the 12 years between those inventories. Wildlife species such as prairie warbler (*Dendroica discolor*) and yellow-breasted chat (*Icteria verens*) that prefer brushy or thicket-covered uplands could be negatively impacted from greater stocking levels, which could decrease understory "thickets" due to lower light levels (Hunter and others 2001). However, other species could be positively impacted from these greater stocking levels. From a wood fiber production perspective, the increased levels of volume per acre assist with lowering costs of accessing the timberland (road and skid trail construction for example).

In the Central Hardwood region, currently 60 percent of the total area of timberland is in the oak-hickory forest type and 51 percent of the total volume is in the oak and hickory species groups. In the previous inventories, 65 percent of the total area of timberland was in the oak-hickory forest type and 56 percent of the total volume was in the oak and hickory species

Table 6.—*All live volume by species group and diameter class in the Central Hardwood region**

CURRENT INVENTORIES		Diameter class (in inches)		
Species group	**Total**	**5.0-10.9**	**11.0-18.9**	**19.0+**
		(Million cubic feet)		
Conifers	2,026.7	1,112.0	876.2	38.5
Oak	18,468.0	4,440.4	9,222.1	4,805.5
Hickory	4,141.6	1,570.6	2,100.1	470.9
Hard maple	2,060.3	695.9	1,016.3	348.1
Soft maple	2,430.7	693.1	1,075.5	662.1
Ash	2,108.3	683.5	1,070.2	354.5
Black walnut	1,209.4	366.4	689.0	154.1
Other hardwoods	11,651.1	3,954.3	4,590.4	3,106.4
Total	44,096.1	13,516.1	20,639.9	9,940.1

PREVIOUS INVENTORIES		Diameter class (in inches)		
Species group	**Total**	**5.0-10.9**	**11.0-18.9**	**19.0+**
		(Million cubic feet)		
Conifers	1,577.8	973.4	566.7	37.7
Oak	16,103.5	4,451.9	8,086.2	3,565.5
Hickory	3,155.3	1,449.0	1,450.7	255.5
Hard maple	1,409.7	514.9	642.9	252.0
Soft maple	1,546.0	487.2	603.1	455.6
Ash	1,519.5	597.5	702.7	219.3
Black walnut	792.6	309.2	418.7	64.7
Other hardwoods	8,023.6	2,970.9	3,221.1	1,831.8
Total	34,127.8	11,754.0	15,692.0	6,682.0

*Study area of Ohio, Indiana, Illinois, Missouri, and Iowa.

groups. The lower levels of volume compared to area could imply that a number of other species exist in the oak-hickory classified timberland.

Increases in volume occurred across all species groups (table 6). While the oak species group increased its total volume between inventories by 15 percent, this was the lowest percentage increase of all species groups. Hard and soft maples, black walnut, and other hardwoods species groups all increased their total volume by more than 40 percent between inventories. In the smaller diameter size classes, the volume of oak stayed static while volume for soft maple increased 42 percent and for hard maple 35 percent. These smaller diameter classes provide a good indication of dominant timberland species 50 to 70 years in the future if there is no major disturbance. Similar trends are found for the medium diameter classes; i.e., low growth levels by oak and high growth levels for more shade tolerant species.

Change Factors

Components of change (growth, mortality, and removals) are important indicators of sustainability. Net growth is equal to gross growth minus mortality. Net growth can be compared to removals to determine the growth-to-removals ratio. A ratio of more than 1 indicates that growth is greater than removals, and hence an increase in inventory volume. Studies across the Central Hardwood region have shown that growth-to-removals ratios have been about 2.5 to 1 (Schmidt 2000). Table 7 exhibits the growth-to-removals ratio for Indiana in 1998 and table 8 exhibits the growth-to-removals ratio for an 8-state region (5 states in this study plus Pennsylvania, Tennessee, and Kentucky) conducted for an independent study (Schmidt 2000). In both cases, growth-to-removals were about 2.5 to 1. This growth-to-removals ratio indicates that each year total volume is increasing at a substantial rate, evidenced by the noted increase in total volume over time.

As would be expected, larger-sized trees have lower growth-to-removals ratios since larger trees have greater economic value from a harvesting perspective and thus are more likely to be harvested (tables 7 and 8). Typically, medium-sized trees have the greatest growth-to-removals ratios due to both the lower likelihood of being harvested and due to the physiological aspects of when the tree species in this region grow best. Growth is also high for the small diameter classes but FIA protocols don't accommodate volume estimates (total volume, growth, mortality) until the individual tree attains at least 5.0 inches in d.b.h.

Forest Structure

The distribution of trees by species and crown class (open grown, dominant, co-dominant, intermediate, and overtopped) describe general forest structure of the forest resource. Crown class distribution is a measure of the dominance of the individual tree's crown compared to the overall stand. Throughout the Central Hardwood region, a low percentage of the trees on timberland are open grown. This is primarily due to the minimum stocking level of 10 percent necessary to qualify as timberland.

From a previous study (Schmidt 2000) oaks were found to be among the most dominant species in terms of crown class distribution in a region that encompasses the Central Hardwood (table 9). Almost 80 percent of all oak trees in the region were considered to be dominant or codominant trees with intermediate, overtopped,

Table 7.—*Growth to removals ratio for Indiana in 1998*

Species group	Total	Diameter class (in inches) 5.0-10.9	11.0-18.9	19.0+
	(Growth to removals ratio)			
Conifers	17.4	13.8	23.7	0.0
Oak	1.9	7.7	2.5	1.2
Hickory	2.7	3.3	3.2	1.2
Hard maple	5.1	9.1	5.4	2.3
Soft maple	5.4	9.8	6.0	2.7
Ash	3.2	5.2	4.3	1.1
Black walnut	2.5	4.8	2.2	1.3
Other hardwoods	2.3	6.6	2.4	1.2
Total	2.6	6.6	3.0	1.3

Table 8.—*Growing-stock growth to removals ratios in the Midwestern United States**

Species group	Total	Diameter class (in inches) 5.0-8.9	9.0-14.9	15.0+
	(Growth to removals ratio)			
Conifers	1.3	2.7	1.3	0.4
Oak	1.9	4.0	2.0	1.3
Hickory	8.6	14.2	9.5	4.2
Soft maple	8.1	31.7	9.8	2.9
Hard maple	2.8	5.0	2.7	1.8
Yellow-poplar	10.5	35.4	16.8	6.5
Other hardwoods	2.3	5.1	2.3	1.3
Total	2.5	5.1	2.6	1.5

*Study area of Tennessee, Kentucky, Pennsylvania, Ohio, Indiana, Illinois, Missouri, and Iowa.

and saplings comprising the other 20 percent. As a comparison, in that study 40 percent of the sugar/black maple trees were considered intermediate or overtopped, partially representing the understory. In general, timberland with an above average percentage of shade tolerant species has a greater percentage of trees in the understory classifications.

DISCUSSION

The trends shown are expected to continue without an increase in the disturbance rate through either human-induced or natural factors. At this point, there are a number of factors that could alter the existing trends. Chipmills have been moving into the Central Hardwood region with resulting increased levels of clearcut harvesting that tend to remove more of the overstory than selective harvesting, which has been used historically. A number of oak pests have been identified that are greatly expanding their historical range (see Moltzan (2003) in these proceedings for an in-depth discussion of the impact of oak pests). If oak wilt and oak decline continue at their recent rate, the overall oak resource might be severely impacted. Discussions about allowing some wildfires to burn out on their own have been taking place and there appears to be an increase in the use of prescribed fire. These changes, and many others to come, could result in important changes in the current trends. However, at this point it appears that trends noted in this study will continue.

As documented, the Central Hardwood's timberland resource is undergoing important changes. Some of these changes are not readily apparent and are currently being masked by the current dominance of the oak resource. However, these changes do have repercussions for all interested in this resource including the timber industries and those concerned with wildlife habitat. For example, woodcock (*Philohela minor*) numbers have declined by 37 percent since 1968 in the central portions of the United States, primarily due to habitat loss and the maturing of the region's forests (Dessecker and McAuley 2001, Smith 1999).

Table 9.—*Crown class distribution by species group in the Midwestern United States**

Species group	CROWN CLASS			
	Open grown	Dominant-Codominant	Intermediate	Overtopped
	(Percentage)			
Conifers	0.2	64.9	32.0	2.9
Oak	0.1	78.0	20.4	1.4
Hickory	0.2	65.9	31.4	2.4
Soft maple	0.1	67.6	29.5	2.9
Hard maple	0.1	60.1	34.0	5.8
Yellow-poplar	0.2	74.2	24.1	1.5
Cottonwood-aspen	0.3	94.9	4.2	0.5
Other hardwoods	0.2	64.7	32.0	3.0
All species	0.2	69.6	27.8	2.4

*Study area of Tennessee, Kentucky, Pennsylvania, Ohio, Indiana, Illinois, Missouri, and Iowa.

The future of the resource lies in the hands of individual private landowners. Their decisions regarding management will dictate the characteristics of the future resource and its resulting products and benefits. As land ownership changes, different objectives for timberland management may emerge. Currently, it appears that some landowners are moving from a focus on wood fiber production toward a broader ecosystem approach. A portion of this change in management philosophy is due to the smaller-sized tracts that are being formed as a result of forest fragmentation. As the average size of timberland ownership decreases, the potential for management for wood fiber production decreases. This will change the resource, resulting in advantages and disadvantages, depending on your outlook.

Overstocked stands are of concern due to their increased potential for pest outbreaks, wildfire, and other threats. In an overstocked status, growth rates can be lowered, stress can be increased, and regeneration can be low due to increased competition. Both over- and understocking can be addressed through management but end results of management actions need to be weighed.

A continuing major driving force in the Central Hardwood region is the aging of timberland. With only 12 percent of the timberland having an average stand age of less than 20 years, later successional types and their associated species are replacing early successional forest types. As plant species composition changes, utilization of timberland will also change.

One reason for increased stocking and aging of the timberland is the harvesting techniques used in this region. Almost all harvesting is done through selection of individual trees for removal, which leaves the majority of the stand intact. This harvesting method does not cause disturbance (changes in light penetration, exposure of bare mineral soil, etc.) to the degree

necessary to enable early successional species and/or species that need disturbance to regenerate.

Prior to European settlement, wildfires and other natural events provided disturbances that enabled early successional forests to maintain themselves. With current management of controlling wildfires, we are allowing succession to progress. As a result, forests are maturing, woody plant species are being replaced, and volume and stocking levels are increasing. If these conditions are the desired goal no major changes are needed, however, if additional conditions are desired, changes in management strategies should be considered.

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