ABSTRACT.—Traditionally, the USFS Forest Inventory and Analysis (FIA) statistics, are presented as totals (e.g., area, volume) for the major forest types or species groups. Much valuable information is hidden in these totals, because most species occur across a wide range of environments and therefore exhibit great differences in standing volume, growth potential, advance regeneration and other characteristics. These differences have significant management implications. In the 1996 Wisconsin forest inventory, all measurement plots were classified according to the Wisconsin Forest Habitat Type Classification System. Because each habitat type represents a segment of an abstract moisture-nutrient gradient, it is now possible to compare and contrast inventory statistics along this gradient. Work is in progress and results will be published in a special Resource Bulletin by the North Central Forest Experiment Station. Some highlights of this analysis are presented here.

The forest statistics commonly reported by the USDA Forest Service, Forest Inventory and Analysis (FIA) program present data only by forest types and major species. While these data provide useful estimates of total quantities (e.g., volumes, acres, removals) for the state, the inventory has, in the past, been unable to account for important variation resulting from great differences in site potential. For example, when it is reported that the oak-hickory forest type represents 2.9 million acres and contains 3.5 billion cubic feet of volume (actual numbers), we do not know what proportions represent poor, medium or high site qualities. We also do not know how much of the oak-hickory type is made up primarily of highly productive and economically valuable red oak, or much less valuable pin, or black oak. To do this, a reliable site classification system is necessary.

In Wisconsin, a forest habitat type classification system has been developed (Kotar et al. 1988; Kotar and Burger 1996). The system classifies stands, or inventory plots, into habitat types by evaluating the composition of the understory plant community. Each habitat type represents a site capability class along a soil moisture/nutrient gradient. The 1996 inventory of Wisconsin’s forest resources included the use of this Habitat Type Classification System.

Analyzing the forest inventory by habitat types enables us to show, for example, how much acreage and volume of each forest type occur on each habitat type. This immediately gives a better picture of actual species composition of a given forest type across the range of site classes. In the above oak-hickory type example, we can now differentiate between those acreages that are succeeding to more competitive species and those that offer greater opportunities for maintenance of the oak type. It also allows us to compare differences in total volume, or volume per acre, across the gradient. Much of the same information can also be examined for other forest types and by region, county or ownership class.

Presenting the vast amounts of available forest statistics in this context can greatly enhance the interpretation of our forest resource base and lead to improved planning. A few examples of the findings are presented here.

SYNOPSIS OF THE FOREST HABITAT TYPE CLASSIFICATION SYSTEM

The habitat type system is a method of site classification that uses the complete floristic composition of a forest community (understory herbs and shrubs, as well as trees) as an integrated indicator of those environmental factors that affect species reproduction, growth, competition, and therefore, community development. Through sampling across a complete environmental gradient of a region, floristic patterns are identified that reflect different positions on the gradient. For example, dry, nutrient-poor; dry-mesic, medium nutrient; and mesic, nutrient-rich.
In practice, keys, based on presence or absence of diagnostic plants, are used to classify forest stands into habitat types.

The Wisconsin habitat type classification system was developed through the sampling and analysis of more than 2,000 forest stands, representing a range of forest environments from very dry nutrient-poor, to mesic nutrient-rich.

Because different combinations of understory plants form communities on the same portion of environmental gradient in different climatic, or physiographic regions, it is necessary to establish habitat types on a relatively small geographic scale. The Wisconsin system is based on five northern, and six southern habitat type regions.

**HABITAT TYPE GROUPS**

In order to simplify the analysis and discussion of the forest inventory data, the similar habitat types from those with lower nutrient levels by hemlock, white pine and balsam fir. Aspen or red maple often dominate successional stands on all habitat types of this group.

**North**

1. **Very dry to dry (VD-D)**

This group represents the driest, least fertile soils of the region. Forests are dominated by pines (primarily jack and red pine) and poor quality oak. Red maple is the most shade tolerant species found on these sites and can replace other species in the absence on natural disturbance or management.

2. **Dry to dry-mesic (D-DM)**

This group is a step up on the soil moisture-nutrient gradient from the preceding group. In addition to jack and red pines, white pine also thrives on these types, as does red oak. White pine is sufficiently shade tolerant to reproduce naturally in mixed stands of oaks, aspen, red maple, and other pines.

3. **Dry-mesic (DM)**

Soil moisture and nutrients are adequate to support shade-tolerant, mesic species such as sugar maple, basswood, and white ash, but not at their optimal levels. Following natural disturbance or logging, red oak, red maple or white pine often assume dominance in the stand. However, without natural disturbance or management, stands on these types tend to succeed to mesic hardwoods.

4. **Mesic (M)**

This group represents the best soil moisture-nutrient condition in the region. Shade-tolerant mesic hardwoods (sugar maple, basswood, white ash, American beech) or hemlock dominate most stands. Less shade-tolerant species gain temporary dominance only following a major disturbance, especially by fire. However, fires are not frequent on these habitat types.

5. **Mesic to wet-mesic (M-WM)**

This group represents a transition from upland to lowland forest. Position of this group in fig. 1 is based entirely on one well-represented habitat type (TMC). However, the group includes several additional habitat types for which the data for calculating the moisture-nutrient coordinates were not available. Our estimates strongly indicate that the field in fig. 1 should extend further up the nutrient scale as shown by the dashed line. Sites with higher nutrient levels are dominated by mesic hardwoods (e.g., sugar maple, basswood, white ash) and those with lower nutrient levels by hemlock, white pine or balsam fir. Aspen or red maple often dominate successional stands on all habitat types of this group.

6. **Wet-mesic to wet (WM-W)**

These are distinctly lowland sites. No specific habitat types were identified. Forests are dominated by swamp conifers (e.g., northern white cedar, black spruce, balsam fir) or by red maple, black ash or aspen. Position of the group in fig. 1 is estimated.

**South**

1. **Dry (D)**

These types represent the driest sandy soils primarily in central and western parts of the state. Jack pine, red pine, white pine, oaks or aspen, comprise most of the stands. Communities are similar to those of northern dry habitat types, but often include white, black, and bur oak in addition to red and pin oaks. Red oak typically does not attain merchantable size.

2. **Dry-mesic (DM)**

These habitat types represent better growth conditions for all species of oak as well as pine. Red maple also competes more strongly on these habitat types than on those of the preceding group. In the absence of natural disturbance or management it is capable of replacing most other species. Sugar maple, however, is absent.

3. **Dry-mesic to mesic (DM-M)**

The soil moisture and nutrient levels on these habitat types are adequate to support moderate growth of mesic hardwoods such as sugar maple and basswood. Red and white oaks grow well on these types and comprise the largest volume in present stands. However, in the absence
Figure 1. Habitat type groups of the northern and southern parts of Wisconsin. Position of each group is a composite of several individual habitat types. Groups indicated with dotted border are estimates.
of management they tend to be replaced by mesic hardwoods.

3a. **Dry-mesic to mesic, phase (DM-M phase)**
These types represent similar soil conditions as those of the preceding group, but have experienced more intense fire disturbance regimes in the presettlement time. As a result, mesic hardwoods have been virtually eliminated from the landscape and are not currently replacing oaks or other intolerant species. For these reasons oak regeneration is relatively easy to achieve.

4. **Mesic (M)**
This group represents mesic, nutrient rich sites that experienced relatively little fire disturbance in presettlement time and continue to be dominated by sugar maple, basswood and white ash. Lack of natural disturbance, or management by light partial cutting favors sugar maple dominance.

4a. **Mesic, phase (M phase)**
These habitat types occupy similar soils as those of the preceding group, but experienced more intense fire disturbance regimes in presettlement time. As a result stands are dominated by various shade-intolerant species and mesic hardwoods are absent.

5. **Mesic to wet mesic (WM-W)**
This group represents poorly drained mineral soils. No specific habitat types have been identified. Best adapted species appear to be red maple and black ash, but many other species occur. Position of the group in fig. 1 is estimated.

6. **Wet-mesic to wet (WM-W)**
This group represents swampy or boggy conditions with either mineral or organic soils. No specific habitat types have been identified. Best adapted species are black ash, red maple and white pine on mineral, and tamarack, black spruce and white cedar on organic soils. Position of the group in fig. 1 is estimated.

**SURVEY PROCEDURES**
FIA information is based on a sampling procedure designed to provide reliable statistics at the state and survey unit levels. More than 5,600 forested inventory plots were measured and each plot was also classified into one of 91 forest habitat types using Habitat Type Field Guides (Kotar et al. 1988; Kotar and Burger 1996). A detailed description of the procedure for the 1996 inventory of Wisconsin can be found in Schmidt (1998).

**SELECTED FINDINGS**

**Habitat Type Group Characteristics**

**Volume distribution**
Figure 2 shows the growing stock distribution across the habitat type groups. Total growing stock volume for a given habitat type group reflects several factors: (1) total acres in that group, (2) productive capacity of the group, and (3) management history. The relatively low volumes of the southern habitat type groups reflect most strongly the low acreage of forest land in that region.

Figure 3 shows growing stock volume distribution on a per acre basis. These volumes reflect the productive capacity of habitat type groups and collective management history. Because of a large sample size and systematic allocation of measurement plots, we are assuming that, at least in the north, management history is not affecting the trends seen in figure 3. In the south, the effects of past practices and presettlement conditions are more evident. For example, the southern DM-M habitat type groups have lower volumes per acre than the corresponding northern groups. This probably reflects more intensive and continuous utilization of the forest resource in the south as compared with the north. The DM-M(P) and M(P) groups are a special case. Stands in these habitat type groups were originally savannas. Presumably, due to intensive utilization, including grazing, stands on these sites have not reached full stocking.

**Occurrence and volumes per acre of forest types**
Forest type is defined as forest land where a given species, or combination of species, form a plurality of live tree stocking.

Figure 4 shows extent and average volumes per acre of various forest types across the northern habitat type groups. Because composition, structure, and productivity of a given forest type differ across the habitat type groups, it is important to know its relative extent. For example, figure 4 shows that red pine forest type is far more extensive on the VD-D than on the M habitat type group, but its growing stock volume (an expression of productivity) is almost twice as high on the M type. The contrast for white pine is even greater. The acreage of white pine forest type is very small on both the VD-D and M habitat type groups, but growing stock volume is again almost twice as high on the M group.

The examination of the oak-hickory forest type is very significant in light of the economic importance of red oak. In the *Wisconsin Forest Statistics Bulletin* we find information on the total area of the oak-hickory type and...
Figure 2. Total volume of growing stock by habitat type group.

Figure 3. Growing stock volume per acre, by habitat type group.
Figure 4. Forest type representation in the northern habitat type groups. A, by area; B, by volume of growing stock per acre.
Figure 4. (continued)
Figure 4. (continued)

1. Red oak or pin oak on VD-D, red oak elsewhere (no hickory)
2. Red maple only on D-DM, DM and M
3. Red maple on VD and DM (no basswood); primarily sugar maple on M; sugar maple and red maple on M-WM; red maple on WM-M
volumes by species groups. However, additional, important information is obtained if we examine the distribution of oak-hickory acreage across the habitat type groups and also compare composition and volumes per acre. For example, figure 4 shows that oak-hickory type acreage is nearly the same on the VD-D and DM habitat type groups (just more than 200,000 acres). However, the volume per acre on the DM group is twice that on the VD-D group. In addition, the composition on the DM group is primarily red oak, while that on the VD-D includes pin oak, a much less economically valuable species. Other patterns, depending on the reader's interests, can be gleaned from figure 4.

SUMMARY BY SPECIES

Some of the data provided by the inventory can be expressed only by forest type (e.g., acres) while others, like volumes per acre, can be calculated for both the forest types and individual species, or, in a few cases, species complexes. Figure 5, shows the distribution of major tree species across the range of the northern habitat type groups as percent of total volume of respective species.

OVERVIEW OF INDIVIDUAL SPECIES' PRODUCTIVITY ACROSS THE HABITAT TYPE GROUPS

Table 1 provides the best overview of the range of productive potential of different habitat type groups, as well as relative performance of each species across the habitat type gradient. The table shows average volumes per tree (by species) for each habitat type group. Average volumes by species per acre alone, could not show these relationships because numbers of trees of each species vary greatly across habitat type groups.

Reading the table by rows, we can follow the growth trends of species across the moisture/nutrient gradient. While volumes per tree are affected by age and spacing, as well as by site conditions, we discovered no sampling bias affecting the age and spacing data. We are, therefore, assuming that differences in volume per tree across the habitat type groups represent differences in site's potential. Reading down the columns we can see the relative performance of each species in a given habitat type group. However, in this case we have to exercise some caution in the interpretation. Management practices do affect the average age of species. For example, hemlock has traditionally been avoided in harvesting because of poor markets. Thus, the average age of hemlock trees is considerably higher than that of other species. The relatively high volumes for hemlock are therefore, at least in part, due to higher average age of hemlock.

Note also that species sequence in the first column follows the moisture gradient, from dry (jack pine), through mesic (sugar maple), to wet (tamarack). The number of columns in which a species is represented also indicates that species "ecological amplitude," or range of its environmental tolerance.

As predicted by the habitat type classification, most species attain their best growth in the mesic range of the environmental gradient. This is also true for species that do not compete well in that environment and occur there only through management intervention or natural disturbance (e.g., red pine, white pine, red oak, aspen). The only deviation from this pattern in table 1, is red pine, which shows the highest volume per tree in the M-WM habitat type group. This would not be expected on the wetter portion of the gradient. However, the M-WM type group includes some habitat types with high early-season moisture conditions, but otherwise well drained soils. These conditions appear to be well suited for red pine growth.

CONCLUSION

The analysis of Wisconsin forest inventory data by forest habitat type class has revealed significant new information about our forest resource. It is also worth pointing out that combining the forest inventory with the habitat type classification has yielded mutual benefits to these two assessment and planning tools. The data from more than 5,600 FIA plots have greatly enhanced the quantitative base of the forest habitat type classification system itself.

LITERATURE CITED

Figure 5. Representation of major tree species across the northern habitat type groups, as percent of total volume of the species shown in each diagram.
Figure 5. (continued)
White/Bur Oak

White/Green Ash

Sugar Maple

Black Ash

Basswood

Figure 5. (continued)
Table 1. Average volume per tree (cubic feet), by species and northern habitat type group.

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<thead>
<tr>
<th>Species</th>
<th>Very dry to dry</th>
<th>Dry to dry-mesic</th>
<th>Dry-mesic</th>
<th>Mesic</th>
<th>Mesic to wet-mesic</th>
<th>Wet-mesic to wet</th>
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