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# Habitat Mapping and Interpretation in New England

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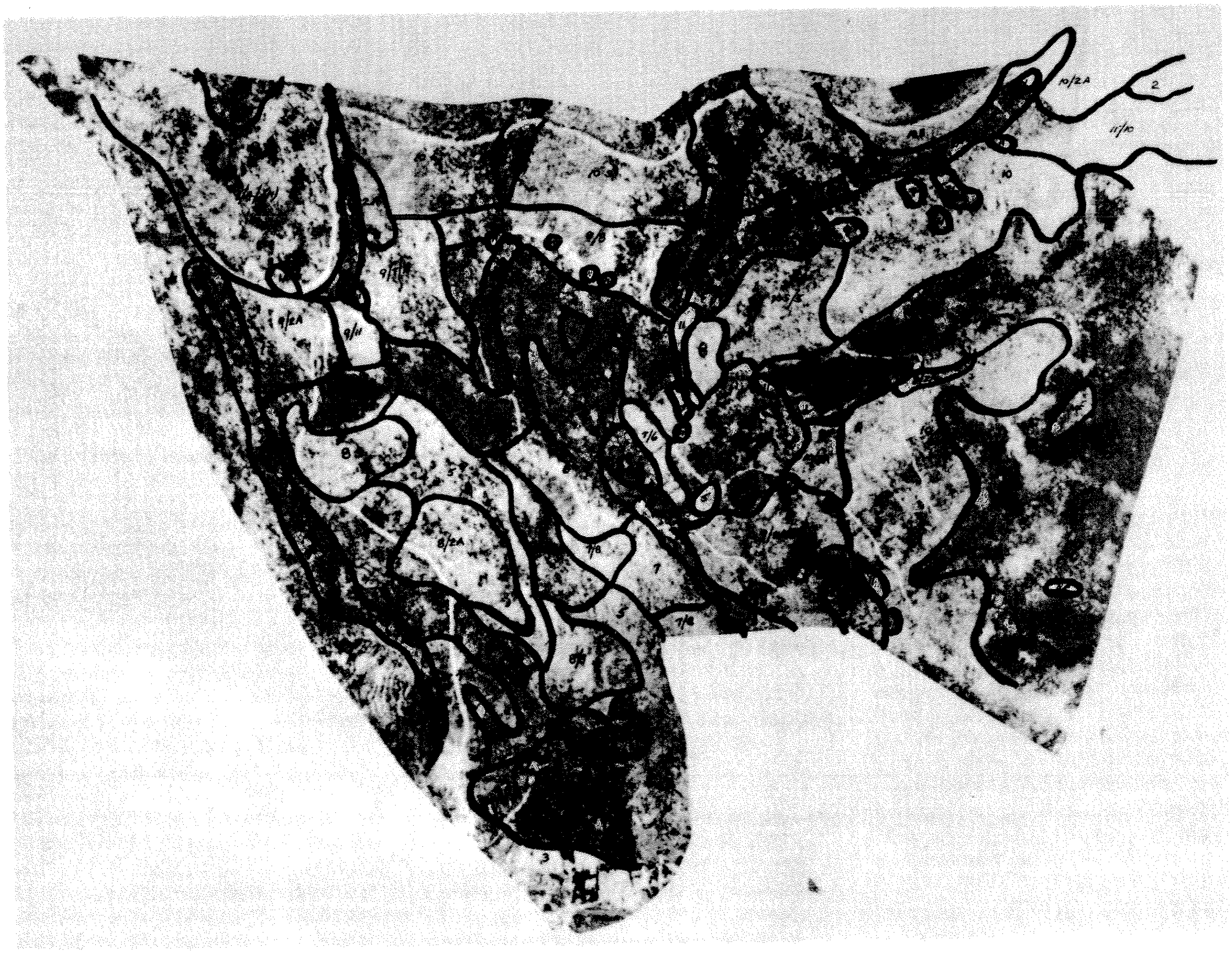

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## Abstract

Recommendations are given on the classification of forest land in New England on the basis of physiographic region, climate (elevation, latitude), mineralogy, and habitat. A habitat map for the Bartlett Experimental Forest in New Hampshire is presented based on land form, vegetation, and soil materials. For each habitat or group of habitats, data are presented on stand composition, understory vegetation, biomass, volume, and diameter development by species.

In this paper I describe methodology and approaches for the classification and mapping of forest habitats in New England. Then, I give an example of habitat mapping on the Bartlett Experimental Forest in central New Hampshire with interpretations on species composition, productivity, and silvicultural approaches.

## Classification Approaches

Many forest land-classification systems have been described for the United States and Canada, and other parts of the world. Bailey and others (1978) emphasize the distinction between taxonomic or place-independent classifications and place-dependent classifications. Taxonomic classifications are systems for grouping objects into homogeneous classes without regard for their geographic affinities. Place-dependent classifications are designed to subdivide existing landscapes into homogeneous geographic units. These systems are designed to segregate forest land into parcels with distinct characteristics or use potentials. I'll discuss four different approaches to classifying forest land:

1. Biological
2. Physical/chemical
3. Production-oriented
4. Biophysical

Biological approaches emphasize natural associations of flora or fauna. Typical examples are the habitat types of Pfister and Arno (1980) or Daubenmire (1952) and the ground vegetation types of Westveld (1951). Maps of major forest regions and cover types (Society of American Foresters 1980) also fall within this category. The biological approach to forest land classification employs the concept that natural associations of plants or animals reflect or integrate the important factors that affect forest use and production.

Physical/chemical approaches depend upon the classification of nonliving factors of the environment. Soil classifications are taxonomic systems falling within this category. Approaches based primarily upon elevation (Bormann et al. 1970) or landform are integrated (taxonomic and place-dependent) systems of the physical/chemical type. This approach assumes that nonliving factors influencing forest use and protection can be determined, measured, and mapped. The approach does not depend upon the availability of suitable, existing vegetation—an advantage in heavily disturbed areas.

Production-oriented approaches are taxonomic systems that relate directly to the land's capacity to produce certain products. These are sometimes referred to as technical or artificial classifications (Bailey et al. 1978). Classifications of areas by average site index, merchantable height, or volume are examples of the production-oriented approach. Within this category I also include methods based on indirect estimates of productivity, for example, regression equations that predict site index. Production-oriented approaches often are closely related to the interests and needs of practicing foresters.

Biophysical approaches are integrated systems where the units are classified by both biological and physical/chemical criteria. The holistic system of Hills (1953) is a pioneering example. The habitat types described by Mueller-Dombois (1965) on the basis of tree-shrub vegetation, soils, and glacial deposit also typify the biophysical approach. The approach is based upon the concept that biological and physical/chemical conditions can be correlated on the ground so that all criteria will share common boundaries. If this can be done successfully, biophysical schemes provide a fairly broad base for evaluating resource use and protection.

Forest land systems are classified in other ways as well. Many systems are hierarchical to some degree. This means that they allow for the definition of large, general units useful for broad planning purposes as well as smaller, more homogeneous subdivisions useful for conducting project work. Some systems are based on single factors; others are multifactor classifications (Bailey et al. 1978). Within the multifactor category, some factors may be considered as criteria necessary for the classification of units, and others may be given less weight as associated characteristics.

The habitat classification described in this paper is a biophysical scheme. Vegetation within New England varies, first of all, because of climate; we see obvious differences in species mixes in northern and southern New England, along the seacoast, in the high elevation zones, and so on. Next, we find differences in vegetation because of the mineralogy of the glacial drift: granite versus schist versus limestone, for example. Finally, within areas of similar climate and mineralogy, vegetation varies between habitats defined primarily by parent soil materials or glacial process.

So a habitat is a small unit of land from a few to over 100 acres lying within a given climatic-mineralogical zone and supporting a distinct successional sequence of vegetation growing on a unique type of soil material. Habitats also are associated with certain landforms, surface conditions, and types of ground flora; these characteristics are useful in mapping. Habitats, thus defined, reflect productivity in terms of species combinations and growth rates, as well as certain management limitations such as windthrow and machine operability. Diagramatically, the system may be represented as:

Climatic regions (geographic subdivision)
↓
Mineralogy (taxonomic subdivision)
↓
Habitats (taxonomic sites having characteristic soils, landforms and chronosequences of vegetation)

### Climatic-mineralogical Zones

A detailed classification of the important climatic-mineralogical zones in New England and adjacent states is impossible at this time. However, available information indicates that the region might be subdivided on the basis of physiographic zones, elevation, latitude, and broad mineralogical classes.

### Physiographic Regions

Lull (1968) published physiographic regions (Fig. 1) adapted from Fenneman (1938) for New England and adjacent states. These physiographic regions are based on broad differences in relief or geomorphology, climate, and proximity to water bodies and, thus, represent a reasonable starting point for segregating and studying the forest vegetation. These physiographic regions correlate to some extent with the major forest regions (Fig. 2) published by Lull (1968). But the correlations are limited because most of the physiographic regions cover a broad range in elevation or latitude, or both, and should be subdivided by these two variables.

## Physiographic Regions

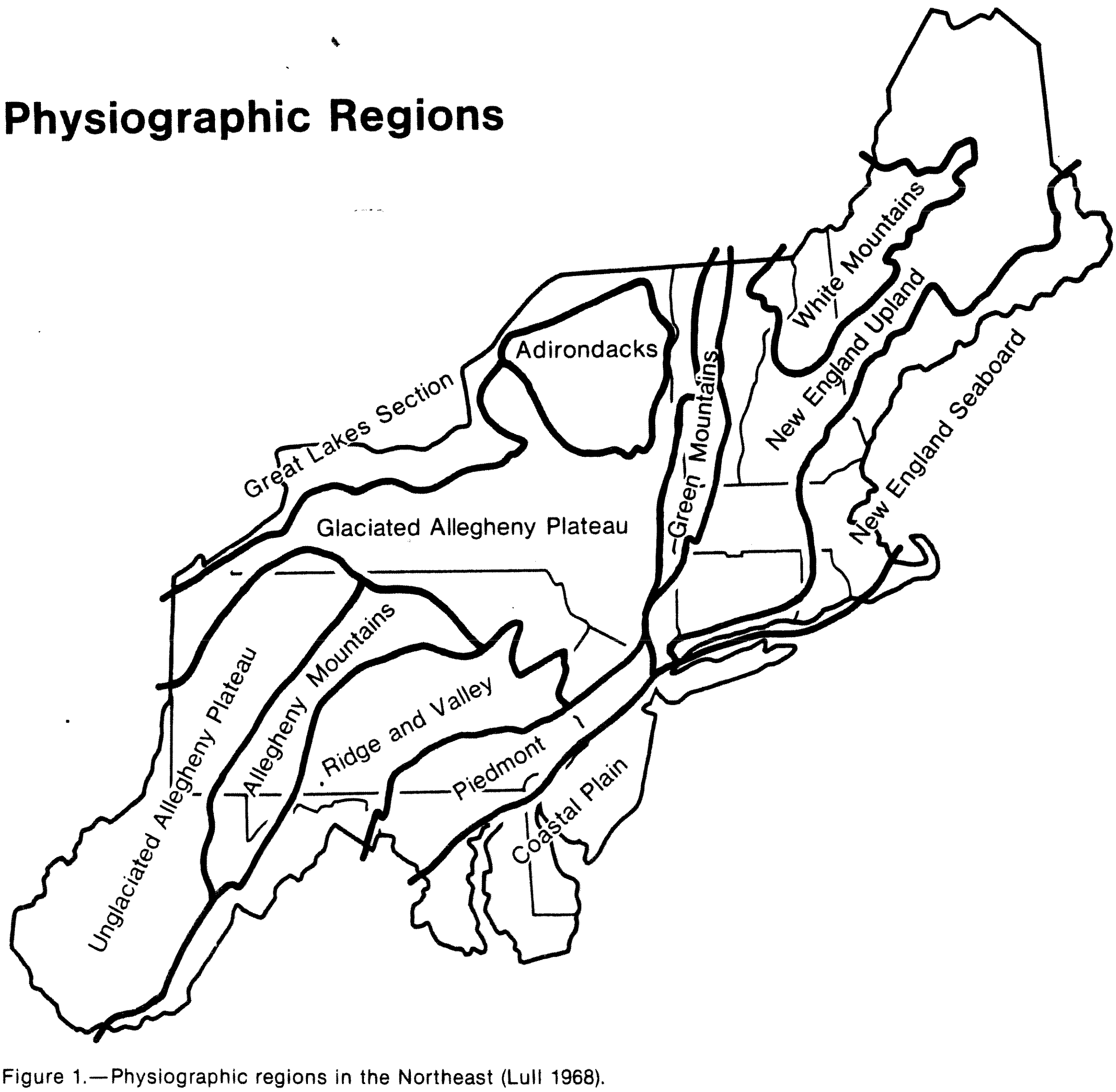


Figure 1.—Physiographic regions in the Northeast (Lull 1968).

### Elevation

In the mountainous physiographic regions such as the White Mountains, Green Mountains, and Adirondacks there is a well-recognized change from hardwood to spruce-fir types above an elevation of 2,500 to 2,700 feet (Siccama 1974, Leak and Graber 1974). If we superimpose this elevational effect on the Green Mountain, Adirondack, and the southern part of the White Mountain physiographic regions, it will account for spruce-fir on Lull's map of the major forest regions (Fig. 2).

The influence of elevation is tempered to some extent by aspect: spruce-fir types tend to grow at lower elevations on colder aspects and higher elevations on warmer aspects. However, this pattern is often upset by habitat condition. For example, the spruce-fir cap on the south side of Mt. Chocorua in New Hampshire begins at 1,800 feet; this is because of habitat condition (shallow bedrock) rather than climatic effect.

Aspect has some additional effects on species mixes. On dry habitats such as shallow bedrock or outwash, oak tends to grow on southerly or westerly aspects in northern New England. And hemlock tends to predominate over red spruce as the aspect gets warmer (Leak 1976). However, I do not regard aspect as a major factor in classifying forest land because its effects are easily overshadowed by the habitat conditions discussed later, and because it is responsible for fairly minor shifts in the abundance of certain species near the limits of their range.

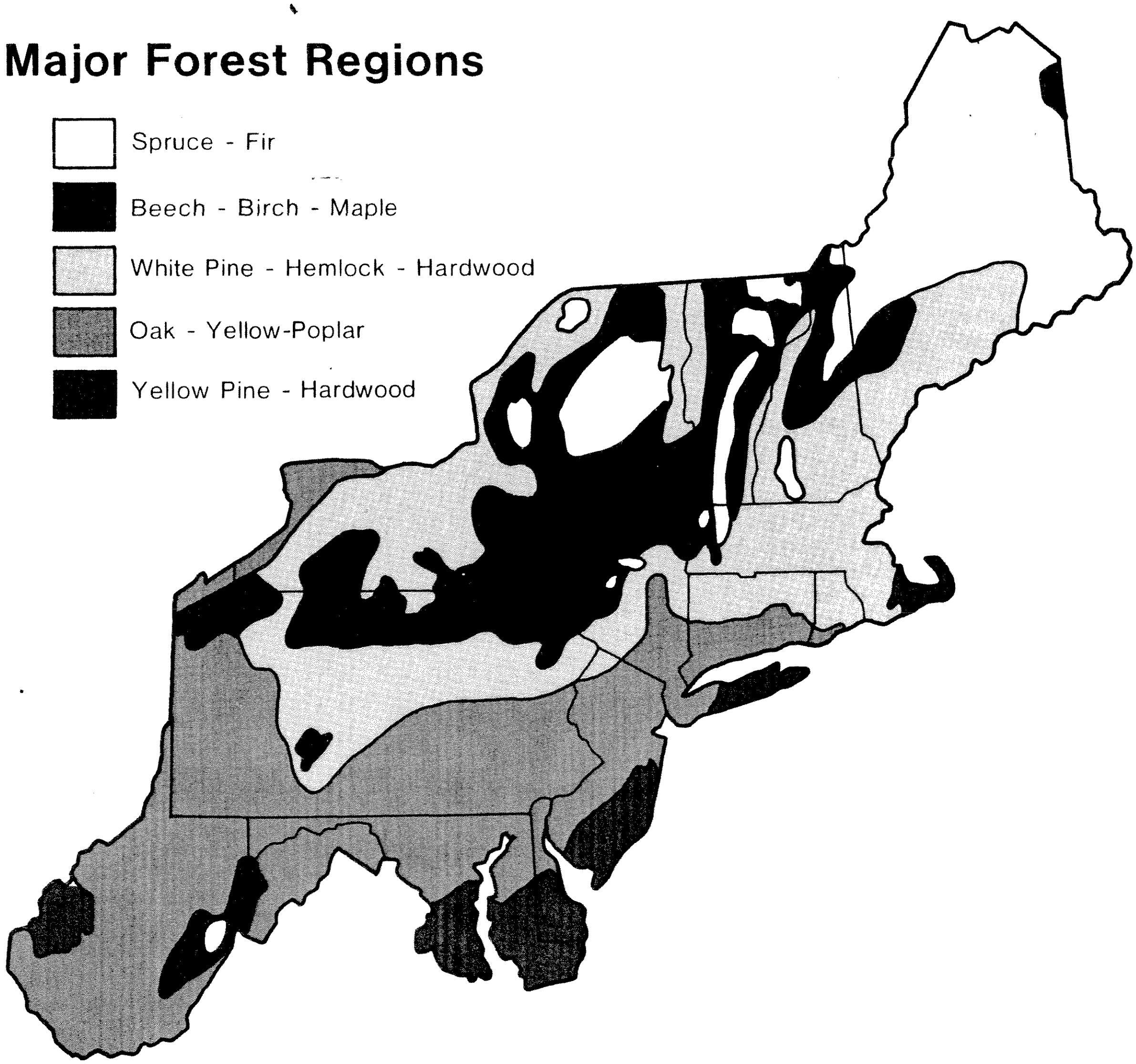


Figure 2.—Major forest regions in the Northeast (Lull 1968).

There is some evidence that as elevation decreases there are increases in productivity and volume (Bormann et al. 1970), the proportion of beech (Leak and Graber 1974), and the ratio of hemlock to red spruce (Leak 1976). However, in classifying forest land in New England, the major distinction is between stands above and below 2,500 feet.

**Latitude**

Some of the physiographic regions outlined by Lull (Fig. 1) span several (up to 7) degrees latitude. A comparison with Lull's map of forest regions (Fig. 2) indicates that some of the larger physiographic regions extend across two or three forest regions. For example, the New England seaboard is spruce-fir in the northern part and white pine (with hemlock and hardwoods) in the southern part. The White Mountain physiographic region is spruce-fir in the north and partly northern hardwoods in the south. Although these differences may be partly due to mineralogy and the prevailing types of glacial deposit, we also see evidence of a climatic effect related to latitude. Differences in latitude of about 1° seem important. This means that stands growing on a given mineralogy and soil material in a given physiographic region will be different in species composition and productivity if they differ in position by 1° latitude. For forest land classification purposes, we should divide physiographic regions into zones that extend no further than 1° latitude: for example, the northern and southern New England seacoast in Maine.

**Mineralogy**

We have known for some time that distinct differences in mineralogy affect species and productivity (Lutz 1958). Some scientists believe that in glaciated regions such as New England the influence of bedrock mineralogy is lost by thorough mixing of the glacial drift. However, Goldthwaite (1948) mapped the glacial drift in New Hampshire into three basic types derived from granite, slaty schist, and crystalline schist (Fig. 3). This was possible because most drift is moved by the glacier only a few miles from its source, though occasionally boulders move many miles. The distinctions among these mineralogies are reflected by differences in general soil texture, rock types, abundance of mica in the soil, and forest vegetation (Leak 1978b). Thus, mineralogy of the drift provides a further breakdown that should be recognized in any biophysical classification of forest land in New England.

**Climatic-mineralogical Zones Summarized**

In studying, classifying, or comparing forest vegetation in New England, account for the influence of climate and mineralogy. One likely approach is to begin with large physiographic regions (Fig. 1). The physiographic regions should be divided into subregions that extend no more than 1° latitude. Distinguish between areas above and below the critical elevational level, which is about 2,500 feet. Finally, distinguish broad mineralogical classes. These subdivisions result in zones that might include several hundred thousand contiguous or noncontinguous acres which is about the size of the zone that we discuss: granitic drift below an elevation of 2,500 feet in the southern half of the White Mountains. Much smaller units than these are required in planning and conducting forestry operations. The definition and mapping of these smaller units, called habitats, are discussed in the remainder of the paper.

## Habitats

A habitat is a small unit of land, from a few acres up to a few hundred acres in size, with a given type of soil material (reflecting a given glacial process), landform and surface condition, and forest vegetation (climax-successional sequence). These are defined within given climatic-mineralogical zones because a certain soil material—for example, wet compact till—will support different vegetation in different climatic-mineralogical zones.

Habitats can be defined broadly or narrowly. For general planning purposes, habitats can be defined on the basis of soil substrate to a depth of 10 to 15 feet, general landform as interpreted from aerial photographs, and climax forest association. These broad units correspond to the ecological land types (ELT) being mapped on the White and Green Mountain National Forests.

In this paper, however, habitats are defined more narrowly on the basis of soil materials to a depth of 2 to 4 feet, landform plus surface conditions, and climax plus successional vegetation. I consider soil material to be the major variable: through its physical and chemical properties, soil material has a direct cause and effect on the nature and productivity of the vegetation. In classifying habitats, the soil materials at the base of the B horizon are examined to assess the original nature of the parent material; the objective is to determine what materials gave rise to the solum (surface and subsoil horizons). Materials within the solum are examined only to confirm the conclusions drawn from C-horizons materials. However, in two cases (enriched and poorly drained habitats), organic matter or excess water in the solum overrides the influence of C-horizon materials.

Early research leading to this habitat taxonomic classification was directed toward understanding the relation of soil materials to species composition and productivity of the vegetation (Leak 1976, 1978a). On the basis of this early research, which included 68 plots in old stands and 151 plots in successional stands on granitic drift, correlations between soil materials, species, and landform/surface conditions were developed. Currently, in mapping the taxonomic units, vegetation and landform/surface conditions are most useful because

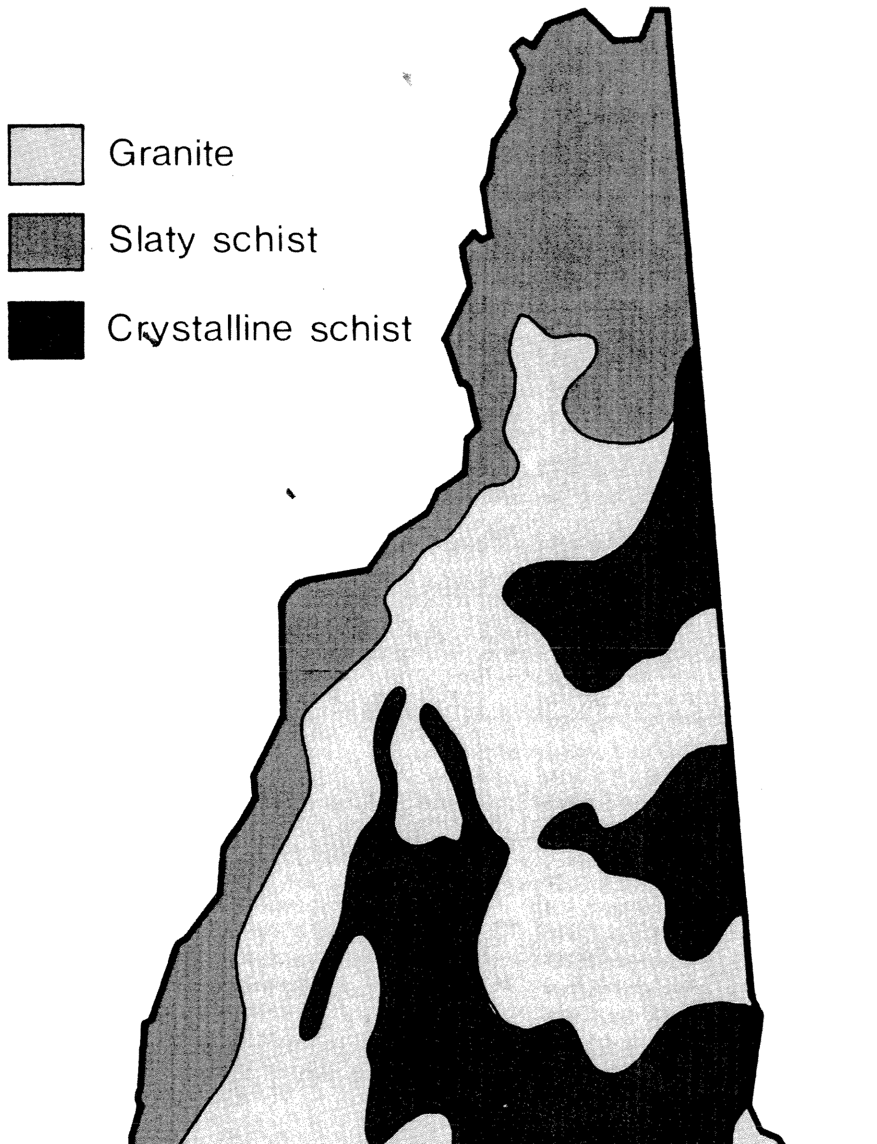


Figure 3.—Mineralogy of glacial drift in New Hampshire, adapted from Goldthwaite (1948).

they can be readily observed. Occasional checks on soil materials are made to confirm the designations. The goal is to obtain compatible and consistent relationships and common boundaries among all these variables.

A description is given for all habitats now recognized in the granitic drift below an elevation of 2,500 feet on the southern White Mountains. The descriptions are numbered according to the map designations used throughout this paper. The types of soil materials and landform/surface conditions will be found in most all glaciated regions, though it is possible that some additional classes would be required to meet local conditions. However, the associated vegetation will vary considerably depending upon climate and mineralogy. For example, the successional and climax vegetation found on granitic drift in the southern White Mountains of New Hampshire (Fig. 4) differs appreciably from the vegetation on schistose drift only a few miles away at the same latitude (Leak 1978b). The schistose drift supports noticeably more sugar maple and less beech in most habitats.

**Habitat Descriptions (Taxonomy)**

1. *Poorly drained*—This area is level with gray or heavily mottled mineral soil throughout the solum. Currently there are pools of standing water or free water in the upper solum. The climax is red spruce greater than hemlock. Successional stands are generally softwood greater than hardwood mixtures of red spruce, eastern hemlock, balsam fir, red maple, and birches (paper and yellow). Areas that have been cleared or repeatedly cut may be mostly red maple. Areas that are wet enough to preclude full occupancy to trees are better classed as wetlands.

   Successional stands result from clearcutting or heavy

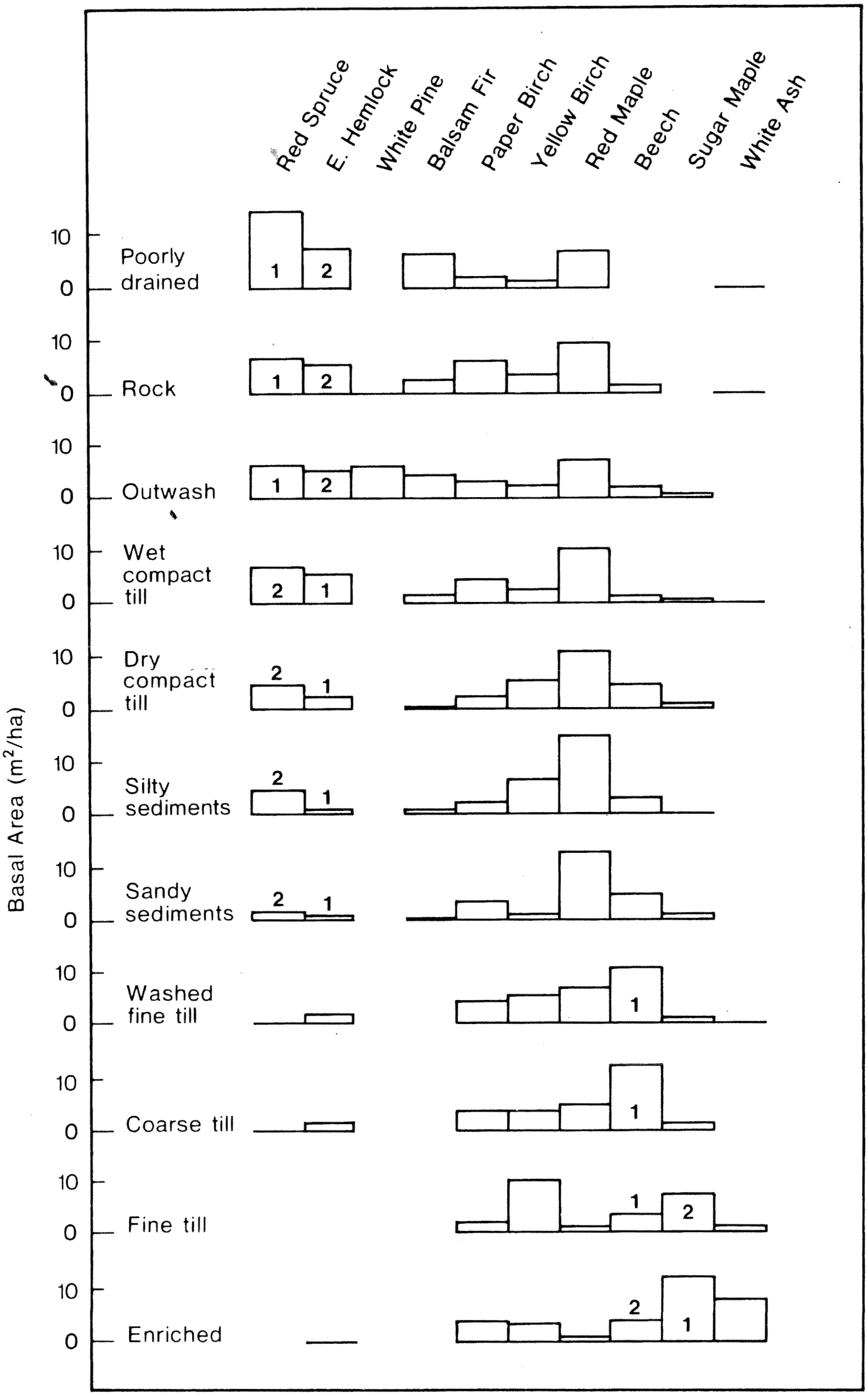


Figure 4.—Basal area in $m^2$/ha by species and habitat for successional stands on granitic drift in the southern White Mountains of New Hampshire. Number 1 refers to the most abundant and number 2 refers to the second most abundant species in older, climax stands.

partial cutting. Climax stands are defined as those stands composed primarily of tolerant species with the understory of similar species composition as the overstory.

2. *Shallow bedrock*—Bedrock, angular boulders, or nearly pure grus (weathered granite) is found as deep as 2 feet (65 cm) below the surface of the mineral soil. This area was plucked and scoured by the glacier, and may be on steep or moderate slopes. Ledges and rectangular boulders (not glacially worn) often are evident. Red spruce greater than hemlock is climax. Successional stands commonly have softwood greater than or equal to hardwood mixtures of red spruce, hemlock, red maple, and birches. On southern exposures, oak is often noticeably present; sometimes hophornbeam and white pine as well.

2A. *Shallow loose rock*—A matrix of partly rounded boulders is found up to 2 feet below the surface of the mineral soil. This condition apparently results from heavy rinsing action along streams or lakeshores. In some cases, the loose rock is sharp angled; apparently, this is colluvium for upslope. This habitat occurs on moderate to flat slopes often associated with drainage ways, or at the base of rocky slopes. The species are similar to those in 2, but productivity and the proportion of hardwoods are generally higher.

2B. *Exposed ledge*—In this area shallow bedrock and expanses of exposed ledge are very evident, resulting in scattered openings in the tree canopy. This area may have originated the same as shallow bedrock (2) and was followed by fire and erosion that exposed areas of ledge. The species are similar to those in 2, but stocking and productivity are lower.

3. *Outwash*—This habitat consists of sands or gravels that have been stratified, at least to some extent, and deposited by moving water. This definition includes both true outwash and ice-contact materials. Stones at the base of the B horizon are generally clean without silt caps. Outwash areas are flat to gently rolling or hummocky, free of surface rocks, and associated with streams or old drainage ways. The climax vegetation is red spruce greater than hemlock. Successional stands are softwood greater than or equal to hardwood mixtures of red spruce, hemlock, white pine, balsam fir, red maple and birches (especially paper birch). White pine is very characteristic of this habitat.

4. *Wet compact till*—Platy basal till compacted by the glacier is found at the base of the B horizon, and mottling or free water is very evident in the B horizon. This habitat is flat or concave and gently sloping with boulders pressed into the surface. The climax is eastern hemlock greater than red spruce. Successional stands are softwood greater than or equal to hardwood mixtures of hemlock, red spruce, red maple, and birches. Some ash is present but is moderate to low quality.

5. *Dry compact till*—This is basal till compacted by the glacier, but contains very little evidence of mottling or free water in the B horizon. C-horizon material usually is mottled and obviously supports water. This habitat is found on moderate upper slopes and knolls, usually above areas of wet compact till. The climax is hemlock greater than red spruce. Successional stands are hardwood greater than softwood mixtures of red maple, birches, beech, hemlock, and red spruce. Successional stands on this habitat contain noticeably more hardwoods than those on wet compact till (4).

5A. *Dry cemented till*—Hard crisp till is evident at the base of the B horizon. There is little or no evidence of free water or water-caused mottling. The habitat is found on low ridges or undulating topography but is not very common or widespread. The origin of this material is somewhat uncertain, but it seems to be cemented into a somewhat porous platy mass. The vegetation is similar to that in 5.

6. *Silty sediment*—This is very uniform (poorly graded) silt and fine sand deposited in slack water; up to 80 percent by weight is silt or finer particles. This material is somewhat sticky and massive and sometimes displays impeded drainage. Coarse fragments and stones are sometimes present, but lie within a matrix of sediments. The topography is level to gently sloping with mostly rock-free surfaces. The climax is eastern hemlock greater than red spruce. Successional stands are hardwood greater than softwood mixtures of red maple, birches, beech, hemlock, and red spruce; sometimes the softwoods are barely evident.

Figure 5.—A red maple/beech/paper birch/aspen stand growing on sandy sediments. Climax is hemlock/spruce, though few softwoods are evident in this successional stand. Biomass and cubic-foot production are adequate, but sawtimber production is low.

7. *Sandy sediment*—This sediment is similar to that in 6 in origin and occurrence. But the materials tend to be dry and single grained due to higher proportions of sand. However, there are too many fine particles for outwash. The climax apparently is eastern hemlock greater than red spruce. Successional stands are hardwood greater than softwood mixtures of red maple, birches (especially paper birch), beech, hemlock, and spruce. Balsam fir or white pine may be present (Fig. 5).

8. *Fine washed till*—The washed tills (8 and 9) apparently are ablational tills that were heavily water worked during deposition so that they contain sections of partially sorted material. The fine washed tills contain sufficient fine particles to produce very prominent silt caps on the buried rocks. These are loose tills which resemble a transition between sandy sediments and till. The topography is sloping or undulating with some surface rocks. The climax apparently is beech. Successional stands are mostly beech, red maple, and birches.

9. *Coarse washed till*—This is the most common of the washed tills. Rinsing action removed most of the silt and finer particles so that the remaining material is loose,

Figure 6.—Typical northern hardwoods on fine till. A good area for saw-timber production of sugar maple, yellow birch, and beech.

coarse, and sandy. However, minimal silt caps are found on buried stones. The topography is sloping or hummocky with moderate numbers of surface rocks. The climax is beech. Successional stands support beech, birches, and red maple. Hemlock and spruce may be present but not predominant.

10. *Fine till*—This till was dumped in place with little evidence of waterworking. The topography is irregular and often steep with many surface rocks. The climax is typical northern hardwoods characterized by beech and sugar maple. Successional stands contain beech, sugar maple, and birches (Fig. 6).

10C. *Fine till over compact till*—This recently recognized habitat is typical fine till underlaid with compacted till. The compacted layer generally is below the base of the B line or is discontinuous. The vegetation is similar to that in 10, but may have a few more ash and slightly higher site capacity. This habitat was recognized because of possible logging limitations caused by this habitat in the spring.

10S. *Silty fine till*—Fine tills may exhibit a noticeable silty feeling. Further research might indicate that these silty tills often are associated with 10C. The vegetation is similar to that in 10, but possibly with a slightly higher productive capacity.

11. *Enriched*—This habitat is small coves and benches in association with tills and compact tills. Organic matter or organic-coated fine materials are incorporated into the mineral soil. Horizonization is poor; the white $A_2$ generally is absent. Drainage varies from well to somewhat poor. Apparently, these areas are enriched by leaf litter, fine materials, or nutrient-rich water continually moving in from upslope. The climax is sugar maple. Successional stands are characterized by white ash and sugar maple with miscellaneous associated species.

A few additional habitat conditions were observed, but our experience with them is limited. Clay sediments are sometimes found and may be quite common in other climatic-mineralogical zones. These are similar to silty sediments, but the materials are much more plastic.

A very compact layer may form in silty or even sandy sediments. This layer acts as a barrier to water. Until further information becomes available, interpret this condition as similar to a wet compact till.

## Relationships of Species Composition to Habitats

Climax vegetation is closely related to the soil conditions represented by groups of habitats. We used discriminant analysis to analyze differences in species composition for 63 prism plots in old climax stands composed mostly of tolerant species. First, a function was developed to segregate several habitats with a softwood climax (shallow bedrock, shallow loose rock, outwash, dry and wet compact tills, poorly drained) from those with a hardwood climax (coarse washed till, fine till, enriched).

The following discriminant function was developed:

$$Z = .4089\ X_1 - 1.3957\ X_2$$

Where:

Z = Function value with midpoint − 9.3614

$X_1$ = Basal area ($m^2$/ha) in softwood

$X_2$ = Basal area ($m^2$/ha) in tolerant hardwoods (beech and sugar maple)

By inserting values of $X_1$ and $X_2$, a value of Z is predicted. Values greater than − 9.3614 denote rock, outwash, compact till, or poor drainage. Values less than − 9.3614 denote tills or enriched sites.

The function was highly significant with a calculated F of about 240. The probability of misclassification was estimated at about .005, equivalent to 2.75 standard deviations. All 63 plots in the data set are correctly classified using this function.

A second discriminant function was developed for the 7 plots in coarse washed or fine till versus the 24 plots on enriched sites:

$$Z = -.8177\ X_1 + .8448\ X_2$$

Where:

Z = Function value with midpoint .2501

$X_1$ = Basal area ($m^2$/ha) in sugar maple

$X_2$ = Basal area ($m^2$/ha) in beech

The function was again highly significant with an F of about 15. Values of Z less than .2501 denote enriched sites. The probability of misclassification was estimated at about 10 percent. Four (all were enriched plots) of the 31 plots were misclassified using this function, an actual misclassification rate of 13 percent.

Because of the practical value of being able to recognize habitats on the basis of species composition alone, I developed a list of seven species groups that characterize the major stand conditions in New Hampshire and probably in adjacent states as well (Table 1). Recognition of these groups, coupled with a general assessment of soil moisture, provides some indication of likely habitats, climax species composition, best species, and possible management limitations. For silvicultural purposes, foresters may find it more convenient to assess stand potentials based on species composition alone—without examining soil materials or landform.

## Mapping

### Procedures

A strong taxonomic framework is a prerequisite to mapping. Although earlier plotwork showed that soil materials was the primary criterion for habitat definition, landform and tree species composition are the most useful criteria in the mapping phase.

Habitat mapping is best done with aerial photos on a scale of 1/15,000 to 1/20,000. Larger scales, though useful for a detailed examination of previously delineated areas, tend to obscure differences in landforms. Smaller scales mask certain small landform distinctions useful in detecting habitats; however, scales of about 1/40,000 are best for defining larger planning units at the ecologic land type level. The photos need to show sharp distinctions between softwoods and hardwoods; thus, leaf-free or infrared photography seems best.

**Table 1.—Characteristics of seven forest types that represent major stand conditions in New Hampshire.**

| Forest[a] type | Soil[b] moisture | Likely habitats | Climax | Best species | Other productive species | Check for these management limitations |
|---|---|---|---|---|---|---|
| Sugar maple/ ash | Adequate | Enriched | Sugar maple | Sugar maple ash | Most hardwoods | Possible excess water in spring |
| | Wet | Enriched | Sugar maple | Sugar maple, ash | Most hardwoods | Excess water and possible occurrence of excess competition following clearcutting. |
| Beech/birch/ sugar maple | Adequate | Fine, or washed fine till, dry compact till | Beech sugar maple | Sugar maple, yellow, and paper birches | Any hardwood except ash | Possibly steep slopes and rocks |
| Beech/birch/ red maple | Dry | Coarse washed till, sandy sediments | Beech or softwoods | Paper birch (or possibly oak) | Red maple, beech, aspen | None |
| | Adequate | Washed fine till, dry compact till, silty sediments | Beech or softwoods | Paper birch, possibly yellow birch | Red maple beech, aspen | Possibly excess water in spring |
| | Wet | Wet compact till | Probably softwoods | Yellow birch paper birch softwoods | Red maple | Excess water and excess competition following clearcutting. |
| Hardwood/ hemlock/ spruce | Dry | Sandy sediments, outwash shallow to rock | Softwoods | White pine, other softwoods, paper birch, possibly oak | Red maple, aspen | Possible shallow bedrock |
| | Adequate | Silty sediments, dry compact till | Softwoods | Softwoods, birches | Red maple, aspen | Possibly excess water in spring |
| | Wet | Wet compact till, poorly drained | Softwoods | Softwoods, birches | Red maple | Excess water, windthrow, and excess competition following clearcutting |
| Hardwood/ white pine | Dry | Outwash, sandy sediments, shallow to rock | Softwoods | White pine, other softwoods, paper birch, perhaps oak | Red maple, aspen, beech | Possibly shallow bedrock |
| | Adequate-wet | Any | Uncertain Present stand probably old-field | White pine in present stand | Uncertain | Possibly excess water |
| Aspen/ paper birch | Dry | Outwash, sandy sediments | Softwoods | Paper birch, white pine, other softwoods, oak | Red maple, aspen | None |
| | Adequate-wet | Any | Uncertain. Present stand may be of fire origin | Paper birch in present stand | Uncertain | Possibly excess water |
| Oak/white pine | Dry | Washed coarse till, outwash, sandy sediments, shallow bedrock | Oak or softwoods | Oak, white pine, tolerant softwoods | Red maple, aspen | Possibly shallow bedrock |

[a] Forest types: In general, the stand should contain at least 50 percent by basal area of the listed species. However, some judgment is needed in applying this rule. For example, a stand of hardwoods with an appreciable component of softwoods in the seedling understory should be considered hardwood-softwood or hardwood-white pine—because these softwoods could be featured in regenerating the stand.

[b] Soil Moisture: *Dry*—This condition occurs on areas of coarse sandy or gravelly outwash, sediments (sandy), and coarse washed till, as well as areas shallow to bedrock or boulders. The soils are loose, coarse, and always dry. Ground flora characteristics of dry areas are sometimes present: blueberries, wintergreen, bracken fern, several clubmosses, wild lily-of-the-valley. *Wet*—This condition occurs on poorly drained areas and wet compact tills. Evidence of excess water is evident at, or just under, the surface. *Adequate*—This condition occurs where soil texture is reasonably fine, a sandy loam or better. A well- to moderately-well drained pan may also occur.

A sample map of the Bartlett Experimental Forest (2,600 acres) is shown in Figure 7. Most of the habitats described earlier are found on this map. However, notice that some map units are combinations of associated habitats that cannot be separately mapped. In such cases, the habitat listed first is the predominant one. Since this map was completed, it has been suggested that classification and subsequent mapping of areas by broad percent-slope classes would assist in making interpretations.

Predelineation is the first step in habitat mapping. This consists of drawing lines around and tentatively naming logical map units based on steroscopic examination of photographs. Mapping is done directly on the photos, or overlays, with easily erasable marking pencil. Before predelineation work it is necessary to know or to determine through reconnaissance the types of materials in the area, their mode of occurrence, and their relationships with the tree vegetation. Elevational conditions on the Bartlett Forest are shown in Figure 8. The following guidelines were followed in predelineating habitats on the Barlett Forest.

*Poorly drained (1)*—This habitat is a flat area in low topographic positions. Stocking may be sparse or clumped. Softwoods are abundant in both young and old stands.

*Shallow bedrock (2) and ledge (2B)*—These habitats are in the uppermost elevational positions, or

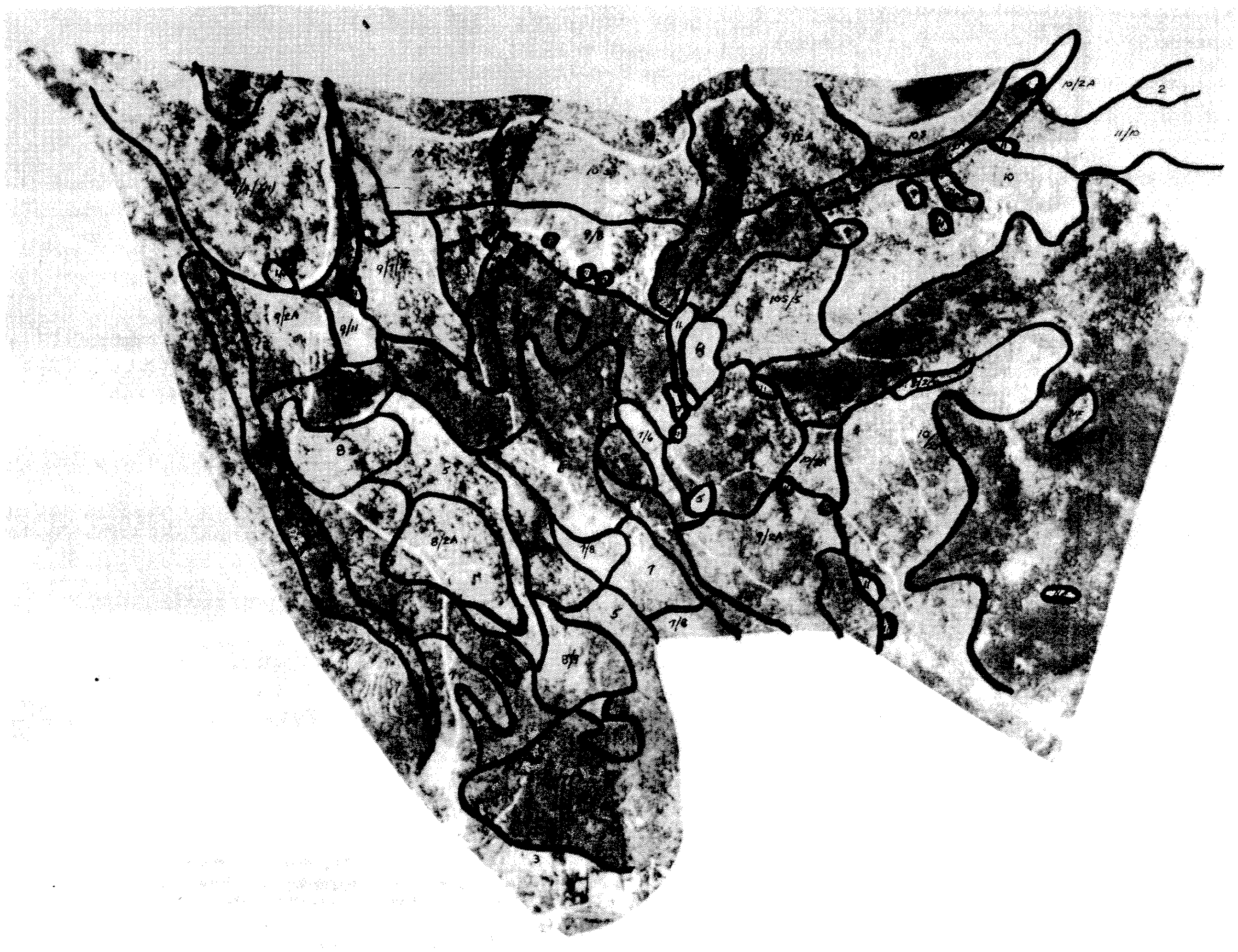

Figure 7.—Habitat map of the Bartlett Experimental Forest, New Hampshire.

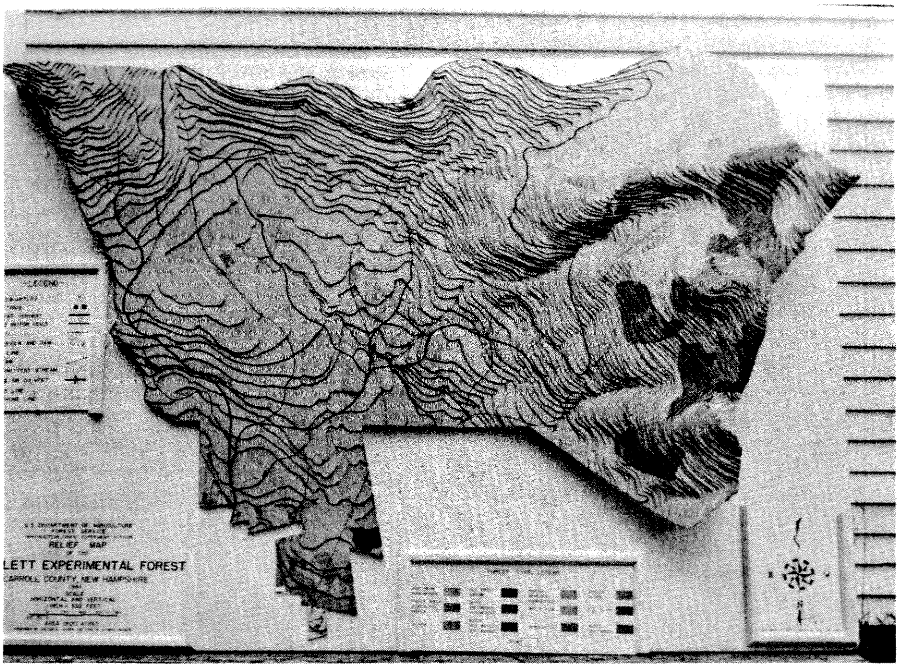


Figure 8.—Topographic model of the Bartlett Experimental Forest.

they may extend down from the upper elevations as fingerlike units. The ledge is visible in places. Spruce, fir, and/or hemlock are abundant in both young and old stands.

*Shallow loose rock (2A)*—This habitat usually is found along existing stream banks or old drainageways. Old stands are softwood and young stands are mixed wood.

*Outwash (3)*—An outwash area is a high, hummocky bank along existing streams (ice-contact materials) or mounded topography in the major valleys. Softwoods including some white pine are abundant in both young and old stands.

*Wet compact till (4)*—This material is on uniform, gently sloping areas at lower topographic positions. Softwoods are abundant in old stands, and mixed woods predominates in young stands. Drainage lines due to overland flow are sometimes evident. Streams are shallowly entrenched.

*Dry compact till (5)*—This compact till usually is found adjacent to and slightly above wet compact till. Topography can be gently sloping to convex and uniform. Old stands are softwood, but young stands are mixed wood or mostly hardwood.

*Dry cemented till (5A)*—This habitat was not mapped on the Bartlett Forest. It is commonly an area of softwood (old stands) or mixed wood (younger stands) on low ridges. This habitat is difficult to distinquish on photographs.

*Silty (6) and sandy (7) sediments*—These habitats are found on gently sloping or rolling, well drained topography at lower elevations. Old stands are softwood and young stands are mixed wood or hardwood. Streams are steep banked and deeply entrenched.

*Washed tills (8, 9)*—Washed tills are characterized by hardwood stands with some softwood admixture on sloping or rolling topography at mid to lower elevations. On the Bartlett Forest, most of the washed tills are found just above and below the major slope break between the upper and lower elevations of the forest (Fig. 8). Streams are uncommon within these units, though well entrenched streams may border them.

*Fine till (10, 10C, 10S)*—This habitat has hardwood stands on moderately steep and irregular topography at mid to upper elevations.

*Enriched (11)*—Enriched habitats commonly are too small to be detected on photographs. On the Bartlett Forest, this habitat usually occurs at the slope break between the upper and lower elevations. In other areas, the alluvial soils with hardwoods adjacent to major streams commonly are typed as enriched.

After predelineation, each mapped unit or a sample of the units is examined in the field to confirm the boundaries and the habitat designations. Boundaries generally are quite accurate; however, habitat names frequently are revised in the field. In each mapped unit examined, a pit is dug to determine the nature of the soil materials; additional auger borings are taken to check for uniformity of materials throughout the unit. It is during field checking that one or two associated habitats often are recognized and designated along with the primary habitat designation.

Based on a random 1,050-point sample of the finished map, the primary habitat conditions on the Bartlett Forest are shallow bedrock, wet compact till, coarse washed till, and fine till. These each account for about 18 percent of the forested area (Table 2). Poorly drained and enriched habitats each account for less than 1 percent of the area. The remaining habitats each account for 2 to 5 percent of the area.

**Relation of Habitat Map Units to Other Map Units**

Two other land classification schemes are used in the area of the Bartlett Forest: the ecologic land types mapped by the White Mountain National Forest and the standard soil survey using soil series or associations mapped by the Soil Conservation Service (SCS). Recent maps of both systems were available for the Bartlett area. The soils

**Table 2.—Percentage of the Bartlett Experimental Forest in each habitat based on 1,050 points.**

| Habitat | Percentage of area |
|---|---|
| Poorly drained(1) | 0.4 |
| Shallow to bedrock (2 and 2B) | 18.2 |
| Loose rock(2A) | 5.2 |
| Outwash(3) | 2.4 |
| Wet compact till(4) | 17.5 |
| Dry compact till(5) | 5.6 |
| Silty sediments(6) | 3.6 |
| Sandy sediments(7) | 5.0 |
| Fine washed till(8) | 5.0 |
| Coarse washed till (9) | 18.6 |
| Fine till (10, 10C, 10S) | 17.6 |
| Enriched(11) | .9 |
| Total | 100.0 |

**Table 3.—Numbers of points falling within each habitat/soil series combination[a]**

| Habitats | Well-drained till (BVC, BVE, BVF, HOE) | Well-drained pan (BEE, MEE, MEF) | Well-drained to moderately well-drained pan (MFC) | Moderately well-drained pan (PLC) | Shallow to bedrock (LVF, LYF, RPF, CDE) |
|---|---|---|---|---|---|
| Poorly drained(1) | — | — | 2 | 2 | — |
| Shallow to bedrock(2) | 12 | 36 | 9 | — | 134 |
| Loose rock(2A) | — | 8 | 40 | 6 | 1 |
| Outwash(3) | — | 23 | 2 | — | — |
| Wet compact till(4) | 4 | 9 | 130 | 40 | — |
| Dry compact till(5) | 7 | 27 | 25 | — | — |
| Silty sediments(6) | — | — | 34 | 4 | — |
| Sandy sediments(7) | 1 | — | 43 | 9 | — |
| Fine washed till(8) | 11 | 10 | 30 | 2 | — |
| Coarse washed till(9) | 1 | 99 | 95 | — | — |
| Fine till(10, 10C, 10S) | 83 | 55 | 46 | — | 1 |
| Enriched(11) | 1 | — | 8 | — | — |

[a] Soil association definitions:
BEE—Becket very stony fine sandy loam association, steep
BVC—Berkshire very stony fine sandy loam association, sloping
BVE—Berkshire very stony fine sandy loam association, steep
BVF—Berkshire very stony fine sandy loam association, very steep
CDE—Canaan-Redstone very rocky gravelly fine sandy loam association, steep
HOE—Hermon very stony fine sandy loam association, steep
LVE—Lyman-Berkshire very rocky fine sandy loam association, steep
LYF—Lyman-Rock outcrop association, very steep
MEE—Marlow very stony fine sandy loam association, steep
MEF—Marlow very stony fine sandy loam association, very steep
MFC—Marlow-Peru very stony fine sandy loam association, sloping
PLC—Peru very stony fine sandy loam association, sloping
RPF—Rock outcrop-Lyman association, very steep

of the area were described by Diers and Vieira (1977) and by Pilgrim and Harter (1977). By drawing a map sample of 1,050 points, we were able to compare habitats, ecologic land types, and soil associations. Examination of areas in the field provided at least a partial explanation for some of the discrepancies among mapping approaches.

*Habitats versus soil associations*—Habitats (Fig. 7) and soil associations (Fig. 9) followed similar boundaries: similar units of land were designated under both approaches. The similarity between mapped unit designations is shown in Table 3. The soil associations were grouped into general classes of parent materials.

The few points that fell in the poorly drained habitat were cross-classified as well-drained to moderately well-drained soils with a pan. This is a reasonable association because poorly drained areas are generally surrounded by moderately drained to somewhat poorly drained pan soils.

The shallow-to-bedrock habitat is similar to the soil associations reflecting shallowness to bedrock; 70 percent of the points are similar.

The habitats classed primarily as loose rock were predominately cross-classified as well-drained to moderately well-drained soils with a pan. This association was not surprising because most of the loose rock was mapped along waterways at lower elevations, and loose rock supports vegetation somewhat similar to that of pans. However, because loose rock is a reasonably common habitat, which often occurs in association with other habitats and has different hydrologic

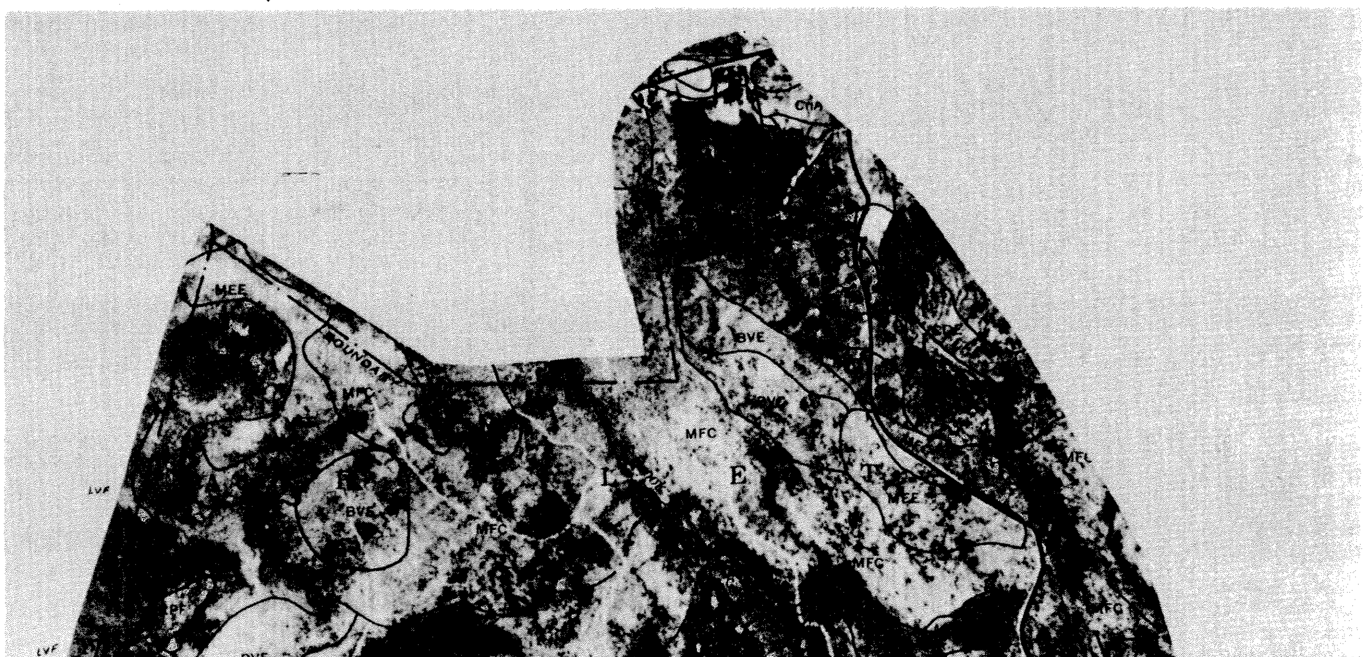


Figure 9.—Soil survey map of the Bartlett Experimental Forest.

properties than pan, the importance of loose rock in determining forest composition and utilization should be evaluated further.

The small amount of outwash habitat in the forest was mostly cross-classified as well-drained soils with a pan. This habitat was not in the usual position for outwash; it was along a stream at fairly high elevations and easily could be mistaken. In general, outwash is classified in similar fashion under all three systems examined in this study.

Most wet compact till (71 percent) was cross-classified as well-drained to moderately well-drained soils with a pan. The dry compact till fell mostly (88 percent) into the well-drained and well-drained to moderately well-drained categories of pan. Thus, there is a reasonable association between the habitat and soil association approaches in mapping these categories.

Both the silty and sandy sediments were primarily cross-classified as well-drained to moderately well-drained soils with a pan. In the Bartlett Forest, both of these habitats were in lower slope positions where pan commonly is found. However, the sediments appear to offer different opportunities than pan with regard to operability, productivity, and potential for intensive management.

Most of the coarse washed till and, to a lesser degree, the fine washed till were cross-classified as well-drained to moderately well-drained soils with a pan. About one-fifth of the fine washed till fell into the soils category of well-drained till, which seems like a more logical category. One reason why there is some discrepancy in the mapping of these habitats is that the washed tills seem to occur in complex associations. Much of the washed till I mapped seemed to be underlaid with pan, which surfaced occasionally. On the basis of plot work, I feel that the washed tills have considerably different management potential than the pans or the typical well-drained tills (Berkshire for example). For example, the coarse washed tills appear to produce heavy amounts of beech; the pans lean toward softwoods, and the typical (unwashed) tills produce rich northern hardwoods (sugar maple/beech).

Approximately 45 percent of the fine till habitat was cross-classified as well-drained till soils (a logical category), and most of the remainder fell into well-drained to moderately well-drained soils with a pan. Field examination of several areas with the SCS state soil scientist, S. Pilgrim, indicated that some areas classed as fine till were underlaid with a firm, platy till and classified as well-drained soils with a pan by SCS mapping. I did not class these as pans because the firm layer seemed to be below the rooting depth, and did not seem to be mottled or discolored, and because the area supported typical northern hardwoods. Since then, a new habitat category (10C) was developed to represent fine till over compact till. This was done because of the possible effects of this pan on operability and site potential (a positive effect perhaps). However, this sort of well-drained pan needs to be mapped separately from the areas mapped as dry compact till.

The few points that fell in enriched habitats were cross-classified as well-drained to moderately well-drained soils with a pan. Enriched habitats are limited in size and number, and apparently there is no analogous soil series. However, enrichment often is mapped in association with other habitats. Thus, this condition may be more important than its acreage indicates.

*Habitats versus ecologic land types*—Table 4 gives the association between habitats and ecologic land types (ELT). Many changes have been made in ecologic land typing since these data were developed, so only a brief and general comparison will be made.

The poorly drained and shallow-to-bedrock habitats were similar to the ELT classifications of imperfectly drained ablational tills and shallow-to-bedrock sites.

Habitats characterized by loose rock and outwash were too small and scattered to be reflected in the ecologic land types.

The wet compact till habitat was similar to the ELT classifications of basal till or imperfectly drained basal till. However, a large number of points (38 percent) fell under well-drained tills. Pans and imperfect drainage sometimes are difficult to assess on aerial photographs without intensive ground checking. The dry compact till habitats also were split between the land types of basal till and well-drained till.

Silty and sandy sediments were classed both as imperfectly drained ablational tills and well-drained tills. This is understandable because some sediments seem well-drained, and others show some evidence of imperfect drainage. The concept of sedimentation is now built into the ELT system.

Fine washed tills were similar to the ecologic land type representing well-drained tills—a logical association.

Much of the coarse washed till habitat was cross-classified as basal till or imperfectly drained ablational till. As mentioned earlier, the coarse washed tills often are complex areas, sometimes underlaid with pan. The ELT system, which classifies substrata to a depth of about 10 feet, could understandably list these as basal till or imperfectly drained areas. However, I think that areas with shallow versus deep pan can be quite different in species, productivity, and operability.

Habitats classed as fine till commonly were cross-classified as basal till. This difference again reflects the ELT approach of looking

**Table 4.—Numbers of points falling within each habitat/ecologic land type combination[a]**

| Habitat | Well-drained tills(5) | Well-drained bouldery tills(5C) | Well-drained to moderately well-drained basal till(3) | Imperfectly drained ablational till(6B) | Shallow to bedrock(2) |
|---|---|---|---|---|---|
| Poorly drained(1) | — | — | 1 | 3 | — |
| Shallow to bedrock(2) | — | 59 | 7 | 1 | 124 |
| Loose rock(2A) | 1 | — | 9 | 44 | — |
| Outwash(3) | — | — | 24 | 1 | — |
| Wet compact till(4) | 70 | 2 | 38 | 73 | — |
| Dry compact till(5) | 30 | — | 28 | 1 | — |
| Silty sediments(6) | 11 | — | — | 27 | — |
| Sandy sediments(7) | 27 | — | 1 | 25 | — |
| Fine washed till(8) | 41 | — | — | 12 | — |
| Coarse washed till(9) | 5 | 1 | 134 | 55 | — |
| Fine till(10, 10C, 10S) | 6 | 58 | 116 | 4 | 1 |
| Enriched(11) | 6 | — | 3 | 1 | — |

[a] Ecologic Land Types:

*ELT 2*—Softwood knolls, ridges, and steep side slopes with ledgy, bouldery shallow sites—these typically are shallow to bedrock with a spruce-fir climax at higher elevations, and with more hemlock and oak at lower elevations.

*ELT 3*—Hardwood with softwood mountain side slopes with moderately deep soils to hardpan—these are well-drained to moderately well-drained soils underlaid by impermeable basal till.

*ELT 5*—Hardwood lower mountain slopes and broad valley floors with very deep ablational tills—these are well-drained tills supporting northern hardwood stands.

*ELT 5C*—Hardwood smooth steep upper mountain slopes with deep, very bouldery ablational tills—these are bouldery, well-drained tills, high in coarse fragments, supporting more beech than ELT 5.

*ELT 6B*—Hardwood flats and swales with imperfectly drained organic surfaces over wet ablational tills—these are less than well-drained soils, apparently due to the influence of pan and lower slope position, supporting a hardwood-softwood mixture.

at deeper layers than the habitat system.

The few enriched areas were too small to be considered under the ELT system.

*Summary on mapping correlations*—Keep in mind the uncertainties involved in comparing mapping approaches. Apparent discrepancies can arise because of differences in: taxonomic or mapping criteria, precise definitions of these criteria, the weighting of criteria in multifactor systems, and the purity of the mapping systems (the variability allowed within units). Although all of these sources of uncertainty have not been evaluated in detail, it seems evident that two technical subjects require additional discussion and specification.

1. We need to look more closely at the types of pans that influence productivity and operability. The problem seems especially important with pans that are well-drained to moderately well-drained. Some pans support rich northern hardwoods; others that are well-drained to moderately well-drained support mediocre hardwoods and have a softwood climax.

2. The concept of washed or water-worked till needs additional evaluation. We should reexamine our definitions of sediments—what they are and how they influence vegetation. The problem is that areas mapped as well-drained tills by the SCS might be classified as sediments or washed tills under the ELT or habitat approaches. Because of different definitions, the coordination of information from the three approaches is difficult.

## Interpretations

To develop information on species relationships and productivity of the habitats mapped on the Bartlett Forest, 145 10-factor prism plots were measured. These plots were systematically located to sample the range of conditions in 27 stands representing 12 habitat mapping units. The sample included even-aged successional stands (mostly about 100 years old) composed of both tolerant and less-tolerant species as well as a few uneven-aged climax stands composed primarily of tolerant species. The stands were uncut during the last 50 years or more.

On each plot, trees were tallied by species and dbh class (over 1.0 inch). Height and age were determined on one potential site index tree per plot, if available. The presence of trees less than 1.0 inch dbh, shrubs, and herbs was recorded by species on eight 1-m$^2$ plots per prism point.

### Species Composition

Species composition in basal area per acre (trees over 1.0 inch dbh) was determined for both successional stands (Fig. 10) and climax stands (Fig. 11). These results closely follow earlier guidelines on the relations of species composition and succession (Fig. 4) to habitat in granitic drift (Leak 1978a). Softwoods are evident in successional stands on poorly drained, bedrock, wet compact till, and silty sediments habitats; red maple is the predominant hardwood on these habitats. The proportion of softwoods in these successional stands varies considerably, however, depending upon cutting history. If an understory was left in the early cuttings around 1900, softwoods are abundant. If the cutting was complete, hardwoods predominate.

Dry compact till and sandy sediments support red maple/beech/birch stands. The washed tills are primarily hardwood stands with beech predominating; some hemlock is evident as well. The enriched habitats are characterized by sugar maple and white ash. Results from the climax stands indicate that beech and sugar maple characterize the fine tills; these species together with birches also typify successional stands. Hemlock and red spruce are climax on the other habitats represented in Fig. 11.

Climax species composition is not necessarily static, however. General observations[1] indicated that beech and sugar maple on fine till habitats tend to alternate in abundance. Results from two climax stands on fine till illustrate this phenomenon:

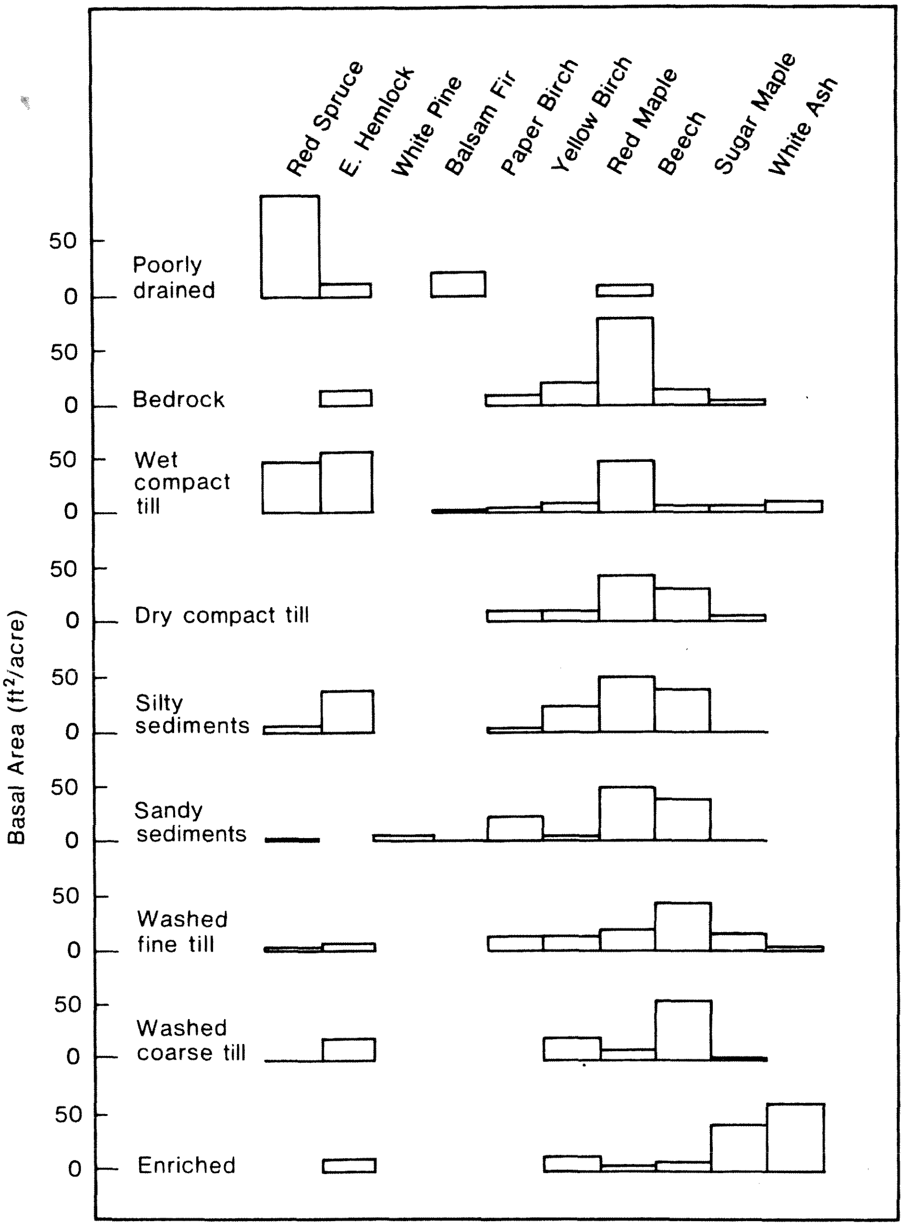


Figure 10.—Basal area per acre by habitat and species for successional stands on the Bartlett Experimental Forest.

| | Beech | | Sugar maple | |
|---|---|---|---|---|
| | *2-8 inches dbh* | *10 inches dbh +* | *2-8 inches dbh* | *10 inches dbh +* |
| | *(basal area in ft$^2$)* | | | |
| Compartment 22 | 6.7 | 86.7 | 16.7 | 6.7 |
| Compartment 35 | 11.7 | 26.7 | 1.7 | 45.0 |

[1] Personal communication, Stanley M. Filip, retired research forester.

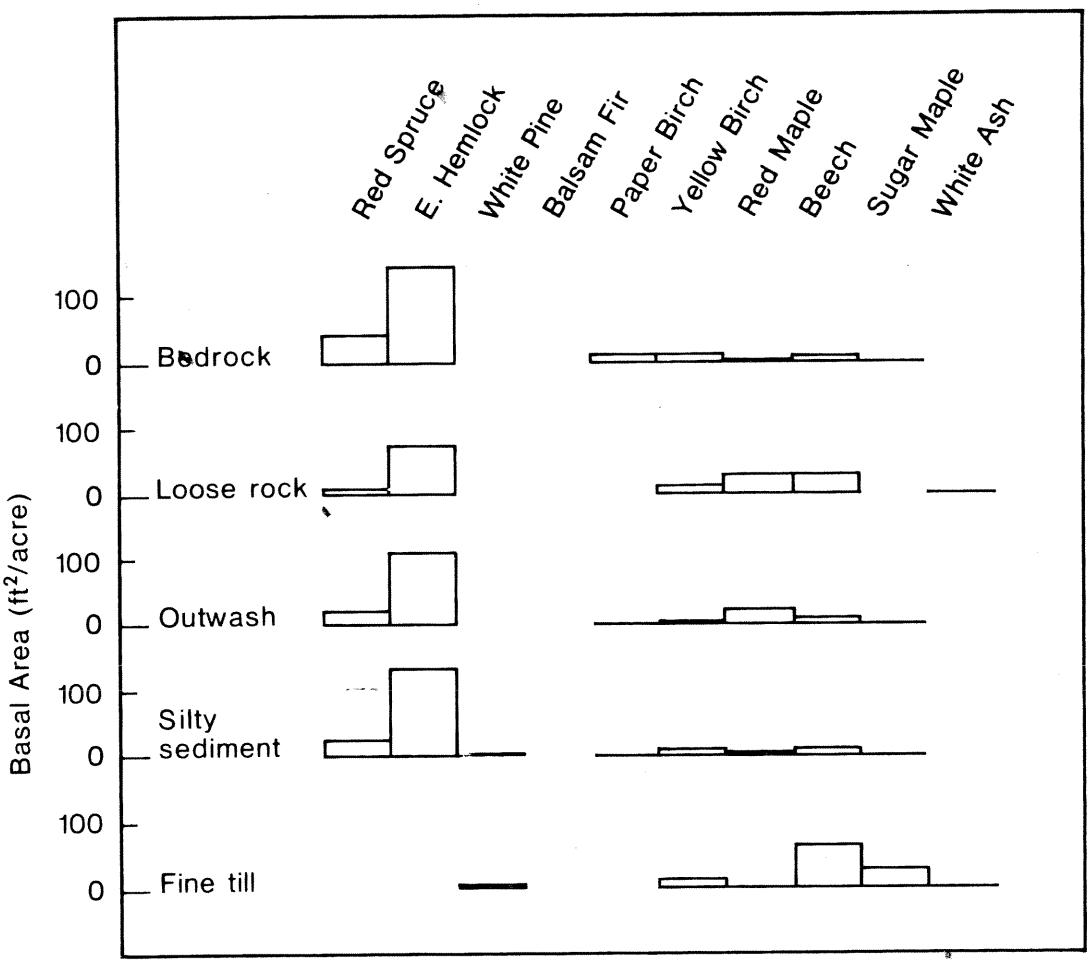


Figure 11.—Basal area per acre by habitat and species for climax stands on the Bartlett Experimental Forest.

On Compartment 22, beech is abundant in the overstory and sugar maple predominates in the understory. On Compartment 35, the situation is reversed. Apparently, species alternation is characteristic of northern hardwoods on fine till, but additional long-term observation will be needed to confirm this hypothesis.

Although species of shrubs and herbs have proved to be of diagnostic value for western habitats (Pfister and Arno 1980) and some earlier eastern classifications (Westveld 1951), these species have not yet been recognized as criteria for defining habitats in the White Mountains.

Results from the Bartlett Forest indicate that certain habitats support a much richer flora (greater numbers of species) than others. The greatest numbers of herbaceous species are found on enriched, sandy sediment, and wet and dry compact till habitats; in several instances, these same habitats

Table 5.—Average numbers of tree, shrub (including small tree), and herbaceous species per stand by habitat and successional stage.

| Habitat | Successional stage | Number of m² plots | Average number of species | | |
|---|---|---|---|---|---|
| | | | Trees | Shrubs and small trees | Herbs |
| Enriched(11) | Successional | 80 | 4.0 | 4.0 | 11.0 |
| Fine till(10, 10C, 10S) | Climax | 96 | 4.5 | 3.0 | 4.5 |
| Coarse washed till(9) | Successional | 80 | 6.0 | 2.5 | 2.0 |
| Fine washed till(8) | Successional | 136 | 6.0 | 3.3 | 5.0 |
| Sandy sediments(7) | Successional | 128 | 7.3 | 4.7 | 15.7 |
| Silty sediments(6) | Climax | 40 | 7.0 | 3.0 | .0 |
| | Successional | 96 | 3.5 | 3.5 | 7.0 |
| Dry compact till(5) | Successional | 80 | 8.5 | 4.5 | 12.0 |
| Wet compact till(4) | Successional | 192 | 6.8 | 6.5 | 14.2 |
| Outwash(3) | Climax | 56 | 3.0 | 3.0 | 1.0 |
| Bedrock(2) | Climax | 56 | 2.0 | 2.0 | 2.0 |
| Loose rock(2A) | Climax | 48 | 6.0 | 3.0 | 3.0 |
| | Successional | 56 | 4.0 | 4.0 | 8.0 |
| Poorly drained(1) | Successional | 16 | 5.0 | 4.0 | 2.0 |

support more tree or shrub species as well (Table 5). Richness bears no clear relationship to moisture, because the sandy sediments are well-drained to excessively well drained and the other three rich habitats tend to be moderately well-drained or wetter.

Species composition of the understory was somewhat variable, though certain patterns existed (Table 6). We examined only those species or species groups of the understory that were present with at least 5 percent frequency in all stands in a given habitat. The frequency of tree species (up to 1.0 inch dbh) resembled the species composition of the overstory: sugar maple and ash were common on the enriched habitats, sugar maple and beech predominated on fine till, and so on. However, some of the demanding species were found in the understory on habitats where they probably will not succeed; for example, although sugar maple occurs with 10 percent frequency on sandy sediments and white ash with 12 percent frequency on dry compact till, I could not expect either species to be common in the overstories on these habitats.

Shrubs and small trees were not particularly diagnostic. However, Canada yew was found mostly on areas underlaid with loose rock. Poorly drained habitats were characterized by sheeplaurel, blueberry, wintergreen, and wild raisin. With regard to herbaceous species, wild oats were most common on enriched habitats. Starflower was characteristic of sandy sediments. Clintonia and wood sorrel were abundant on wet compact till, and sphagnum and goldthread were unique on the poorly drained areas. Although there were appreciable differences among habitats, the overall herbaceous species composition resembled the oligotrophic (low base) series reported by Siccama and others (1970).

In general, knowledge of understory species composition seems to be useful in helping to identify *certain* habitats, but is not consistent enough to be used as a major criterion in habitat taxonomy or mapping.

**Stand Productivity**

Aboveground biomass per acre was determined by applying the equations by Whittaker and others (1974) for stems and branches to the prism-plot information from the Bartlett Forest. Biomass for species not represented by the Whittaker equations was estimated by using his sugar maple equations and correcting for specific gravity. To supplement this information, I included previously reported plot information (Leak 1979) for sapling and pole-timber stands from granitic areas near the Bartlett Forest. Curves of biomass per acre over age were nearly identical for most hardwood habitats (hardwood climax: habitats

Table 6.—Average frequency (percent occurrence on 1-$m^2$ plots) of tree, shrub (including small trees), and herb species per stand, by habitat and successional stage (includes only those species greater than or equal to 5 percent frequency on all areas in each habitat/successional category).

| Species | Habitat and stand category | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Enriched (11) | Fine till (10, 10C 10S) | Coarse washed till (9) | Fine washed till (8) | Sandy sediments (7) | Silty sediments (6) | | Dry compact till(5) | Wet compact till(4) | Outwash (3) | Bedrock (2) | Loose rock (2A) | | Poorly drained (1) |
| | Successional | Climax | Successional | Successional | Successional | Climax | Successional | Successional | Successional | Climax | Climax | Climax | Successional | Successional |
| **TREES** | | | | | | | | | | | | | | |
| Beech | 32 | 52 | 68 | 69 | 57 | 25 | 44 | 45 | 17 | — | — | 58 | 9 | — |
| Sugar maple | 68 | 51 | 15 | 22 | 10 | — | — | — | — | — | — | — | 5 | — |
| Red maple | — | — | 15 | 37 | 31 | 22 | — | — | 14 | — | — | — | — | 56 |
| Yellow birch | — | — | — | — | — | — | — | — | — | — | — | — | — | 19 |
| White ash | 28 | — | — | 18 | — | — | — | 12 | — | — | — | — | — | — |
| Red spruce | — | — | — | — | — | 28 | — | — | — | 25 | 21 | 19 | — | 31 |
| E. hemlock | — | — | — | — | — | 40 | 14 | — | — | 21 | 14 | 33 | — | 56 |
| Balsam fir | — | — | — | — | — | — | — | — | 14 | — | — | — | — | 6 |
| **SHRUBS** | | | | | | | | | | | | | | |
| Hobble bush | 42 | 35 | 16 | 33 | — | 12 | 44 | 64 | 42 | 11 | — | 29 | 43 | — |
| Striped maple | 36 | 40 | — | — | 16 | 5 | — | 34 | 40 | — | 11 | 17 | 12 | — |
| Canada yew | — | — | — | — | — | — | — | — | — | — | — | 8 | 5 | — |
| Blueberry | — | — | — | — | — | — | — | — | — | — | — | — | — | 62 |
| Wintergreen | — | — | — | — | — | — | — | — | — | — | — | — | — | 38 |
| Sheeplaurel | — | — | — | — | — | — | — | — | — | — | — | — | — | 25 |
| Wildraisin | — | — | — | — | — | — | — | — | — | — | — | — | — | 6 |
| **HERBS** | | | | | | | | | | | | | | |
| Wildoats | 49 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Indian cucumber | 20 | — | — | — | 25 | — | 8 | 30 | — | 23 | — | 12 | 5 | — |
| Wild lily-of-the-valley | — | — | — | — | 85 | — | — | 26 | — | — | — | — | — | — |
| Starflower | — | — | — | — | 51 | — | — | — | — | — | — | — | — | — |
| Sarsaparilla | — | — | — | — | 18 | — | — | 24 | — | — | — | 6 | 20 | — |
| Clubmoss | — | — | — | — | 36 | — | — | — | — | — | — | — | 5 | — |
| Trillium | — | — | — | — | — | — | — | 6 | — | — | — | — | — | — |
| Clintonia | — | — | — | — | — | — | — | — | 22 | — | — | — | — | — |
| Wood sorrel | — | — | — | — | — | — | — | — | 36 | — | — | — | — | — |
| Moccasin flower | — | — | — | — | — | — | — | — | — | — | — | — | 5 | — |
| Woodfern | — | — | — | — | — | — | — | — | — | — | — | — | 7 | — |
| Sphagnum | — | — | — | — | — | — | — | — | — | — | — | — | — | 94 |
| Goldthread | — | — | — | — | — | — | — | — | — | — | — | — | — | 6 |

number 8 to 10) and softwood habitats (softwood climax now supporting hardwoods, mixed wood, or softwoods: habitats number 2 to 7) (Fig. 12). Climax hardwood stands[2] averaged about 40,000 dry pounds per acre heavier than softwood stands though there were too few observations to detect a significant difference. The white ash/sugar maple stands characteristic of enriched habitats averaged greatest in biomass; one softwood stand on a poorly drained habitat averaged least. The equations for hardwood and softwood standing aboveground dry biomass in thousands of pounds per acre are:

$$\text{Hardwood:Dry Wt.} = 1.2955 + 3.2182\,(\text{age}) - 15.4854\,(\text{age}^2/1000)$$
$$n = 11$$
$$R^2 = .97$$

$$\text{Softwood:Dry Wt.} = -0.8552 + 3.1728\,(\text{Age}) - 14.8337\,(\text{Age}^2/1000)$$
$$n = 28$$
$$R^2 = .94$$

These equations were fitted to points representing stands of varying size and age. Thus, the $R^2$ values provide a rough measure of goodness of fit.

Note that these curves of biomass over age are substantially different from the living biomass accumulation curve reported by Bormann and Likens (1979, Fig. 2, Chapter 6). The Bormann-Likens curve peaks sharply at about age 175; whereas, my curves generally flatten off at age 100 to 120. The Bormann-Likens curve is essentially a straight line from origin to peak; whereas, my curves represent the more natural parabolic growth form. The Bormann-Likens model shows a substantial drop from peak biomass accumulation to the climax or

[2] These climax stands contained trees of up to about 200 years old, so climax stand age in Figure 12 was set at 200 years.

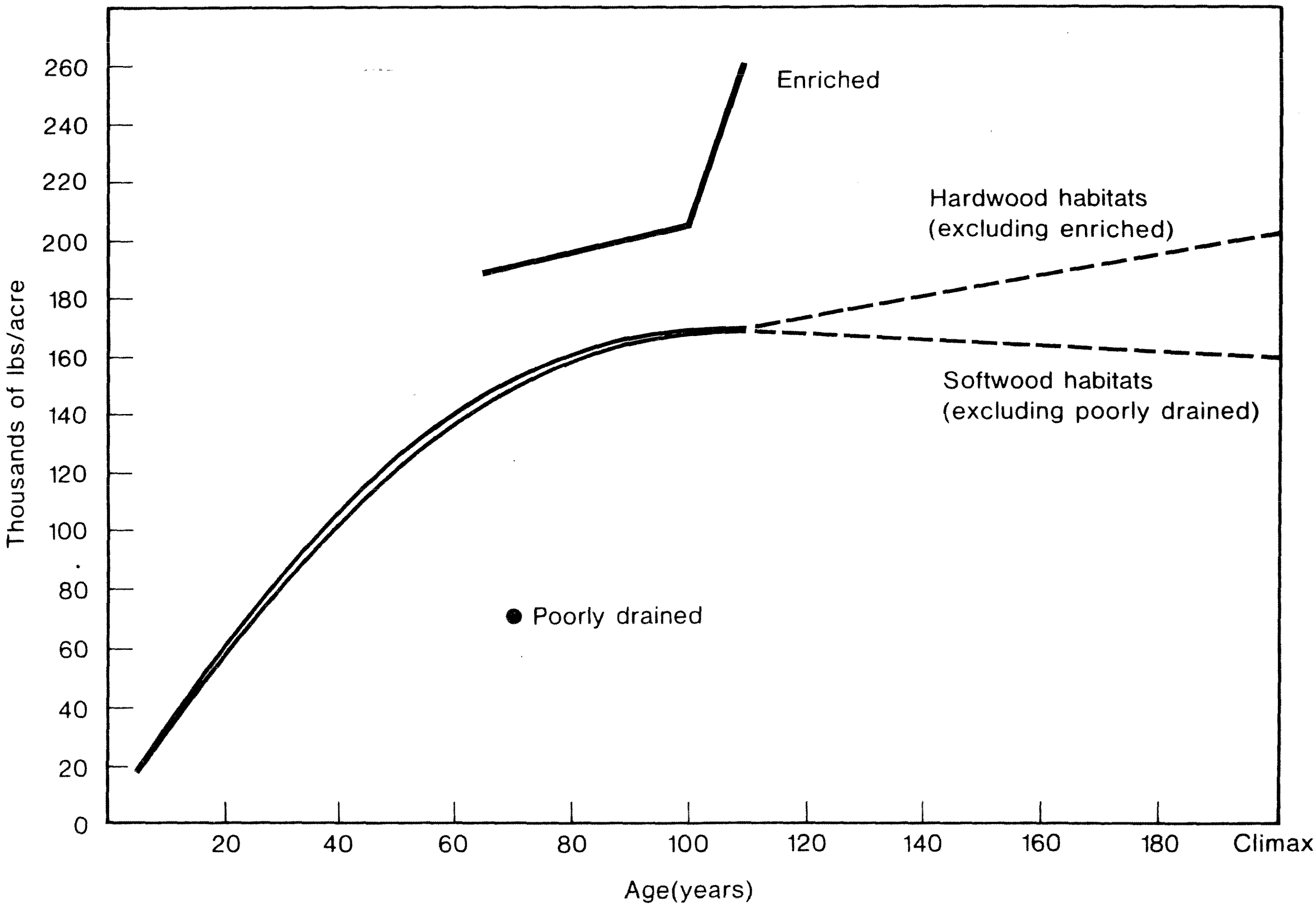


Figure 12.—Aboveground biomass (stems and branches) in dry weight over stand age by habitat groups.

steady state. My curves indicate a slight drop in biomass of climax softwood stands and a slight increase in biomass of hardwoods. The Bormann-Likens curve peaks at about 490 metric tons per hectare of living biomass, which equals 437,000 pounds per acre. If we reduce this by approximately 20 percent to account for roots, twigs, and leaves, the aboveground biomass in stems and branches is about 350,000 pounds per acre. On the Bartlett Forest, the estimated maximum aboveground biomass per acre for climax northern hardwoods is 200,000 pounds; though, it is indicated that stands on enriched habitats are considerably higher—to at least 250,000 pounds.

Volumes by habitat followed a different pattern than that of biomass. Whereas softwoods and hardwoods were similar in biomass production, softwoods were considerably more productive in both cubic feet and board feet. Softwood stands (including mixed wood stands with 24 percent softwood or more) supported significantly more cubic volume by age 70 to 90 or older than hardwoods growing on either hardwood habitats (numbers 8 to 10) or softwood habitats (numbers 2 to 7). Enriched stands were about equal to softwood stands in cubic volume (Fig. 13). In board-foot volume, softwood (including mixed wood) stands and hardwood stands on enriched habitats were much more productive than the other

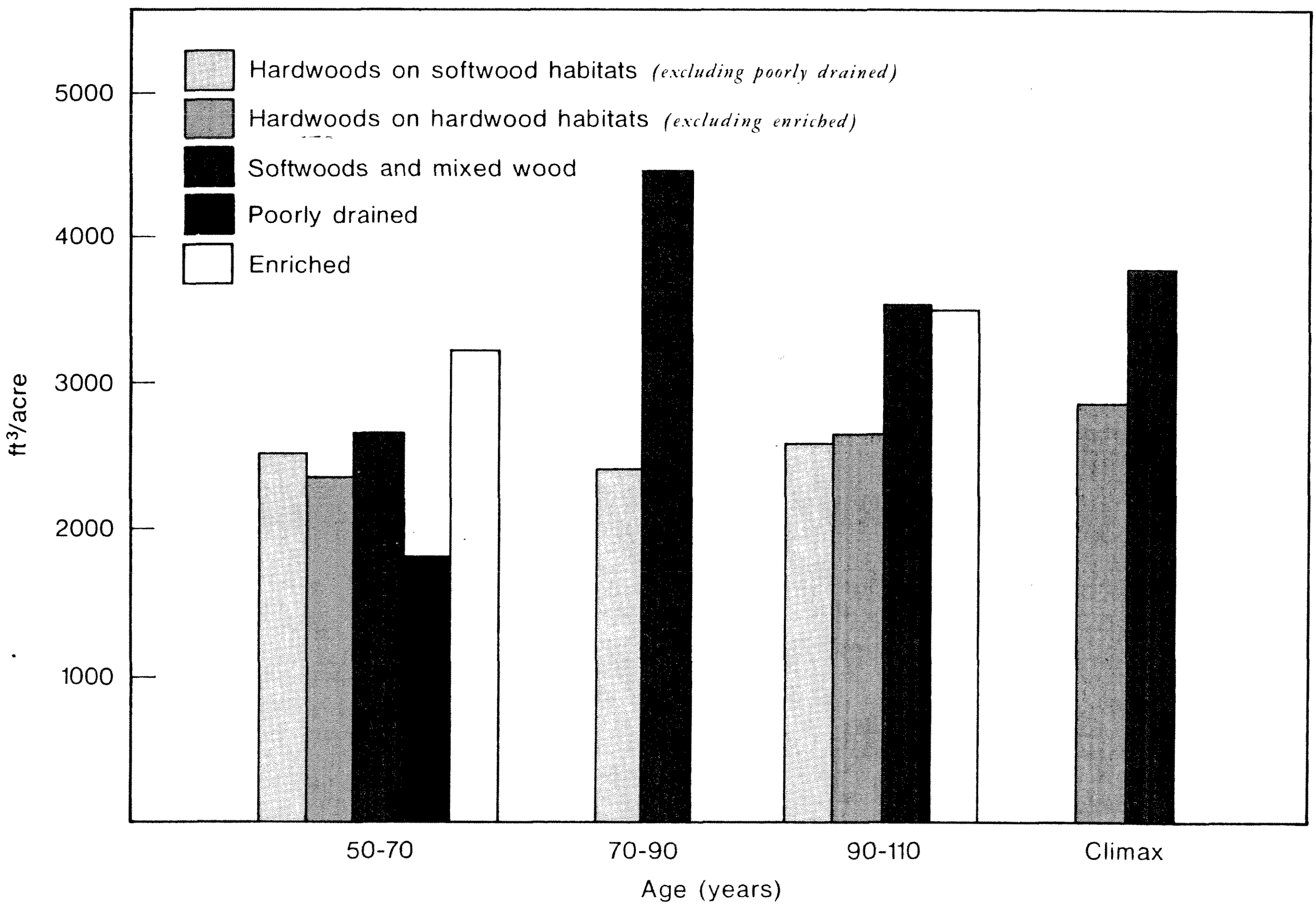


Figure 13.—Average cubic-foot volume per acre by habitat groups and stand age.

stands. Hardwoods growing on hardwood habitats produced more (40 percent at age 90 to 110) board-foot volume than the successional hardwoods found on softwood habitats (Fig. 14), though this difference was not significant.

**Species Productivity**

On the basis of past work (Leak 1978a), average site index by species and habitat apparently provides some basis for comparing the suitability of habitats for growing given species. Additional work in sapling and poletimber stands (Leak 1979) indicated that certain species differed among habitats in mean annual diameter growth.

In the present study on the Bartlett Forest, site index by species was extremely variable; only very demanding species such as white ash showed any noticeable trends in site index by habitat. Apparently, when an entire stand (rather than individual plots) is classified by habitat, there is substantial within-stand variation in site index.

The use of diameter-growth differences of unmanaged stands seemed to be a better possibility for evaluating species productivity. The use of mean diameter of all trees 1 inch dbh and larger did not work because diameter development was obscured by the small trees; even heavy sawtimber stands exhibited mean diameters of only 8 to 10 inches. Mean diameter of trees 8 inches dbh and larger provided a better indication of species development, but even with this measure there was high variability. Finally, I calculated average diameters of the largest trees per species, based on an average of one large tree per plot. For example, if we had seven plots in a stand, the average was based on the seven largest trees per species. Mean diameter was calculated by this method, corrected to a base age of 100 years,[3] and showed some reasonably distinctive differences among habitats (Table 7). However, none of these differences proved significant due to the small numbers of areas (samples) represented. Sugar maple and white ash grew best on the enriched habitats; mean diameters were 4 1/2 to 7 inches larger on the enriched habitat. Beech grew largest on well-drained sites such as the washed tills and sandy sediments. Red maple and paper birch grew fairly well on all habitats, a pattern that has been noted before (Leak 1979). Yellow birch did well on the enriched habitat, and tree sizes in the

[3] Corrected $\bar{D} = \frac{\bar{D} \times 100}{\text{stand age}}$

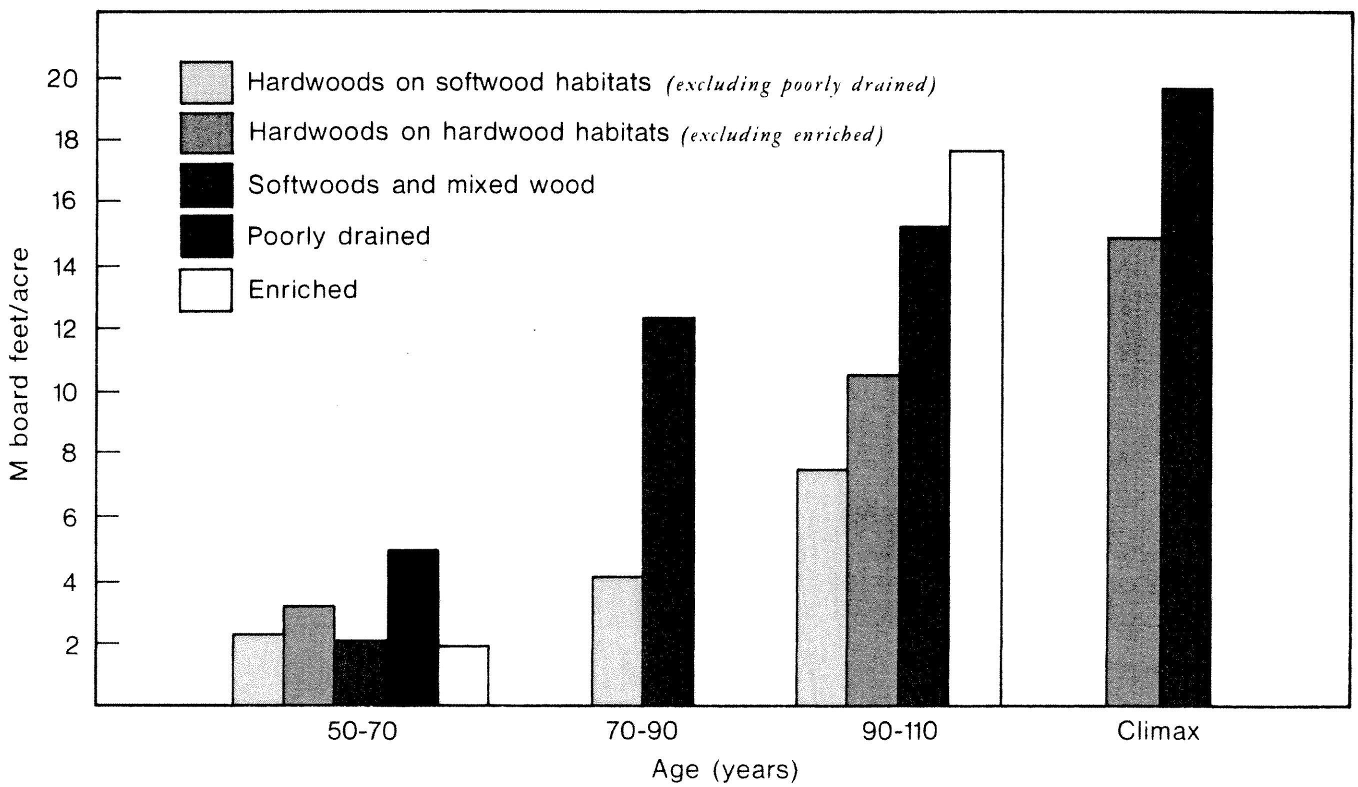


Figure 14.—Average board-foot volume per acre by habitat groups and stand age.

**Table 7.—Mean diameter of largest trees (average of one tree per plot) at 100 years and in climax stands by species and habitat, in inches.**

| Habitat | Beech | Yellow birch | Sugar maple | Red maple | Paper birch | White ash | Red spruce | Eastern hemlock |
|---|---|---|---|---|---|---|---|---|
| | | | | *At 100 years* | | | | |
| Enriched(1) | — | 17.3 | 19.6 | — | — | 21.1 | — | — |
| Washed tills(9 and 8) | 15.2 | 14.2 | 12.5 | 13.4 | 15.4 | 16.8 | — | 13.3 |
| Sandy sediments(7) | 14.8 | — | — | 17.0 | 13.6 | — | — | — |
| Silty sediments(6) | 12.0 | 12.6 | — | 16.9 | — | — | — | 22.2 |
| Dry compact till(5) | 12.5 | 12.0 | 9.6 | 14.6 | 13.8 | — | — | — |
| Wet compact till(4) | 9.8 | 11.2 | 9.4 | 16.8 | 14.3 | 16.0 | 14.8 | 18.6 |
| Poorly drained(1) | — | — | — | — | — | — | 13.6 | — |
| | | | | *Climax* | | | | |
| Fine tills(10, 10C, 10S) | 23.1 | 20.3 | 18.0 | — | — | — | — | 22.0 |
| Silty sediments(6) | 13.2 | 11.2 | — | — | — | — | 17.6 | 21.2 |
| Outwash(3) | 18.6 | — | — | 20.0 | — | — | 16.9 | 20.0 |
| Bedrock(2) | — | — | — | — | 10.0 | — | 18.3 | 25.7 |
| Loose rock(2A) | 14.0 | 14.3 | — | 17.7 | — | — | 14.0 | 21.3 |

climax stands indicate that this species also does well on fine till. Yellow birch performance on the washed tills was higher than expected, but perhaps because the fine washed till was predominant or present in all of these areas. Earlier work (1978a) indicated that site index of yellow birch was higher than that of paper birch on wet compact till, but that the reverse was true on dry compact till. However, the diameter information in Table 7 indicates that the compact tills are mediocre in comparison to the enriched sites and fine till for growing yellow birch.

**Silvicultural Implications**

The information presented so far on the relationship of habitat to species composition, stand productivity, and species performance provides some logical silvicultural implications for the Bartlett stands. These implications, which follow, are consistent with the general silvicultural directions previously defined for stands on granitic drift in the White Mountains (Leak 1980).

11. *Enriched*—This habitat is well-suited to the production of sugar maple and white ash sawlogs and veneer. Shelterwood seems the best regeneration technique for ash, and either shelterwood, selection, or group selection would be best for sugar maple. Early weedings or cleanings to favor increased proportions of these species should be economically worthwhile. These would be followed later by commercial thinnings. Cultural work around sugar maple should be light enough or delayed long enough so that low live branches are not abundant.

    Paper and yellow birch also regenerate and grow well on these sites. Strips or small clearcuttings are the appropriate regeneration method. Openings should be small in low-lying or wet areas to prevent excess herbaceous growth and frost damage; logging or roading activity may need to be controlled on these wetter enriched sites during the spring.

10. 10C. 10S. *Fine till*—This habitat is well-suited to the production of northern hardwood sawtimber—sugar maple, yellow birch, and paper birch. Beech often will occupy up to 50 percent of the stand. Any regeneration method suited to the desired species is acceptable. Early cultural work should be economically worthwhile provided that it improves species or product potential. Roading and logging restrictions are minimal, except when fine till is underlaid by a compact layer (10C).

9. *Coarse washed till*—Beech is abundant and well formed on this habitat. Paper birch is capable of producing bolts and small to medium sawtimber. Although results are somewhat conflicting, I still favor paper birch over yellow birch based on both productivity and regeneration possibilities. Red maple is a much better possibility than sugar maple. Early cultural work directed toward increasing the proportion of paper birch should be economically acceptable. Roading and logging restrictions are minimal.

8. *Fine washed till*—This habitat has a potential similar to the coarse washed till. It could produce small to medium

sawtimber, bolts, and cordwood of primarily beech, red maple, and the birches. Yellow birch has a higher potential on this habitat than the previous one. Cultural work that favors increased proportions of birch with sawlog or boltwood potential should be worthwhile. Operating restrictions are minimal.

7. *Sandy sediments*—Softwoods (including hemlock, spruce, white pine, and some balsam fir) are the most productive on this habitat in terms of board- and cubic-foot volume. Because hardwoods often are abundant in successional stands, carefully designed shelterwood cuts probably would be needed to increase the softwood component. The best hardwood species are beech, red maple, and paper birch; yellow birch seems unproductive on these very well-drained materials. Hardwood product objectives should be fiber, boltwood, and small or lower-grade sawlogs. Cultural investments in young stands to increase the proportion of paper birch might be worthwhile. Operational constraints are minimal.

6. *Silty sediments*—Softwoods, especially hemlock and spruce, are more productive in board- and cubic-foot volume than the hardwoods. Hardwoods are abundant in successional stands and shelterwood systems may be needed to increase the softwood component. Paper birch, yellow birch, and red maple are moderately productive on this habitat. Beech is common but seems less productive here than on drier sites. These habitats may be too wet for logging or roading in early spring and after heavy rains.

5. *Dry compact till*—Softwoods again are the best volume producers. The best hardwoods are maple and paper birch; the logical product objectives are fiber, boltwood, and small or lower-grade sawlogs. Yellow birch seems less productive than paper birch on this habitat, though results are somewhat conflicting. Cultural efforts in young hardwoods should favor paper birch. Beech, though abundant, is not as productive here as on drier sites with unrestricted rooting. Operational problems often occur in spring and after heavy rains.

4. *Wet compact till*—Softwoods are most productive and usually are abundant. The best hardwoods are red maple, yellow birch, and paper birch; product objectives for hardwoods should be limited to fiber, bolts, and small to medium sawlogs. Cultural investments to increase the proportion of paper and yellow birch in young stands may be worthwhile. Operational problems are common, and this might limit logging and roading activities to winter.

3. *Outwash*—Softwoods are productive, and white pine is especially suitable on this habitat. The best hardwoods are red maple and paper birch; bolts, fiber, and small sawlogs are reasonable objectives. Cultural work in hardwoods should favor paper birch. Early cultural work to favor increased growth and sawlog production in white pine has economic potential. Operational problems are minimal.

2. *Shallow bedrock*—Despite the shallow soil, softwood stands on this habitat may have high cubic- and board-foot volume. The best hardwoods are red maple and paper birch; fiber and boltwood are the logical product objectives. Because of the shallow soils and difficulties in logging, I suggest minimal management effort: light selection or group selection cutting of the accessible areas to maintain the softwoods.

2A. *Loose rock*—Softwood stands again are more productive than hardwoods. Red maple and paper birch are the best hardwood species, although a few good yellow birch are found associated with waterways. Fiber, boltwood, and a few small sawlogs are logical hardwood products. Logging restrictions are minimal unless the slopes are steep. Cutting methods may include small clearcuttings or strip-cuttings for birch as well as selection and shelterwood cuttings.

1. *Poorly drained*—Softwoods are more productive than hardwoods. However, even softwood productivity in weight and volume is limited by excess water. I recommend minimal timber management: light selection or group selection cuttings during winter. Large openings may result in frost damage and herbaceous competition.

## Applications

### Approaches

Recognition of habitats such as those defined in this paper provides guidance on species to grow, regeneration cutting methods, potential productivity, and managerial constraints (problems with windthrow, logging, and roading). In the granitic areas of the southern White Mountains, the habitat definitions and interpretations in this publication should apply quite well. In other climatic/mineralogical zones, the definitions and interpretations will vary, and an effort will be required to develop and implement a habitat classification. Because of the great diversity that exists in New England in types of ownership and objectives of management, the effort will vary in intensity and detail. At least three approaches are possible depending upon the expertise and resources available.

1. *Biophysical classification*—Map a forest property (or the commercial forest land) into habitats or land types based on landform, vegetation, and soil materials. A small-scale map can be prepared for planning purposes, and it can be used with a more detailed map for project work. This approach requires both soils/geologic and botanical skills. A considerable amount of reconnaissance or plot work will be required to develop the habitat taxonomy and mapping criteria.

2. *Forest type classification*—Evaluation of stand potential may be based on forest type alone. The types listed in Table 1 provide a reasonable starting point because our work has already indicated that they are common species associations that sometimes reflect differences in site. However, the main limitations on the use of forest types alone are (1) lack of information on operability, and (2) differences that are not site related and cannot be readily duplicated because of past cutting history and other types of disturbances.

   This approach can be slightly refined through an assessment of soil moisture adequacy (Table 1). This soil moisture assessment provides a sharper definition of species suitability and operational constraints.

   Both approaches can be applied either through mapping of the forest property or by evaluating each stand as it is scheduled for silvicultural treatment.

3. *Forest type/forest soils classification*—If soils maps are available, they can be used as a starting basis for assessing habitat conditions. This approach can be undertaken as a mapping project or as a means to assess stands scheduled for silvicultural treatment. With a soils map in hand, a reconnaissance of the property will show how forest types such as those in Table 1 change in relation to changes in soil types or associations. Concentrate on fairly significant changes in forest type: valuable hardwoods, less valuable hardwoods, mixed woods, and softwood. And, it may be necessary to subdivide or lump soils units to reflect important change in forest condition.

   Notes should be taken on species and condition of overstory and understory; estimates of stocking and site index also can be taken if time warrants. Soils limitations are available from the soils map interpretations. Given this information, a forester can recognize and list the major soils-vegetation associations and develop logical interpretations on: species to favor, cutting methods to regenerate favored species, potential problems with competition from weeds, trees and shrubs, areas suited to intensive management, wildlife considerations, and limitations on roading and logging.

**Agricultural Areas**

The classification of habitat conditions in areas disturbed by agriculture requires special consideration because the vegetation often is different than usual. Old-field or pastured stands frequently contain more white pine, spruce, or hemlock than would usually be found on a given soil material. In evaluating such areas, the composition and quality of the existing vegetation can be used as a guide on how to treat the present stand. However, regeneration cutting practices should be based on an evaluation of soil materials and understory tree vegetation. It seems that such disturbed areas will begin to revert to the natural forest vegetation by the second rotation. For example, old-field white pine growing on a hardwood site will seldom regenerate successfully or easily to white pine because of hardwood competition.

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## List of Species

| *Scientific name* | *Common name* |
|---|---|
| *Trees:* | |
| *Abies balsamea* (L.) Mill. | Balsam fir |
| *Acer rubrum* L. | Red maple |
| *Acer saccharum* Marsh. | Sugar maple |
| *Betula alleghaniensis* Britton | Yellow birch |
| *Betula papyrifera* Marsh. | Paper birch |
| *Fagus grandifolia* Ehrh. | American beech |
| *Fraxinus americana* L. | White ash |
| *Picea rubens* Sarg. | Red spruce |
| *Pinus strobus* L. | White pine |
| *Tsuga canadensis* (L.) Carr. | Eastern hemlock |
| *Shrubs and small trees:* | |
| *Acer pensylvanicum* L. | Striped maple |
| *Gaultheria procumbens* L. | Wintergreen |
| *Kalmia angustifolia* L. | Sheep laurel |
| *Taxus canadensis* Marsh. | Canada yew |
| *Vaccinium angustifolium* Ait. | Low, sweet blueberry |
| *Viburnum alnifolium* Marsh. | Hobblebush |
| *Viburnum cassinoides* L. | Wild raisin |
| *Herbs:* | |
| *Aralia nudicaulis* L. | Sarsaparilla |
| *Clintonia borealis* (Ait.) Raf. | Clintonia |
| *Coptis groenlandica* (Oeder) Fern. | Goldthread |
| *Cypripedium acaule* Ait. | Moccasin-flower |
| *Dryopteris spinulosa* (O. F. Muell.) Watt. | Woodfern |
| *Lycopodium annotinum* L. | Clubmoss |
| *clavatum* L. | |
| *lucidulum* Michx. | |
| *Maianthemum canadense* Desf. | Wild lily-of-the-valley |
| *Medeola virginiana* L. | Indian cucumber |
| *Oxalis montana* Raf. | Wood sorrel |
| *Trientalis borealis* Raf. | Starflower |
| *Trillium erectum* L. | Trillium |
| *undulatum* Willd. | |
| *Uvularia sessilifolia* L. | Wild oats |
| *Sphagnum* spp. | Sphagnum |



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Leak, W. B. Habitat mapping and interpretation in New England. Broomall, PA: Northeast. For. Exp. Stn.; 1982; USDA For. Serv. Res. Pap. NE-496. 28 p.

Recommendations are given on the classification of forest land in New England on the basis of physiographic region, climate (elevation, latitude), mineralogy, and habitat. A habitat map for the Bartlett Experimental Forest in New Hampshire is presented based on landform, vegetation, and soil materials. For each habitat or group of habitats, data are presented on stand composition, understory vegetation, biomass, volume, and diameter development by species.

ODC: 182.22:114.33

**Keywords:** land classification, site, soils, northern hardwoods.

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