VEGETATION MAPPING AS A GUIDE TO BETTER SILVICULTURE

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INTRODUCTION

Difficult and challenging problems confront the forester today. Disastrous floods, critical water shortages, and the uninterrupted trend of forest depletion have focused attention on the important role forests play in the strength, economy, and prosperity of the Nation. Forests are increasingly prized for recreation, the protection they afford sources of water, and beneficial effects on stream flow and erosion. These factors contribute much to the health and well-being of the public; hence they should receive full consideration in the shaping of forest policy and management objectives.

The forester faces the very real problem of managing the forest resources at a profit and accomplishing this without injury to the productive powers and protective values of the soil and forest. This is a large order. It is tantamount to eating your cake and having it too.

Too often forestry is treated simply as an economic and engineering problem. When it is, cutting operations leave large areas exposed to wind and water. Soil porosity is decreased; recreational and other basic forest values are seriously impaired; the very elements that give forests their value are destroyed. Under such mismanagement, stand composition and quality deteriorate, and the forest becomes easy prey to a host of insects and diseases.

The spruce-fir forests are a good case in point. Continued clear-cutting of these forests has not only reduced their watershed-protection value, timber yield and quality; it has also greatly increased their susceptibility to insect attack. Clear-cutting has greatly increased the proportion of balsam fir, the favored host of the destructive spruce budworm. Witness also the rapid spread of birch die-back and beech scale with its accompanying Nectria canker in our northeastern hardwood forests. These pests have their origins in the consistent creaming of the forest for the best trees, leaving extensive areas dominated by cull and weakened trees—conditions ideal for the outbreak of native and introduced forest pests.

ECOLOGY THE BASIS FOR SOUND SILVICULTURE

How can we control the destructive agents that threaten to curtail and impair the usefulness of the forests? How can we promote and maintain conditions favorable to multiple use with a minimum of detriment to the forest?

The answer lies in the application of sound silviculture, silviculture based upon biological facts and principles. Intelligent management of our forests cannot be achieved without thorough knowledge of the behavior of tree species and stands. Foresters must know how specific forest types react to the various habitat factors if serious errors in silviculture are to be avoided.

Nature, unguided by man, produces a forest that is in complete harmony with the soil and the plant and animal life it supports. Such a forest is the climax forest toward which vegetation is always tending. Stable tree associations, characteristic of climax types, are best adjusted to meet the impact of antagonistic forces. Such forests are inherently healthy; under good management they are easily maintained in a high state of vigor, thus increasing their capacity to resist damage from insects, disease, and other destructive agents.

For every tree species or group of species, there is an optimum site. To try to grow species ill adapted to the site is but an open invitation to inroads by damaging pests. Nature vigorously protests against violation of her laws; disregarding them can lead only to serious trouble.

Numerous examples of such violations can be cited. Nectria canker occurs in certain northern hardwood stands in New England because they occupy sites that were originally in possession of pure softwoods or softwood-hardwood mixtures. Persistent cutting of softwoods only—and subsequent fires—made possible the complete occupation of these sites by northern hardwoods despite site factors adverse to their satisfactory development. To control this troublesome disease, foresters face the difficult task of reconverting these sites to their original composition. To attempt to maintain northern hardwoods on such sites is foolhardy. Another example is the damage the Tympanis canker and the European pine shoot moth are inflicting on red pine planted south of its natural range.

There is much to indicate that the more closely the forester adapts his silvicultural practices to the natural laws operating in a given site, the more simple become his problems of timber production. This is not meant to imply that the climax forest type necessarily represents the ideal toward which management should invariably be directed. In the Northeast, for example, fires, repeated cuttings, and other disturbances have so altered soil conditions that early establishment of species natural to the site may be difficult or even inadvisable. The impact of introduced foreign pests may force us to strive for compositions different from those that characterized the original site. Moreover, the high value of certain subclimax species such as Douglas-fir, black cherry, and white pine may justify efforts to maintain them as dominants in the stand. Nevertheless, compositions characteristic of climax associations should be used as guides for setting up silvicultural objectives. Such an approach is basically sound. Such silviculture will greatly expedite the attainment of the multi-purpose goals of forest management.

Mapping Forest Vegetation

Since climax forests provide the key to successful forest management, the first step in a program for placing the silviculture of a region on a firm basis is the classification of its forests into natural forest types. Such an undertaking in the Northeast is not easily accomplished. Opportunity for presenting a truly accurate picture of its original forest cover disappeared more than 200 years ago. Today much of the Northeast's forest cover is a hodge-podge of temporary types in varying stages of succession. This, however, need not deter attempts to reconstruct the climax forest associations of the region. Schemes for accomplishing this will be discussed in this paper.

In the past, men like Shantz, Zon, Clements, and others have taken a leading role in classifying and mapping the major units of vegetation in the United States. But these classifications are too broad and general in character to meet the needs of the average forester. To be of real value to a forester, type maps should be on a relatively large scale. More informative are the forest-type maps currently being made by the U. S. Forest Service in conjunction with its survey of the Nation's timber resources.

Such a survey is at present in progress in the Northeast. The latest techniques of aerial-photo interpretation are employed for determining timber volume and type and stand boundaries. With the aid of stereoscopes and checking on the ground, skilled interpreters can delineate forest types from aerial photos—with surprising speed and accuracy. This is particularly true with photos taken in the fall when leaves are in the process of coloring. Such photos afford maximum contrasts in shading, thus greatly facilitating identification of forest types and tree species.

But it should be borne in mind that type mapping of the sort conducted by the U. S. Forest Service is concerned primarily with the quantity and quality of the present timber crop. The basis for type classification is more one of economics than ecology. The intrinsic value of the tree species now making up the stands, and their potentialities as an industrial resource, are the controlling factors. The species or species group that constitutes 50 per cent or more of the timber stand determines the type designation. Under this scheme existing tree cover, irrespective of its ultimate development, provides the basis for type classification.

Such a classification is purely utilitarian, but justifiably so. Should the types have an ecological equivalent, this is wholly coincidental. Thus, it often occurs that sites radically different ecologically from one another nevertheless receive uniform type designations simply because the predominating species or species groups are currently the same. On the other hand, an ecologically uniform site may be divided into several cover types because of variation in stand composition occuring within the unit. In basic site classification, boundaries are stable.

Determining Climax Type from Current Forest Cover

Where the forests have undergone only minor modifications, cover-type maps may still provide the clue to the climax type. But in the Northeast, where forest disturbances have been rampant and radical, the original forest over extensive areas has undergone profound changes. For example, pure stands of old-field spruce and pine now occupy soils that prior to cultivation supported fine stands of hardwoods. On the other hand, years of cutting for spruce and fir only in mixed spruce-hardwood stands have converted extensive areas to pure hardwoods. Elsewhere forests of pin cherry, mountain

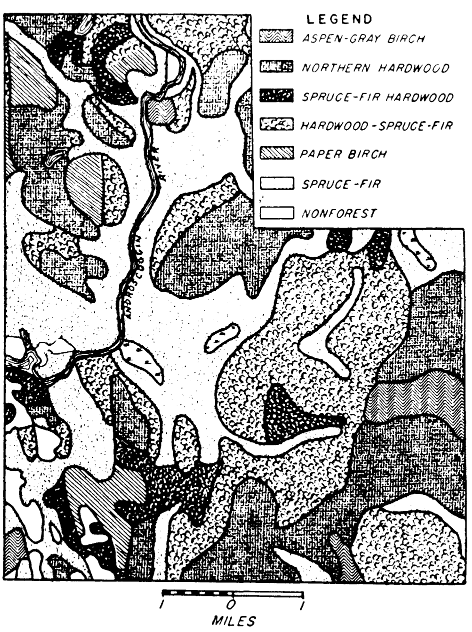

Fig. 1. Present forest cover types in a portion of the Milan, New Hampshire, quadrangle.

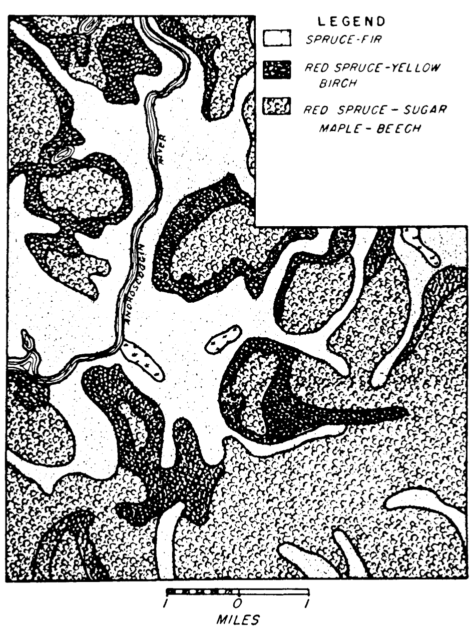

Fig. 2. Climax associations of the same area (Fig. 1), as interpreted from present cover types.

maple, aspen, and paper birch have taken possession of the land in the wake of heavy cutting, fires, and insect epidemics.

To interpret each and every temporary type variant in terms of climax associations calls for more knowledge about forest-type succession than has been gathered to date in the Northeast. However, as our fund of knowledge on forest succession increases, interpretation of temporary cover-types into climax associations can be undertaken with increased confidence. Illustrative of such an attempt are the two maps shown for portions of the Milan quadrangle in northern New Hampshire. Figure 1 is the cover-type map prepared by the Forest Survey unit of the Northeastern Forest Experiment Station. Figure 2 is an interpretation of these types into climax associations.

Determining Climax Type Through Site-type Classification

If cover-type maps solve only part of the problem of reconstructing the natural forests, what other recourse is there?

Cajander's (1926) site-type classification, in which indicator plants are used to identify site, presents one possibility. This system is based upon the thesis that specific plants (indicator plants) forming a part of the minor vegetation in the forest are associated with soil quality and natural succession. This concept recognizes that vegetative communities constitute distinct entities developed and arranged in accordance with definite biological laws and are not mere aggregations of plants brought together by chance. Such plant associations are well differentiated and are very constant for the same site type. Even though the stand is subjected to disturbance, the ground vegetation quickly comes back into equilibrium. A plant community is an excellent indicator of site, for it is the integration of all the factors that govern growth. Through this principle, it is possible to develop a classification of ground-vegetation types that are indicative of site-quality classes. From these, sites can be identified in terms of natural forest types.

Each plant association is characterized by one or several plants that are biologically dominant. It is true that a specific plant species may be common to several associations, but in one of them it is hardier and better able to withstand competition than its associates. It is this that provides the key to the recognition of various plant associations. It should not be assumed, however, that plant communities can always be recognized at a glance. One needs training and experience to be able to classify them correctly.

It is important to remember that in basic type delineation we are dealing with site factors that are presumed to obtain under climax conditions. It should not be inferred from this, however, that appraisal of existing site factors can be ignored, particularly those factors that enjoy a certain degree of stability. Slope, elevation, aspect, drainage, soil texture, soil depth and pH value are all of primary importance and should be kept in the foreground. The form and vigor of plant communities faithfully reflect the over-all effects of these factors. Although based on present conditions, they do provide a ready index for site-type determination.

Development of Site-type Classification in the Northeast

In the Northeast, considerable progress already has been made in defining the various forest types floristically. The Northeastern Station began detailed studies of the minor vegetation in the spruce-fir and northern hardwood types as early as 1924.[1] Other agencies followed with similar studies elsewhere in the region. Interest was stimulated further by the Finnish forester Ilvessalo

[1] These studies were based on milacre transects established in the major forest types of the spruce-fir and northern hardwood region. On each quadrant the frequency and comparative area in possession of each ground-cover species encountered was determined.

TABLE I. *Tentative forest-type—site-type classifications for spruce-fir and northern hardwood region of the Northeast*

Forest type	Society American Foresters type number	Topographic position	Minor-vegetation type*	Characteristic humus type	Ultimate forest-type group	Species to favor
Black spruce	23	Swamp	Sphagnum-Ledum	Peat or bog-like formation	Softwoods	Black spruce, Red spruce, Balsam fir
Red spruce	18	High slope	Oxalis-Hylocomium	Mainly greasy mor		
Balsam fir	22	Flat	Hylocomium-Hypnum Cornus-Maianthemum	Mainly felty mor		
Red spruce	18	Flat	Hylocomium-Hypnum Cornus-Maianthemum	Mainly felty mor		
Paper birch-red spruce-balsam fir	20	Upland flat	Cornus-Maianthemum	Greasy or felty mor	Mixed wood	Red spruce, Balsam fir, Yellow birch, Paper birch
Red spruce-yellow birch	16	Bench-gentle slope	Oxalis-Cornus	Greasy or felty mor		
Red spruce (old field)	18	Bench	Oxalis-Cornus	Old-field mor		
Red spruce-sugar maple-beech	17	Lower slope	Viburnum-Oxalis	Granular mor		
Red spruce (old field)	18	Well-drained sites	Viburnum-Oxalis	Old-field mor		
Yellow birch	15	Lower slope and benches	Viburnum-Lycopodium Viburnum	Granular mor and fine mull	Hardwoods	Sugar maple, Yellow birch, Red spruce, White ash, Black cherry, Basswood
Sugar maple-beech yellow birch	12	Low ridges, gentle slopes, deep soils	Viburnum-Taxus Oakesia-Maianthemum	Fine and medium mull		
Sugar maple	14	Coves, well-drained sites	Arisaema	Medium and coarse mull		

* *Sphagnum* spp., sphagnum moss; *Ledum groenlandicum*, Labrador tea; *Oxalis acetosella*, wood sorrel; *Hylocomium splendens*, feather moss; *Hypnum crista-castrensis*, feather moss; *Cornus canadensis*, bunchberry; *Maianthemum canadense*, Canada mayflower; *Viburnum alnifolium*, witch hobble; *Lycopodium lucidulum*, shiny clubmoss; *Taxus canadensis*, ground hemlock; *Oakesia sessilifolia*, oakesia; *Arisaema triphyllum*, jack-in-the-pulpit. Scientific nomenclature follows Gray's Manual, seventh edition, 1908, for flowering plants, and Grout's Mosses with a handlens, 1924, for mosses.

(1929) following his site-type classification work in Canada and the United States in 1927. Of particular note is Heimburger's (1934) work in the Adirondack region. In recent years the Dominion Forest Service and other Canadian research agencies have contributed liberally to the literature on site-type classification (Holman 1929, Brunkman 1936, Sisam 1938, Linteau 1940, Ray 1941).

A tentative forest-type—site-type classification for the spruce-fir and northern hardwood forests of western Maine, New Hampshire, Vermont, and the Adirondacks is presented in Table I. This classification is to a large degree based on the systematic studies of forest stands and minor vegetation conducted by the above-mentioned workers and agencies. The major forest and minor vegetation types and other features such as soil, drainage, and humus formations (Heiberg 1941) that help to identify them are also listed.

Application of the Site-type Theory to Spruce-fir—Northern Hardwood Region

It is pertinent at this stage to discuss briefly the potential value of floristic-type mapping as a guide to better silviculture. This can be done effectively by illustrating its application to a group of forest types common to the northeastern forests.

It will be seen (Table I) that the spruce fir-northern hardwood forests have been divided into three classes: (1) predominantly softwoods, (2) varying mixtures of softwoods and hardwoods, and (3) prodominantly hardwoods. Within these broad groups 12 forest types are now recognized (Society of American Foresters, 1932). Opposite each forest type is listed one or more ground-vegetation types. The ground-vegetation types here set up are arranged on a scale of ascending soil fertility. Thus each forest type is assigned its proper niche in the site-quality scale, as

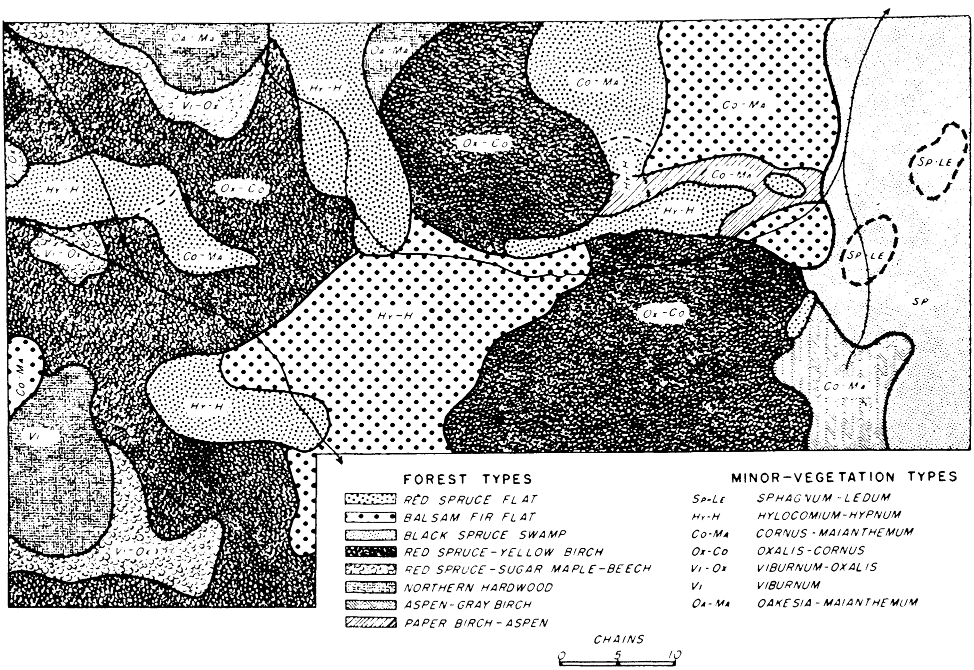

Fig. 3. Relationship between forest type and ground-vegetation type on a portion of the Gale River Experimental Forest, Grafton County, New Hampshire.

well as its ground-vegetation type equivalent.

For some forest types, two ground-vegetation types are listed. In such instances it may be assumed that at least two ecological types of different fertility levels comprise the forest type.

A ground-vegetation-type map is the practical equivalent of a type management map. Therein lies its real value, for ground-vegetation types can be translated directly into site potentialities. Thus they serve to identify the true forest characteristics of the site even though these have become masked. A map of a segment of the Gale River Experimental Forest in northern New Hampshire shown in Figure 3 illustrates the relationship existing between forest types and ground-vegetation types. It is of interest to note that four forest types have a minor vegetation type (Cornus-Maianthemum) common to them all. It may be assumed that these forest types constitute one biological entity and currently represent transitional stages in a successional series which if left undisturbed would ultimately attain a common climax (spruce-fir).[2] On the other hand, elsewhere on the map appear forest types containing more than one vegetation type. These are illustrations of forest types embracing two ecological entities of different fertility levels. Since correct site appraisal is the key to sound silviculture, ground-vegetation-type maps can be used as guides for proper orientation of silvicultural goals. Once the property has been classified into sites, the problem of setting up correct silvicultural goals and attaining the full productive capacity of the soil is made infinitely easier.

Let us consider for a moment the significance of this concept in terms of the forest types listed in the table. The ground-vegetation type equivalent of the red spruce-yellow birch type, for example, is Oxalis-Cornus. Even should the present tree cover, owing to the past cutting practices, consist mainly of hardwoods, the presence of *Oxalis acetosella* and *Cornus canadensis,* key indicators of softwood sites when they occur in combination, warns the forester against managing primarily for hardwoods. Here silviculture should be aimed at reestablishing the normal softwood representation. This is further indicated by the presence of abundant advance spruce-fir reproduction (Recknagel 1933).

On these sites, particularly where some *Viburnum alnifolium* comprises part of the ground vegetation, yellow birch attains good development as well as spruce and fir. Management for a red spruce-yellow birch association appears fully justified silviculturally. On the best soils of the Viburnum-Oxalis type, sugar maple is a legitimate objective, in addition to yellow birch. This is indicated by the preponderance of hardwood over conifer reproduction on these sites (Recknagel 1933). On the Sphagnum-Ledum, Oxalis-Hylocomium, and Hylocomium-Hypnum sites, the only logical and practical goal is softwood production.

On the other hand, to strive for spruce-fir dominance in the various Viburnum associations and the Oakesia-Maianthumun and Arisaema associations can lead only to

[2] The place in succession of the forest types depicted on the map are judged to be as follows:

Type name	*Place in succession*
Red spruce flat	A climax—spruce-fir
Balsam fir flat	Subclimax to spruce-fir
Black spruce swamp	A climax
Red spruce-yellow birch	A probable climax
Red spruce-sugar maple-beech	A climax
Northern hardwoods	A climax
Aspen-gray birch	A pioneer type followed eventually by spruce-fir
Paper birch-aspen	A pioneer type followed eventually by spruce-fir

disappointment. The deep, fertile soils characteristic of these sites strongly favor hardwoods. Under the keen competition these hardwoods exert, red spruce has little opportunity of becoming established, except through costly cultural measures. Here management should be directed to the production of high-quality hardwoods. This is indicated by the presence of such herbaceous plants as *Oakesia sessilifolia, Arisaema triphyllum, Impatiens biflora,* and *Laportea canadensis,* and such shrubby growth as *Viburnum alnifolium, Cornus alternifolia,* and *Ribes cynosbati.*

Techniques of Site-type Mapping

What are the possibilities of recognizing and mapping site type through aerial photo interpretation? Aerial photos are being successfully employed in cover-type mapping even to the extent of delineating stands into height, density, and condition classes. Where the forests still occur in their natural state, site-type delineation is an almost routine job of aerial photo interpretation, since climax forests directly express site quality.

But where the true character of the forest has become obscured and plant indicators are substituted as indices for site-type, the problem becomes more complex because ground vegetation cannot be identified on aerial photographs. Such identification can be greatly aided, however, through cross-classification of related factors. Certain basic factors visible on the photos and subject to appraisal are important in the determination of site.

Topography, for example, is one site factor that can readily be recognized on aerial photographs. Topography, in turn, strongly influences the character of the soil, a second important site factor. Stereoscopic study of topography in terms of aspect, location, elevation, and degree of slope provide excellent leads on broad soil groups. The experience of Moesner (1948), Hills (1950), and others indicates that skilled interpreters can readily classify forest areas into sites based on topographic position and soil groups. Losee (1942), in his attempts to map site-types from aerial photos, found that these soil patterns corresponded reasonably well with ground-vegetation types. This is not surprising: the site-type theory is essentially based on soil classification, indicator plants serving as indices of soil quality.

A skilled photo interpreter who can recognize site relationships, if further fortified by first-hand knowledge of the region and a thorough understanding of forest types and the significance of key tree species, should be able to prepare a site-type map that satisfactorily expresses the capabilities of the land for forest production. Within such broad basic sites, however, are likely to occur not one, but several different plant associations. Such a site-type map may well be a disappointment to those who insist that ground-vegetative types are the acme of site-type classification. Where a further breakdown is needed to bring out important site differences, these broad groupings provide a convenient framework.

If aerial photo analyses fail to provide the degree of site-type refinement needed for management purposes, it will be necessary to resort to ground mapping. Where ground-vegetation-type mapping is the objective, the techniques employed in regular forest-type mapping will be found adequate. In fact, the mapping should, if possible, be conducted in conjunction with the regular forest survey by assigning to the survey crew a skilled vegetation mapper. This makes for greater economy and accuracy.

Mapping can best be accomplished through the standardized system of parallel traverse lines at sufficient frequency to cover all variations in vegetation. At regular intervals along these lines, the mapper determines the ground-vegetation type, records it on his base map, sketching in the type boundaries as he proceeds. The mapper should be an experienced ecologist familiar with both the primary and subordinate vegetation of the region. He must also have a discerning eye for forest-type trends and succession.

From the silviculturist's point of view, the principal value of a site-type classification lies in its potentialities for identifying forest types biologically of the same value. The reaction of biologically equivalent types to long-term application of a given intensity of forest practice should be reasonably uniform. Thus an accurately developed site-type classification enables the forest manager to delineate his property into zones requiring uniform silvicultural treatment. From a forest manager's standpoint, only the extent to which the site-type classification successfully portrays biologically equivalent types justifies its application.

The site-type concept is not the one and only answer to the problem of site classification. It is not infallible. Certain radically disturbed areas may defy classification for an indeterminate period. Some foresters thoroughly familiar with the forest types of a region rely wholly on arboreal growth for site identification. Nevertheless, plant indicators used in conjunction with other site manifestations, such as tree height, tree associations, soils, and land forms, will aid in a more accurate delineation of forest sites. The dendrologist attempting to identify a tree solely by a bark sample welcomes a sample of its leaves, twigs, and flowers. So the silviculturist aiming at rational forest management welcomes any new significant factor that will enable him to identify forest site with a higher degree of accuracy.

Summary

The key to sound silviculture is ecology: intelligent management of our forests cannot be achieved without thorough knowledge of the behavior of tree species and stands and their relation to their habitat. For every species or group of species there is an optimum site. To try to grow species ill adapted to the site is an open invitation to inroads by damaging diseases and insects.

Attainment of productive, resistant forests can be greatly facilitated by striving for stand compositions that are natural to the sites. The first step in a program for placing the silviculture of a region on a firm basis is the classification of its forests into climax associations natural to the site. This is not a simple undertaking in regions where repeated cutting and fire have greatly altered the composition of the original forest.

The author describes two schemes for reconstructing the original forest associations in the spruce-fir and northern hardwood regions of the Northeast (1) through interpretation of the existing forest cover types and (2) through the use of indicator plants that form part of the minor vegetation in the forest. He presents a site-type classification showing what species the forest manager should favor on sites characterized by certain ground vegetation types. Techniques of site-type mapping are described briefly.

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