FOREST SITES — A DISCUSSION

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ABSTRACT

Site is not a simple concept. When studied in relation to forest growth it is found to be more than climate and topography and soil. It includes not only these and other environmental features, but also communities of plants and animals. More accurately it is found to be the dynamic and complex interrelation and interaction of all features, inorganic and organic, past and present, which have resulted in the given forest stand. The natural unit of biological study is site interpreted in this largest sense—corresponding to the "ecosystem" of ecologists—and the goal of the study is the understanding of relationships.

The role of physiography in the site complex is perhaps better appreciated than the role of historical circumstances, such as fire, or of vegetation itself, in conditioning the development of plant communities.

Examples of the effect of severity of fire on the genesis and development of mixedwood stands are given. The influence of vegetation on itself and on soil is discussed, particular attention being given to the phenomenon of frozen layers in the soil. A plan found useful in the field for collecting ecological data relevant to forest site studies is outlined.

At the present time much interest is being shown in Canada among foresters in the classification of forest sites, an interest arising from the general recognition that sound management of forests must be based on systematized knowledge of the relationships between trees and the lands on which they grow. Less well recognized, perhaps, is the complexity of the entire problem, and the consequent difficulty of working out a satisfactory system of classification. In the following article it is proposed to examine briefly the concept of site and to illustrate a few of the complications of site analysis in the field.

THE IDEA OF SITE

The common definition of site as the combination of biotic, climatic and soil conditions of an area in reference to capacity to produce forests, seems simple and straightforward. It suggests that with a few basic studies of plant and animal communities, of climate and soils, the cause-effect relationship between environment and forest will be laid bare. A very little field work

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soon shows that this expectation is over-optimistic. Everyone who has studied forest stands closely in the hope of explaining their general and unique features of composition, structure and rate of growth, appreciates the difficulty of comprehending and evaluating the many interacting effects of climate, soil, topography, biota and historical circumstances which together constitute "site" at a given time and place. Moreover when attention is focused on the forest itself and on the life histories of its constituent species, it becomes apparent that vegetation does not stand outside the system but is a part of it, conditioning, as it is conditioned by, the whole.

The opinion commonly held in the past that site is the simple sum of a number of discrete "factors"—light, heat, moisture, etc., each independent of the others—does not fit the facts. A more accurate picture is now being presented in a growing body of biological literature, showing the factors as mutually interacting parts of a whole, apart from which they have limited meaning. This realization has led to the concept of the ecosystem, i.e., site in its largest sense including vegetation, as the natural unit of biological study (Tansley, 1935).

The idea of the ecosystem becomes clearer when looked at from the point of view of words and our thought processes. By its nature, language breaks the perceived world into pieces and therefore leads us to think in terms of separate things—for example, "organism" as distinct from "environment," where actually there may be no real separation. In the same way the site factors (including those which appear to stem from vegetation itself) are distinct in name only; on the operational level they exist as an intricate web of interacting influences.

A few examples illustrate the trend away from fragmentation of the organism-environment complex in a search for simple causes. Cain (1944) pointed out that the environment is, in his term, "holocoenotic," which means that the factors do not act separately and independently but mutually and in balance. Watt (1947) has drawn attention to the necessity of considering vegetation as participating in the complex, reacting on the environment and directly influencing its own structure and development. In his latest publication, Hills (1952) has presented an able discussion of the wholeness of site and the consequent necessity of classifying physiographic, biologic and cultural features as they relate to one another within the whole system.

Study and analysis are of course facilitated by treating an ecosystem as if it consisted of separate parts, such as the environmental factors and the various forest species, but it should never be forgotten that these parts are not in fact separable, and after the analysis they must be put back together again. Similarly, for purposes of classification of site, certain features are abstracted from the whole to provide the frame of reference, but their prominence should not be interpreted as exclusive importance. To quote from Hills (op. cit.): "Physiographic features have been chosen to constitute the logical frame of reference for total site because they are the features which remain most easily recognizable in a world of constant

change. *This does not mean that they are considered to be the most important site features at all times nor necessarily at any time.*"

Possibly the most important concept for the biologist is that of inter-relatedness and organization in the phenomena which he studies. This being so, it follows that basic studies in forest sites must be concerned with the search for relationships which underlie the dynamic "balance and change" observable in forest stands.

In the following paragraphs an attempt is made to trace a few of the significant aspects of developing forest communities with particular stress on the vegetation as it influences itself and the soil. In the light of what has been said above, it need hardly be pointed out that there is no intention here of minimizing the significance of physiographic features in the site complex. However it seems to the writer that an accent on the role of vegetation is perhaps justified in order to restore a balance to the concept of total site. The examples to be used are not all real in the sense of being demonstrable in one place, but neither are they fictitious—they are based on the impressions gained during three years of study of white spruce regeneration in the southern boreal forests of Manitoba and Saskatchewan.

DEVELOPMENT OF MIXED AND SOFTWOOD STANDS

In the "B18 Mixedwood" section of the boreal forest, stands usually have their genesis in fire. The severity of the burn has a profound influence on the subsequent forest due to differences in the habits of reproduction of the two main tree species, aspen poplar and white spruce. Light fires, which merely burn over the top of the humus layer, stimulate suckering of aspen and encourage a vigorous growth of perennial minor species (shrubs and herbs) on the forest floor. Spruce is dependent on small seed for its regeneration, therefore it finds the above conditions of severe competition unfavorable for establishment. The result is generally the development of a pure poplar stand. On the other hand intense fires, by consuming the entire humus layer, simultaneously reduce the vigor of the aspen suckers, eliminate most of the minor vegetation and expose mineral soil, making possible the rapid invasion of spruce—provided always that seed is blown in and subsequent climatic conditions are favorable. In the latter eventuality, a spruce stand with scattered poplar is likely to result. The initial forest type in a given place may not depend therefore on particular features of site so much as on chance fire, the severity of which is related among other things to type of humus layer, the latter related in its turn to prior cover type as well as to local climate, topography, and soil, etc.

Two stands such as are described above will differ considerably in their development. The "light fire" hardwood stand will probably be invaded by spruce which, after twenty or thirty years, finds a suitable seed bed in the form of decayed, fire-killed logs. Slowly an uneven-aged mixedwood type will develop, and finally with the dying out of the aspen there will appear a rather open softwood type in which the mature spruce are of large size. By

contrast the "intense fire" even-aged softwood stand will at maturity consist of many more stems, though individuals will not be particularly large in girth due to the initially high density.

From the point of view of site analysis, several complications involving growth rate enter the picture as the stands develop. For example, the spruce that invade on decayed wood under an aspen overstory will grow very slowly at first, taking twenty to thirty (or more) years to reach breast height, while seedlings on a clean burn will attain the same height in ten or fifteen years, other things being equal. Therefore the relationship between total age and height may vary considerably on equivalent areas according to stand history. To a certain extent this particular difficulty in growth studies may be overcome by relating age-at-breast-height to total height since the influence of the initial substratum may be expected to diminish as the trees grow out of the seedling stage.

Another complication, to which mixedwood stands are particularly liable, is the suppression of spruce by the poplar. Where the two species are established together on normal sites, the poplar usually forms the overstory due to its initially faster growth rate. The spruce eventually catches up, but as it grows into the hardwood canopy its leaders are abraded and broken by the swaying poplar branches. In recent papers Kabzems (1952) and Kagis (1952) have discussed the prevalence of this damage in young mixed stands in Saskatchewan. Kagis has estimated that about 58 per cent of the spruce in the 50- to 60-year-old stands suffer a certain amount of top whipping. It seems

FIGURE 1

Growth of two White Spruce before, during (dotted lines) and after suppression by Aspen overstory (stem analyses in 1952)

likely that in dense poplar stands a much higher percentage will be adversely affected at one or another stage of development. Kabzems states that as a result of the initial suppression by poplar, "the average height of white spruce in mixed stands does not reach the height of white spruce in pure or softwood stands." The effects of suppression are illustrated graphically in Figure I. The data are from stem analyses of trees which had clearly suffered suppression by aspen.

Note that when the spruce were about 40 feet tall their growth was slowed to several inches per year by leader whip. Not only the height growth, but also diameter growth of spruce is reduced by poplar competition, as has been proved in the field by comparing trees growing beside aspen with trees of the same age located nearby but having unhampered crown development. Of course, in densely stocked softwood stands diameter growth is also reduced due to intra-specific competition, and the writer has never seen such stands produce stems of large diameter.

MINOR VEGETATION AND STAND DEVELOPMENT

Up to this point the development of the dominant trees in the two forest types has been emphasized to show how composition, density and rate of growth depend on, or at least stem from, the nature of the originating disturbance—in this case on the severity of fire. There is, of course, a parallel and an equally distinctive development of the undergrowth, initiated by the fire and conditioned thereafter by the forest overstory. The dependence of minor vegetation on tree cover is generally conceded, except where stands are very open. Common subsidiary communities of poplar and mixed-wood stands are those characterized by tall shrubs (e.g. *Viburnum*, *Corylus*, *Prunus*), and by tall broadleaf herbs (e.g. *Aralia*, *Aster*, *Epilobium*, *Solidago*), while typical of the white spruce (softwood) stands are small evergreen herbs (e.g. *Linnaea*, *Pyrola*, *Goodyera*, *Lycopodium*), and feather mosses (e.g. *Hylocomium*, *Hypnum*, *Calliergon*, *Dicranum*). These layer communities are to a large extent reflections of differences in ecoclimate (i.e. the local conditions of light, temperature, moisture, nutrients) which in turn are related to density of canopy, quality of humus layer, root competition in the upper soil, etc.

One contributing cause of variations in minor vegetation between forest types seems to have been overlooked in the past—it is the mechanical action of accumulating litter on plants of the forest floor. Field observations have shown that much of the mortality of the initially small white spruce seedlings under hardwood and mixedwood stands can be attributed directly to smothering by poplar leaves. Undoubtedly other small plants which are similarly limited in powers of vertical growth, or whose growth habit is mainly in the horizontal plane (rosette and procumbent plants), are eliminated in the same way from types characterized by a large annual fall of broad leaves. This may provide a partial explanation for the absence of such species as *Pyrola*

chlorantha, *Moneses uniflora* and *Goodyera repens* from hardwood stands, and their fidelity to coniferous stands.

SOIL AND STAND DEVELOPMENT

If attention is turned from vegetation to soil, the complexities appear again, though in a different form. Soil, like vegetation, is a part of the ecosystem, conditioned in its development by the interaction over periods of time of climate, topography, parent material, animals and plants. Hence to understand why a given profile exists and to interpret it as an indicator of forest growth potential is perhaps as difficult as to understand and interpret plant communities for the same purpose.

Soil profiles are not necessarily stable. In the example used before, severe fire can have an appreciable effect within a few years on a soil profile. Instances have been seen where complete burning of the humus layer over a grey-wooded soil resulted very rapidly in a color change of the A2 horizon from ashy grey to blackish grey, and a pH change in the same horizon from strongly acid to alkaline. The developing post-fire vegetation soon exerts its influence, species composition and density determining the type and amount of organic matter deposited on top of and in the mineral soil. At the same time the intensity of leaching, the soil climate, etc., are affected, and appropriate changes take place in the profile.

A particularly interesting relationship between vegetation and soil has come to light during the last few years of field work in the B18 Mixedwoods. It is the occurrence of frozen layers in the subsoil under various forest stands.

Several examples are given below:

1. Date: June 30, 1950

Location: Riding Mountain National Park, Manitoba.

Forestry Branch Research Area, North shore Clear Lake.

Cover Type: Aspen stand with scattered large spruce.

Some spruce regeneration 14 to 40 years old in dense thickets.

Soil: A black "meadow" profile developed on clay till.

Frozen layer encountered at about four feet depth in pit dug in the middle of a spruce "thicket". The frozen layer was hard, but when chopped out in pieces it rapidly thawed and fell apart into soft wet granules.

2. Date: July 16, 1952

Location: Porcupine Forest Reserve, Saskatchewan.

Armit Area; 1½ miles west and 1½ miles south of "Mile 15".

Cover Type: Cut-over spruce-poplar type, now quite open but having some small spruce regeneration in thickets.

Soil: A dark "meadow" profile on clay till.

Frozen layer encountered at about two feet depth in the middle of a spruce sapling thicket. No frozen layer in the soil of adjacent openings.

3. Date: July 16, 1952

Location: Porcupine Forest Reserve, Saskatchewan.

Armit Area, near junction of roads to Armit and Westgate.

Cover Type: Mature aspen

Soil: A grey-black profile on silty clay loam.

Frozen layer encountered at about five feet depth. It was noticed that free water was present in the profile between four and five feet depth, i.e. a water table was perched on the ice pan.

The three examples, taken from field notes, illustrate what may be a phenomenon of widespread occurrence in northern forests. It is common knowledge that in the B18 section ice sometimes lasts through the summer under the moss in black spruce and tamarack swamps, but little seems to be known about the persistence of frozen soil layers under white spruce and poplar on other sites. If this condition *is* common then its importance to the problems of site may be great, particularly in the light of the third example above which clearly showed that a frozen stratum can influence moisture regime by impeding drainage.

The profound influence of forest cover on soil temperature is unquestioned. Particularly pertinent to the present discussion are studies by Belotelkin (1941), and Ronge as quoted by Tamm (1950). In New Hampshire, Belotelkin compared freezing of the ground under spruce and hardwood stands, and in the open, over a period of three years, and found that the soil froze deepest and thawed latest in the spruce types. In northern Sweden Ronge found wide differences under dense and thinned stands of spruce—in the former where the snow covering on the ground remained thin throughout the winter, a frozen layer became markedly developed and persisted well into July. Suppose then the following sequence of events in our northern mixed-wood section: Given a moist soil and low winter temperatures—the result will be a frozen stratum which forms first at the surface of the ground and grows downward, its maximum thickness depending on the winter climate, texture of the soil, the insulating effects of humus and snow layers, etc. With the return of warmer weather in the spring, the frozen layer will thaw from the top downward (and possibly also from the bottom upward), the rate of thaw being influenced among other things by the density of the forest canopy and by the quantity and quality of the humus layer. As long as the frozen layer exists it will act as a "pan", holding the rains of spring and early summer above it, tending to make the upper profile wet. Along in July the ice pan will melt and disappear, and for the remainder of the season drainage of the profile will be improved. On land cleared by cutting or burning the frozen stratum will melt away early in the spring, resulting in better profile drainage (i.e. drier soil) than that which obtains under forest cover, other things being equal. With the same proviso, profile drainage will improve earlier in the summer under hardwood than under dense softwood stands.

Apart from the actual finding of frozen ground while digging soil pits, certain profile features have been noticed which strongly suggest that ice pans have been present. Incipient gleization of the A and B horizons has been observed in soils whose physical characteristics are such that one would not hesitate to classify them as "very well drained". No apparent reason for the state of impeded drainage, suggested by the brownish mottling in the A and B horizons, can be seen either in texture or structure of these profiles. Temporary ice pans in the soil would furnish a reasonable explanation.

Though there is an element of conjecture in this discussion, it does serve to show how the moisture regime and profile appearance of a soil may reflect the influence of vegetation.

CONCLUDING REMARKS

In the foregoing discussion the interpretation of events on the basis of vegetation has purposely been emphasized. It would not be difficult to choose other features of the site complex and trace the same events to them. As an example, consider the role of soil texture—it seems likely in the light of certain field observations that severity of fire is often related to texture of the surface soil horizons. It is reasonable to assume that the humus layer over a well-drained sandy soil will dry out more rapidly than the humus layer over a clay, hence the probability of a clear burn is greater over light-textured soils. Following the former arguments that spruce invades most easily on bare mineral soil, it might be expected that softwood rather than hardwood or mixedwood stands would commonly develop on light-textured soils, and this can actually be observed in some areas. Again, the texture of a soil influences its temperature relations. Heavy-textured soils are commonly wet (here topography ties in too) and wet soils are cold soils. Therefore frozen layers should persist longer in clay than in sandy soils as has been observed.

It is difficult to escape the conclusion that all features of total site are important and need to be taken into account before the whole can be interpreted in a satisfactory way. Where then should site studies begin? Actually it may not matter where they begin so long as the investigator realizes the nature of the problem and is willing to follow out its various ramifications. One man may choose to concentrate on studies of vegetation in all its phases of succession; eventually he will find that a knowledge of soils is essential to interpret what he sees. Another may have a predilection for the study of soil moisture regimes, but he will soon be led to an examination of the role of plant communities.

FOREST SITE DATA

During several years of field work on the problem of white spruce regeneration, a plan was developed for collecting information on many of the significant features of site. An outline is presented below, not with any claim to completeness, but with the thought that some may find it useful as a framework within which improvements can be made. A similar basic description has been outlined in less detail by Kabzems (1951).

The unit of study has been the plot, usually 1/5th acre in size, set out in such a way as to sample a relatively homogeneous part of a selected forest community. The advantage of the plot is that it directs close scrutiny to a limited area, with the result that the study becomes more intensive than would otherwise be the case. Also the comparison of different stands is facilitated.

1. The stand as it is now

Each study begins with a forest stand whose origin, present status and future potentialities are not known. The first step is to get a quantitative idea of what exists now, the composition, density, volume, rate of growth and vigour of the stand. Later, from this knowledge, it may be possible to gauge past and future development.

The following notes are taken:

- (a) Tally of all trees by species in inch-diameter classes.
- (b) For selected individuals of each species—the diameter at breast height, age at breast height, and total height.
- (c) Stem analyses of several dominants.
- (d) Comparative notes on radial growth, taken from the increment cores used to establish tree ages.
- (e) Vigor and health of the stand as judged from the growth measurements as well as from such things as the appearance of the crowns (e.g. conical or club tops in spruce), soundness of the trunks, etc.
- (f) Estimate of previous mortality in the stand as judged from the amount of dead wood standing and down.

2. The stand in its dynamic aspects

Various lines can be explored to learn the genesis of the stand, the effects on it of disturbance, its relationship through succession to other types:

- (a) Nature of the initiating disturbance as indicated by fire scars, wind-fall, cut stumps.
- (b) Time since disturbance—from fire scars, release rings on trees close to cut stumps, age of dominant aspen.
- (c) Records of fire are often preserved as ashy lines with charcoal in the humus layer or between humus layer and mineral soil. Charcoal boiled in paraffin and allowed to "set" can be sectioned and identified under a microscope—a clue to prior stand composition.
- (d) Evidence of antecedent communities can sometimes be found in the humus layer, for example under spruce stands at the bottom of the humus layer have been found chokecherry pits, and in other cases fragments of broad-leaved aquatic plants and snail shells.
- (e) Substratum of dominant trees—dig under conifers and note whether they seeded in on bare mineral soil, ashy soil, decayed wood, or humus.

(f) It is important to know, in our mixed stands at least, the comparative ages of the different species. It may be necessary to gather a good deal of age data in order to find whether the stand is even-aged throughout (invasion in one wave), even-aged in patches, several-aged throughout, etc.

(g) A comparison with adjacent communities of different ages but with the same topographic and soil conditions points to probable effects of disturbance and the direction of succession.

3. Reproduction of trees

A study of seedlings and saplings throws light on stand development, past, present and future.

(a) Tally of seedlings by species in one-foot height classes. This is generally done over the entire plot unless seedlings are very abundant, in which case the tally is confined to the 20 milacre quadrats used to sample minor vegetation as described in the next section. Relative abundance and vigor of seedlings of the different species indicate the probable succession.

(b) Stem analyses of selected seedlings and saplings, to show rate of growth at this critical stage of development.

(c) Origin of the reproduction whether from root sprouts or from seed (if the latter, from what seed source). Notes are made on relationships between establishment and micro-habitat, wherever the influence of topography, climate and substratum can be discerned.

(d) Factors entering into mortality and survival are studied through an examination of rooting habits, vigor, rate of growth, biotic influences. It has been found possible to determine years of damage to terminal or lateral branch tips by counting back the annual bud scars of adjacent undamaged laterals.

4. Undergrowth or minor vegetation

Study of the undergrowth as an integral part of the forest community is of importance for an understanding of tree reproduction. With more knowledge it may be possible to use the entire plant community as an indicator of site productivity.

Data have been gathered in 20 milacre quadrats mechanically spaced over the plot. A special field sheet has been designed, down the left side of which the shrubs, grasses, herbs and mosses are listed. Twenty columns are provided, one for each quadrat, and here the species are tallied according to cover-abundance using the following scale (after Braun-Blanquet):

- + covering less than 1 per cent of the ground
- 1 covering 1 to 5 per cent of the ground
- 2 covering 5 to 25 per cent of the ground
- 3 covering 25 to 50 per cent of the ground
- 4 covering 50 to 75 per cent of the ground
- 5 covering 75 to 100 per cent of the ground

When the tally is complete, the frequency of occurrence and the total abundance is calculated for each species at the right side of the page. Rare plants seen on the plot, but not occurring in the quadrats, are added to the

list. A card is then prepared for the plot listing the species in decreasing order of importance using the frequency and abundance data. It is then possible to see at a glance what "layer community" dominates—whether shrub, herb, grass or moss—and what are the abundant, common, occasional, and rare plants. Comparison of different plots is facilitated, and the study of constancy and fidelity of species is simplified.

Since the height of dominant plants sometimes bears a significant relationship to the soil, it has been the practice to note the average height of the (usually few) very abundant species, for example: *Corylus* 48", *Aralia* 18".

5. Physiography

In the physical environment are found many significant features which condition forest growth. Here the study has followed the system of Hills (1950, 1952). The following brief outline shows what information has been considered of greatest value:

(a) Climatic region within which the study is made—as yet there is little known on this aspect of site.

(b) Physiographic region—some information is available in geological bulletins and in soil survey reports.

(c) Topographic conditions (slope, aspect, exposure) and local climate affecting the stand which is being examined.

(d) The soil—a pit is dug on the plot for profile examination. The soil description sheet has space for a sketch of the profile and for the following notes:

1. Identification of the soil association based on profile color and on nature of the parent material—e.g. the Sylvania association: grey podzolic fine textured sandy loam soil developed on sandy alluvial-lacustrine deposits.
2. Description of the profile (the association member):
Humus layer—its thickness, quality, etc.
Mineral soil horizons—their color, texture, structure, pH, stoniness, etc.
Pore pattern of the parent material.
Moisture regime and ground water level; indications of gleization.
Temperatures of the different horizons.
3. The rooting zone for trees—growth can sometimes be related to depth of rooting.

The above information provides a broad basis for the examination of numerous relationships within the ecosystem. When more field work has been carried out along such ecological lines, it should be possible by study and comparison of results to discover recurring patterns in developing forest communities. Until that time, classifications of site will of necessity be tentative and incomplete.

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