SITE QUALITY AND THE pH FACTOR

By

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A Thesis

Presented to the Faculty

of the

School of Forestry

Oregon State College

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science

December, 1947

Approved:

Redacted for privacy

Professor of Forestry

FOREWORD

The results presented in this paper are not ones secured by the author himself but rather are a condensation of findings of various authors. Although the findings may not be of a definite nature, it is hoped that the results may encourage further research into the subject.

I wish to take this opportunity to thank E. V. Dannen, Assistant Professor of Soils, and George Barnes, Professor of Forestry, for advice in connection with this report.

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INTRODUCTION

In considering the foundations of silviculture from an ecological viewpoint, the forest must necessarily be regarded as a definite biological entity composed of innumerable organisms; and its environment, as that of any organism, is the resultant of all the external conditions that influence it[2]. Thus, the forest and its environment can be understood only by dividing this environment into its various components. In American forestry work this is known as site.

Both the kind and quantity of vegetation produced per unit of area are correlated with site factors. A change in one or more of these environmental factors causes a change in site quality. This is a term used by foresters to indicate the productive capacity of an area of forest land, usually for a given species or a combination of species[2].

It has always been the practice in the past to base site quality on yield rather than to work it out from factors known to influence it. Although it is generally recognized that site quality is determined by edaphic, physiographic and biotic factors, very little has been done to determine site quality through their use. Rather, site is usually determined by a measure of the rate of growth of an existing stand.

Several means of determining site quality have been proposed. Probably the one in most common usage today is that of determining the height in feet of the average dominant tree in a stand at some arbitrarily chosen standard age, usually 50 or 100 years. This method gives reasonably satisfactory results in normally stocked stands.

Another method that has been developed is the use of plant indicators. This method, first developed by Cajander of Finland, gives

indications of being a real contribution to determining site quality[2]. This theory has been tried to a limited extent by Korstian and Ihessalo. The principal difficulty to date has been the identification of useful plant indicators.

Still a third method which has been tried in only a few known instances is the use of the pH factor. Although it is known that soil acidity does affect tree growth, it has never been determined just how important it is.

While much has been done in the study of soil characteristics as they affect agricultural crops, little has been done with forest soils. Probably the main reason for a lack of studies along this line was the seemingly inexhaustibility of forests. Now that the "golden era" is passing, more will undoubtedly be done.

The purpose of this study was to pick one isolated phase of soil characteristics and to determine if there was enough connection to warrant further study into the matter. The pH factor was selected and a study made of all known reports to determine if there was a definite connection between it and site quality. It is hoped that this relatively simple factor might prove the key to the whole puzzle.

IMPORTANCE OF THE STUDY

The importance of such a study can hardly be overemphasized. In European forests, records have been kept of relatively small tracts for years. By consulting these records, it is relatively easy to determine the growth characteristics of any particular area. However, in this country it is not so simple. With us, this phase of forestry is relatively new.

Prior to the last few years, little attention was paid to the ability of an area to grow trees well. It has been largely a system of purchase of existing stands ready to be marketed and the capabilities of the land were of little importance. But this era is rapidly passing and a new one is approaching.

As long as an existing stand can be studied, the problem of site quality is a minor one. But with large portions of our best forest land already cutover or burned over, the question of just which land is most productive is of primary importance. If some relatively simple yet accurate method of determining site on bare land can be developed, many of our forest owners can proceed with more confidence. Knowing which land has the best possibilities before it is necessary to spend money on it would pave the way for a greater era of private forestry.

It was with these problems in mind that this study was conducted. It was not conducted with the aim of producing a definite method but was planned in the hope that the results would be encouraging enough to indicate further research to be in order.

Lacking facilities to secure proof of a definite trend, it was hoped, through presentation of sufficient information on the subject, to initiate a study into soil factors. Although the field is new, it is a broad one and should furnish plenty of opportunity to develop some new ideas.

BACKGROUND TO SUBJECT

General

Each site seems to possess certain essential factors which makes that site different from others. Although the weighted value of each of these factors cannot be determined with any degree of accuracy, they can be divided in four categories[2]:

1. Climatic factors
2. Edaphic factors
3. Physiographic factors
4. Biotic factors

Although these factors are generally recognized as being all important to site quality, no one has been able to make a satisfactory system of using them to determine site quality. Yet it seems obvious that if the proper combination of these factors could be found, an easier method of determining site quality would result.

Soil Acidity

The importance of soil acidity has long been a subject of study by German foresters. It has been established that most forest trees, and especially those of the Douglas fir type, do not do well in soils that are alkaline. However, it seems probable that seedlings are more sensitive to acidity than are older trees[1].

Alkaline soils definitely seem to support grasses rather than trees. This fact was established by Ruffin as early as 1855. However, the unfavorable effect of alkalinity may be due not only to the toxicity of the hydroxyl ions but also to the unavailability of nutrients such as phosphorous, iron or manganese[1].

Measurement of the pH Factor

The measurement of soil acidity usually involves the actual or active acidity of soil-water suspensions or water extracts. Electrometric methods are more precise but equipment was not available for use. In these experiments, water extract was used in pH determination.

In pure water, hydrogen ions and hydroxyl ions are present in exceedingly low, but equal, concentrations. In 10,000,000 liters of pure water at 22° C, there is 1 gram of hydrogen ions and 17 grams of hydroxyl ions. The concentration of hydrogen ions, therefore, is 1/10,000,000 or decimally, .0000001. Obviously this is an awkward method of expressing such low concentrations. A far more convenient method is the use of pH values. This method, developed by a Danish chemist, Sorensen, uses the logarithm of the reciprocal of the hydrogen ion concentration. For example, in a concentration of pure water, the ratio is 1/10,000,000. The reciprocal is 10,000,000 and the logarithm of this number is 7. Consequently, the pH factor of pure water is 7.

It must be remembered that changes in pH values are geometric and not arithmetic. Solutions having values of 6, 5, 4 and 3, respectively, are 10, 100, 1000, and 10,000 times as acid as pure water. In other words, the hydrogen-ion concentration is 10, 100, 1000 and 10,000 times as great. As the hydrogen-ion concentration (acidity) increases, the pH value decreases and vice versa.

Rather narrow pH limits are specified for optimum development of various species. In view of the fact that optimum pH values vary in different soil types, the only accurate deductions can be made through the study of each soil type separately. The best known list of such pH preferences is that of Spurway in Technical Bulletin 132,

Michigan Agriculture Experiment Station.

Previous Studies

Although many experts have made research on soil acidity, very little attempt has been made to tie them in with site quality. There is a great deal of information on the definition of acidity, its effect on plants, its sources, and other related subjects. Many of the studies have been made by foresters, mostly German and French. A few American foresters such as Toumey have been making experiments but it is still a relatively new field.

Sources of Soil Acidity. Soil acidity may be caused by the presence of either free organic or inorganic acids; or by leaching processes which remove the alkaline normally present. Soils are saturated with hydrogen which gives an acid reaction; or, are base-saturated causing either neutral or alkaline conditions.

The normal condition of soils in dry areas is to be alkaline while those in areas of high rainfall are usually acid. The acid condition is caused by the leaching of bases from the soil as the excess moisture drains off. As most forests are in regions of relatively high rainfall, almost all forest soils are acid.

The decomposition of forest litter is a great source of acid[3]. Almost all coniferous litter is acid while hardwoods are less acid[4]. As litter is constantly added to coniferous forest cover, soil acidity continues to increase as long as the forest cover remains uninterrupted. Moisture percolating through the soil dissolves a large portion of the losses in the litter, leaving an acid condition. As this continues, the surface becomes more and more acid. The leached portions are deposited a foot or two under the surface forming a hardpan. This

process is called podzolization, which is the condition of most of the forest soils in this area.

Another condition which may create an acid condition is the anaerobic condition of the soil[5]. This is the condition of soil in bogs and other areas with an excess of soil water. Under these conditions of poor aeration, decay of the raw humus is not complete, thus creating an acid condition[5].

Factors Affecting pH Values. Although it is known that pH values change somewhat during the year, the exact nature of the change is not known. G. R. Clarke stated that in England, the pH was highest during the period of most active tree growth. However, Nehring, working in Germany, recorded the highest values in winter and the lowest in the summer. Joffe reported still a third finding that the highest readings were in autumn. Although the changes do not usually exceed 0-8pH, this is large enough to require a different set of values for each time of year. Also, the wide divergence in results seems to indicate that accurate periodic results would be hard to obtain. Also, it may be possible that the trend in results may not be constant for different areas.

Soils representing the different groups are known to differ materially in acidity. Surveys have shown that podzol soils are most acid, followed in order of decreasing acidity by lateric soils, chernozem soils, and desert soils. The chernozem soils are slightly acid to neutral, and all desert soils are alkaline[6].

Marked differences are frequently observed in the pH of different horizons of a given soil. The A horizon is usually most acid in most podzolic soils with the B horizon having the least. This

is caused by the translocation of bases from the A horizon, as a result of leaching, to the B horizon[1].

Vegetation exerts a strong influence on soil acidity through its litter and through its affect on soil temperature and moisture. Most soils supporting conifers tend to be more acid than those supporting hardwoods[7]. While most conifer stands tend to increase acidity, most hardwood stands tend to decrease it. Cajander in Finland found that continued planting of spruce had created a condition of acidity so severe as to prevent reproduction of spruce on the area[12]. Species whose foliage contains a high content of bases tend to prevent the development of excessive acidity in the surface layers. The introduction of hardwoods in conifer stands seems to result in decreased acidity[1]. This may necessitate a change in silvicultural practices in some areas of intensive management. The rotational trend of forest types was noted by the author in some of the Spruce-Beech forests of Germany and a reduction of acidity may be the reason for it.

Silvicultural operations, such as heavy thinnings and reproduction cuttings, are known to result in decreased soil acidity in some instances. Fertile soil responds more readily than infertile soils. The reduction in acidity appears to result from higher soil temperature, more precipitation reaching the soil, and changes in soil flora and fauna. Fires generally result in a reduction of soil acidity because of ashing of part of the organic matter and possibly because of decomposition of soil minerals.

Influence of Acidity on Plant Growth. According to Lutz and Chandler, there is little evidence that low pH is responsible for the poor growth of forest trees. Even in agricultural plants, which are

probably more sensitive than forest trees, low yields seem to occur only at exceedingly low pH values (pH 3 or less)[1]. However, it is known that the addition of lime to certain soils markedly increases yields. Several investigators have found that low pH values for forest soils are not incompatible with high site quality.

Although the direct effects of soil acidity appear unimportant, the same statement cannot be made of indirect effects. Just how important these changes may be cannot be stated. It seems probable, however, that seedlings are more sensitive than older trees[1].

Acid soils seem to be more favorable for the development of forest vegetation than do alkaline soils. Calcerous soils almost invariably support grasses[8]. However, it may be argued that the general absence of commercial forests is due to the lack of moisture and not to the nature of the soil. Frequently this might be true but certain areas, such as the "Black Belt" in Alabama and Mississippi in forested regions, still seem to be more favorable for grass than trees.

In certain cases, soil acidity may have a very advantageous effect under certain conditions. In many nurseries, acidity is encouraged and the pH value is kept below 6.5 to prevent damping-off fungi, eelworms and other organisms[9].

INDIVIDUAL STUDIES

Great Basin Experiment Station

Experiments were conducted at the Great Basin Experiment Station in Utah to determine the effect of acidity on the survival of Western yellow pine. Although this is not directly influential in site determination, it does show the influence of acidity on the establishment of a certain forest type.

These experiments were conducted to determine the effect of the different soil types on regeneration of Western yellow pine. A series of six different soils of varying degrees of acidity were secured and Western yellow pine seed was planted in each.

The first soil was a lodgepole pine type taken near Big Springs, Idaho. It was of basaltic origin from the Yellowstone plateau and was very acid.

The second was called "manzanita" soil and was secured from the manzanita bush type in Ephraim Canyon, Utah. The soil was derived from reddish brown sandstone rock and was slightly acid.

The third type was called a "white fir" soil as it was taken from that type of cover. The reaction was almost exactly neutral.

The fourth type was a loamy fine sand from a natural yellow pine area of the Mauti National Forest. The soil was slightly alkaline.

The fifth soil was called "aspen" soil and was taken from an aspen type near the Great Basin Experiment Station. It was decidedly alkaline in reaction.

At the time the work was started (1914), the present day methods of determining soil acidity were not developed. In these experiments, the lime-water method was used. In this method, lime

and water are added until a neutral reaction results. In the alkaline soil, the degree of alkalinity was estimated.

Samples of soil from each of the plots were placed in boxes 18" x 18" x 18". Fifty seeds of Western yellow pine were planted in each box. Each soil was kept moist and the number of seedlings alive at the end of the year was as follows:

Seedlings At End of First Season[12]

Soil Type	No. of Seedlings
Lodgepole	40
Manzanita	33
White fir	38
Pine	36
Aspen	26
Clay	14

According to Baker, who wrote up the experiment, the only apparent controlling factor was that of lightness of the soil. After seedlings were once established, however, soil fertility seemed to be the most important. In any event, acidity is clearly not a limiting factor[12].

Local Studies

Probably the most important study of local significance was made by Jack Pickup in 1941. A study was made of an area near the Peavy Arboretum and served as the basis of a thesis on the same subject treated here.

Originally it was planned to conduct experiments to determine soil acidity of the different site classes in this same area. However, in view of previous experiments along the same lines, an effort was made to correlate it with other experiments.

The area studied in this section is of fairly recent forest type. The area was grassland with a few scattered oaks as recently as seventy-five years ago. Up until that time, the area was repeatedly burned to insure a grass crop. As soon as this practice was abandoned, oak took over the area. This, in turn, is being replaced by Douglas-fir.

Soils of the Area. Normal forest soils of the Willamette Valley are of two types. One is of basaltic origin while the other is of sand shale origin[10]. The better type is the former with Aiken and Olympic the most common series. The Olympic is a brownish soil while the Aiken is red in color. The soil class is mostly a silty clay loam.

These soils are two of the most common forest soils of the Willamette Valley. Therefore, the results of the study on these soils should give a fair indication as to conditions to be found on comparable areas with the same soil series. Naturally, other soil series will give altogether different results and would necessitate another set of experiments to determine any trend that might be present.

Methods of Study. The study was made by going from a known value to an unknown one. The site class of the different areas was determined by standard methods of increment borings and height measurement. Soil samples were then taken from each site class and the acidity determined in the laboratory. The results were tabulated and conclusions were drawn from the results.

Samples were taken from A, B, and C horizons and the results compared. Each soil series was kept separate from other series. Also, samples were taken from areas as nearly the same as possible.

Clark's colormetric system of determining pH was used in the laboratory tests. Although this method is not as accurate as some others,

it is the best method for relatively inexperienced men. A small sample of soil is placed on a spot plate. A small amount of distilled water is added to the soil and the solution is allowed to settle. One drop of an indicator was then added and the solution compared to Clark's chart.

Results of Local Study. The results obtained in these local tests were in line with others reported by Lutz and Chandler[1] and by Toumey[2]. This seems to indicate that further tests along this line are probably useless unless more accurate methods of testing are devised.

Although the findings are interesting, they seem to prove very little. All of the averaged pH ratings fall within a narrow margin of six-tenth of a point. The range in individual samples was only from 6.0 to 7.0. Furthermore there does not seem to be a general trend from the higher sites to the lower ones. Both the Site I and Site V areas showed exceptions.

A tabulated result of the findings is as follows:

(11)

TABLE I

AVERAGE pH RATINGS FOR THE HORIZONS WITHIN EACH AREA

Horizon	Site I		Site II		Site III	
	Area 8	Area 4	Area 7	Area 3	Area 6	Area 2
A	6.60	6.35	6.55	6.65	6.35	6.45
B	6.40	6.35	6.45	6.35	6.30	6.05
C	6.20	6.20	6.40	6.20	6.25	6.15

Horizon	Site IV		Site V	
	Area 10	Area 1	Area 5	Area 9
A	6.35	6.45	6.45	6.65
B	6.20	6.25	6.15	6.20
C	6.10	6.10	6.25	6.25

One thing borne out by these experiments is the tendency of the B and C horizons to be more acid than the A horizon. This is not entirely in keeping with the idea that the leaching of minerals from the A horizon causes it to become more acid. The findings seem to be more indicative of the laterites than of the podzols. The probable reason is the recent transition from a hardwood type to a coniferous type.

Conclusions drawn from this experiment will be treated in a later section along with those drawn from the study as a whole.

Other Local Studies

Ray E. Ellis made a study of the pH values on Site I areas of the McDonald Forest in 1939[13]. His findings coincided with those of Nemic and Kvapil[7] in that the denser the stand, the more acid the soil. However, the variation in pH values seems to rule out any correlation between site quality and pH values.

CONCLUSIONS

The results of the local experiments serve only to convince the author that the findings of various authors concerning other regions are also true for this one. The variations in pH ratings between the different site classes seems to be too small to make any method of determining site quality a practical one. Although there seems to be a slight trend in some of the tests, the results on others show that tests made in one area would not work on another area just a short distance away.

One thing wrong with the local experiments was the selection of the area to be used. The area is so recently changed from a grass-oak association that the conditions cannot be accepted as correct for the average coniferous forest. Normal factors which tend to create a more acid condition of coniferous forests have not had time to work. Also, the large proportion of maples and oaks present in the forest type serve to prevent this change from taking place. This undoubtedly explains the very high pH ratings found in the experiments.

One fact remains, however, which seems to substantiate the original belief of the author. If the pH values for the B horizon only is studied, it can be noted that there is a slight trend from a more alkaline condition in the Site I to a more acid condition in the Site V areas. This might indicate a trend if the same soil series is studied under comparable conditions for all sites.

Another factor found in the local experiments was that the lower site classes seemed to occur on the higher sloped and near ridge tops[11]. Whether this is due to the increased leaching of these

areas and the translocation of valuable nutrients to the other slopes, or to the fact that the soil is shallower than the lower slopes, is not known. It seems that this result can be disregarded as inconclusive.

Probably the most vital evidence pointing to the affect of pH values on site determination is a study of its indirect effects. It has been proven in other experiments that bacteria are greatest in soils that are nearly neutral[5]. As bacteria are known to be beneficial[1], this should indicate that the better sites would probably be more alkaline than the poorer ones.

Evidence as a whole, taken from all available sources, seem to indicate that there is little or no direct correlation between pH values and site quality. Most of the authors seem to be firmly convinced that nothing can be determined along that line.

In the experiments conducted by Baker in Utah[12], it was rather definitely proven that acidity was not the controlling factor in regeneration of pine stands. Although it may have been a contributing factor, it definitely was not the controlling one.

Some experiments have shown a definite correlation between forest species and acidity. Nemec and Kvapil[7] have come to the following conclusions:

(a) Coniferous forests show a greater acidity than a deciduous forest of the same region.

(b) Acidity of soils under conifers varies directly as the density of the stand.

(c) The degree of acidity may vary during the year.

Again we have ample evidence that there is some sort of correlation but it seems to be too general to use for purposes of site determination.

The local experiments also brought out evidence against pH values being conclusive in site determination. The open sites, usually on the south and west slopes, were quite often the poorer sites. However, these areas usually proved to be the more alkaline, which should have made them better sites.

With factors on both sides, it seems that no definite conclusion can be drawn. Of the many studies investigated, Mr. Pickup seemed to be the only one still convinced that there was a definite correlation[11]. Although most of the authors studied seem quite sure that there is no correlation, there seems to be insufficient information to definitely indicate either way.

There is one thing definitely borne out by the experiments, that is that the key to the whole situation seems to rest on the edaphic factors. One can find all of the different site classes under seemingly identical climatic, topographic, and biotic conditions. This seems to indicate the "missing link" lies in the measurement of soil characteristics. If some method can be devised for measuring the value of different soil factors, it is believed that the problem of site classification will be eliminated.

It would be obviously possible, if we knew how to integrate all of the factors involved, to determine site by studying the physical factors above[3]. However, it is not known just how much study would be required before suitable results could be obtained.

Although the results obtained seem to discount any connection between pH values and site quality, the theory cannot be discounted because of lack of accurate information. Most of the methods of measurement are too inaccurate to insure definite results. Also,

most of the tests are of too general a nature to be of much value.

RECOMMENDATIONS

The most important recommendation to be made is that any future studies will be wasted unless done by an experiment station or a qualified soil expert working with the forestry department. It seems probable that site determination can be narrowed to the soil factors and that the only problem is to find the factor or combination of factors that make one soil different from others.

One frailty in the tests made using acidity as a base is the method of measurement. The colormetric system does not seem to be accurate enough to definitely establish a trend. An electric method of measurement is available but requires trained personnel to obtain satisfactory results.

Another "must" on any set of future experiments is the choice of an area that is more typical of a coniferous cover. The timber type must be all of one species or the results are almost sure not to be a true sample. The results of any study in an area such as the McDonald Forest would not be true for most other areas because of the mixed cover.

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