FORESTS AND SOILS – SOILS AND FORESTS

A SUMMARY BY

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INTRODUCTION

After many decades working in forestry, if one thing has been consistent, it has been that so many people have said: "I'd like to know more about soils". The following is a primer that borrows from a number of technical references, and from a fair amount of technical and field experience. Many papers and references deal with soils, and conversely, many deal with forests and forestry. This is an attempt to interweave the two for a general understanding of how forests and soils interact.

This paper will not duplicate other resources. I will assume people will know what sand, silt and clay are, and how to determine what one has, and the best reference for terminology and soil basics is: Field Manual for Describing Soils, published by the Ontario Institute of Pedology at the Guelph Agricultural Centre, and the University of Guelph, O.I.P. publication No. 85-3, ISBN 0-88955-046-6. This is the reference for the 1985 version, but there are probably more recent ones. When you order this manual, you have the option of ordering the "on-site" tables, which I will refer to below. There are other texts that are classics, such as by Brady (Soil – Plant Relationships) and by Ken Armson, a former soils professor from the University of Toronto, Faculty of Forestry.

BASIC SOIL/FOREST RELATIONSHIPS

Northern Ontario

By Northern Ontario, this means the portion of Ontario that occurs on the Precambrian Shield. The soils in this area are derived primarily from granitic materials from igneous rock. Consequently, buffering capacity is low, as well as cation exchange capacity (nutrient exchange sites) and base saturation (available nutrients). This means that these soils do not contain, retain, and exchange nutrients as readily as soils south of the shield. Because of low buffering capacity, they are also more susceptible to acid precipitation. They inherently are more acidic, with a lower pH (more free hydrogen ions present in solution), and microbial activity in the soils is much slower than in the south.

Besides being lower in inherent fertility than more southern soils, these soil characteristics often result in the formation of a "duff" layer, on the surface of the soil, of partially decomposed organic matter, of varying depths, sometimes reaching 15 centimetres or more. This duff is composed of partially decomposed needles, leaves, and feather mosses which usually cover the forest floor. This occurs particularly in the boreal forest. The significance of this layer is that regeneration of trees is impeded by the presence of the duff. One cannot rely on natural seeding, without fire or some other disturbance, as seed that germinates in moist spring conditions will die as the duff dries out in the summer. Consequently forestry operations must include provision to remove or reduce the duff to create better seedbed conditions, or even to prepare the site for tree planting (you can't plant trees into duff). This reduction occurs naturally in a forest fire; or in the case of a prescribed fire, fire weather indices are chosen that will reduce this duff a prescribed amount. Forest fires also release nutrients from the duff and forest vegetation, causing rapid forest re-growth for many species, particularly those such as jack pine and black spruce that are fire dependent. Initially, during a fire, there is a tremendous loss of nitrogen as vegetation burns, but this is rapidly replaced subsequent to the fire, partially due to the abundance of the other nutrients that have been released.

In the absence of fire, in order to reduce the duff and expose mineral soil, or a mix of organic and mineral soil, machinery such as barrels and chains, pulled by bulldozers, or disc trenchers, and other site preparation tools, are used to break up the duff and soil, and any slash (branches and tops), left by logging. Obviously, this equipment could not operate in a selection harvest, as it could not work around trees left standing, so this equipment works best where all trees are removed in a clear cut or strip shelterwood. As it happens, the primary species, black spruce and jack pine, require full light anyway, which lends them to clear cutting. Seed from jack pine cones, normally opened in crown fires, will open in contact with the heat from the ground, and seeds will germinate after these mechanical treatments. This combined operation is called scarification. Similar treatments to prepare a site for aerial seeding or tree planting are called site preparation. A very low percentage of the nutrients in a forest are removed by harvesting the stems of the trees. Most of the nutrients in a tree are in the crown and roots. As long as the branches and tops are left on the site after logging, and little soil disturbance takes place, little soil deterioration occurs.

In Central Ontario, still on the shield, but in the Great Lakes St. Lawrence forest, sugar maple and other heavier seeded trees do not have the same problem germinating, as the light seeded conifers farther north. Duff is less evident here, although a fermentation layer is still present, often from 1 to 3 centimetres in thickness, under the leaf litter. The exception to the heavier seed of maple ash and cherry, is yellow birch and hemlock, which sometimes require special regeneration practices to encourage them to regenerate. In all cases, some soil disturbance will aid tree regeneration, as a better seed bed is created. White pine benefits from soil disturbance, as well as from prescribed burning under uniform shelterwood harvesting, to prepare the site for seeding from the residual canopy.

Southern Ontario

South of the shield, in the Great Lakes St. Lawrence and Deciduous forests, soils are derived from shales and limestones which are sedimentary rocks. Consequently, the soils are higher in free carbonates (calcium and magnesium carbonate) and have a higher buffering capacity, higher pH, higher cation exchange capacity, higher base saturation, and much higher microbial activity. Often, whatever leaves fall in autumn are decomposed by the end of the following summer. This creates a much higher nutrient turnover than in the north. The downside of this rapid breakdown, is that exposed soils are subject to compaction and deterioration from pedestrian or livestock traffic, as there is little natural protection for the soil surface. Seeding is controlled more by light and predation on the seed, than by lack of opportunities for seed germination. Therefore, shade tolerant species such as sugar maple can be harvested under an all-aged selection silvicultural system. Mid tolerants such as oak and hickory respond better to the uniform shelterwood system, sometimes using prescribed fire to control the shade tolerants and understory shrub species.

SOILS AND TREE GROWTH – SITE INDEX

Foresters use a measure called site index to determine productivity of a site or of a soil. This index says that using a base age of 50 years, better soils and better sites will grow taller trees. In Northern Ontario, site index curves derived by Plonski are used. These curves are summarized in six classes, from 5 (poorest) to X (best). This provides a comparison of which sites will grow a species best, and indicates which sites are best suited for a particular species. For instance, one site may grow jack pine better than black spruce, while one site may grow jack pine better than another site will grow jack pine. Sites 5 and 4 are often called "protection forest" and are not harvested, while sites 3, 2, 1, and X are considered "production forest".

In the south, most sites result in an "X" under the Plonski system, because the Plonski curves were developed in the north. Back in the '70's, an A.R.D.A. (Agricultural Rehabilitation and Development Act) study was done by Dave Love, another U. of T professor, which plotted site index of hardwood stands in southern Ontario. Coincidentally, the results showed that some American site index curves by Hahn, Gorviantz and Carmean were consistent with the site index curves derived by A.R.D.A. for hardwoods in southern Ontario. In the south then, the "X" can therefore be broken down into 3 further classes, using the American curves. Similarly, growth in the south is higher than in the north, for hardwoods, and several American studies by American authors have been found to predict forest growth in southern Ontario, since soils and sites are comparable. Growth in this case means growth in basal area per acre, cubic feet per acre, and board feet per acre, as these studies are done in the U.S. which uses the imperial system.

WHAT IS SOIL?

As stated above, I am assuming people know what sand, silt and clay are and how to determine what one has through field tests. Also, I am not going to go into moisture holding capacity, or air space in detail. This information is available in many other sources. What I will do, is explain a few basics that people should understand before they can appreciate forest soils/tree relationships.

In forestry, when people refer to "soil depth", they may be referring to two different things. Often the term is used to refer to depth to bedrock. This is relevant in northern Ontario, eastern Ontario, and in some areas of the Niagara Escarpment. Generally, depending on the location, it can be a few inches to several hundred feet. The other meaning for soil depth is: depth of the weathered soil profile.

All of Ontario soils have been laid down by glacial action. This has resulted in many basal tills, terminal and interlobate moraines, as well as outwash sands and gravels, deltaic sands, lacustrine silts and clays, and wind blown deposits. These landforms constitute the parent materials in which our soils formed over the last 12-15,000 years. Anyone interested in the subject of landforms should get a copy of The Physiography of Southern Ontario by Chapman and Putnam.

Soil formation takes place by chemical, mechanical and biological weathering that acts on the soil particles. Eventually soil horizons are formed of varying materials and chemical properties. In the south, because the parent materials are calcareous, the first materials that were removed by organic acids and normally acidic rain, were the calcium and magnesium carbonates. Consequently, if you have a soil profile developed, lacking free carbonates, then this defines the weathered soil or "solum". Once you dig below the solum and find material that still has free carbonates present, then this is now still parent materials and "not soil". The parent materials still reflect the conditions as the material was laid down in the original landform. The way to determine if you have reached the bottom of the solum is by testing the material with 10% hydrochloric acid. If you put a few drops on the material, and it fizzes, then you are at the parent materials and "not soil", and the fizz is caused by calcium carbonate. If no fizz occurs, but you can hear a crackling, like Rice Crispies, then this is the sound magnesium carbonates make. This is not so easy in the north, if there are no free carbonates, and one must look for other evidence of soil formation and horizonation to determine profile depth.

SOIL HORIZONS AND TREE GROWTH - The Basics

In Canada, soil horizons are grouped as "A", "B", or "C" horizons.

"A" horizons are eluviated horizons with loss of some iron, aluminum, organic matter or clay. An "Ah" has been subsequently enriched with incorporated organic matter and an "Ap" is a plow layer. "Ah" horizons can be confusing to determine soil texture, as the more organic matter that is present, the more the soils feel to have clay present, as the organic matter acts as a substitute for clay. For instance, a loamy sand may feel like sandy loam, and a loam may feel like a silt loam or clay loam. Many a forester or forestry technician has been made to look a fool by not going below the "A" to texture the "B". An "Ae" demonstrates a marked loss with no subsequent noticeable addition of organic matter, causing the horizon to appear light coloured. The American system calls this "Ae" an "E" horizon. To be called thus, an "E" horizon must also show significant colour difference by a Munsell colour chart in both hue and chroma.

"B" horizons on the other hand show iluviation or additions of iron, aluminum or clay deposited from the material above it:

- brownish, with slight additions: "Bm". "Bm" horizons can be present with slightly different colour and texture and be broken down into a "Bm1" and "Bm2".
- reddish with significant additions of iron or organic matter: "Bf", "Bhf"
- brownish with significant clay additions: "Bt". With Queenston shales being the source of the clay in Hamilton-Wentworth Region and Brant County, sometimes the Bt appears reddish. For instance, if the "Bm" is a loam, with the clay additions the "Bt" may test out as a clay loam, or silty clay loam.

"C" horizons are relatively unweathered parent material, and "Ck" are those "C" horizons that effervesce with hydrochloric acid.

If there is a significant textural change within the profile, a roman numeral II is used to separate the horizons. For instance if the texture in the "B" shows a silty clay overlying a sand, the silty clay would be a B, while the lower sand would be a IIB. This would most likely indicate a different mode of deposition of the parent material, i.e. an outwash versus a till or loess.

Many of the forest soils in northern Ontario show a marked "Ae", and very little clay, and are therefore classed as Podzols. The areas known as the "little clay belt" and the "clay belt" actually are silt to a large extent rather than clay. Silt deposits are usually found where glacial ponding was comparatively short lived, while clay only settled out of lakes where they existed for a long period of time.

Many of the forest soils in the south are Luvisols, showing a pronounced "Bt" horizon immediately above the "C" or "Ck" horizon. This "Bt" has resulted from accumulations of clay percolating down from the "A" and the other "B" horizons. These luvisol profiles can be up to a metre or more in depth, and the deeper profiles are obviously better for growth, as they provide more opportunity for rooting, nutrient absorption, and water absorption. However, it must be realized that often there are "feeder roots" close to the surface in the "Ah", that recover nutrients, and which can be severely damaged by surface soil compaction.

In terms of moisture availability, the "Bt" often functions as a "hesitation layer". In other words, the moisture percolates downward and the clay, accumulated in the "Bt", slows this downward movement creating the opportunity for trees to access it. The "Bt" will sometimes be mottled, which is a rusty colour in the soil indicating fluctuating water content or a semi-permanent water table. This mottling is caused by an oxidation reaction with iron. Any horizon with mottling will be designated with a "g"; for instance, a "Btg" or a "Ckg". If the soil is permanently saturated, on the other hand, then grey gley (pronounced glye like lye) colours will be present and the horizon is given the designation such as for a "Bt" with gley: "BtG", or for a gleyed "C", a "CG". This colour can be seen on the tops of the furrows where a farmer plows up a low area that may be seasonally flooded. It is often assumed to be clay, but can be any texture.

Similarly, there may be changes in texture within the profile that cause moisture hesitation. These are called "textural discontinuities". If, for instance, a sand overlies a clay, or vice versa, the moisture will hesitate before it crosses from one texture into the other. This is caused partially by increased surface tension between water and clay within the clay material, versus within the sand.

Other moisture relationships occur such as a "seepage site", called a telluric site. This is where there is lateral soil movement, perhaps along textural discontinuities. In some cases, this condition can enhance tree growth considerably, as the moisture bathes the roots with a nutrient solution somewhat like hydroponics. Often these sites occur along the sides or on lower slopes of hills and moraines, where water seeps to the surface as springs or empties into wetlands.

The above two conditions, textural discontinuities, and telluric sites, can occur frequently. For instance, often glacial outwash rivers deposited sands and gravels on top of the previously deposited glacial tills. These are the Bookton soils. Often loess, or windblown deposits blanket glacial tills. In Huron County, the Harriston loam soils are a loess deposit over the Huron clay loam tills.

SOIL HORIZONS AND TREE GROWTH – Neat Stuff

As materials weather and horizons form, the soil particles, particularly silt and clay, aggregate into peds that aggregate again to form soil structure in various forms. This aggregation facilitates moisture movement, rooting, and root access to moisture, as small roots follow the peds. Roots also take advantage of old root channels abandoned by roots of trees that have died. Roots also take advantage of coarse fragments (rocks), as water follows the surface of these fragments, and consequently so do roots. Clay skins can also form on these fragments which additionally offer moisture to roots.

A story is told in England of a calcareous hard pan that had formed in soils under the acidic litter of Scots pine. As it turns out, the hard pan had formed prior to the plantation being established, while the land was in pasture and heath. The hard pan had formed because after the initial hardwood forest had been cleared, trees did not blow over any more, mixing the soil, and the stationary soil formed the hard pan through the subsequent years, from moisture percolation and deposition of the calcium. It is therefore beneficial in some ways, if the forest is disturbed from time to time, to mix up the soil materials.

SOIL HORIZONS AND TREE GROWTH – More Complicated

If one combines soil texture and the location of the mottled (g) or gleyed (G) horizons, if present, one can compute "Moisture Regime". This varies from a moisture regime "0", Dry, to a "9", Very wet. This is a useful ecological feature for comparing sites. Indicator species have also been used to predict moisture regime. For instance, jewelweed, sometimes called touch-me-not is often found on moist sites in woodlots on a fresh 2 to very fresh 3 site.

By combining soil texture and depth to mottles, one can also predict site index for a specific tree species. This is the basis of the "on site" tables included in the Ontario Institute of Pedology soil manual, referred to at the beginning of this paper. These tables allow one to figure out:

- which species will grow best on a soil or site.
- which species are "off site", or in the wrong place.
- what species to plant on a site.
- which species are best to manage silviculturally, on a site.
- which silvicultural system will work on a site.

For instance, using oak as an example, the best sites for growing oak are problematic in that there may be too much competition from other species such as maple and ash, which will also do very well on these good sites. Therefore, some of these best sites may be allowed to convert to more tolerant hardwoods, by selection cutting, with a loss of the oak and of regional diversity. On less productive sites, the stands could be managed for a mixture of oak and tolerant hardwoods. Progressing to even less productive sites, where maple and ash are less suited; these sites may be managed for oak alone, and probably should be, to maintain representation of this species in the landscape. Usually, a uniform shelterwood system will be used, with herbicides or prescribed fire to control the unwanted tree and shrub understory that would out-compete the oak. In the U.S., many of our species that we proclaim as "Carolinian" and therefore hold sacred, are considered weed species when managing oak stands, and these species are removed so they will not compete with the oak. On the poorest sites, pine would probably be a better choice than any hardwoods.

DETERIORATED OR DISTURBED SITES AND SOILS

Where sites have been eroded or disturbed by soil movement and mixing, calcareous "Ck" may be at, or near the soil surface, or mixed in with weathered soil. This is often found to be the case on eroded farm land where mixed "Ck" and "Bt" form the plow layer, becoming a "Bpthk". Studies have been done personally, and by Agriculture Canada, that have found that it is not uncommon to have 20% of a farm field exhibiting free carbonates at the surface. If not calcareous, often the "Bt" horizon is at the surface and is being actively farmed. Silt soils, and loamy fine sands are particularly subject to erosion. A similar situation can exist on urban land, where soil has been removed and replaced, on golf courses that have been re-graded, or in gravel pits that have been restored to farm land or to golf courses. Often, during construction activities, whatever is supposed to be topsoil is retained, but "B" horizons are not. Usually the "topsoil" replaced is a mixture of "A", "B", and "Ck", and is spread over "Ck" to a depth of a few inches. In this case, tree species that are suited to the site, can be severely restricted. Often, in the past, foreign species such as Manitoba maple, Norway maple, Siberian elm, European linden, black locust, Asian mulberry, London plane tree, Mugho pine, Austrian pine, European larch and foreign shrubs have been planted on disturbed sites. Some of these, such as Norway maple, are now considered invasive. Foresters and pedologists are always walking around carrying acid bottles, looking for a reaction from free carbonates on these sites. When our children ask what we did today, the answer is "I walked around and dropped acid".

Many eroded sites that were old farmland, that were replanted with red pine, were found not to be suited to red pine because of the high pH. Although death was originally blamed on acid rain, the opposite was true. The high pH limited the tree's ability to take up the nutrients, even though they were present, and the trees died. If a carbonate reaction takes place, it is likely that the pH can be as high as 8.5, which is too high for many species. In addition, because the material is unweathered, the cation exchange capacity and base saturation may be low, and nutrients in short supply. Currently, a similar thing is happening to Austrian pine. A disease called a shoot blight, which normally affects Scots pine on poor sites, is now affecting Austrian pine in towns and cities, on disturbed sites.

Wildlife shrubs, planted on poor, calcareous sites, have poor nutrient status, reflecting the poor nutrient status of the soils. They can therefore be nothing but "junk food", and are avoided by wildlife.

The problem with pesticides may not be the pesticides so much as the degraded soils. Pesticides applied to degraded soils encounter very little or significantly reduced microbial activity to break them down, and therefore, there is a greater likelihood that they wind up in ground or surface water.

If pH is too low, for instance in a tree nursery, or a farm field, calcium can be added to raise it. If the pH is too high, flowers of sulphur can be added to lower it, essentially creating acid rain to lower pH. However, these materials should be incorporated, or mixed in with the soil, and in a forest situation, this is impractical.

SUMMARY

Tree and soil relationships are a fascinating topic. Unfortunately these relationships sometimes are not well understood, or subject to misinformation or misguided assumptions. I hope I have created a more realistic picture of how trees and soils interact. If I have provided insufficient information on some of the technical matters, please follow up with some of the references noted. Please realize that many soil texts, though, are not specific to trees.