Influence of Geologic and Pedologic Factors on Health of Sugar Maple on the Allegheny Plateau

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Popular Summary

Decline of sugar maple (*Acer saccharum* Marsh.) has been a problem on the Allegheny Plateau of Pennsylvania since the mid-1980's (Kolb and McCormick 1993; McWilliams et al. 1996). Horsley et al. (this volume) found that declining stands were distinguished from non-declining stands by a combination of repeated insect defoliation and low foliar calcium and magnesium concentrations. Stands that exhibited only one of these two conditions remained healthy. Information is needed (1) to determine whether low foliar nutrient concentrations are related to soil quality, (2) to determine key parameters and threshold values that describe soil conditions which might predispose a stand to decline, and (3) to develop methods to predict the distribution of susceptible sites across the landscape. Furthermore, information about the role of acid deposition in inducing soil fertility problems remains elusive.

The present study was initiated to examine soil factors leading to sugar maple decline on the Allegheny Plateau. Soil description and sampling were conducted at a number of plots, spanning the geographic range of the Plateau in northwestern and north-central Pennsylvania and adjacent southwestern New York. Plots include a range of stand heath conditions, landscape positions, and bedrock and glacial geologic influences.

Methods

Study plots were established at 19 sites described by Horsley et al. (this volume) across the Allegheny Plateau from Chautauqua County, New York in the west to Tioga County, Pennsylvania in the east. Study plots span a wide range of soil parent materials and geologic influences found on the Allegheny Plateau. At each site, two or three plots were established to span the elevational distribution of sugar maple. County soil surveys and reconnaissance observations were used to locate one representative sampling pit per plot. Pedon description, according to National Resource Conservation Service methods, was conducted to a depth of at least 130cm, unless bedrock was encountered at a shallower depth. Samples for chemical analysis were collected by genetic horizon. Additional forest floor samples (O and A horizons) were collected by the pin-block technique (Federer 1984) at three locations in each plot. This provided information on spatial variability in surficial horizons as well as the ability to express nutrient levels on a landscape area basis. Soil samples were analyzed for pH, extractable cations and organic matter content generally following the methods of Robarge and Fernandez (1987). Forest composition and health measurements are described in Horsley et al. (this volume).

Results

Surveyed sugar maple stands were located on all physiographic positions from summit to footslope, on soils that ranged from moderately deep to very deep, well drained to poorly drained, and included soils of four orders (Inceptisols, Spodosols, Alfisols, and Ultisols). All declining stands were located on summit, shoulder or upper backslope physiographic positions on Ultisols. Declining stands had lower extractable calcium and magnesium and higher exchangeable aluminum than non-declining stands. Subsoil horizon chemistry was a better predictor of decline than chemistry of the forest floor or upper mineral horizons.

Overall, a great variety of nutrient conditions was measured. For example, extractable concentrations of calcium, magnesium and aluminum each ranged over a factor of 250. Further analysis is planned to determine which chemical parameters for which horizon or sequence of horizons best correlates with foliar chemistry and health parameters.

Soils in unglaciated upper landscape positions contained lower concentrations of extractable nutrient base cations compared with other landscape positions. Soils on upper and lower landscape positions of glaciated sites and in lower landscape positions on unglaciated sites had similar moderate to high base cation content. Mineralogy also played a role in site nutrient status. Plots influenced by calcareous bedrock, such as the Oswayo and Huntley Mountain Formations, contained the highest concentrations of soil extractable base cations. Some plots at mid to lower physiographic positions contained seeps. Chemistry of seep water corroborated site nutrient status indicated by soil extractable cations. No declining stands were located on plots containing seeps; seeps did not occur in landscape positions where decline was observed.

Discussion

Nutrition appears to be a predisposing factor in sugar maple decline on the Allegheny Plateau. Declining stands are marked by low foliar calcium and magnesium concentrations, which follow low concentrations of extractable pools of these elements in the soil. The variation in site quality across the Plateau might be explained by a model that considers the location of weathering reactions and the effect of landscape position on delivery of weathering products to the rooting zone.

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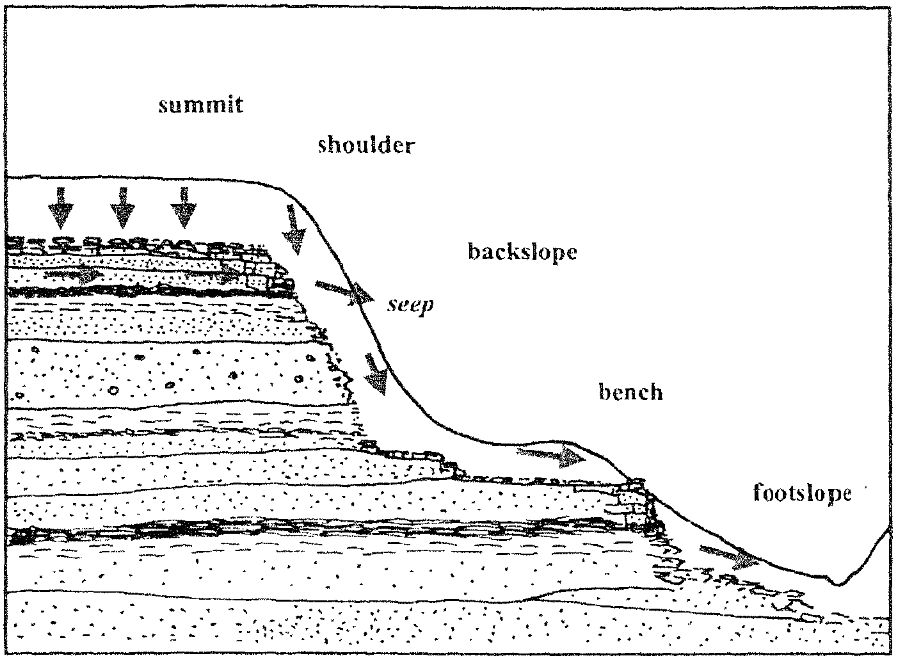

Figure 1.—Schematic cross section of the unglaciated portion of the Allegheny Plateau. Patterned areas represent interbedded sandstone, siltstone and shale bedrock. Soils are developed in relatively thick, weathered residuum, colluvium and alluvium shown as the unpatterned area above the bedrock. General locations of physiographic positions where sugar maple plots occurred are labeled. Arrows indicate generalized hydrologic flowpaths.

Mineralogy of unglaciated soils is dominated by primary minerals such as quartz and muscovite, which are resistant to weathering, and secondary minerals such as kaolinite and illite, which are stable in the soil environment. Weatherable minerals are confined to lower portions of the regolith well below the rooting zone or within bedrock. Thus the delivery of weathering products, such as calcium or magnesium ions, to the rooting zone is limited to portions of the landscape where water flowpaths bring ions released from bedrock or deeper regolith to the soil (Figure 1). Such locations may be those where water that has percolated into the bedrock is forced laterally back into the regolith by a strata of low permeability, thereby influencing soil chemistry and in some cases creating seeps. On other portions of the landscape, particularly unglaciated summits, shoulders and upper backslopes, nutrient inputs are confined to atmospheric inputs; nutrient conservation by biomass cycling is particularly important on these sites.

In contrast, on glaciated portions of the Plateau, much of the weathered regolith was removed by glacial erosion. Soils are developed in glacial till (Figure 2), which incorporates relatively unweathered material freshly exposed by glacial erosion. Thus, weathering reactions occur within the rooting zone, creating less contrast in weathering inputs by landscape position. However, even on glaciated sites weathering in the rooting zone may be limited where glacial till is largely derived from bedrock units with few weatherable minerals.

Although none of the soils investigated contained carbonate minerals, weathering of carbonate-bearing bedrock may contribute to soil fertility at both unglaciated and glaciated sites in mid to lower landscape positions on certain bedrock formations. Some of the highest concentrations of base cations in soil and seep water occur in this situation. These sites may be best suited to management of relatively high nutrient-demanding species such as sugar maple and white ash. Further analysis is planned to develop predictive tools for identifying site quality.

The role of acid deposition in contributing to sugar maple decline remains unclear. Acid deposition has been shown to reduce extractable base cations in soil based on theoretical grounds and in laboratory studies (Lawrence et al. this volume). Long-term depletion of exchange pools has been documented by retrospective studies (Shortle and Bondietti 1992; Lawrence et al. this volume) and in field-based mass balance studies (Bailey et al. 1996; Likens et al. 1998). However in the present study, the base cation-poor sites where sugar maple decline has occurred are located in landscape positions and on bedrock formations that one would expect to have the lowest nutrient levels, based on

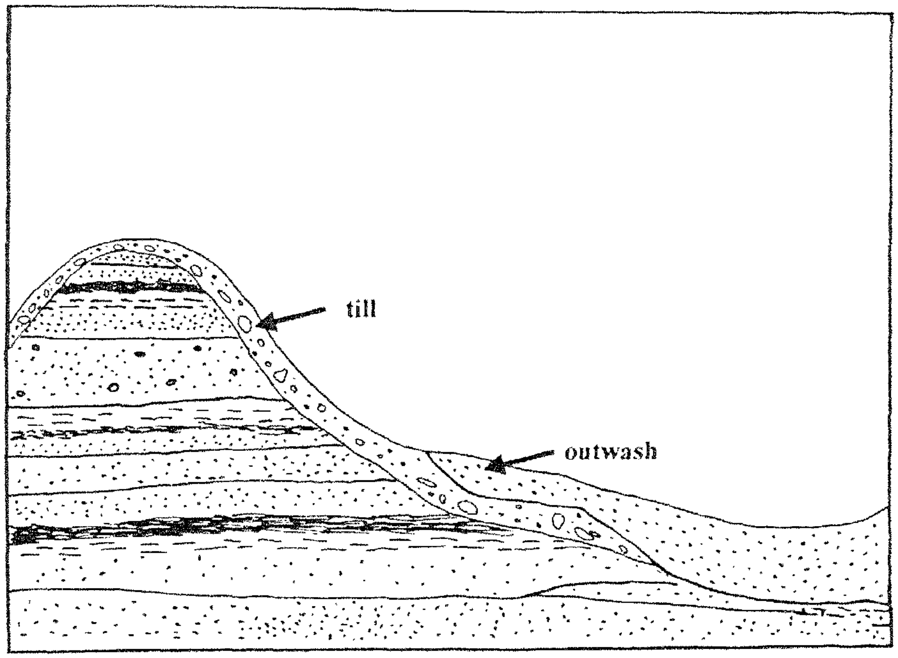

Figure 2.—Schematic cross section of the glaciated portion of the Allegheny Plateau. Soils on glaciated portions have developed in relatively thin glacial till on upper portions of the landscape and in glaciofluvial deposits (e.g. outwash) in lower valleys.

lack of weatherable minerals in the rooting zone and lack of hydrologic pathways to deliver weathering products from deeper sources. Given the available evidence, one would reasonably hypothesize that nutrient depletion due to acid deposition has increased the portion of the landscape with nutrient values below a critical, but as yet undetermined, threshold. However, in light of the great variety of nutrient concentrations attributable to landscape position, mineralogy and soil development, the extent that sugar maple decline is due to acid deposition remains speculative.

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