

Plant Morphological Characteristics as a Tool in Monitoring Response to Silvicultural Activities

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Abstract.—Monitoring environmental change through documentation of species composition becomes problematic when compositional changes take several years to occur or simply do not occur following silvicultural treatment. Morphological characteristics (e.g., leaf area, node density, bud number) change in many plant species in response to factors such as light availability, soil compaction, and organic matter removal. As a monitoring tool, morphological characteristics: 1) detect plant responses soon after treatment, 2) reveal underlying factors that produce changes in plant condition and composition, 3) allow prediction of short-term growth response and long-term forest development, and 4) may aid in communicating effects of silvicultural treatments.

INTRODUCTION

Information on changes in environmental factors and plant species brought about by silvicultural treatments is essential for communicating the beneficial or detrimental effects of a given treatment, and for selecting appropriate future management options. In the past, monitoring efforts tended to focus on the effects of silvicultural treatments on commercial tree species, game species of wildlife, and watershed hydrology. Effects of current silvicultural practices on non-commercial plant species, non-game wildlife, and ecological interactions within managed ecosystems are less well understood. As demand grows for simultaneous yields of forest products and a multitude of other forest values, the need for information on how silvicultural options affect all categories of species and their interactions within managed stands will increase. This information will be vital for communicating how silviculture can meet the demand for multiple forest values and for evaluating the success of various treatments.

Changes in the composition of tree, shrub, and herb species in the understory are frequently used by land managers to monitor changes in the environment and plant species response following the implementation of silvicultural practices. Documentation of compositional changes allows managers to infer impacts of silvicultural treatments on timber species as well as shrubs and herbs, some of which

may be threatened, endangered, or produce special forest products. This method, however, has several limitations. *Merely documenting changes in species composition does not identify the underlying factors responsible for the loss or gain of plant species on a site.* Without this knowledge, it is difficult to fine-tune silvicultural practices in order to prevent the loss of certain species or encourage colonization by others. A second limitation is that compositional changes may occur very slowly following treatment. Thus, it may be necessary to wait several years to assess the effect of a given treatment. Populations of certain species may persist for long periods, despite the fact that they are declining and will eventually be replaced by better-adapted species. Finally, species composition may not change at all following treatment. Due to the innate plasticity in many plant species, individual species may respond by changing their growth form and morphology. These changes can be quite subtle or dramatic (depending on the species and type of silvicultural treatment), and can be correlated with light quantity and quality, water availability, and soil physical and chemical properties.

CHANGES IN MORPHOLOGICAL CHARACTERISTICS

Following a change in environmental conditions, changes in morphological characteristics can occur from the scale of entire plants to the scale of individual leaves, buds, flowers, and fruits. Perhaps the most familiar morphological characteristics are those at the level of entire shoots such as live crown ratio, crown shape, and multilayer vs. monolayer distributions of foliage (Horn 1971; Kramer and Kozlowski 1979). Morphological characteristics of stems as well as entire shoots include length or height, seasonal patterns of internode lengths, node density, total leaf area, and the density and distribution of flowers, fruits, leaves and buds (Bonser and Aarssen 1994; Canham 1988; Dahlem and Boerner 1987; Huffman et al. 1994a; Sipe and Bazzaz 1994; Stafstrom 1995; Tappeiner et al. 1987; Wilson 1995). At smaller scales, differences can occur in the area, width, length, shape, orientation, and thickness of leaves, the size and shape of buds, and the size, shape and seed characteristics of fruits (Abrams and Kubiske 1990; Collins et al. 1985; Goulet and Bellefleur 1986; Harrington and Tappeiner 1991; Huffman et al. 1994a; Jurik 1986; Niinemets 1996; Waller and Steingraeber 1995). Morphology of underground parts important in vegetative reproduction also change with environmental conditions and can be predicted to some extent from above-ground morphology (Huffman et al. 1994a,b).

An entire tree, shrub, or herb can be considered as an array of repeating individual units or modules (Bell 1991; Harper 1977; Stafstrom 1995; Watson and Casper 1984; White 1979). Widespread differences exist in the overall

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morphological plasticity of species and their ability to modify certain types of modules due to differences in evolved strategies and evolutionary constraints (Abrams and Kubiske 1990; Ashton and Berlyn 1994; Goulet and Bellefleur 1986; Niinemets 1996; Pickett and Kempf 1980; Sipe and Bazzaz 1994). Thus, co-occurring species may respond quite differently to a given change in the environment. For example, on long-term soil productivity sites, we measured significant changes in the morphology of trembling aspen, *Populus tremuloides* Michx., (Figure 1) and bracken fern, *Pteridium aquilinum* (L.) Kuhn (Figure 2), in response to soil compaction and organic matter removal, while no significant changes occurred in the measured morphological characteristics of co-occurring large-leaved aster, *Aster macrophyllum* L., or strawberry, *Fragaria virginiana* Mill.. Further, Abrams and Kubiske (1990) found that plasticity in leaf structural characteristics varied among 31 hardwood and conifer tree species in response to open and closed canopy conditions. Important trade-offs can exist between the ability to change morphological characteristics in response to environmental conditions and reproductive or mechanical requirements (Mattheck 1995; Waller and Steingraeber 1995). It is also possible for species to respond to an environmental change through physiological rather than morphological adjustments (Collins et al. 1985).

RELATIONSHIPS BETWEEN MORPHOLOGY AND ENVIRONMENTAL CONDITIONS

Due to the strong influence of environmental conditions on plant development in many species, morphological characteristics can be correlated with a number of above- and below-ground factors. Leaf weight/area ratio was significantly higher in open locations than in understory locations in 23 of 24 hardwood species studied (Abrams and Kubiske 1990). We found similar increases in leaf weight/area ratio with more gradual decreases in canopy cover in northern hardwood stands representing uncut, 75% cover, 50% cover, and clearcut conditions (Figure 3). The steady increases in leaf weight/area ratio from uncut to clearcut conditions in some species (Figure 3) suggests that it may be possible to relate leaf weight/area ratio to more subtle differences in canopy cover than those that we studied. In addition to morphological responses to fine-scale differences in conditions, it is possible to relate changes in plant morphology to conditions that change over short time intervals. Good relationships have been demonstrated between climatic variables such as previous day incoming solar radiation and daily increases in the length of the shoots of red pine, *Pinus resinosa*, Ait., and aspen (Perala 1983). With respect to above-ground responses to below-ground conditions, we found significant changes in stipe length and frond length of bracken fern in response to soil compaction and organic matter removal on long-term soil productivity sites established on both fine- and coarse-textured soils (Figure 2).

RELATIONSHIPS BETWEEN MORPHOLOGY, PHYSIOLOGY, AND PLANT CONDITION

In addition to serving as indicators of environmental conditions, certain morphological characteristics also indicate current physiological status. Live crown ratio in trees, for example, provides an indication of the amount of photosynthesizing tissue relative to respiring tissue (Kramer and Kozlowski 1979). In general, the greater the proportion of photosynthesizing tissue to respiring tissue, the greater the amount of photosynthate available for growth. Leaf weight/area ratio is an indicator of the amount of photosynthesizing mesophyll tissue in a leaf, which, in turn, influences the leaf's photosynthetic capacity (Jurik 1986). Insights on current plant condition gained from examination of morphological characteristics, such as the differences in form between vigorous and suppressed trees, can be used to predict future success of a plant. It is also possible to directly relate future success to morphological characteristics. For example, the number of interwhorl buds was strongly related to the vigor of Douglas-fir, *Pseudotsuga menziesii*, (Mirb.) Franco, seedlings (Tappeiner et al. 1987), and the length of 1-year-old needles on Ponderosa pine, *Pinus ponderosa*, Dougl. Ex Laws., var. *ponderosa*, seedlings was an indicator of future height and diameter growth (McDonald et al. 1992).

A PROPOSED METHOD

Our goal is to develop a method in which morphological characteristics are used as indicators of environmental conditions resulting from silvicultural treatment. The first step in developing this method would be to select appropriate plant species. These species: 1) must exhibit plasticity in their morphology and physiology, 2) should occur over a broad geographic region and occupy as large a range of habitat types and stand conditions as possible, and 3) should exhibit changes in morphological characteristics that are easily measured. The next step would be to link changes in morphological characteristics with known changes in environmental conditions such as temperature, humidity, light, and soil moisture that follow silvicultural treatment. When relationships are identified, their quantity and quality should be examined across regions and habitat types. For example, in our work on long-term soil productivity sites, we found significant differences in morphological characteristics of trembling aspen in response to compaction and organic matter removal on fine-textured soils in Upper Michigan, but not on coarse-textured soils in Lower Michigan. The final step in developing the method would be to identify its limitations. Potential problems include genetic variation within species and variation in morphological characteristics within individuals due to developmental stage or age (Coleman et al. 1994; Hanson et al. 1986). Some morphological characteristics such as leaf weight/area ratio and node density vary substantially within individuals. Standard sampling positions for these characteristics would be

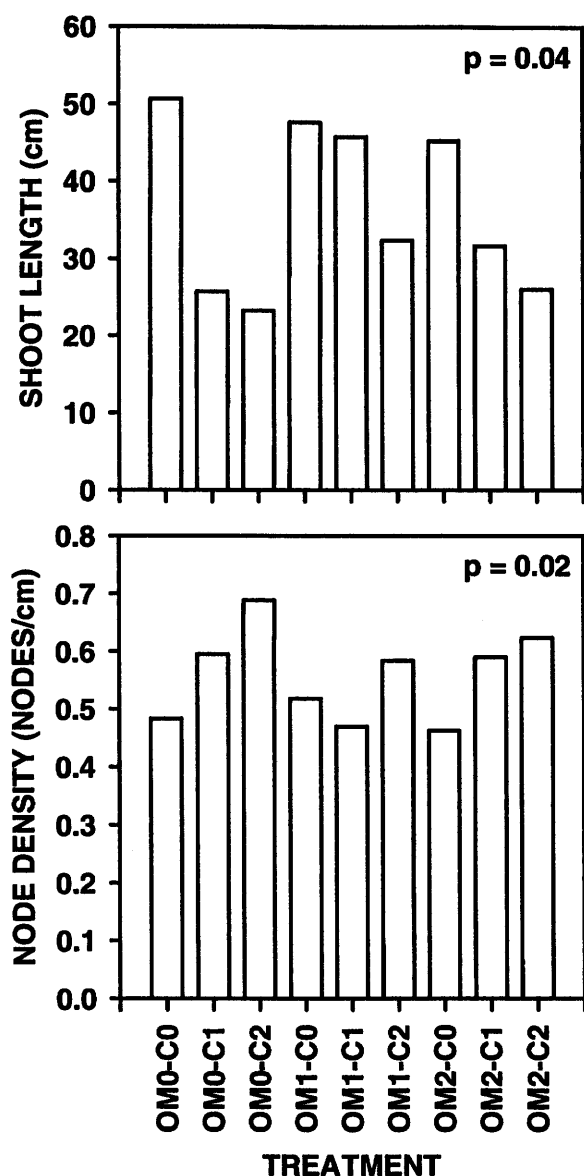


Figure 1.—Morphological differences in current-year shoots of equal-aged trembling aspen in response to combinations of organic matter removal and compaction treatments on a long term soil productivity site established on the Ottawa National Forest. Treatment codes are as follows: OM0 = no organic removal, OM1 = moderate organic matter removal, OM2 = severe organic matter removal, C0 = no compaction, C1 = moderate compaction, C2 = severe compaction. All plots were logged prior to receiving organic matter and compaction treatments. Significant differences in shoot dry weight, shoot diameter, and leaf dry weight of trembling aspen were also found among treatments on this site.

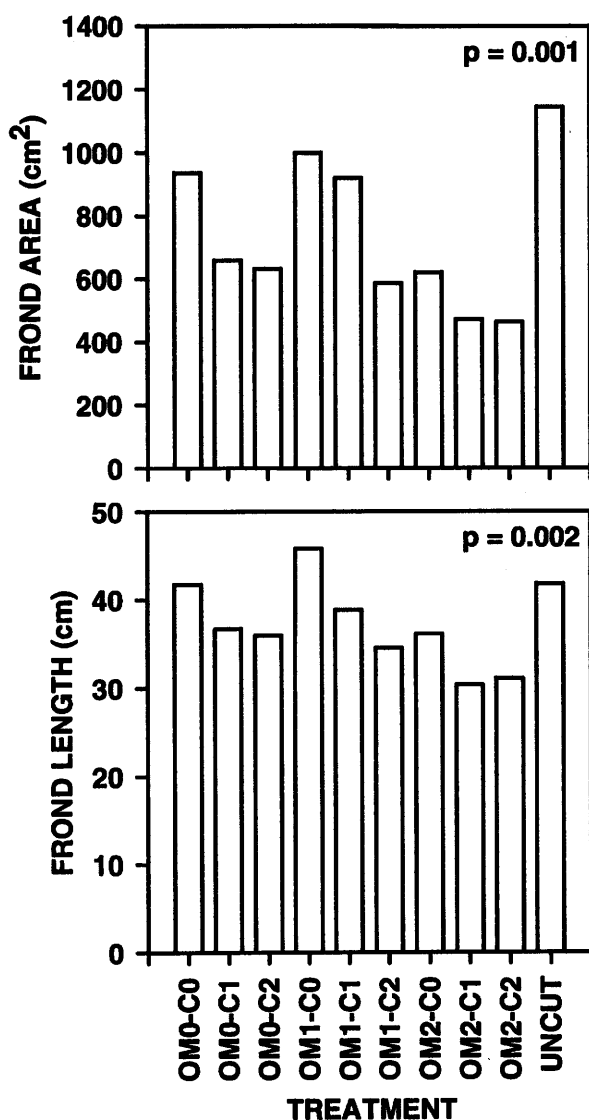


Figure 2.—Differences in morphological characteristics of bracken fern in response to combinations of organic matter removal and compaction treatments on a long term soil productivity site established on the Ottawa National Forest. Treatment codes as in Figure 1. Uncut = no organic matter removal, no compaction, and no cutting. Significant differences in stipe length and frond dry weight were also found on this site. Significant differences in stipe length and frond length in bracken fern were found in response to similar treatments on a long term soil productivity site on coarser-textured soils on the Huron-Manistee National Forest.

necessary. Another problem related to development is that plants originating from vegetative reproduction may differ from those developing from seed during the early stages of development. These potential problems can be overcome, however, with careful choice of indicator species and sampling conditions.

CONCLUSIONS

Properly used, morphological indicators could be a valuable addition to the land manager's tool kit for monitoring changes brought about by silvicultural practices. Morphological characteristics have the advantages of: 1) allowing rapid assessments of the effects of silvicultural treatment, 2) revealing the underlying environmental factors responsible for changes in the condition of plants following treatment, 3) providing indications of the physiological status and condition of individuals, and 4) providing information for the prediction of the future status of plant populations and forest development. As a communication tool, the more easily-observed changes in morphological characteristics and their significance could be pointed out on field trips to illustrate the benefits of silvicultural treatments. Due to their direct link with the current growth and vigor of species, certain morphological characteristics may be a more effective communication tool than attempting to describe the past or predicted future condition and occurrence of species on a site.

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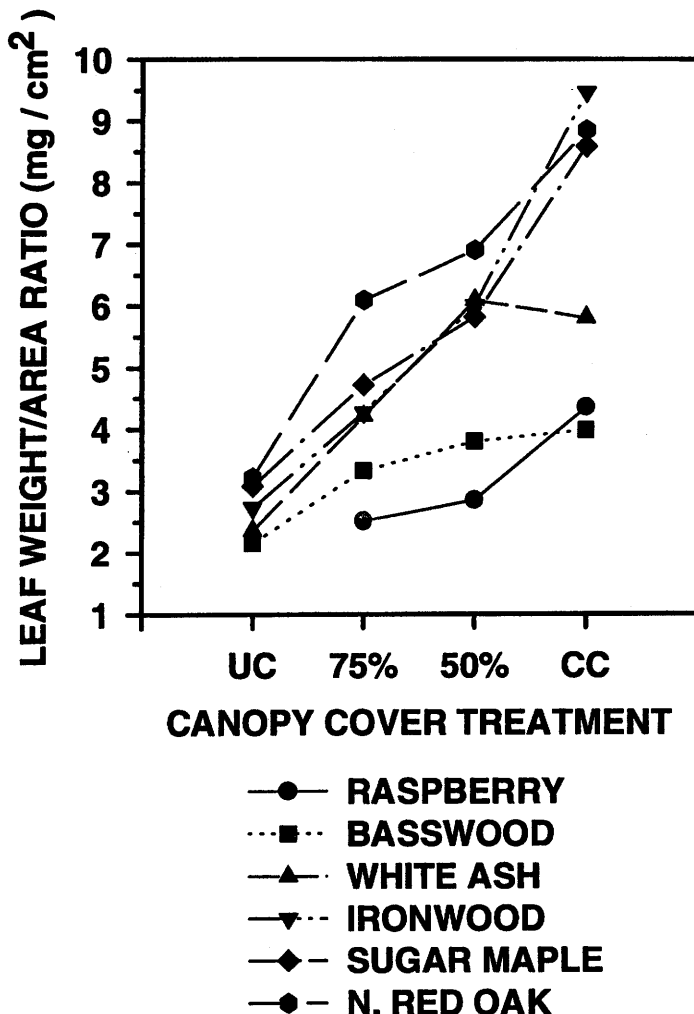


Figure 3.—Differences in leaf weight/area ratio of raspberry and five hardwood species across adjacent northern hardwood stands thinned and clearcut to achieve different amounts of canopy cover. Treatment codes are as follows: UC = uncut (control), 75% = 75% canopy cover, 50% = 50% canopy cover, and CC = clearcut.

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