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USING STRONG INFERENCE TO FALSIFY DIFFERENTIAL EQUATION MODELS OF SUGAR MAPLE HEIGHT GROWTH—DISCUSSION

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Abstract.Leary and Johannsen (2010; Leary and Johannsen. 2010. Using strong inference to falsify differential equation models of sugar maple height growth. MCFNS 2(1):1-11) envision growth modeling as a search for a single precise line like those depicting the laws of physics. However, it is unlikely that such a complex process as tree growth can be captured by our simple, usually empirical models. Instead of carrying out the experiment so as to get a clean result, it may be more realistic to start with enclosing the field of growth trajectories between two boundary lines representing the two opposite explanations of a studied relationship. Understanding complex process is more likely by combining opposites rather than falsifying one of them. Then, the modules delineating the boundaries can be joint in a single model that describes a more complex and fluid central tendency.

Keywords: critical thinking, growth equations, Popper, simple and complex problems, strong inference.

Discussion

An attractive feature of this paper is the awareness about developments in the mainstream of science and philosophy. Too often forestry research has the stuffy air of attempts to reinvent the wheel. In other disciplines, the results obtained 10-15 years ago are mostly obsolete. In contrast, our area has not grown beyond the century-old site index classification. The methods we use for determining stand density and tree growth developed in the fist part of the last century, if not earlier. We are rarely inspired by insights gained by modern scientists such as Platt or by philosophers of science such as Popper. Starting with the title "Using strong inference to falsify differential equation models of sugar maple height growth", this paper breaks with this stodgy tradition and embraces Platt's 'strong inference' and Popper's falsification. To be on a par with this spirit that I admire, I will skip technical cavils and restrict my comments to conceptual issues raised by the authors.

My admiration of the approach of the paper is mixed with doubts in its correctness. As most scientists and philosophers, Platt and Popper are interested in separating truth from falsity. This division is relevant only to simple problems: is this object heavier than water of the same volume? Do these seeds germinate faster at 15^oC or 25^oC? Is the integer a greater than b? Designing simultaneously several alternative hypotheses, a method proposed by Platt (1964) under the name "strong inference," calls for excluding all but one "right" alternative. But the yes or no answer cannot resolve conflicting or complex problems. Is forest succession orderly and predictable? Is nature causal or random? Do we learn by taking things apart or by putting them together? Is my knowledge objective or subjective? The "yes or no" is not the answer relevant to these problems because both opposites are true at the same time, though not in the same respect. Telling truth from falsity is a limiting case of a more general and challenging problem: how to refine truth from an elusive brew of half-truths, quarter-truths, and pure nonsense.

Forcing the "yes or no" answers to complex problems produces one-sided theories in science and philosophy. Popper's philosophy is a good example of such theories resulting from the inability to reconcile critical and positive thinking, verification and falsification, trusting and questioning facts. He believes that scientific theories are always hypothetical and the search of lasting knowledge is futile and spurious. What we take as truth is not yet refuted error; science consists of conjectures that have not yet been rejected. Science progresses from falsified theories to those which will certainly be falsified in the future. Refutation, or falsification, is much more effi-

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cient than confirmation because one negative instance (a black swan) is sufficient to reject a hypothesis (that all swans are white), while no number of white swans can prove it. Scientific theories can be decidedly falsified, but never inductively verified.

A special target of Popper's critical thinking is inductive reasoning. In agreement with Hume, Popper views induction as logically invalid. Unlike Hume, he believes that induction is unnecessary as well. Falsification allows scientists to cut out the pesky step of induction and combine intellectual satisfaction (logical validity) with technical efficiency (only one negative observation is needed). The problem with Popper's attempt to get rid of induction is his failure to notice that induction sits right in the center of his own theory. Suppose that after seeing many white swans we happened to observe a dark-colored bird. To ascertain that it is a black swan and not a grey goose, we would have to compare one feature of the bird after another with the description in an identification manual. This process is clearly inductive: it goes from particular features to a general conclusion about the bird.

Popper's assault on certainty and verification is equally self-defeating. If testing has no natural end point, the whole enterprise of science would be pointless. To Popper (1983), science has no certainty, no rational reliability, no validity, no authority. Yet, he is certain that verification is useless and misleading, that the rationality of science lies solely in the critical approach, and yet that nothing is certain. But falsification of the theory that all swans are white is impossible without verification that a given creature is a black swan; the statement "it is false that all swans are white" is the consequence of "it is true that this swan is black." Falsification without verification cannot exist.

Unlike Platt's and Popper's approach, growth modeling does account for opposites. This is clearly described in Zeide (1993). Each model form (LTD, TD, YD) includes two modules working in opposition. The paper concluded that it is a good idea to dispense with a misleading precision read into growth equations. This point escapes the authors of the reviewed paper when they write:

Zeide (1993) compared model classes based on standard error of estimated Norway spruce height, diameter, and volume derived from data published by Guttenberg (1915) and found several model classes were indistinguishable as judged by the standard error of estimates, thus falling short of Platt's imperative to 'carry out the experiment so as to get a clean result.'

What needs to be doubted is Platt's imperative. Growth equations tell us that to describe reality we need to combine opposites rather than to falsify one of them.

In more detail, the proposed approach to growth modeling and science in general is described in Zeide (2008). It starts with first principles arranged in nested pairs of opposites. They include infinity implicit in reproduction and finite space, cell proliferation and the reducing proportion of live cells, environmental stress and adaptations reducing it, density-dependent and density-independent factors, increasing average size of trees and decreasing number of trees per unit area, and others.

This approach admits that each complex problem has two opposing sides. We need to find these opposite poles before joining them in a single solution. Unlike the consecutive unfolding of the Hegelian thesis and antithesis, the opposites are considered concurrently. The described growth-density model is made of several pairs of opposites. They are arranged in three levels. At the upper level, density-independent growth of single trees is presented as the opposite of density-dependent growth of competing trees. Further dualities are distinguished within each of these processes.

Dualities of growth. We may never know how many factors determine tree growth, but one thing as certain as any mathematical proposition: all these factors either facilitate growth or restrain it. The basic positive process of tree growth is cell division. The processes that restrain growth include aging and impediments associated with increasing tree size. Within the positive group of forces, the activity of living cells is offset by the inactivity of deadwood. The positive, or expansion module fuses these opposites in a single equation. Growth restraints are opposed by adaptation, which extenuates the resistance to growth. Both restraints and adaptation to them are united in the decline module. The expansion and decline modules are the extremes that bracket all possibilities of growth: the growth is maximal when $p = 1$ and $q = 0$and minimal when $p = 2/3$ and $q \rightarrow \infty$. Analytic expression of these processes provides a meaningful and accurate model of growth comprising three pairs of opposites arranged in two levels. The model generalizes empirical growth equations and exposes biological mechanisms that justify the structure of the equations.

Dualities of density. The density model reflects the conflict between average size and number of trees per unit area. Stand density grasps both in a single number. The density of undisturbed stands is maintained at a normal level by a balance between growth and mortality. Besides the effect of average size, internal factors such as aging also decrease the number of trees. The effect of density on growth includes the limitation of resources and adaptation to it: density diminishes the availability of light but promotes its more efficient utilization. Both processes of limitation and adaptation are joined in. Together with the growth model, the model of density effect provides a model of stand dynamics.

Dualities of equations. Along with these forestry-specific opposites, the model comprises (and resolves) the opposition of change and constancy common to any equation. Change comes in two streams represented by the dependent and independent variables. Constancy is the hardware of the equations: its form and parameters. They transform the flux of input (independent variables) into that of output (dependent variable).

Duality of the approach. The model reflects two directions of research, top-down and bottom-up. It starts with the overall outcome: tree growth combining the action of all known and still unknown processes. Then, behind the "top" variable of growth (increment), we expose two underlying "bottom" groups of factors, positive and negative. Age and size served as proxies for these opposite sides of growth. If other growth predictors, such as stand density, carbon dioxide concentration, and vegetation period are known, they can be used to specify either of the groups of factors. The approach includes both splitting and joining the branches. It is a combination of both top-down and bottom-up directions. The bottom-up branch brings together all positive and negative factors in a model predicting growth of single trees and the entire stand. We return to the whole tree attaining some understanding of growth mechanisms. Uniting opposite directions of inquiry is a common strategy of learning, known as analysis and synthesis, differentiation and integration, taking things apart and putting the pieces together.

With regard to the differential equation models of height growth sugar maple, I think that we need one comprehensive model describing height growth as well as that of other tree dimensions for sugar maple and any other species. The specifics of height or diameter, of sugar or red maple should be reflected by parameters and not the model form.

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