Thoughts on modelling pine stem density

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November 21, 2017

Originally from email attachment sent from Barry to Alex on October 20, 2017, following discussion of determining pine stem denisty from stand management diagrams during Alex's visit to GLFC.

Beaudoin et al. (2014) provide data on pine % and stand volume on 250m x 250m pixels. From this we can compute pine volumes, m^3/ha. They also provide ages of leading species. In mixed landscapes such as the boreal plains, pine is a low % of the volume and rarely leads, so stand age and pine volume will be – we assume – somewhat independent of one another. To the extent that stand age is determined by time-since-fire, then homogenous ages across species within stands means that stand age might correlate better with pine age. Can we therefore use pine volume and stand age to derive stems per hectare? The reason we want stems/ha is so that we can cause MPB, in a red-top model, to subtract stems from the landscape. (MPB don't remove xylem volume; they kill stems.) Stem density, however, is a function of age, and changed dynamically as a product of self-thinning over time. (This underlies the principle of stand management diagrams.) As pure stands of pine self-thin the growing space created allows diameter increments to rise. So diameter growth is not a smooth function of age, but, rather, punctuated. Height growth, in contrast, is less stymied by crown closure, so is a smoother function of stem/stand age. A critical determinant of the intensity of self-thinning is site richness, which includes soil texture, soil depth and soil moisture – a fact which underlies the "site productivity index" concept. We may have maps of stand volumes and leading-species ages, but we do not have corresponding maps of site quality. And we don't know diameters and heights, (also these are somewhat correlated and may be inferred from stem volumes). Given the multi-determined nature of volume growth over time, and accumulated volume over space, we lack the necessary inputs to inferentially calculate (with accuracy) stem densities. Thus these will have to be estimated, and rather crudely. While age is a coarse determinant of stem and stand volume over time (and space) it is a stronger determinant in early life (age 0-60) than later in life (60-160) [reference needed]. Given we are talking about a landscape that is dominated by mature forests (except where they've burned recently), age may be a rather poor predictor of volume, and a rather weak variable for making inferences about stem densities. Given all this imprecision, it is perhaps just as meritorious to compute average/expected stem density in (250m)^2 cells by dividing cell/stand volume by mean per-stem volume. So 80m3/ha, with average tree volumes of 0.4 m^3/stem represents a mean stem density of 200 (pine) stems per hectare (with the rest of the volume being non-pine; hence the well-below average stocking of 1125 stems/ha). This is crude. More precision can come from the use of SDMDs (especially if there are better data on ages and site qualities), but at some cost. In the boreal plains region (where we are modeling MPB invasive spread) we expect site qualities don't vary nearly as much as in the rockier geography of BC and Quebec [reference needed].

More advanced approaches have been contemplated, for example, making use of TIPSY/TASS inspired yield projections. In fact Allan and Barry noted that TIPSY and SORTIE-BC produce very different age distributions even for pure lodgepole stands originating post-fire. The SORTIE approach retained a much larger cohort of suppressed trees in the endemic niche that could harbor endemic populations of MPB. In contrast, such a large suppressed class is not simulated in TIPSY (because of its focus on commercial merchantability).

Eastern researchers (*e.g.*, Candau, Fleming) began researching these aspects in 2009-11, but well after Allan and Barry had considered them in 2008, and realized that long-term forecasting would require linking with well-parameterized grown and succession models that were beyond our interest/ability to program de novo. And why re-invent the wheel? C&F concluded Peter Newton on how to approach this issue for jack pine (building from experience in the lodgepole system). At the time, many of us expected and hoped significant funding for MPB in jack pine would materialize. However after 2011 that never happened. Therefore work on beetle-succession modeling stagnated.

For long-run forecasting of eruptive behaviour in mixed-age (mixed-cohort) forests (with endemic niche plus epidemic niche) or for determining the efficacy of stand "sanitation" it would be valuable to re-visit these earlier ideas. But for the purposes of invasive spread modeling in the AB-SK border region all this may be overkill for our modest objective of evaluating eruptive potential in the short-run, as determined by spatial variations in forest attributes and microclimate, and effort put into attack-cluster spot detection and removal (given continual immigration). These are going to be the primary determinants of eruptive potential in the next few decades, not endemic niche characterization – especially when "sanitation" is not even remotely considered as a practical stand management tactic.

One caveat here is the high abundance of mistletoe-infected pine in AB/SK, which, unburned, could represent a massive endemic niche. We don't to dismiss this possibility in the mid-term; we do want to focus on simpler scenarios in the immediate term.

We evaluated some materials from Rich Fleming regarding these ideas. We will check in with Peter Newton as to the appropriateness (cost/limitations) of our proposed approach. It may be overly simplistic, but it may be "good enough".

See also Nunifu (2009).

References

Beaudoin, A, P Y Bernier, L Guindon, P Villemaire, X J Guo, G Stinson, T Bergeron, S Magnussen, and R J Hall. 2014. "Mapping attributes of Canada's forests at moderate resolution through kNN and MODIS imagery." *Canadian Journal of Forest Research* 44: 521–32. doi:10.1139/cjfr-2013-0401.

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