LETTER

If forest dynamics in Canada's west are driven mainly by competition, why did they change? Half-century evidence says: Climate change

In a recent paper (1), Zhang et al. present analyses of "forest dynamics" inferred from measurements collected during 1958–2009 at permanent sample plots (PSP) distributed across Canada's western forests. Their results are almost unanimous in showing widespread increases in mortality, and declines in relative growth and recruitment (figure 2 in ref. 1). Zhang et al. conclude these trends are explained primarily by changes in stand-scale competition, and that recent changes in climate are of secondary importance. Surprisingly, Zhang et al. do not explain the temporal changes in competition they detected. We accept that stand dynamics depend upon competition for light, nutrients, and water, but argue that climate affects the supply of these resources. We find some major problems with the report by Zhang et al., including misinterpretation of results and a critical lack of clarity on key model assumptions, which cast serious doubt on their conclusions.

First, Zhang et al.'s (1) results show strong impacts of annual precipitation on growth, mortality, and recruitment of trembling aspen (the dominant boreal broadleaf species) (figure 3 G–I in ref. 1). In fact, precipitation may not be the strongest predictor of aspen decline because water availability also depends on evapotranspiration, which generally increases with air temperature (2–4). In their *Supporting Information*, Zhang et al. (1) report no "strong" evidence for interactions between competition and climate indices, and dismiss climatic moisture index (2) as a predictor because it appeared strongly correlated with precipitation. However, coniferous and broadleaved trees likely respond differently to moisture deficits, so this predictor should properly have been retained explicitly in Zhang et al.'s (1) nonlinear models, with species added as an interaction term. Omitting these terms could underestimate the effects of drought on conifer stand dynamics.

Second, most of the PSP data are from the 1970s–1990s, when local climates caused episodic dieback and stand mortality of drought-sensitive trembling aspen in the boreal plains (2). It is possible that other regions dominated by coniferous species were not so affected, which might support Zhang et al.'s (1) hypothesis that past climate has been of secondary importance to competition where conifers dominate. Zhang et al. recognize this apparent lack of sensitivity "could quickly change" with climate warming (1). We contend that climate-sensitivity of soil moisture availability is likely to have affected past competition, and will become increasingly important for all forest types, both as observations accrue for the anomalously warm (and undersampled) 2000–2009 decade, and as the climate continues to warm throughout the 21st century (3). Moreover, PSPs provide biased samples of forest dynamics by not accounting for frequent occurrence of stand-replacing disturbances, such as wildfires and outbreaks of insect pests (5). Zhang et al. (1) base their conclusions on observations at undisturbed PSPs, overlooking the critical role of climate-sensitive disturbances when scaling up to the landscape or entire forests.

Yield models used in forest management typically do not account for climatic effects, which will cause increasingly unreliable yield projections as climate changes. Zhang et al. (1) suggest this can be resolved by incorporating climate-sensitivity in next-generation models. We agree this is an urgent (and challenging) problem to address. Such models will be essential for projecting how climate change affects forest dynamics, at both stand and landscape scales, to ensure forest management remains sustainable in coming decades.

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1 Zhang J, Huang S, He F (2015) Half-century evidence from western Canada shows forest dynamics are primarily driven by competition followed by climate. *Proc Natl Acad Sci USA* 112(13):4009–4014.

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4 Anderegg WRL, et al. (2015) Tree mortality predicted from drought-induced vascular damage. *Nat Geosci* 8(5):367–371.

5 Price DT, et al. (2013) Anticipating the consequences of climate change for Canada's boreal forest ecosystems. *Environ Rev* 21(4):322–365.

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