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What governs the effects of permafrost thaw on boreal forest dynamics?

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Boreal forests are located at latitudes that are predicted to experience some of the greatest warming on the planet. Forests growing on permafrost may be particularly vulnerable, with accelerated soil warming and permafrost degradation linked to changing patterns of tree growth and longevity. Many have speculated that thawing permafrost, through its effects on soil water content and ground stability, will increase forest mortality across the boreal region. However, recent evidence indicates mixed forest responses to permafrost thaw. In some areas, the onset of thaw is followed by increased tree growth and increased forest cover area. In other sites, thaw has been linked to decreased growth and forest cover loss. It is currently poorly understood what determines these contrasting responses, and the roles that different environmental and climatic factors may play. This leads to two major issues: (1) uncertainties in predicting the effects of future permafrost thaw on carbon dynamics in northern ecosystems, and (2) poor understanding of where scientific and conservation efforts should be focused. Here, we present a review of the recent evidence of permafrost thaw effects on boreal forest dynamics and propose an explanation for the differing responses across sites. We argue that the outcome is controlled by a set of factors that influence two major pathways and the interactions between them: (1) permafrost-soil water content and (2) soil water content-plant growth. We present a series of conceptual models explaining these interactions and highlight the largest sources of uncertainties. Based on these, we propose a set of hypotheses and methodologies to guide future research in this area.