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Canadian Forest Service – Great Lakes Forestry Centre

Vulnerability of Canadian forest tree species to climate change

INTRODUCTION

As part of the Forest Change Initiative (under Natural Resources Canada's Climate Change Adaptation Program), Canadian Forest Service (CFS) scientists are assessing the potential impacts of climate change on Canada's forests. This knowledge will be helpful in the development of future forest policy and in the establishment of alternative forest management strategies. Scientists anticipate that climate change will result in more frequent and severe disturbances such as droughts and fire, causing changes in forest dynamics. Cumulative stresses might increase species' susceptibility to pests and diseases. In response, tree species can persist in their current location by coping with new growing conditions through tolerance and short term adaptation, or by evolving over longer time scales. A species may also relocate (migrate) via seed or propagule dispersal to a more favorable habitat, eventually resulting in a range shift. Overall, individual tree species vary in their ability to tolerate, adapt and move. It is therefore critical for our understanding of future forest composition to study the mechanisms underlying vulnerability to climate change.

Species such as willow that produce abundant, easily-dispersed seeds may adapt more easily to climate change

A species' vulnerability depends on its degree of exposure (i.e., the degree of environmental change a species will experience), its individual sensitivity to altered growing conditions and its adaptive capacity (i.e., ability to accommodate or cope with those environmental changes). Current climate envelope models, which show the range of suitable growing conditions, can predict the degree to which species are likely to be exposed to climatic changes. However, they do not incorporate species' individual sensitivity or adaptive capacity. While knowledge on mechanisms determining sensitivity is available, it tends to be fragmented by field of research and by species, thus limiting "scaling up" initiatives aimed at whole-community responses. The adaptive capacity of living organisms remains largely unknown but over the next decade more research efforts will be dedicated to unravelling this specific attribute.

GREAT LAKES FORESTRY CENTRE ROLE

Trees' sensitivity and adaptive capacity are the result of complex phenomena reflecting mechanisms that occur and interact at different scales, from the cellular to the community level. To better understand these mechanisms, aggregation of knowledge from diverse disciplines is required. One way to achieve this integration of information is to use the functional trait approach, which focuses on plant characteristics that play a role in their fitness (growth, establishment, and survival). Great Lakes Forestry Centre (GLFC) scientist Isabelle Aubin is part of a multidisciplinary team of CFS and university scientists who are working together to define the key mechanisms involved in species' fitness to arrive at a suite of traits that could provide a means of measuring a species' sensitivity and adaptive capacity to climate change. The examples of drought sensitivity and ability to migrate are presented below.

Drought sensitivity

Knowledge on the ecophysiology and morphology of tree species can provide important indicators of their response to drought. Information on rooting depth and leaf stomatal response can inform researchers on tree capacity to avoid internal stress from drought, while xylem capacity to resist embolism or "cavitation" (the formation of air bubbles that block water transport and which may lead to tree death) and species' capacity to resume water transport in embolised vessels after a water shortage are crucial to assess the risk of drought-induced mortality. Researchers also use knowledge from population dynamics to assess a species' recovery potential. When a drought subsides, some species that have suffered heavy stem mortality may be able to recover at a population level due to effective vegetative reproduction, or specific seed traits.

By collating knowledge from different disciplines, researchers are able to determine which species are likely to withstand drought more easily. Characteristics of such species include deep root systems, sensitive stomatal control, cavitation-resistant xylems, and abundant carbohydrate stores. Additionally, species with a high capacity for population recovery after drought (good production of highly dispersed seeds and/or strong clonal propagation, such as trembling aspen) are also more likely to persist in their current range.

Ability to track climate change

Currently, climate envelope models allow researchers to predict where the climatic conditions that a species is experiencing now will move to under various climate change scenarios, but they do not allow them to assess the likelihood of a species actually reaching and colonizing this new area. To achieve this next step, researchers are collating information on the reproduction dynamics of tree species and evaluating their relative importance in a Canadian context. Successful colonization is determined by a species' overall reproductive effort: the number of seeds that are produced by an individual and the proportion that are viable. Researchers also have to take into account the time to reach sexual maturity and the frequency of good seed years thereafter. For each of these seeds, the capacity to move to a new location will depend on traits associated with dispersal mode (wind-borne, carried by birds or cached by squirrels) that will influence how far seeds travel and where they settle.

Reaching a new habitat is not enough to guarantee that a species will be able to establish a new population. Researchers are therefore taking into account traits that reflect a species' ability to tolerate inbreeding and grow in small populations, such as its level of clonality, and its reliance on self-pollination. Scientists must also account for the probability of specialized species encountering their specific fungal symbiont (one they cannot live without - e.g. mycorrhizae), pollinator or germination requirements. Thus, generalist species that reach maturity quickly, produce large amounts of wind-borne or bird-dispersed seeds and are able to spread asexually once they have reached a new habitat will be better able to follow their climatic conditions.

Tree adaptive capacity: toward an integration of genetic data

Scientists can deduce that widespread species with large populations and high levels of both genetic diversity and fecundity are more likely to adapt. The work of forest geneticists provides an important population-level perspective on adaptation, and contributes a crucial layer of information on adaptive capacity to this multidisciplinary initiative. For instance, forest geneticists are clarifying the role of selective pressures in shaping genetic diversity, a key element of adaptive capacity. Recently, the advent of new genomic technologies has allowed the emergence of new sub-disciplines including landscape and ecological genomics. These new research fields offer the opportunity to draw direct links between genetic markers and phenotypes. These relationships are crucial to a better understanding of tree fitness under changing environmental conditions.

CONCLUSION

CFS scientists in the Forest Change Initiative are leading the way in bringing together multidisciplinary groups and knowledge integration to develop a greater understanding of how species might respond to climate change. Ecological knowledge from various fields of specialization can be incorporated into models that try to project the state of Canada's forest into the future and allow for the development of appropriate management strategies. Models that are based on different layers of information and a broader range of data will improve decision-making and assist in the identification of species requiring management actions for their conservation.

Some key traits for tree sensitivity to drought and ability to track climate change

Drought tolerance
deep root systems
sensitive stomatal response
capacity to resist embolism
ability to resume water transport in embolised vessels

Recovery from drought
ability to reproduce vegetatively
high seed production
good seed dispersal ability
seed bank persistence

Migration and establishment ability
high seed production
high seed viability
short time to sexual maturity
frequent good seed years
good seed dispersal ability
ability to reproduce vegetatively

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POLICY PERSPECTIVE

Natural Resources Canada conducts research relating to the protection of the forest resources of Canada under the *Forestry Act*. Climate change adaptation has been identified as a priority for the forest sector by the Canadian Council of Forest Minister's (CCFM). The CFS is a member of the Climate Change Task Force, which works collaboratively to develop improved assessments of the impacts of climate change on forests and prepare suitable responses to these impacts to ensure a healthy ecosystem and sustainable forest resources.

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