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CANADIAN FOREST SERVICE

Forest Change—TOOLS

Including ecological knowledge in biophysical predictions: A trait-based approach

How is vulnerability assessed?

Not all species will react equally in the face of rapid environmental change. A species' **vulnerability** depends on its degree of **exposure** (i.e., the environmental change it will experience), its individual **sensitivity** to altered growing conditions, and its **adaptive capacity** (i.e., its ability to accommodate or cope with those environmental changes).

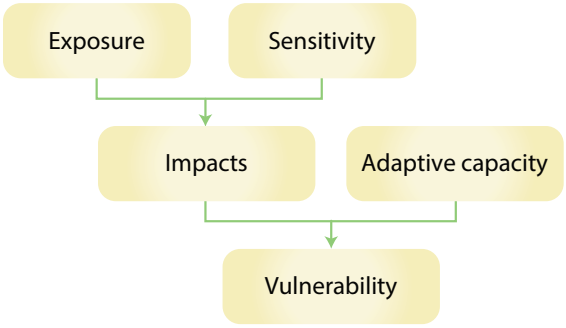

Figure 1. Factors to consider when assessing a species' vulnerability.

How can traits be useful?

Traits are plant characteristics that affect growth, establishment, and survival. Functional traits can help determine the response of an organism to an environmental stressor. This approach helps identify the sensitivity of a given species and indicates its potential response.

Including traits in vulnerability assessments may help provide a more complete picture of forest response to climate change. For example, climate envelope models currently allow researchers to predict where the climatic conditions that a species is experiencing now will occur under various climate change scenarios. However, they do not inform us whether a species can persist under the new climatic conditions, or the likelihood of a species actually reaching and colonizing the new area.

Mechanisms and traits related to drought tolerance

Tolerance to drought can arise through

- avoidance—the extent to which an individual limits its exposure to drought through mechanisms such as efficiency of water uptake and mitigation of water loss,
- resistance—the ability of an individual to withstand drought through mechanisms such as xylem resistance to cavitation, and
- recovery—the ability of an individual or a population to recover after drought through mechanisms such as vegetative reproduction.

Characteristics of a drought-tolerant 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 well-dispersed seeds and/or strong clonal propagation) are more likely to persist in their current range (see Table 1).

Mechanisms and traits related to capacity to migrate

A species' capacity to migrate to track climate depends on its ability to

- reproduce,
- disperse seed, and
- colonize a new area.

A species that is able to migrate is therefore one that reaches maturity quickly, produces large amounts of viable seeds, and has frequent good seed years. In addition, these seeds need to be effectively dispersed, with wind-borne and bird-dispersed seeds potentially moving greater distances. However, simply reaching a new habitat is not enough to guarantee that a species will be able to establish a new population. A species that is able to tolerate inbreeding and grow in small populations has a better chance of establishing viable populations in a new location (see Table 2).

Table 1. Traits underlying species response to drought. (For definitions of traits related to drought, see Table 1 in Aubin et al. 2016).[a]

Species	Trait				
	Max. rooting depth (cm)[b]	Stomatal size (µm)[c]	Xylem resistance to embolism (ψ_{50};* MPa)[c]	Re-sprouting ability[b]	Seed persistence in the seed bank (yr)[b]
Acer saccharum Sugar maple	273	10.5	–3.18	Medium	1
Carya glabra Red hickory	127	18	–1.11	Low	<1
Fraxinus americana White ash	180	24.4	–1.92	Medium	2–5
Picea mariana Black spruce	61	NA[d]	–5.26	Medium	<1
Pinus banksiana Jack pine	220	NA	–3.35	None	Aerial bank
Pseudotsuga menziesii Douglas-fir	348	NA	–4.68	None	1–2
Populus tremuloides Trembling aspen	240	24	–2.74	High	1
Quercus rubra Red oak	220	13.8	–1.61	Medium	1

[a] Quantitative trait values represented in this table are calculated as an average of values available from the Traits of Plants in Canada (TOPIC) database. Values may be based on limited data points and may not represent the range of conditions under which a species grows. Values can vary between individuals of the same species depending on environmental conditions at a given site and/or their genotype.

[b] Drought tolerance tends to increase with higher values.

[c] Drought tolerance tends to decrease with higher values.

[d] Not available.

* Xylem pressure at which 50% of the xylem conductivity in the stem is lost through cavitation.

Table 2. Traits underlying different species migration potential. (For definitions of traits related to migration, see Table 2 in Aubin et al. 2016.) [a]

Species	Trait							
	Seed production (seeds/ha)[b]	Seed viability (%)[b]	Age to sexual maturity[c]	Frequency of good seed crops (yr)[c]	Main seed dispersal vector	Seed terminal velocity (m/s)[c]	Seed weight (no. seeds/ kg)[b]	Vegetative reproduction[b]
Acer saccharum Sugar maple	20 000 000	95	22	2–7	Wind	0.95	14 400	Medium
Carya glabra Red hickory	10 820	85	30	1–2	Gravity, bird, mammal	NA[d]	441	Low
Fraxinus americana White ash	105 650	55	20	3–5	Wind	1.35	22 000	Medium
Picea mariana Black spruce	1 000 000	60–90	10	2–6	Wind	0.63	891 000	Medium
Pinus banksiana Jack pine	5 000 000	70–85	5	1	Wind, bird, mammal	0.74	288 000	None
Pseudotsuga menziesii Douglas-fir	1 600 000	80–95	10	4–5	Wind, water	NA	7 150 000	High
Populus tremuloides Trembling aspen	204 000	60–95	9	5–7	Wind, bird, mammal	0.75	92 800	None
Quercus rubra Red oak	125 000	60–100	25	2–6	Gravity, bird, mammal	NA	276	Medium

[a] Quantitative trait values represented in this table are calculated as an average of values available from the Traits of Plants in Canada (TOPIC) database. Values may be based on limited data points and may not represent the range of conditions under which a species grows. Values can vary between individuals of the same species depending on environmental conditions at a given site and/or their genotype.

[b] Migration potential increases with higher values.

[c] Migration potential decreases with higher values.

[d] Not available.

How can this information be used?

Figures 2 and 3 provide information on tree vulnerability in Canada, integrating ecological knowledge on sensitivity to drought and ability to migrate with biophysical predictions on exposure. Using these two types of information together can inform management options. For example, if there is a higher tree biomass exposed to drought, but the species shows a high ability to overcome drought stress, either through recovery potential or avoidance, the management approach should focus on conserving a species in place. If there is a higher tree biomass exposed to drought, but the species shows high migration capacity, management options might include ensuring landscape connectivity. On the other hand, assisted migration might be an option for a species that is drought sensitive, that has a limited ability to migrate, and for which a higher tree biomass is at risk.

How is the information expressed visually?

The information has been mapped with a two-dimensional, color-coded legend to indicate the degree of exposure and sensitivity. The maps represent vulnerability based on data from the 22 most abundant tree species in Canada. The x axis represents the projected exposure to altered conditions relative to their current habitat. The y axis represents the sensitivity based on trait information.

Drought

The colors in each corner can be interpreted as follows:

- green—a lower tree biomass is exposed to drought and the species are less sensitive,
- orange—a lower tree biomass is exposed to drought but the species are more sensitive,
- blue—a higher tree biomass is exposed to drought but the species are less sensitive, and
- pink—a higher tree biomass is exposed to drought and the species are highly sensitive.

Migration

The colors in each corner can be interpreted as follows:

- green—the species are a relatively short distance from their suitable habitat and have a high capacity to migrate,
- orange—the species are a relatively short distance from their suitable habitat but have a lower capacity to migrate,
- blue—the species are a relatively long distance from their suitable habitat but have a high capacity to migrate, and
- pink—the species are at a relatively long distance from their suitable habitat and have a lower capacity to migrate.

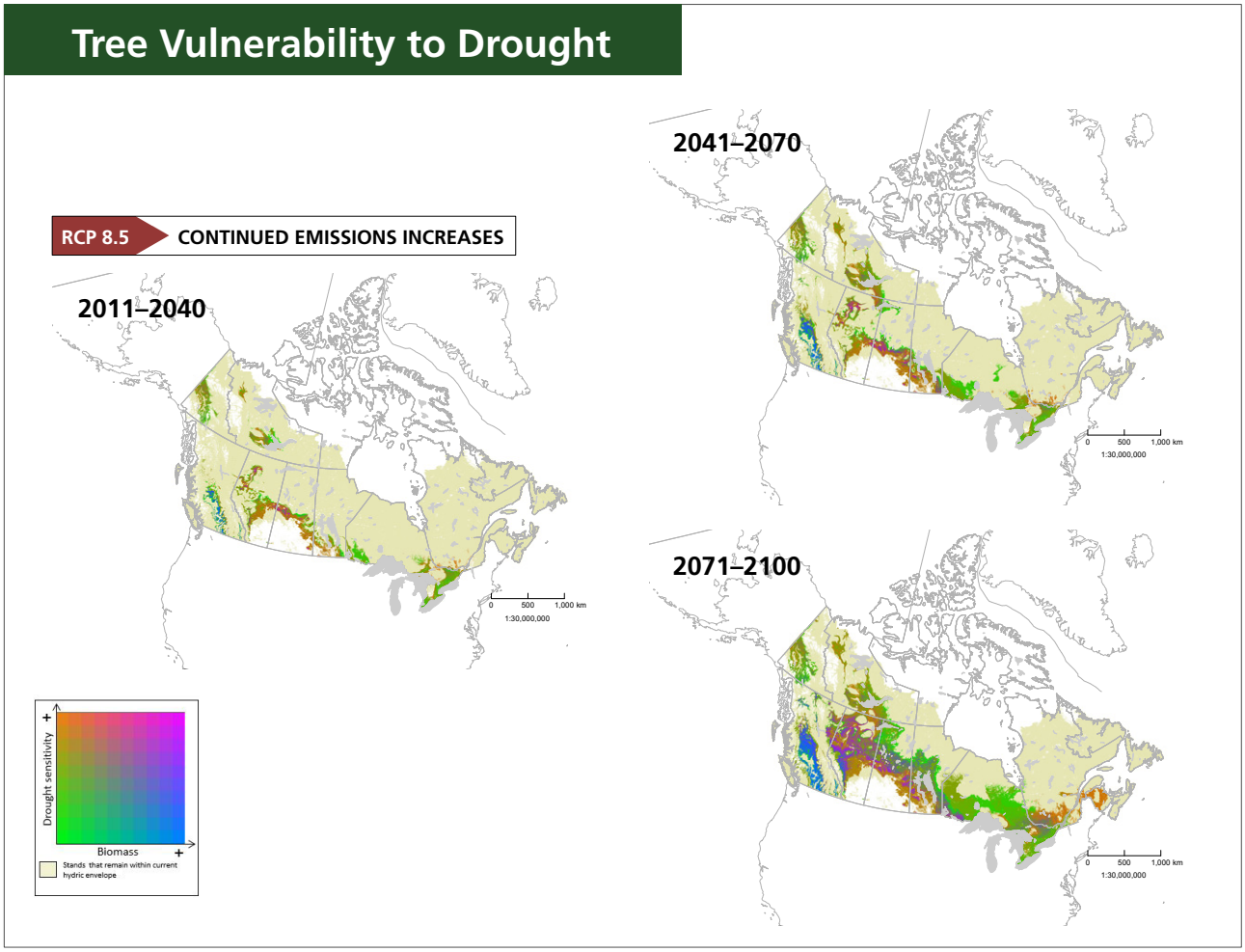

Figure 2. Tree vulnerability to drought under different time frames. Under the Representative Concentration Pathway 8.5 (continued emissions increases) climate scenario, area at risk of tree drought sensitivity is increasing over time.

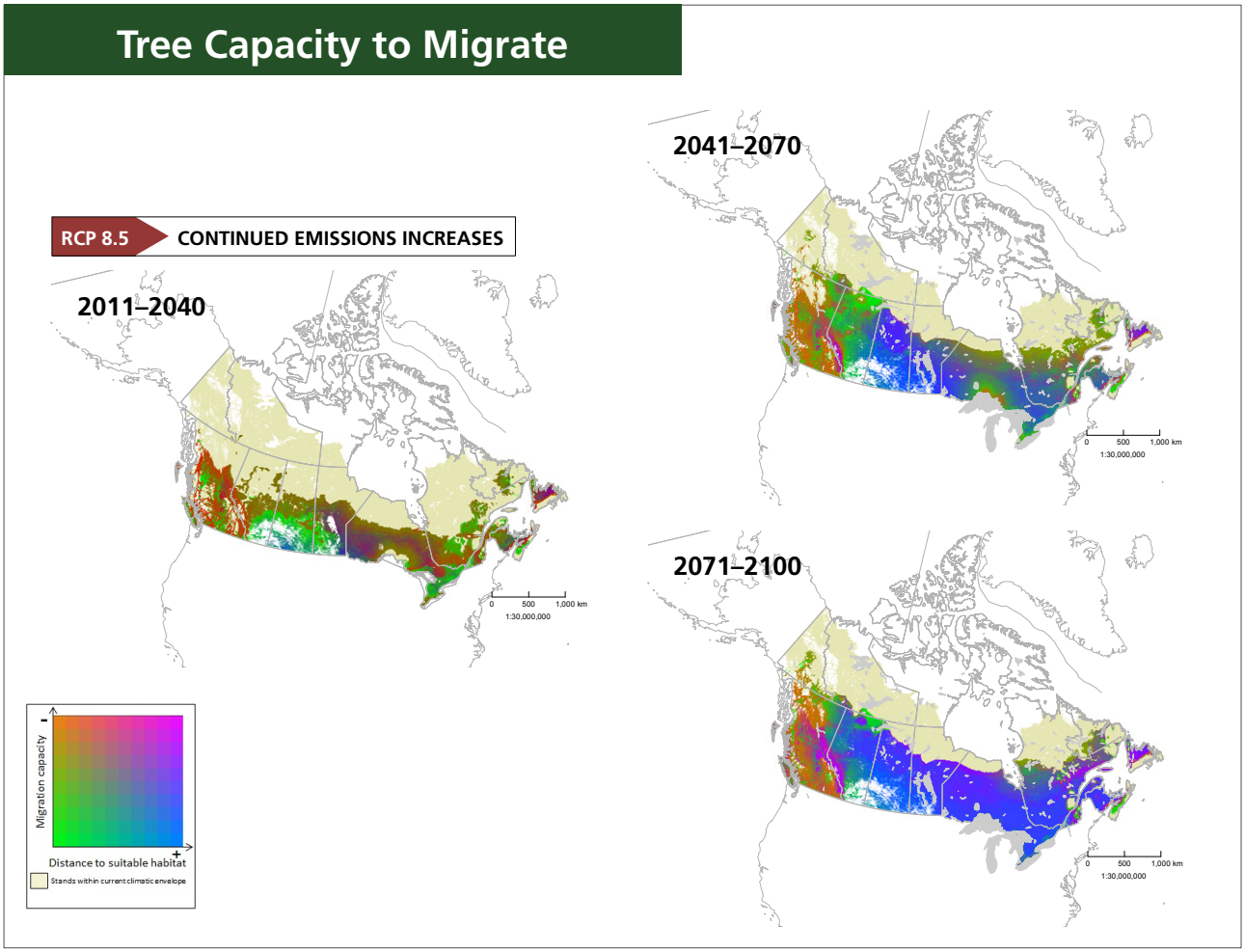

Figure 3. Tree capacity to migrate under different time frames. Under the Representative Concentration Pathway 8.5 (continued emissions increases) climate scenario, distance to suitable habitat is increasing over time.

Is vulnerability expected to change over time?

Figures 2 and 3 show the projected tree vulnerability to drought and tree capacity to migrate. The beige area shows stands within the current hydric envelope or current climatic envelope. Comparing the short-term and long-term projections shows that vulnerability from both exposure and sensitivity is increasing over time.

References

Aubin, I.; Munson, A.D.; Cardou, F.; Burton, P.J.; Isabel, N.; Pedlar, J.H.; Paquette, A.; Taylor, A.R.; Delagrange, S.; Kebli, H.; Messier, C.; Shipley B.; Valladares, F.; Kattge, J.; Boisvert-Marsh, L.; McKenney, D. 2016. Traits to stay, traits to move: a review of functional traits to assess sensitivity and adaptive capacity of temperate and boreal trees to climate change. Environ. Rev. 24(2):164–186; doi: 10.1139/er-2015-0072.

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