Guidelines for interpreting the output of the DIVERSE seed selection tool

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This tool supports the selection of tree species and seed sources for reforestation under climate change by matching projected future climates of a target ecosystem or forest management area with historical climates across North America. As illustrated in Fig. 1, projected climate conditions shift geographically over time, such that future climates at a given location correspond to climates that currently occur further south or at lower elevations. The tool uses these climate and soil analogues at a fine-scale ecosystem level to identify species likely to remain suitable and to recommend seed sources adapted to future conditions.

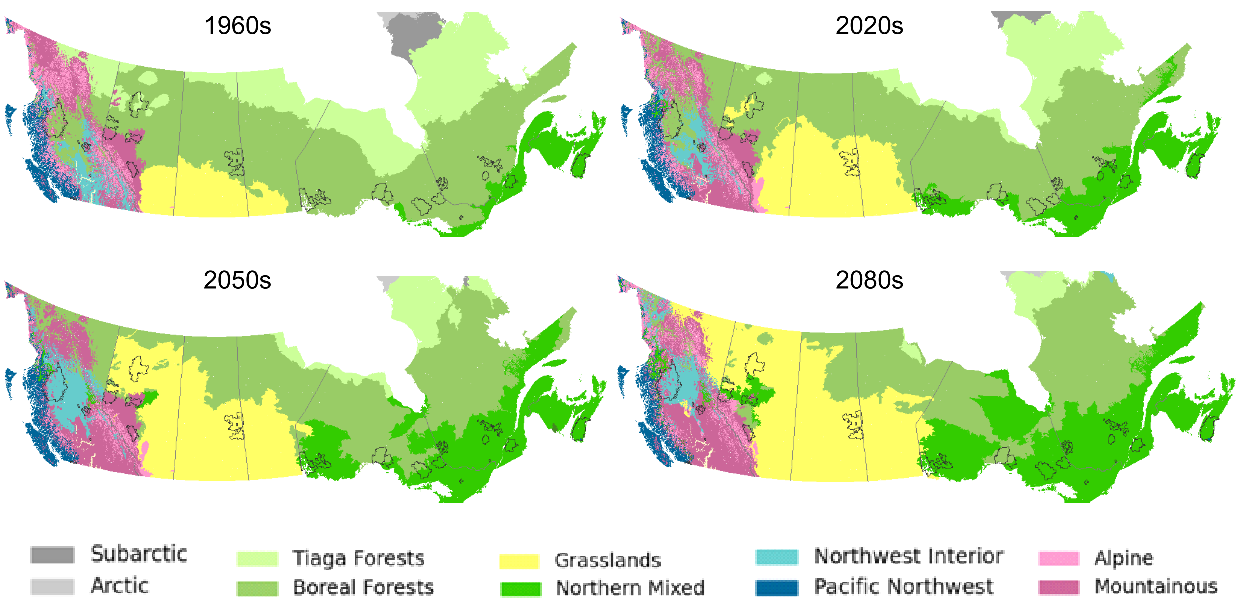

Figure 1. Shifts of suitable climate habitat based on CMIP6 SSP2-45 (middle-of-the-road) multi-model climate projections. Colors represent a majority biome classification, according to the 5 closest source-target ecosystem climate matches. Forest management areas used in subsequent summaries (Fig. 2) are shown as black outlines.

Step 1: ***Select tree species that have a future under climate change***

The results are presented as species frequency tables for each ecosystem and time period. These tables show the relative proportion of each species across the ecosystem land base, based on the average of the five closest climate-matched regions. Species frequencies therefore represent expected importance under a given climate, rather than exact predictions for any specific site. There are three versions of this table.

1. FMA-level summary. This is a weighted average across the entire FMA land base. You can download these tables for your FMA from the tool home page: https://tinyurl.com/diverse-sst. An abbreviated example is shown in Table 1 below.

2. Ecosystem-level tables. Most FMAs contain multiple ecosystems, especially in large or mountainous regions. In these cases, recommendations need to be interpreted at the ecosystem level within the FMA. The tool provides a table for each ecosystem; follow the link "table for this site" on individual target site pages.

3. Quick-view table. At the top of each individual target site page, a simplified version of the table is shown, formatted for quick visualization. It includes only the most important species and presents the same data with a different layout (rows and columns reversed).

How to interpret these table (example below)

- What does it mean if a species retains its relative frequency over time (e.g., sugar maple)? Good news! You can keep planting the species, but you should not use the same local seed sources. Most wide-ranging species consist of locally adapted populations.
- What does it mean if a species declines over time (e.g., paper birch)? This is not necessarily cause for alarm. Trees tend to have wide climatic tolerances (their fundamental niche). However, it is a good risk avoidance strategy not to push these limits, but rather plant within the realized climate niche. It is therefore prudent to gradually shift to other species or seed sources over time.
- What does it mean if a species increases over time (e.g., red maple)? These species are likely to become more suitable under future climates. They may already occur at low abundance and can be considered as candidates for increased use or gradual introduction.
- What does it mean if new species appear at low frequency (e.g., American elm)? These may represent emerging climate matches. However, low-frequency species should be interpreted with caution, as they may be associated with specific site conditions (e.g., riparian areas or particular soils).
- What does it mean if the proportion of non-forested or agricultural climate habitat increases? You may be running out of motivation to plant trees in the future. Climatic conditions may support other land uses, or no longer support forest trees.

Table 1. Abbreviated species selection table for the Halliburton forest management area.

Scientific name	Common name	1960s	1990s	2020s	2050s	2080s
	non-Forested	39.07	34.29	38.29	32.35	36.52
	Agriculture	4.69	4.61	20.82	36.55	76.30
Acer saccharum	sugar maple	10.75	7.72	6.76	6.38	3.09
Pinus strobus	eastern white pine	5.07	7.8	7.05	5.18	1.72
Acer rubrum	red maple	4.54	6.84	8.94	9.35	5.21
Quercus rubra	northern red oak	2.43	3.14	2.89	3.63	3.27
Betula papyrifera	paper birch	4.59	4.05	1.39	0.48	0.16
Abies balsamea	balsam fir	4.25	4.14	1.79	0.3	0.03
Prunus serotina	black cherry	0.43	1.02	2.21	3.13	4.43
Ulmus americana	American elm	0.11	0.15	0.7	1.38	2.73
Quercus alba	white oak	0.08	0.11	0.36	2.56	3.52
Fraxinus pennsylvanica	green ash	0.06	0.04	0.21	1.43	3.75

***Step 2:* Select appropriate seed sources for the species of your choice**

Once suitable species have been identified, the next step is to select seed sources that are adapted to future climate conditions. Even if a species remains suitable, local seed sources may no longer be optimal. Most wide-ranging species consist of locally adapted populations, and transferring seed sources is a key strategy for adapting to climate change.

The tool identifies suitable seed sources by linking future climate conditions at the target site to ecosystems that currently experience similar climates. Climate matching is performed first, and soil similarity is then used as a secondary constraint. Increasing the soil constraint restricts candidate seed sources to ecosystems with more similar soil conditions, while relaxing it allows a broader set of climate matches. In practice:

- Start with climate matching to identify candidate seed source regions (values <0.5 recommended)
- Use the soil slider to exclude ecologically implausible matches (values <0.5 recommended)
- Match species to site conditions using silvics and local knowledge (not covered by the tool)

Non-climatic factors remain critical for site-level reforestation decision. While the tool identifies climatically and broadly edaphically suitable species and seed sources, it does not evaluate site-level conditions. Species should be matched to local soils, moisture regimes, and microsites based on where they occur within the source ecosystems. Especially infrequent species may be niche specialists (e.g., riparian habitats or specific soil conditions) and should be matched to target sites accordingly.

Consider observed and projected climate trends

Observed and projected climate trends should be interpreted together. Ultimately, management needs to respond to actual climate change, not projections. At the same time, short-term variability can be high, and decadal changes are often noisy compared to longer-term climate normals. Keep in mind that decadal changes are noisier than 30-year climate normals. The analogy is that of a man and a dog on a long leash. To assess direction, follow the path of the man (30-year normals), not the dog (decades).

The example Fig. 2, generated by the tool for each target site, illustrates this: short-term (decadal) positions can fluctuate (solid lines), often within the natural range of spatial variability of an ecosystem (dashed circle), while longer-term trends show a clearer directional shift toward future conditions (dashed arrows). Interpretation should therefore focus on the overall trajectory rather than individual decades.

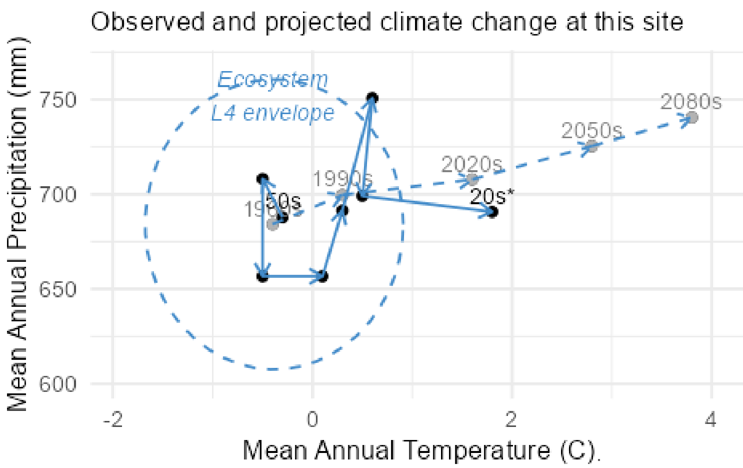

Figure 2. Observed and projected climate change for an example site, provided by the tool. Consecutive decadal periods (solid arrows, black markers) and 30-year climate normals (dashed arrows, gray markers), based on weather station observations from 1951 to 2024 (e.g., 1950s = 1951–1960 mean; 2020s* = 2021–2024 mean) and CMIP6 multimodel projections for future periods (2020s, 2050s, 2080s).

What if historical climate change (historical decades 1950s to 2020s) does not align with future projections in approximate magnitude and direction? Then caution is in order. If climate warms faster (or slower) than projected, plant for conditions further ahead in time (or less so). Increased precipitation can compensate for increases in temperature in terms of viable species choices. If historical climate change indicates that your site has become drier than predicted, compensate by planting for conditions further ahead in time (or vice versa).

Maintenance of forest habitat, shifts in diversity, and long-distance climate matches

Changes in climate can affect both the overall availability of forest habitat and the range of tree species that may be supported. It is therefore useful to consider these two aspects together when interpreting future conditions. The following results summarize projected changes in total forest climate habitat and the diversity of potential tree species across the participating forest management areas.

In most FMAs, the total amount of forest climate habitat remains relatively stable over time (Fig. 3b). This indicates that climatic conditions are expected to remain broadly suitable for forest tree species, even under projected warming. Declines are limited to a small number of areas, particularly near the southern boreal margin (e.g., Peace River East, Pasquia–Porcupine), where increasing proportions of grassland or agricultural climate habitat are projected. For most regions, this suggests continued potential for forest cover, with localized incursions of non-forest climate conditions.

At the same time, the diversity of potential tree species habitat generally increases in many FMAs (Fig. 3c), especially in central and eastern regions. This reflects the northward movement of species associated with warmer climates, leading to a broader range of species that may become suitable over time. In contrast, western FMAs tend to show more stable diversity, with smaller changes in species options.

A different pattern emerges in some western regions, where future climates have no close nearby analogues (e.g. Blue Ridge and Grande Prairie, Fig. 3a). In these cases, climate matches occur over longer distances with eastern regions by the 2050s and 2080s (c.f., Fig. 1) with diversity increases by the 2080s (Fig 3c) reflecting these potential options. These long-distance matches of eastern species could be considered for testing and gradual introduction.

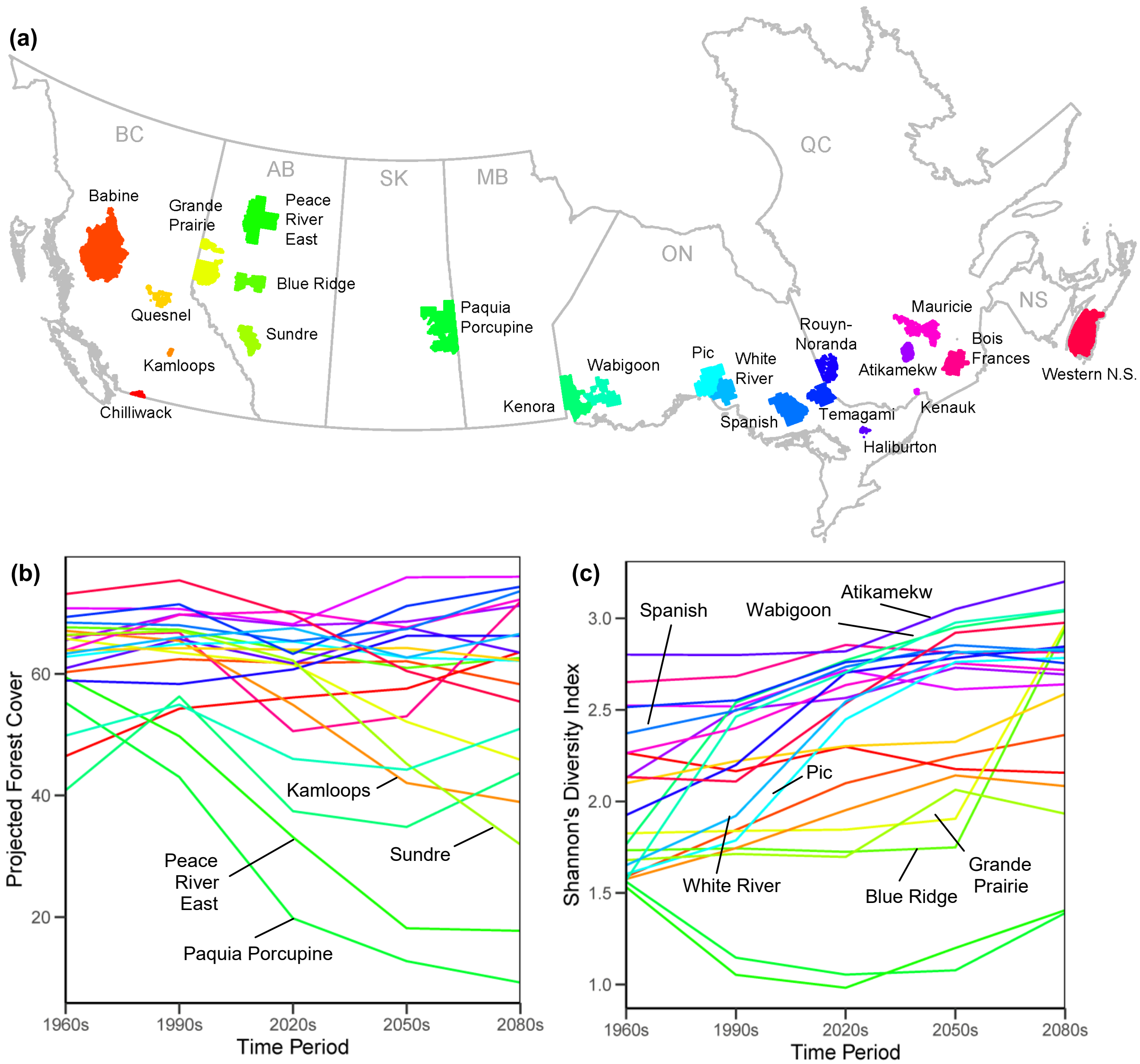

Figure 3. Maintenance of climatic habitat for forest tree species, summarized for 22 forest management areas of DIVERSE project participants **(a)**. The line plots show the sum of historic and future climate habitat **(b)**, and the diversity of potential tree species habitat **(c)**.

Conclusion

We are now at the mid-point of the 2020s climate period. In many regions, forests are now being regenerated under conditions that differ from those under which existing stands developed (e.g. see Fig 1). This creates an opportunity to begin incorporating climate-informed species and seed sourcing into current reforestation programs. Over time, such experience can help refine choices and reduce uncertainty, so that future decisions are informed by practice rather than extrapolation.