About the North America Seed Selection Tool (NA-SST)

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This web tool (http://tinyurl.com/na-sst & http://tinyurl.com/diverse-sst) is meant to support the selection of well adapted tree species and seed sources for reforestation under observed and projected climate change. This tool is a work in progress carried out under the auspices of the DIVERSE project.

The **basic method** is that we calculate a proportional basal area of tree species from gridded US and Canadian data for Level-4 ecosystem delineations (BC: BEC Variants, AB: NSR Variants, rest of Canada: Ecodistricts, US: L4-Ecoregions). Next, the frequencies are scaled with remotely-sensed land and tree cover data so that species' frequencies + non-forested = 100% of the ecosystem land base. (If classified as forested at the biome level, agriculture/urban areas count towards climate habitat for trees).

For the **climatic analysis,** we use historical PRISM & ERA5 data and CMIP6 future projections, using an 8-model ensemble for the SSP2 – "Middle of the Road" scenario to characterize past and future ecosystem climates in times steps of consecutive 30-year normal periods (1951-1980, 1981-2010, etc.) as well as consecutive decades (1951-1960, etc., where the 20s* are the 2021-24 average).

Changes to **species frequencies** are then inferred by matching climates of target ecosystems (1990s, 2020s, 2050s, 2080s) with historical climates of source ecosystems (1960s) using multivariate climatic distance matrices for 12 bioclimatic variables. The species frequency tables are based on the average of the five closest climate matches (including for the historic 1960s baseline projection).

Some comments on interpretation:

- What does it mean if a **species retains its relative frequency** over time? 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? This is not necessarily cause for alarm. Trees tend to have incredibly wide climatic tolerances (their fundamental niche). However, when it comes to planting, it's a great risk avoidance strategy to not push the fundamental niche limits, but rather plant within the realized climate niche (i.e., climates where species would naturally occur). That way, you avoid pests and diseases that also like the warmer climates. So, best to shift to other species over time.
- What does it mean if the proportion of **non-forested** and/or **agriculture** 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.
- What about **non-climatic factors** when migrating seed sources to address climate change? Nothing could be more important! As usual, use the Silvics of North America (or local reforestation handbooks from source ecosystems) to match species to target sites equivalent to where they occur in the source ecosystem. Especially infrequent species may be niche specialists (e.g. riparian, specific soils, etc.).
- What if historical climate change (historical decades 1950s to 2020s) does not align with the future projections in approximate magnitude and direction? Then caution is on order! Ultimately, we need to adapt to actual climate change, not the projections. That said, 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 the direction, follow the path of the man (30-year normals), not the dog (decades)!
- That said, 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. So, if historical climate change indicates that your site **got drier** than predicted, compensate by planting for conditions **further ahead** in time (or vice versa).

A two-pager on further details, known issues and planned improvements

- Working with previously developed gridded US and Canadian species distribution data that were developed with similar methodology appears to work quite well. However, there are some discontinuities along the US-Canadian border, and we are working on building our own **species distribution models** with deep neural network methodology that may include more species and cover the entire continent, including Mexico.
- Also, current species distributions and derived frequency tables appear to include species misidentifications or species planted outside their natural range. However, these will be low-frequency entries. You may **disregard anything that is low frequency**, especially if appearing and disappearing erratically over time. The tables are sorted, so that low frequency species are at the end. For assisted migration applications in a reforestation context, we should focus on reasonably common species populations listed in the top half of the tables.
- **Uncertainty in future projections** is not quantified yet. The plan is to avoid predictions based on an average ensemble, and to run multiple individual AOGCM projections instead, as explained on this page: http://tinyurl.com/ClimateNA (scroll down to scenario selections). With that, we can update the table of projections to double-metrics: 8.26% (>0.99), meaning an average projected relative abundance of 8.2%, and a >99% probability that there is suitable climate habitat for the species. For lower frequency entries, you may get results like 0.12% (0.34), which would suggest some caution.
- We have so far not addressed potential issues with **non-analogue climate conditions**. From previous research, our subjective judgment is that a scaled climate distance less than 0.5 represents a good multivariate climate match. Minimum values of 1 unit would correspond to projected climate conditions that we have not experienced before (e.g. see the 2080s scale slider minimum of 1 here, corresponding to no-analogue conditions identified in Fig 4 of this study). At present, the tool recommends species based on an unweighted average of the five closest climate matches and does not report the climate distance.
- Another task going forward is a **sensitivity analysis** regarding the choice of climate variables that we use for climate matching, as well as their scaling. Our intuition is that this methodology is fairly robust, but we have not formally quantified this yet. Further, not all variables of ecological importance correlate well with standard climate variables (e.g., the frequency and severity of unseasonal frost events). We are working on incorporating these aspects into the projections and climate matching methodology.
- Our approach to use **ecosystem delineations** as a proxy for climate conditions has some big advantages. Recommendations for assisted migration can be very easily communicated (i.e. move from this ecosystem to that ecosystem), but the ecosystem delineations must be climatically fairly homogenous units, and they should track species communities well. There are **issues in mountainous areas** of North America, where ecosystem delineations are neither homogenous in climate or tree species composition. We have, for this reason introduced some elevation bands, but not in a way that tracks species communities. We are working on determining correct elevation bands or latitudinal divisions to fix these issues.
- In principle, we can process any geographic delineation as source or target region. This includes forest management areas (e.g. as target region in this version: http://tinyurl.com/diverse-sst). Delineations can also represent seed sources, such as deployment areas for improved seed from **tree breeding programs**, or other **seed zone systems** (which can be species specific). Over the next months we will be working on including a variety of operational seed zone systems (as targets) and seed collections, or seed orchard regions (as sources).