A Multi-Species Assessment of Relative Genetic Degradation Risk from Climate Change and Other Threats

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High-elevation Fraser fir-red spruce forest, North Carolina

Emerald ash borer, recently detected in the Appalachian region.

Introduction

Changing climate conditions and more frequent and serious insect and disease infestations may result in population-level forest tree extirpation or widespread decreases in productivity. In the face of these challenges, it is important to safeguard existing adaptedness and to create conditions conducive for future evolution and productivity.

Diverse management and genetic conservation strategies will be needed to ensure successful regeneration and restoration of species with different characteristics and threat susceptibilities. This will be a particular challenge in species-rich regions.

To facilitate the effective use of limited resources, we developed the Forest Tree Genetic Risk Assessment System (ForGRAS), which ranks the predisposition of tree species to genetic degradation based on ecological and life-history traits, species-specific projections of climate change pressure, and predictions of insect and disease susceptibility.
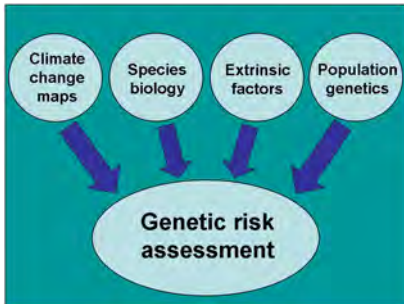
Figure 1: This assessment of genetic susceptibility incorporates climate change projections, knowledge about species biology (fecundity, seed dispersal, etc.), extrinsic factors (fragmentation, exploitation, etc.), and population genetics.

Methods

We used the ForGRAS framework to conduct a risk assessment **(Figure 1)** for 131 forest tree species native to the Southern Appalachians **(Inset 1)**. The assessment's four steps are described in Potter and Crane (2010):

1) Determining the area of interest and the species within it;

2) Selecting risk factors and conservation modifiers to include in the assessment;

3) Collecting relevant data for each species and calculating risk factor and conservation modifier index scores; and

4) Weighting these index scores, calculating a final score for each species, and ranking the species based on their final scores.

Inset 1: The Southern Appalachian Mountains

❖ **Highly diverse flora** (> 130 tree species)
- *High-elevation species*
- *Endemics/near-endemics*
- *Northern species with southern disjuncts*
- *Common Southern species*
- *Uncommon Eastern species*

❖ **Threats**
- *Insects and diseases*
- *Climate change pressure*
- *Tendency toward small, isolated populations*
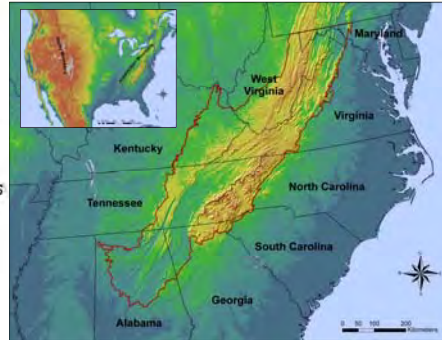
Inset Figure 1: The Southern Appalachians, as defined for this project, encompasses seven high-elevation ecoregions south of the Mason-Dixon line.

Risk Factors

The ForGRAS framework incorporates 10 indices, based on a review of ecological and life-history traits that predispose tree species to genetic degradation **(Table 1)**. The risk factors consist of 20 intrinsic and five external risk sub-factors. Examples include seed crop frequency and reproductive maturity (sub-factors for Regeneration Capacity), and predicted decrease in suitable habitat and predicted distance to future suitable habitat (sub-factors for Climate Change Pressure).

Users decide which factors and sub-factors to include, and assign weights for each. The weighted scores are summed to give risk ratings for each species, which are then ranked.

Table 1: The risk factors and conservation modifiers included in this risk assessment .

Intrinsic Risk Factors	External Risk Factors	Conservation Modifiers
(A1) Population Structure	**(B1)** Insect and Disease Susceptibility	**(C1)** Endemism
(A2) Rarity/Density	**(B2)** Climate Change Pressure	**(C2)** Conservation Status
(A3) Regeneration Capacity		
(A4) Dispersal Ability		
(A5) Habitat Affinities		
(A6) Genetic Variation		

Note: For this assessment, we assigned a weight of 0.1 to each intrinsic risk factor, 0.15 to the external risk factors, and 0.05 to the conservation modifiers. (The weights sum to 1.)

Data

The tree species data used in the ForGRAS assessment are freely available, including:

- Forest Inventory and Analysis data (www.fia.fs.fed.us) **(Figure 2)**.

- Forecasts of Climate-Associated Shifts in Tree Species (ForeCASTS) maps (www.forestthreats.org/tools/ForeCASTS) **(Figure 3)**.

- Silvics of North America information (www.na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm).

- Tree distribution maps (http://esp.cr.usgs.gov/ data/atlas/little).

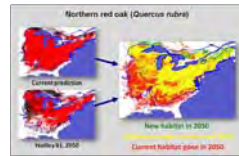**Figure 2: FIA plots in the Southern Appalachians.**

Figure 3: ForeCASTS climate change map.

Results and Discussion

Table 2: The 25 Southern Appalachian tree species with the highest risk rating scores.

Rank	Species	Score
1	Carolina hemlock (*Tsuga caroliniana*)	63.1
2	September elm (*Ulmus serotina*)	62.5
3	Fraser fir (*Abies fraseri*)	55.0
4	blue ash (*Fraxinus quadrangulata*)	54.6
5	butternut (*Juglans cinerea*)	54.5
6	Shumard oak (*Quercus shumardii*)	53.8
7	Table Mountain pine (*Pinus pungens*)	52.8
8	Carolina silverbell (*Halesia carolina*)	52.6
9	American chestnut (*Castanea dentata*)	52.5
10	black ash (*Fraxinus nigra*)	52.2
11	Ohio buckeye (*Aesculus glabra*)	52.2
12	eastern hemlock (*Tsuga canadensis*)	52.1
13	swamp white oak (*Quercus bicolor*)	51.4
14	red pine (*Pinus resinosa*)	50.3
15	Carolina ash (*Fraxinus caroliniana*)	49.8
16	Virginia roundleaf birch (*Betula uber*)	49.3
17	spruce pine (*Pinus glabra*)	48.9
18	rock elm (*Ulmus thomasii*)	48.7
19	red spruce (*Picea rubens*)	48.7
20	chalk maple (*Acer leucoderme*)	48.5
21	painted buckeye (*Aesculus sylvatica*)	48.5
22	balsam fir (*Abies balsamea*)	48.1
23	black maple (*Acer nigrum*)	47.7
24	nutmeg hickory (*Carya myristiciformis*)	47.6
24	yellow buckeye (*Aesculus flava*)	47.6

Southern Appalachian tree species at greatest genetic risk tend to have small distributions, occur at higher elevations, and/or be threatened by insects or diseases **(Table 2)**.

ForGras is a flexible tool for planning management and conservation activities, evaluating the genetic resources of species, and detecting their vulnerabilities. It accounts for multiple threats that may result in severe genetic impacts, and it can be applied for any area for which appropriate data exist.

Reference

Potter, K.M.; Crane, B.S. 2010. Forest Tree Genetic Risk Assessment System: A Tool for Conservation Decision-Making in Changing Times. User Guide, Version 1.2. [Online]. www.forestthreats.org/current-projects/project-summaries/genetic-risk-assessment-system-description-120610.pdf.