The Effects of Soil Moisture, Soil Temperature and Air Temperature on *Picea rubens* Distribution: MaxEnt Modeling in a Small Forested Catchment

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Red Spruce Story

Cabin Mountain, WV (Clarkson, 1964)

- Historically larger extent- 200,000 ha red spruce forest in WV (Clarkson, 1964; Lewis, 1998; Adams et al., 2001)
- Extensive logging around 1880 decimated population (Clarkson, 1964; Lewis, 1998)
- Today: 24, 000 ha in WV (Adams et al., 2001)
- One of the most endangered forest types in the Central Appalachians (Christensen et al., 1966; Noss et al., 1995)

Red Spruce Restoration

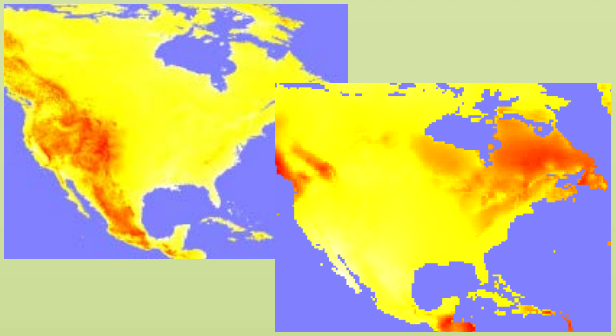
- Interest in restoring red spruce forests
  - Ecosystem services
- But finite resources…
- Where are the best sites to focus restoration money and efforts?
- Use models to help answer this question

MaxEnt

- Species distribution model (Fleishman et al., 2001; Phillips et al., 2004; Elith et al., 2006; Pearson, 2010)
- Inputs:
  - Presence-only data (Pearson, 2010)
  - Environmental variables (Pearson, 2010)
  - Covariates must be a surface (raster)
- Looking for places on the landscape that are similar to conditions at presence locations

Occurrence points

+



Environmental Variables

MaxEnt Metrics

- Permutation Importance (PI)
  - Used to assess variable importance
  - Large value = more influence on model, especially when large decrease after that variable (Kalle et al., 2013)
- Area Under the Curve (AUC)
  - Metric used to assess model performance
  - Plot of true positive rate (y) vs false positive rate (x)
  - Use for *relative* comparisons between models that used the same data
    - Closer to 1 the better

How is this study different from previous red spruce modeling efforts?

- Numerous modeling efforts (Iverson et al., 2008; Beane et al., 2013; Madron, 2013; Nauman et al., 2015)
- Most do not use microclimatic variables
  - If microclimatic variables used, they are coarse (Iverson et al., 2008; Beane et al., 2013; Madron, 2013)
  - Using coarse climatic data does not capture relationships between red spruce and microclimate
- Not much literature on specific microclimatic req's

Objectives of Study

1) Determine which microclimatic variables (if any) are most important to red spruce presence
2) Compare model results generated using only topographic variables to model results generated using both topographic and microclimatic variables

Study Area
Snorting Lick Run Watershed

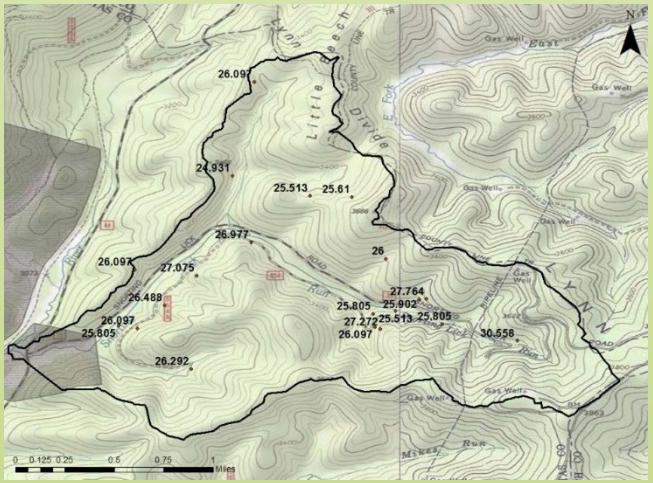
- Size: 5.4 km^2
- Elevation: 780-1425 m
- Geology: Hampshire and Chemung Formations
- Vegetation
  - Mostly deciduous
  - Some hardwood-conifer and conifer

Site Selection within SLR Watershed

- Microclimatic data collection at 20 sites for almost 1 year
  - 20 random, spatially-distributed sites
  - Air temperature, soil temperature, soil moisture
- 18 sites had red spruce (presence-only sites)

Microclimate Variable Creation

- Created 107 microclimatic variables (based on limited literature)
  - Focused on extremes, such as hottest/coldest/driest instantaneous values or values over periods of time
    - hottest August daily mean air temperature for each plot - any date
    - warmest December daily mean soil temperature for each plot - any date
    - driest July daily mean soil moisture for each plot - any date
- Need raster datasets: converted point data to raster with kriging/cokriging



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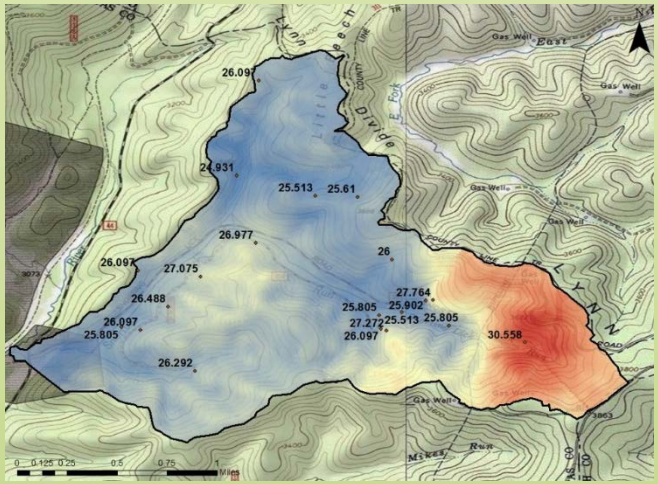
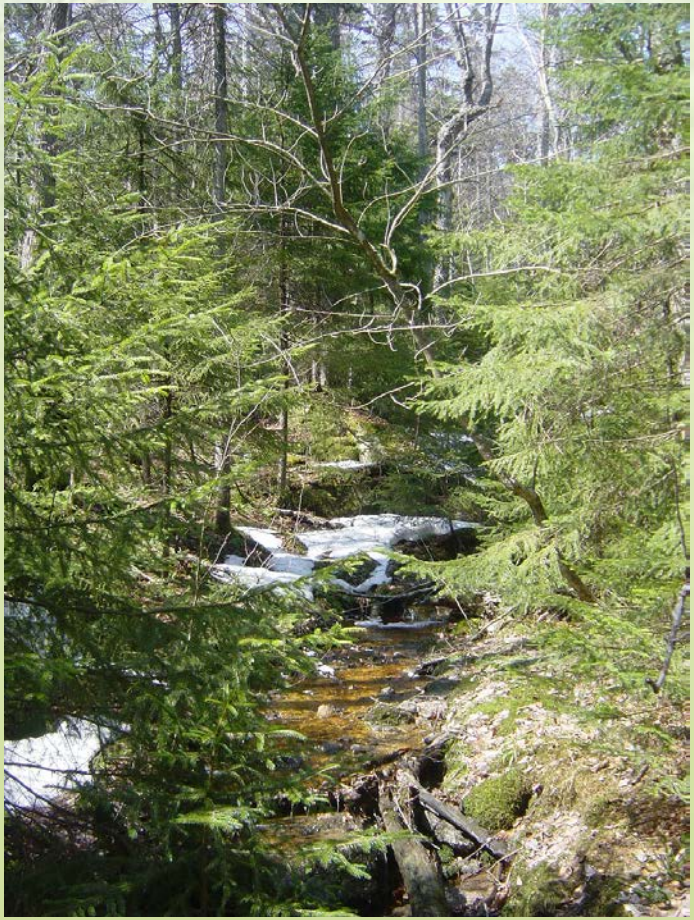


Topographic Variables

- 10 DEM derived variables
  - Aspect
  - Proximity to stream channels
  - Slope and slope position
  - Plan and profile curvature
  - Convergence
  - Wetness index



MaxEnt Inputs

- 18 presence-only data points
- 10 topographic variables
- 107 microclimatic variables
  - 20 air temperature
  - 54 soil temperature
  - 33 soil moisture

Preliminary Model Runs

- First ran 4 preliminary runs using only:
  - Topographic variables
  - Air temperature variables
  - Soil temperature variables
  - Soil moisture variables

Best model performance →

Model	AUC Value
Topographic variables only	0.800
Air temperature variables only	0.794
Soil temperature variables only	0.781
Soil moisture variables only	0.690

Preliminary Permutation Importance

Topographic Variables

Variable	PI (%)
Altitude above channel network	70
Topographic wetness index	7

Air Temperature Variables

Variable	PI (%)
August absolute maximum temperature any day	30
August daily minimum temperature any day	20

Soil Temperature Variables

Variable	PI (%)
August absolute maximum at 0 cm any day	26
August daily minimum at 25 cm any day	14

Soil Moisture Variables

Variable	PI (%)
July daily maximum at 50 cm any day	26
Driest 24 hour period at 0 cm	23
August daily maximum at 50 cm any day	12

Final Run

AUC = 0.82, only slightly higher than topographic only (AUC = 0.80)

Variable	Type	PI (%)
Altitude above channel network	Topographic	37
August absolute maximum any day	Air Temperature	24
August absolute maximum at 0 cm any day	Soil Temperature	18
Driest 24 hour period at 0 cm	Soil Moisture	12
July daily maximum any day at 50 cm	Soil Moisture	9

Agreement/Disagreement Analysis

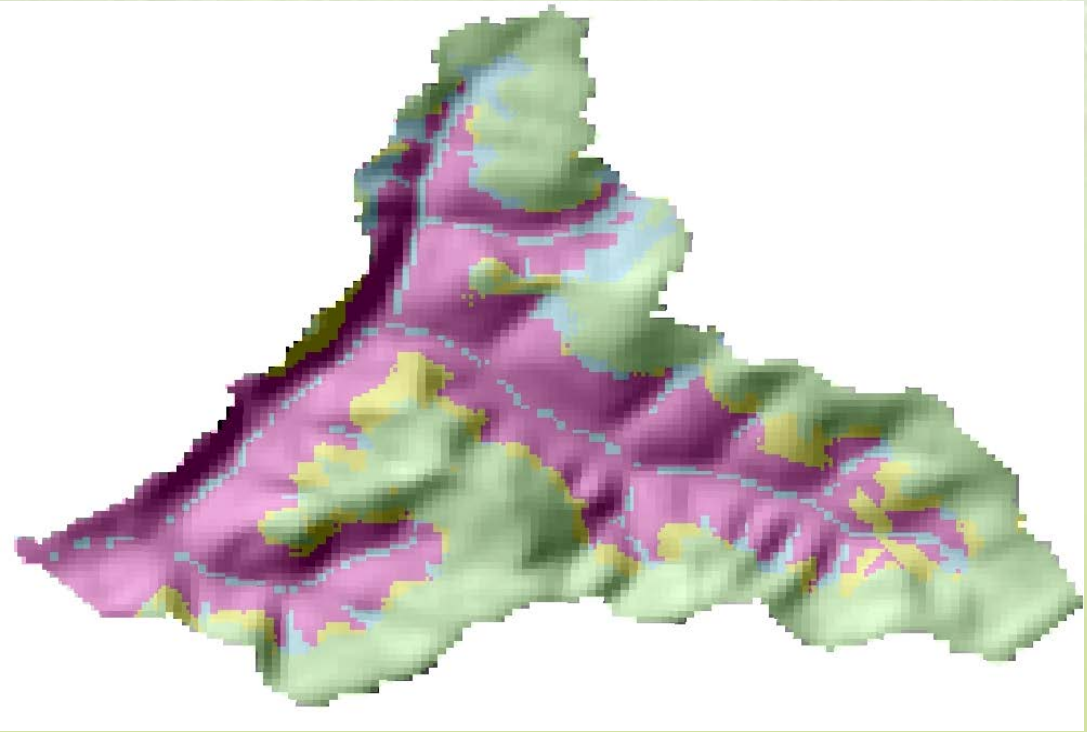
- Needed to compare model outputs using the topographic only and final model which used the 5 most important variables
  - Note that altitude above channel network used in both
- Used median values for each model to separate high and low relative occurrence rates for the agreement/disagreement analysis
  - > median classified as high
  - =/< median classified as low

Agreement/Disagreement Results

Agreement/Disagreement: Meaning	Percentage
Agreement: Both models predict high ROR	41
Agreement: Both models predict low ROR	41
Disagreement: Topographic only model predicts high ROR, topographic and microclimatic model predicts low ROR	9
Disagreement: Topographic only model predicts low ROR, topographic and microclimatic model predicts high ROR	9

- 82% agreement
- 18% disagreement

Agreement/Disagreement Results



- Green- both low ROR
- Pink- Both high ROR
- Yellow- Topographic only model predicts high ROR, Final model predicts low ROR
- Blue- Topographic only model predicts low ROR, Final model predicts high ROR

- Agreement that
  - Higher ROR occurs at lower elevations of watershed
  - Lower ROR occurs at high elevations of watershed

Summary- Obj 1: Which Variables Important?

- **Most important microclimatic variable**: August absolute maximum air temperature
- **Least important**: soil microclimatic variables al
- The process of trying to convert point data into surface data necessary but not extremely effective
- Microclimatic conditions are highly variable over short distance- may have needed a more dense sampling network
- Air temperature performed well and is easier to measure- consider for future research efforts

Summary- Obj 2: Compare Topo Only vs. Topo + Micro

- AACN most important topographic variable, and more important than microclimate variables used
- Both the topographic only and final model predict the highest ROR at the lowest elevations of the watershed (as low as 2500 ft)
- Focus restoration at the highest elevations of landscape first, then target landscape positions that promote cooler air and soil temperature and soil moisture that may act as microrefugia and connectivity for red spruce under projected climatic conditions

Questions?

Study 2: Topographic Variables

Topographic Variables	
aspect	linear aspect calculated using geomorphometry and gradient metrix toolbox (Evans et al., accessed 2017)
aacn	altitude above local stream channel
baselevel	elevation of nearest channel point to each pixel in its given watershed
converg	overall measure of concavity
lsfactor	slope-length factor from USLEas calculated in SAGA GIS
plancurv	curvature perpendicular to slope direction
profcurv	curvature parallel to slope direction
slope	slope gradient (rise/run) in fraction units
slpos	index from 0 (valley floor) to 100 (ridgetop) of slope position (Hatfield, 1996)
twi	topographic wetness index

Study 2: Air Temperature variable

Variable	Description
Air Temperature	
julavgdaytime	average July daytime air temperature for each plot
augavgdaytime	average August daytime air temperature for each plot
janabsminanyday	coldest January 30-min air temperature for each plot - any date
febabsminanyday	coldest February 30-min air temperature for each plot - any date
julabsminanyday	coolest July 30-min air temperature for each plot - any date
augabsminanyday	coolest August 30-min air temperature for each plot - any date
novabsminanyday	coldest November 30-min air temperature for each plot - any date
decabsminanyday	coldest December 30-min air temperature for each plot - any date
julabsmaxanyday	hottest July 30-min air temperature for each plot - any date
augabsmaxanyday	hottest August 30-min air temperature for each plot - any date
jandailyminanyday	coldest January daily mean air temperature for each plot - any date
febdailyminanyday	coldest February daily mean air temperature for each plot - any date
juldailyminanyday	coolest July daily mean air temperature for each plot - any date
augdailyminanyday	coolest August daily mean air temperature for each plot - any date
juldailymaxanyday	hottest July daily mean air temperature for each plot - any date
augdailymaxanyday	hottest August daily mean air temperature for each plot - any date
absmaxanyday	hottest 30-min air temperature for each plot- any date
absminanyday	coldest daily mean air temperature for each plot- any date
anntempalldata	annual mean from monthly means of all 30-min readings
anntempbioclim	annual mean from monthly means as average of monthly maximum and minimum

Study 2: Soil Temperature Variables

Soil Temperature	
febabsminanyday0cm	coldest February 1-hr soil temperature for each plot - any date
febabsminanyday25cm	coldest February 1-hr soil temperature for each plot - any date
febabsminanyday50cm	coldest February 1-hr soil temperature for each plot - any date
febdailyminanyday0cm	coldest February daily mean soil temperature for each plot - any date
febdailyminanyday25cm	coldest February daily mean soil temperature for each plot - any date
febdailyminanyday50cm	coldest February daily mean soil temperature for each plot - any date
decabsminanyday0cm	coldest December 1-hr soil temperature for each plot - any date
decabsminanyday25cm	coldest December 1-hr soil temperature for each plot - any date
decabsminanyday50cm	coldest December 1-hr soil temperature for each plot - any date
decabsmaxanyday0cm	warmest December 1-hr soil temperature for each plot - any date
decabsmaxanyday25cm	warmest December 1-hr soil temperature for each plot - any date
decabsmaxanyday50cm	warmest December 1-hr soil temperature for each plot - any date
decdailyminanyday0cm	coldest December daily mean soil temperature for each plot - any date
decdailyminanyday25cm	coldest December daily mean soil temperature for each plot - any date
decdailyminanyday50cm	coldest December daily mean soil temperature for each plot - any date
decdailymaxanyday0cm	warmest December daily mean soil temperature for each plot - any date
decdailymaxanyday25cm	warmest December daily mean soil temperature for each plot - any date
decdailymaxanyday50cm	warmest December daily mean soil temperature for each plot - any date
janabsminanyday0cm	coldest January 1-hr soil temperature for each plot - any date
janabsminanyday25cm	coldest January 1-hr soil temperature for each plot - any date
janabsminanyday50cm	coldest January 1-hr soil temperature for each plot - any date
janabsmaxanyday0cm	warmest January 1-hr soil temperature for each plot - any date
janabsmaxanyday25cm	warmest January 1-hr soil temperature for each plot - any date
janabsmaxanyday50cm	warmest January 1-hr soil temperature for each plot - any date

Study 2: Soil Temp Variables (con't)

jandailyminanyday0cm	coldest January daily mean soil temperature for each plot - any date
jandailyminanyday25cm	coldest January daily mean soil temperature for each plot - any date
jandailyminanyday50cm	coldest January daily mean soil temperature for each plot - any date
jandailymaxanyday0cm	warmest January daily mean soil temperature for each plot - any date
jandailymaxanyday25cm	warmest January daily mean soil temperature for each plot - any date
jandailymaxanyday50cm	warmest January daily mean soil temperature for each plot - any date
julabsminanyday0cm	coolest July 1-hr soil temperature for each plot - any date
julabsminanyday25cm	coolest July 1-hr soil temperature for each plot - any date
julabsminanyday50cm	coolest July 1-hr soil temperature for each plot - any date
julabsmaxanyday0cm	warmest July 1-hr soil temperature for each plot - any date
julabsmaxanyday25cm	warmest July 1-hr soil temperature for each plot - any date
julabsmaxanyday50cm	warmest July 1-hr soil temperature for each plot - any date
juldailyminanyday0cm	coolest July daily mean soil temperature for each plot - any date
juldailyminanyday25cm	coolest July daily mean soil temperature for each plot - any date
juldailyminanyday50cm	coolest July daily mean soil temperature for each plot - any date
juldailymaxanyday0cm	warmest July daily mean soil temperature for each plot - any date
juldailymaxanyday25cm	warmest July daily mean soil temperature for each plot - any date
juldailymaxanyday50cm	warmest July daily mean soil temperature for each plot - any date
augabsminanyday0cm	coolest August 1-hr soil temperature for each plot - any date
augabsminanyday25cm	coolest August 1-hr soil temperature for each plot - any date
augabsminanyday50cm	coolest August 1-hr soil temperature for each plot - any date
augabsmaxanyday0cm	warmest August 1-hr soil temperature for each plot - any date
augabsmaxanyday25cm	warmest August 1-hr soil temperature for each plot - any date
augabsmaxanyday50cm	warmest August 1-hr soil temperature for each plot - any date
augdailyminanyday0cm	coolest August daily mean soil temperature for each plot - any date
augdailyminanyday25cm	coolest August daily mean soil temperature for each plot - any date
augdailyminanyday50cm	coolest August daily mean soil temperature for each plot - any date
augdailymaxanyday0cm	warmest August daily mean soil temperature for each plot - any date
augdailymaxanyday25cm	warmest August daily mean soil temperature for each plot - any date
augdailymaxanyday50cm	warmest August daily mean soil temperature for each plot - any date

Study 2: Soil Moisture Variables

dry24hr0cm	driest 24-hr mean soil moisture for each plot in May-Sept 2016
dry24hr25cm	driest 24-hr mean soil moisture for each plot in May-Sept 2016
dry24hr50cm	driest 24-hr mean soil moisture for each plot in May-Sept 2016
dry7day0cm	driest 7-day mean soil moisture for each plot in May-Sept 2016
dry7day25cm	driest 7-day mean soil moisture for each plot in May-Sept 2016
dry7day50cm	driest 7-day mean soil moisture for each plot in May-Sept 2016
dry30day0cm	driest 30-day mean soil moisture for each plot in May-Sept 2016
dry30day25cm	driest 30-day mean soil moisture for each plot in May-Sept 2016
dry30day50cm	driest 30-day mean soil moisture for each plot in May-Sept 2016
julabsminanyday0cm	driest July 1-hr soil moisture for each plot - any date
julabsminanyday25cm	driest July 1-hr soil moisture for each plot - any date
julabsminanyday50cm	driest July 1-hr soil moisture for each plot - any date
julabsmaxanyday0cm	wettest July 1-hr soil moisture for each plot - any date
julabsmaxanyday25cm	wettest July 1-hr soil moisture for each plot - any date
julabsmaxanyday50cm	wettest July 1-hr soil moisture for each plot - any date
juldailyminanyday0cm	driest July daily mean soil moisture for each plot - any date
juldailyminanyday25cm	driest July daily mean soil moisture for each plot - any date
juldailyminanyday50cm	driest July daily mean soil moisture for each plot - any date
juldailymaxanyday0cm	wettest July daily mean soil moisture for each plot - any date
juldailymaxanyday25cm	wettest July daily mean soil moisture for each plot - any date
juldailymaxanyday50cm	wettest July daily mean soil moisture for each plot - any date
augabsminanyday0cm	driest August 1-hr soil moisture for each plot - any date
augabsminanyday25cm	driest August 1-hr soil moisture for each plot - any date
augabsminanyday50cm	driest August 1-hr soil moisture for each plot - any date
augabsmaxanyday0cm	wettest August 1-hr soil moisture for each plot - any date
augabsmaxanyday25cm	wettest August 1-hr soil moisture for each plot - any date
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augdailyminanyday25cm	driest August daily mean soil moisture for each plot - any date
augdailyminanyday50cm	driest August daily mean soil moisture for each plot - any date
augdailymaxanyday0cm	wettest August daily mean soil moisture for each plot - any date
augdailymaxanyday25cm	wettest August daily mean soil moisture for each plot - any date
augdailymaxanyday50cm	wettest August daily mean soil moisture for each plot - any date