Arbutus Menziesii Possible Habitat Change by Twenty-Second Century Assuming A2 Scenario

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GIS: Modeling & Analysis (ENVS 420) - Fall 2014

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Introduction

We are aware that climate change is significantly impacting the earth's delicate ecosystems and the process is only increasing. Areas that were once climatically suitable habitats for certain species are ceasing to be and new habitats are being created. Modeling and analysis is needed to provide a template for forest management needs in order to anticipate where preservation efforts will be necessary, or in some cases, ineffective. We were contracted to analyze potential climate change impacts on forests in Western North America and specifically to create a GIS model for analysis using climate variables and tree species. This paper details how was accomplished and how the model can be replicated.

For our test study, we focused on the Arbutus menziesii (Pacific Madrone). This is a hardwood species found along the Pacific Coast. It is the most widely distributed tree species on the Pacific Coast and is native to the east coast of Vancouver Island and the western portion of mainland British Columbia (lat.50°N) to as far south as Paloma Mountain in San Diego county California (lat.33°N). Overall, the species spans a distance of 1883 kilometers along the western slopes of Coast Ranges in Washington, Oregon and California. Necessary climate conditions for the Arbutus menziesii are mild temperatures with prolonged cloudy periods and minimal daily fluctuations. Winter climate is typically wet and mild whereas summer climate is typically cool and relatively dry with long frost free periods. Temperature extremes range from -21° to 46°C. Annual rainfall is typically 457mm to 4216mm.

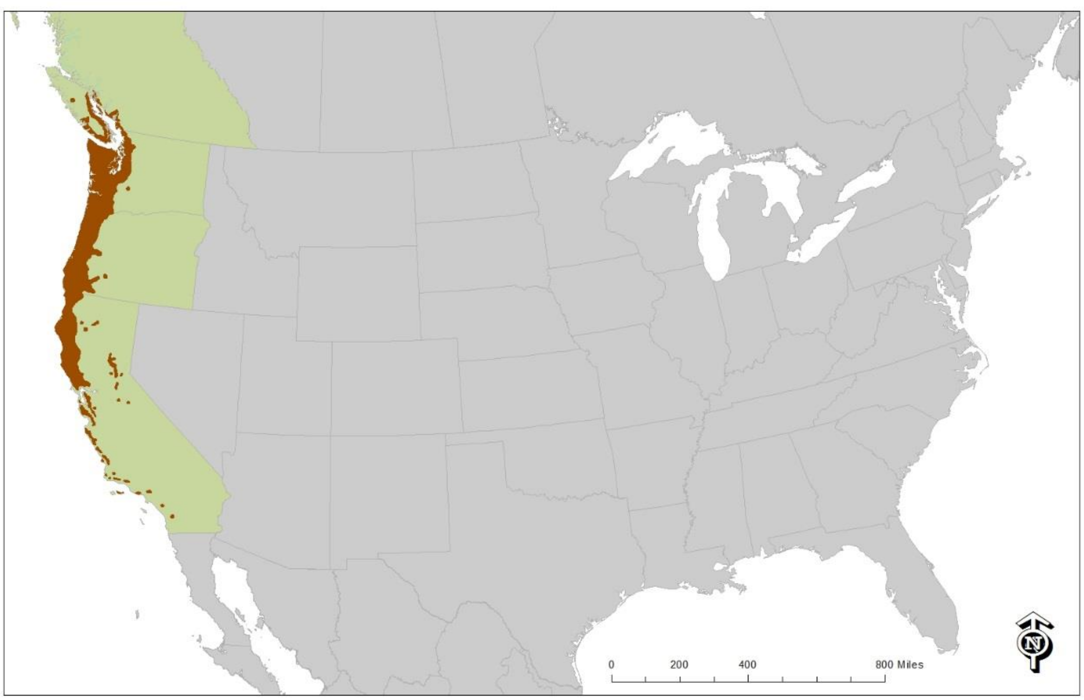


Figure 1: Arbutus menziesii Current Range

Data

We collected data for Arbutus menziesii as well as climate records, both historical and future, in order to create an accurate climate projection. Tree data collected for analysis came from http://esp.cr.usgs.gov/data/little/ which gave us range limits for the Pacific Madrone. The data was not originally projected, but we were able to locate the correct coordinate system in the metadata (which was GCS_DAD1927) and use the 'define projection' tool to assign the correct coordinate system to the shapefile. This vector data and was in meters. Climate records (both historical and future) were obtained from http://www.ualberta.ca/~ahamann/data/climatena.html. The climate data are raster data at 1km resolution and cover North America. The unit of measurement is meters. For historical climate records we downloaded the 24 bioclimate variables in ASCII for the 1961-1990 normal period. For the future climate records we downloaded data for the USA with the 2080s future period and emission scenario A2* that encompassed the 24 bioclimate variables.

The climate variables we've selected for our analysis are as follows:

- MSP: mean summer (May to Sep) precipitation (mm)
- Tave_wt: winter (Dec to Feb) mean temperature (°C)
- Tave_sm: summer (Jun to Aug) mean temperature (°C)
- PPT_wt: winter (Dec to Feb) precipitation (mm)

All of data was reprojected in Lambert Conformal Conic with a Central Meridian at -105. The temperature data (Tave_wt and Tave_sm) was originally in tenths of degrees Celsius but we converted it to display as full degrees. Finally, for quick visualization, we also symbolized precipitation and temperature using the standard graphic bars.

*A2 scenarios are based on (Intergovernmental Panel on Climate Change – www.ipcc.ch/ipccreports/srs/emission/index.php):

- Relatively slow demographic transition and relatively slow convergence in regional fertility patterns.
- Relatively slow convergence in inter-regional GDP per capita differences.
- Relatively slow end-use and supply-side energy efficiency improvements (compared to other storylines).
- Delayed development of renewable energy.
- No barriers to the use of nuclear energy.

Methods

The steps of this analysis were conducted as follows:

1. Created an mxd with all future climate variables (raster datasets) as well as the tree extent shapefile.
2. Used raster calculator to convert the temperature variables to full degrees Celsius
3. Set the symbology for all raster layers to temperature or precipitation bar
4. Created an historical climate envelope by determining the range of each climate variable the Arbutus menziesii currently exists in. This was done by creating a batched zonal statistics table with our tree data and our four climate variables. This provided the mean temperature and mean precipitation levels found in the trees current known region as well as e standard deviation. We entered the figures into an Excel table (figure 2) from where we determined a wider range of suitability using standard deviations.

Mean	Stan. Dev.	-2	2	Variable	File
16.97	2.19	12.59	21.35	Summer Mean Temp	Tave sm
4.89	2.4	0.09	9.69	Winter Mean Temp	Tave wm
752.99	335.19	82.61	1423.37	Winter Precip.	PPT wt
90.83	70.06	0	230.95	Summer Precip.	MSP

Figure 2: Historic Envelope

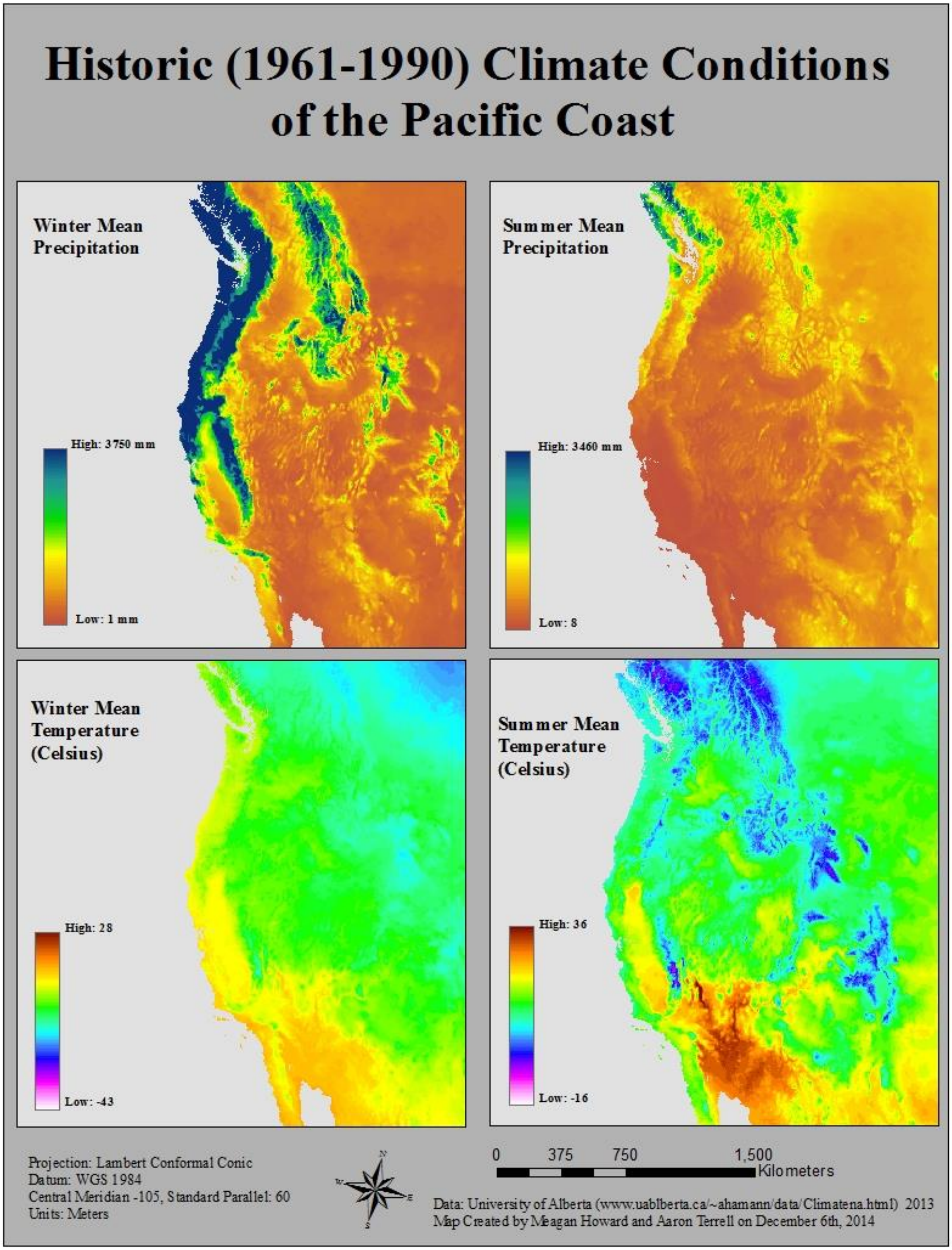
5. The next step was to use Raster Calculator to produce two new rasters, one for the historic range and one for the future. The algebra used for this particular calculation: ("%Hist_Summer_Temp%" >= 12.59) & ("%Hist_Summer_Temp%" <= 21.35) & ("%Hist_Winter_Temp%" >= 2.4) & ("%Hist_Winter_Temp%" <= 1423.37) & ("%Hist_Winter_Precip%" >= 82.61) & ("%Hist_Winter_Precip%" <= 1423.37) & ("%Hist_Summer_Precip%" >= 0) & ("%Hist_Summer_Precip%" <= 230.95)

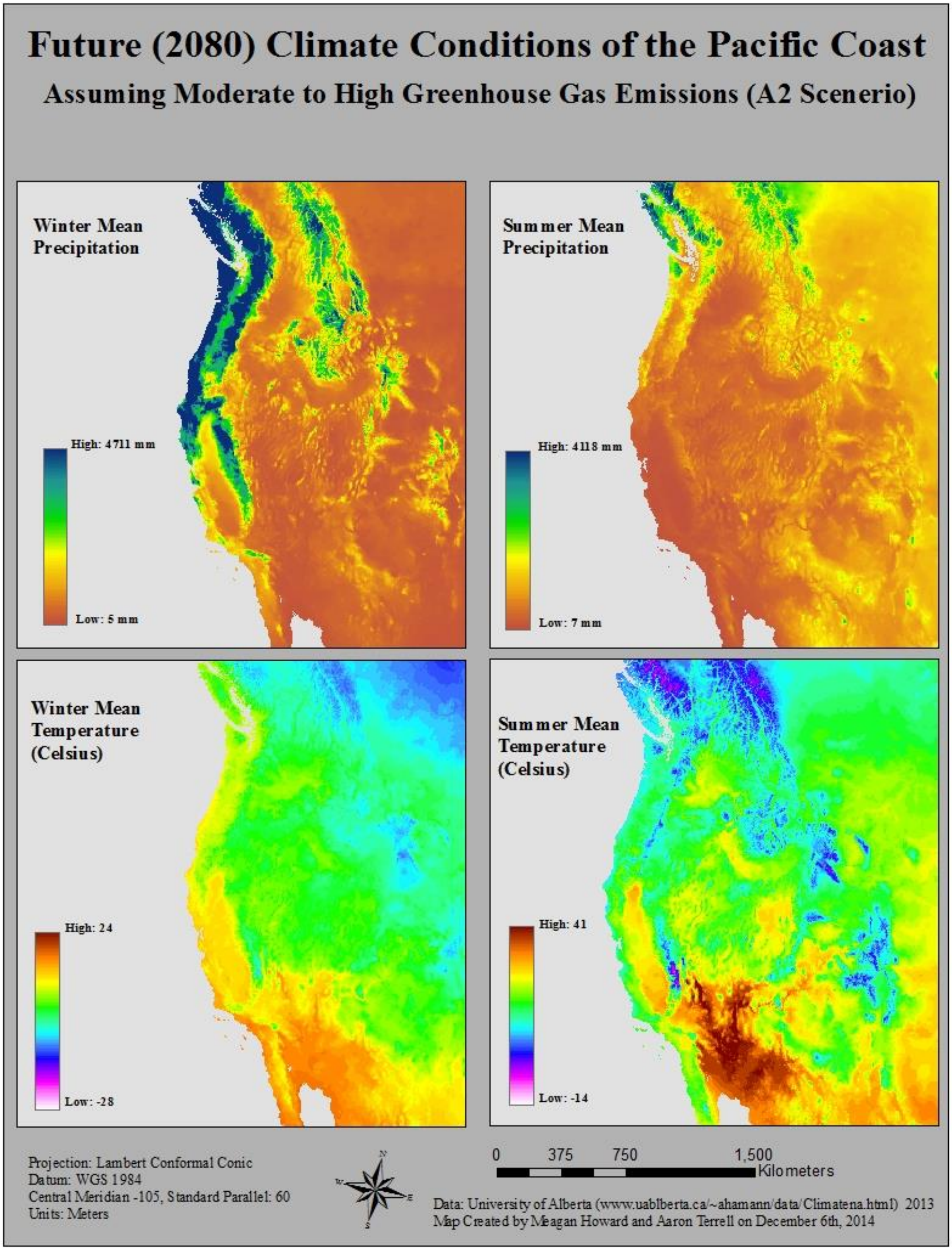
   For the future calculation we replaced the inputs with those of the 2080 climate variables.
6. Then we used Raster Calculator again and subtracted the historical raster from the future raster to determine the change. We symbolized those areas that received -1 (loses suitability) as blue, and those that received a 1 (gains suitability) as green, and removed color for 0.

Results

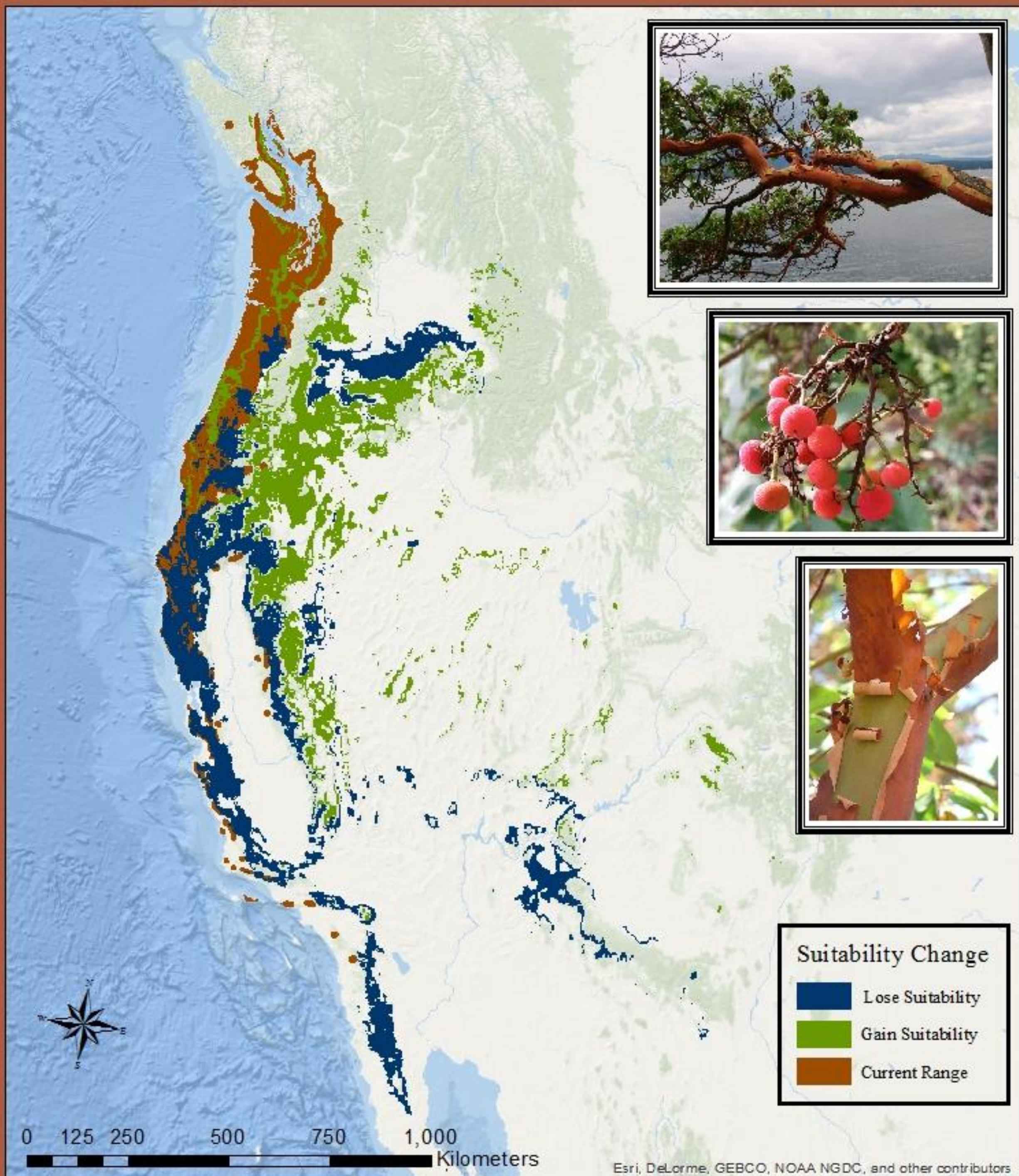
The result of our historic and future calculations (step 5 above) were two binary raster files with cells indicating 1 (criteria met) and 0 (not met). The change in suitability raster (step 6 above) was also a raster dataset with three different cell values: -1 (loses suitability), 1 (gains suitability), and 0 (not suitable at any point). Our results from the historic envelope did not accurately depict where Arbutus menziesii is currently known to exist. We originally assumed a proposed range of 1.5 standard deviations but the resulting suitable area was much narrower than where the species is known to exist (for example, most of the Puget Sound and the Olympic Peninsula were deemed unsuitable with this analysis). Therefore the range was broadened to two standard deviations, which still excludes much of the PNW, and also extends far to the east (even some into AZ). The error in our analysis has been identified and will be discussed later in this report.

We mapped the historic climate (page 5) as well as the future climate (page 6) for visual reference of the climate change this region is likely to experience. The map of habitat suitability of Arbutus Menziesii can be found on page 7.


Historic (1961-1990) Climate Conditions of the Pacific Coast
Winter Mean Precipitation
High: 3750 mm
Low: 1 mm
Summer Mean Precipitation
High: 3460 mm
Low: 8
Winter Mean Temperature (Celsius)
High: 28
Low: -43
Summer Mean Temperature (Celsius)
High: 36
Low: -16
Projection: Lambert Conformal Conic
Datum: WGS 1984
Central Meridian -105, Standard Parallel: 60
Units: Meters
N
W
E
S
0
375
750
1,500
Kilometers
Data: University of Alberta (www.uablberta.ca/~ahamann/data/Climatena.html) 2013
Map Created by Meagan Howard and Aaron Terrell on December 6th, 2014


Future (2080) Climate Conditions of the Pacific Coast
Assuming Moderate to High Greenhouse Gas Emissions (A2 Scenerio)
Winter Mean Precipitation
High: 4711 mm
Low: 5 mm
Summer Mean Precipitation
High: 4118 mm
Low: 7 mm
Winter Mean Temperature (Celsius)
High: 24
Low: -28
Summer Mean Temperature (Celsius)
High: 41
Low: -14
Projection: Lambert Conformal Conic
Datum: WGS 1984
Central Meridian -105, Standard Parallel: 60
Units: Meters
0 375 750 1,500 Kilometers
Data: University of Alberta (www.uablberta.ca/~ahamann/data/Climatena.html) 2013
Map Created by Meagan Howard and Aaron Terrell on December 6th, 2014

Arbutus Menziesii (Pacific Madrone) Change in Habitat Suitability Between 20th and 21st Centuries



Climate Data: University of Alberta (www.uablberta.ca/~ahamann/data/Climatena.html); Tree Species Data: USGS and USDA Forrest Service
Projection: Lambert Conformal Conic; Datum: WGS 1984; Central Meridian: -105, Standard Parallel: 60; Units: Meters

Map Created by Meagan Howard and Aaron Terrell on December 6th, 2014

Conclusion

Our results show that suitability will increase for the Pacific Madrone to the north and decrease significantly in the south. While our range does not account for pertinent geologic factors, it is reasonable to conclude from this analysis that the Arbutus menziesii in much of the Californian and Oregon coasts are going to be increasingly vulnerable due to rising temperatures. This shift in suitability will be significant to forest management and ecology conservation efforts. Many mammal species feed off the Arbutus Menziessi berries (such as, raccoons, mule deer, and bears) and the trees are nesting sites for various species of birds.

It is clear by noting the current range of Arbutus menziesii that our climate calculation may not be entirely accurate and there are likely other factors that must be considered in the analysis. If we were to continue with this specific analysis, we would use additional climate variables such as Heat Moisture Index, proximity to the coast (less than 300km), and allow for a maximum precipitation level of greater than 2 standard deviations.

To amend or replicate this analysis, please see the model 'TreeClimate' in this reports associated geodatabase.