Predicting the occurrence, vulnerability and future distribution of major tree species in the Pacific Northwest in response to climatic change

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CONTEXT

In the Pacific Northwestern (PNW) region of North America, climatic conditions have significantly warmed since a predominantly cool period between 1950 and 1975. To assess the implications of this shift in climate, we first mapped monthly climatic data from 1950 – 2005 at 1 km resolution, across the region using CLIMATE WNA, which is based on PRISM surfaces.

We asked:

What are the implications of this shift in climate for the vulnerability of native tree species? In places where climatic conditions are interpreted to be less well suited, is there evidence of increased disturbance as assessed by remote sensing?

METHODS

First we assessed how the observed seasonal climatic variation during the cool moist phase (1950-75) affected photosynthesis and growth of Douglas-fir (Pseudotsuga menziesii) using a process-based growth model (3-PG) and then compared responses with more recent climatic conditions. Like other models 3-PG makes use of modifiers which are dimensionless values, varying between zero (shut down) and unity (optimum).

3-PG has been used in many studies and is available from the authors and free to download from the website of this new book.

The modifiers represent the degree to which photosynthesis is limited by
(a) water,
(b) atmospheric vapour pressure deficits
(c) suboptimal temperatures, and
(d) frost damage

We then defined competitive climatic niches of other tree species in reference to physiological thresholds expressed for Douglas-fir using data obtained from a total of 22,771 plots distributed throughout the region.

We next applied the 3-PG model to predict stand growth/ LAI @ 50 yr using 1950–75 average climate at the plots. The model was then stopped and used in species-specific decision-tree models to predict distributions that could be compared with field survey data and USFS Little (1971) range maps. A confusion matrix was developed which provides an indication of the positive and negative predictive power was well as kappa statistic.

A decision tree for lodgepole pine shows the 1st rule is based on summer growth, with species with less growth favourable other species. The second rule is based on summer temperature, with sites averaging less than optimum the most common. A third rule includes only those sites where the spring VPD modifier is < 0.80, with a further delineation based on the winter soil moisture.

The overall accuracy of the models was 82%, with noble fir the most accurate (93%) and lodgepole pine (88%) the poorest. Overall the presence of a species was predicted with slightly more accuracy than its absence (82% versus 81% respectively). Overall Kappa was 0.74.

We assumed a measure of a species response to climate change is inversely proportional to the modelled probability of presence. We evaluated the fitness by calculating the fraction of a species’ range that was no longer deemed suitable for each of the years between 1976-2006. We then defined as “vulnerable” those cells within a species’ baseline range that were unsuitable for 15 years or more of the 1976-2006 timeframe.

Finally, we compared with ecoregions areas designated across the PNW as vulnerable in reference to baseline climatic conditions (1950-1975) with the MODIS disturbance index which utilizes a simple ratio of annual-maximum composite land surface temperature and annual-maximum greenness to identify inter-annual changes in surface energy partitioning.

The proportion of species in each ecoregion designated as highly vulnerable and the areas recognized as recently disturbed from the MODIS Disturbance Index are well correlated (R² > 0.65).

CONCLUSION:

• This hybrid approach has promise,
• Partial validation: predicts reasonable values of max LAI, recorded distributions of 15 conifers,
• Stressed areas in ecoregions correlate with the fraction of forested areas observed as recently disturbance,
• Models appear to be accurate based on plot data,
• New NASA funded project underway to test model predictions with regeneration surveys in regions identified as stressed and recently disturbed.

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