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

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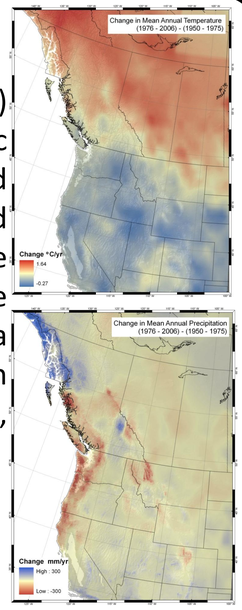
CONTEXT

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.



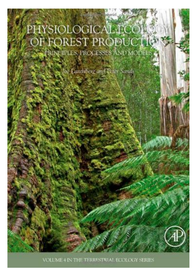
We asked:

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

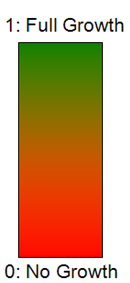
First we assessed how the observed seasonal climatic variation during the cool moist phase (1950-75) affected photosynthesis and growth of Douglas-fir (*Pseudotsuga menziesii*) using a process-based growth model (3-PG) and then compared responses with more recent climatic conditions. Like other models 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.

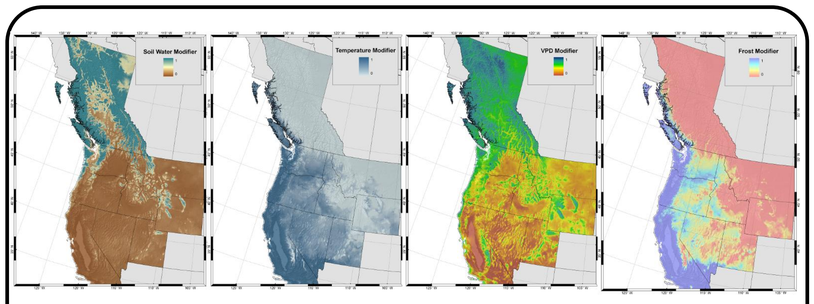


The modifiers represent the degree to which photosynthesis is limited by

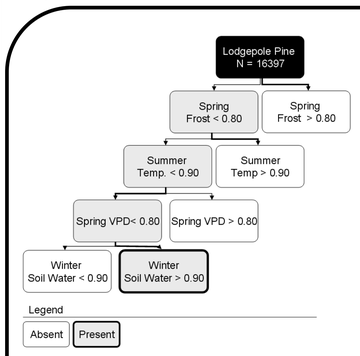
(a) water,
(b) atmospheric vapour pressure deficits
(c) suboptimal temperatures, and
(d) frost damage



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.

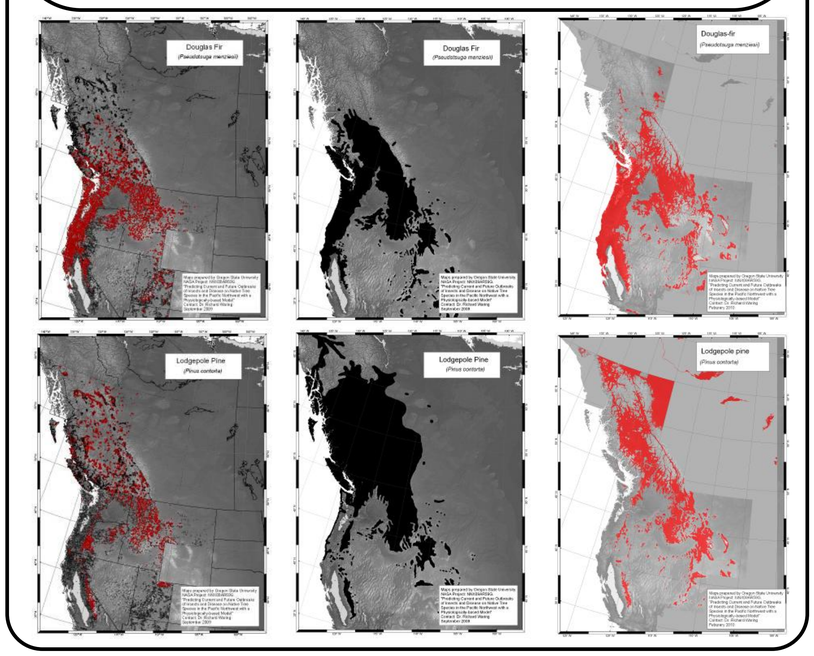


A decision tree for lodgepole pine shows the 1st rule is based on spring frost, with sites with less frost favouring other species. The second rule is based on summer temperature, with sites averaging less than optimum the most common. A third rule includes only those sites where the spring VPD modifier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

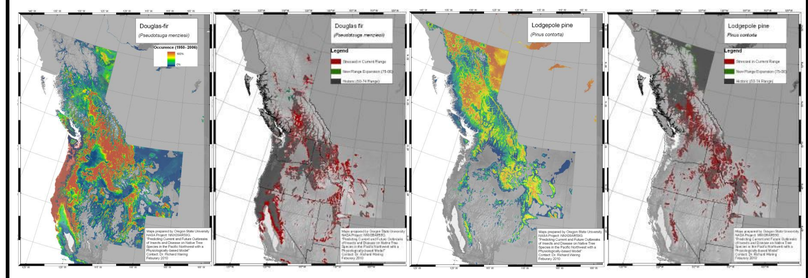
The overall accuracy of the models was 82%, with noble fir the most accurate (93%) and lodgepole pine (68%) the poorest. Overall the presence of a species was predicted with slightly more accuracy than its absence (82% versus 81% respectively). Overall Kappa was 0.74.

Per cent correct classification for classification trees for 15 selected species. *Landis & Koch (1977) have suggested the following ranges of agreement for the kappa (κ) statistic: < 0 poor; 0–0.21 slight; 0.21–0.4 fair; 0.4–0.6 moderate; 0.61–0.8 substantial; 0.81–1.0 excellent.

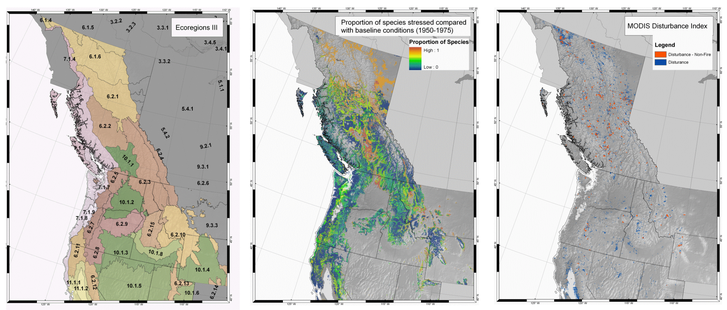
Species	Presence Accuracy (%)	Absence Accuracy (%)	Overall average (%)	κ (*)
Douglas-fir	76	70	73	0.584
Lodgepole pine	68	72	70	0.495
Ponderosa pine	84	82	83	0.785
Western red cedar	80	77	78	0.711
Mountain hemlock	78	78	78	0.711
Sitka spruce	90	88	89	0.884
Pacific silver fir	85	83	84	0.821
Whitebark pine	84	82	83	0.797
Englemann spruce	78	68	73	0.574
Western hemlock	81	78	80	0.740
Alaska yellow cedar	89	91	90	0.879
Noble fir	93	93	93	0.921
Western larch	81	81	81	0.754
Subalpine fir	76	75	76	0.654
grand fir	80	83	82	0.805



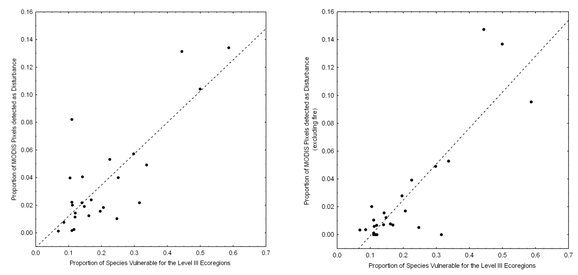
We assumed a measure of a species response to climate change is inversely proportional to the modelled probability of presence. We evaluated the fitness by calculating the fraction of a species' range that was no longer deemed suitable for each of the years between 1976 -2006. We then defined as "vulnerable" 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 (R^2> 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.

Acknowledgements: This study was supported by the National Aeronautics and Space Administration (NASA Grant NNX09AR59G) to Waring as part of the Biodiversity and Ecological Forecasting program and a Canadian NSERC Discovery grant to Coops. We gratefully acknowledge the assistance provided by Dr Tongli Wang (UBC) and Dr Andreas Hamann (UA) for access to software for the derivation of the climate surfaces. Plot data in British Columbia was compiled by Dr Andreas Hamann (UA) and US FIA data by Dr Todd Schroeder. MODIS Disturbance Index analysis undertaken with Dr Steve Running and NTSG (University of Montana).

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