Context-dependent hierarchy of plant community predictors from the Oregon Coast Range to the eastern slopes of the Cascade Mountains

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Introduction

Hierarchy theory has proved a useful organizing concept in the field of landscape ecology (O'Neill et al. 1986). The concept of scale is inherent in the theory in that broad-scale, long-term patterns and processes constrain localized, short-term patterns and processes. Vegetation has been shown to be associated with a variety of environmental conditions including climate and elevation (broad-scale), as well as disturbance, succession and local topography (local scale).

We hypothesize that different local variables will emerge as important predictors of plant community types among ecoregions with differing climatic constraints. We also hypothesize that our scale of observation will dictate how well we are able to observe correlations with the localized variables. (i.e., at broad scales, climate and elevation will dominate our models, while at localized scales, we will be able to observe the effects of local topography, disturbance and imagery variables.)

Methods

Study Areas

We chose these two ecoregions in Oregon because of their contrasting climates. The coast range has a strong maritime influence, and a Mediterranean type climate with cool, wet winters and warm, dry summers. The East Cascades climate is more continental. It is colder in the winters, and hotter in the summers, and drier year round. The topography of both ecoregions is mountainous (sea level to 1248m in the Coast Range and 842-2578m in the East Cascades).

Design

We built four models per ecoregion. One includes all of the available plots covering the area. The other three are built from small-scale subsamples of the plots, selected from within 40,000ha squares (20km x 20km).

Plot Data

Our database includes plots from several different vegetation survey programs. These include the Forest Inventory and Analysis program with the US Forest Service, Current Vegetation Survey from the US Forest Service and Bureau of Land Management, and Ecology plots from a variety of sources. Each plot is assigned to an Ecological System (NatureServe), based on species composition, within our database.

Spatial Data

Spatial data used in model building and mapping include variables describing climate (Type = C), topography (Type = T), soil parent material (Type = S), disturbance history (Type = D), location (Type = L), and imagery (LANDSAT and derivatives, Type = I). All data are mapped at 30m resolution. Climate data are derived from DAYMET modeled climate, and are resampled from their original resolution (1km) to 30m to allow mapping.

Statistics

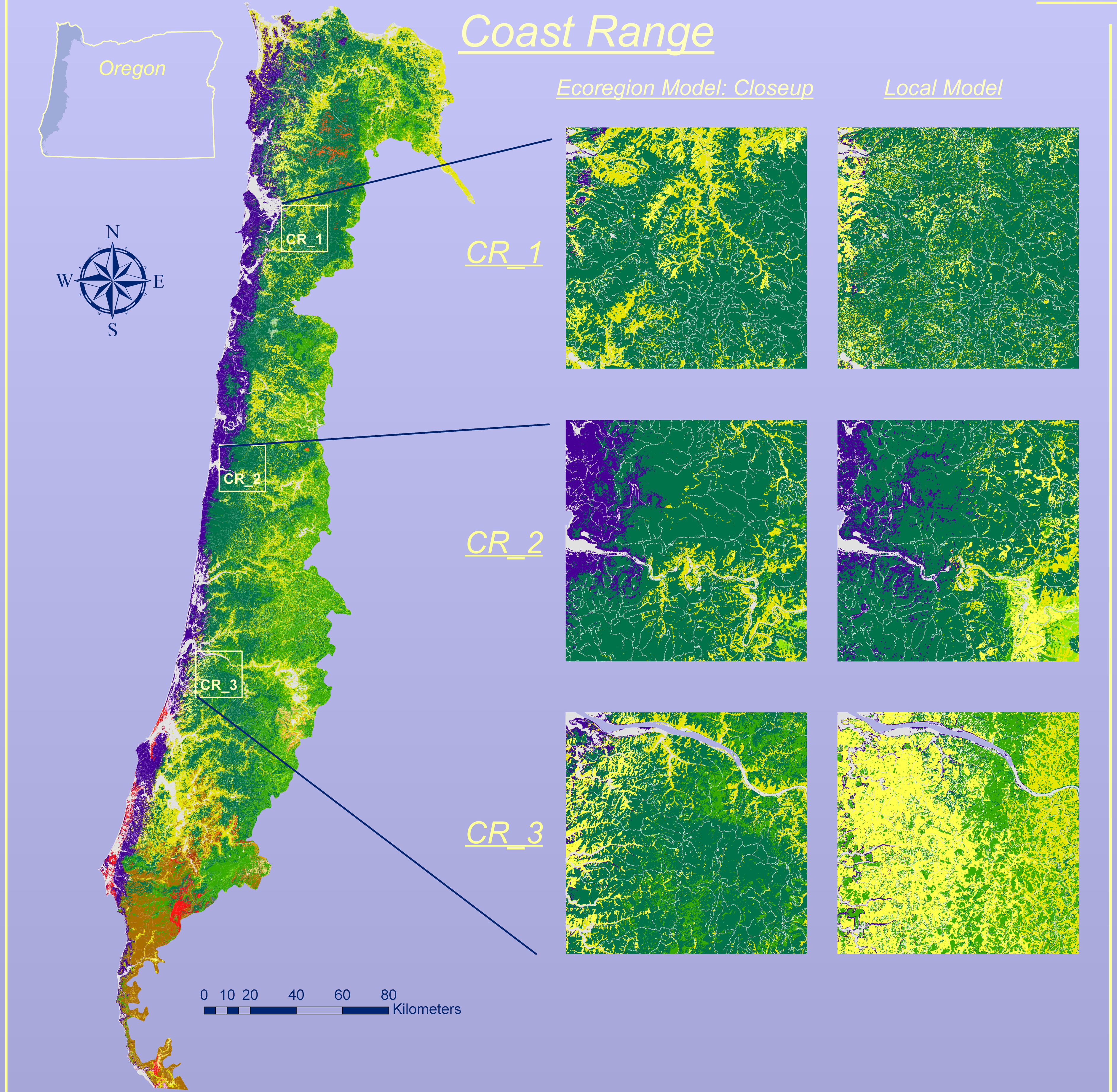
We built 20-variable random forest models (Breiman 2001) within the R statistical package, and then created pixel-by-pixel model predictions from our spatial data. We selected variables using a backwards selection procedure, starting with 121 predictor variables from our spatial data. We used the variable importance measure of 'mean decrease accuracy' to select which variable to eliminate at each step. Mean decrease accuracy is calculated by measuring model prediction accuracy with and without randomly permuting each explanatory variable in turn. Local models were built with the best 20 variables. Ecoregional models contained 35 (Coast Range) and 26 (East Cascades) variables. Only the top 10 variables are shown here.

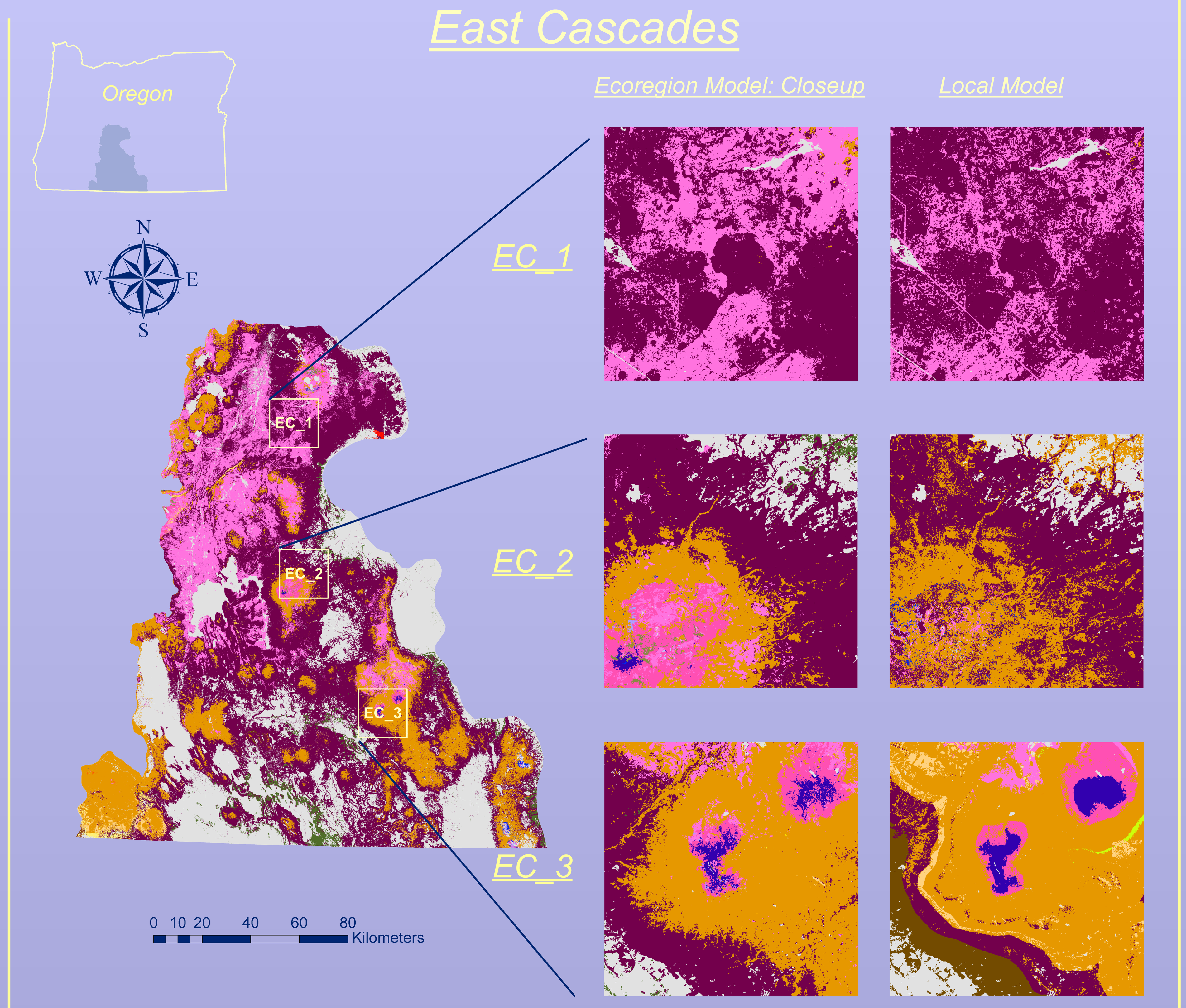
Random Forest models are an extension of Classification and Regression Trees. Our 'forest' models were created by building 500 classification trees, each from a different (random) subset of plots and explanatory variables. Model predictions are an aggregate of the prediction of each tree. Each tree 'votes' for a particular ecological system. The system with the most 'votes' is the prediction of the forest as a whole.

References

Breiman, L. 2001. Random Forests. Machine Learning 45:5-32.
NatureServe 2008. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Databases. Arlington, VA, U.S.A.
O'Neill, R.V., D. L DeAngelis, J.B. Waide and T.F.H. Allen. 1986. A hierarchical concept of Ecosystems. Princeton University Press, Princeton, New Jersey.
Ohmann, J.L. and M.G. Gregory. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest neighbor imputation in coastal Oregon, U.S.A.Canadian Journal of Forest Research, 32:725-741.

Results





Coast Range Ecoregion

Variables	Type	Importance
Y	L	0.56
DEM	T	0.55
STRATUS	C	0.54
X	L	0.54
CVPRE	C	0.53
AUGMAXT	C	0.53
ANNHDD	C	0.53
CONTPRE	C	0.52
ANNFROST	C	0.52
FOG	C	0.51
Total Error		0.357
Kappa		0.499
n		3306

CR_1

Variables	Type	Importance
TM500	I	1.51
MTM500	I	1.44
CONTPRE	C	1.22
MTM700	I	1.18
TC300	I	1.13
MTC300	I	1.13
TM700	I	0.76
ADTC100	I	0.68
ANNSWRAD	C	0.44
STDTC500	I	0.29
Total Error		0.072
Kappa		0.447
n		38

CR_2

Variables	Type	Importance
SMRTP	C	0.97
SMRTMP	C	0.95
MTM500	I	0.95
DIFTMP	C	0.93
AUGMAXT	C	0.93
MTM700	I	0.91
ADR5400	I	0.76
CONTPRE	C	0.73
MTC300	I	0.73
SMRPRE	C	0.7
Total Error		0.179
Kappa		0.378
n		135

CR_3

Variables	Type	Importance
FOG	C	1.82
DIFTMP	C	1.48
ADTM500	I	1.46
MR4300	I	1.42
STRATUS	C	1.41
STDR4300	I	1.34
STDTC300	I	1.27
STDTC100	I	1.27
STDTC200	I	1.21
MTC600	I	1.2
Total Error		0.458
Kappa		0.433
n		30

East Cascades Ecoregion

Variables	Types	Importance
Y	L	0.56
SLPPCT	T	0.56
X	L	0.54
DEM	T	0.54
MTM400	I	0.54
DIFTMP	C	0.53
ADR5400	I	0.53
IDSURVEY	D	0.53
CONTPRE	C	0.52
ANNVP	C	0.52
Total Error		0.574
Kappa		0.301
n		3602

EC_1

Variables	Types	Importance
CANOPY	I	1.32
Y	L	1.08
MTC200	I	0.9
MR5700	I	0.86
R5400	I	0.79
MR5400	I	0.71
STDTM200	I	0.7
ADTM400	I	0.65
STDTM400	I	0.63
SLPPCT	T	0.6
Total Error		0.457
Kappa		0.27
n		74

EC_2

Variables	Types	Importance
R5400	I	0.66
CVPRE	C	0.56
TC400	I	0.49
MTC400	I	0.49
SMRPRE	C	0.43
MR4300	I	0.08
LACUSTRINE	S	0
ORGANIC	S	0
LANDSLIDE	S	0
SEDIMENTARY	S	0
Total Error		0.344
Kappa		0.396
n		51

EC_3

Variables	Types	Importance
ANNPRE	C	1.44
DEM	T	1.37
SMRTMP	C	1.37
DECMINT	C	1.36
SMRPRE	C	1.36
DIFTMP	C	1.33
ANNFROST	C	1.31
ANNVP	C	1.26
ANNHDD	C	1.03
IDSURVEY	D	1.02
Total Error		0.265
Kappa		0.417
n		49

California Coastal Closed-Cone Conifer Forest and Woodland
California Coastal Redwood Forest
California Montane Woodland and Chaparral
Columbia Plateau Western Juniper Woodland and Savanna
East Cascades Mesic Montane Mixed-Conifer Forest and Woodland
East Cascades Oak-Ponderosa Pine Forest and Woodland
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland
Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland
Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland
Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Woodland
Klamath-Siskiyou Xeromorphic Serpentine Savanna and Chaparral
Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland
Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland
Mediterranean California Mesic Mixed Conifer Forest and Woodland
Mediterranean California Mixed Evergreen Forest
Mediterranean California Mixed Oak Woodland
Mediterranean California Red Fir Forest
Mediterranean California Subalpine Woodland
North Pacific Broadleaf Landslide Forest and Shrubland
North Pacific Dry Douglas-fir Forest and Woodland
North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest
North Pacific Hypermaritime Sitka Spruce Forest
North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest
North Pacific Lowland Mixed Hardwood Conifer Forest and Woodland
North Pacific Maritime Coastal Sand Dune and Strand
North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest
North Pacific Maritime Mesic Subalpine Parkland
North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest
North Pacific Mountain Hemlock Forest
North Pacific Oak Woodland
North Pacific Wooded Volcanic Flowage
Northern California Mesic Subalpine Woodland
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
Northern Rocky Mountain Subalpine Woodland and Parkland
Rocky Mountain Aspen Forest and Woodland
Rocky Mountain Lodgepole Pine Forest
Rocky Mountain Poor-Site Lodgepole Pine Forest
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland
Sierran-Intermontane Desert Western White Pine-White Fir Woodland

Discussion

Coast Range

In the Coast Range, climate variables dominated the ecoregional model, but imagery variables were important locally. This was consistent with our original hypothesis.

In CR_3, there were pronounced effects from modeling with a local sample. North Pacific Broadleaf Landslide Forest and Shrubland was more prevalent.

East Cascades

In the East Cascades, the overall pattern was not as clear. There were two strong imagery variables within the ecoregional model, and local model structure was variable.

EC_1 and EC_2 contained imagery variables, but EC_3 contained nearly all climate variables. This could possibly be due to a strong elevation gradient here that would likely correspond with a very strong climatic gradient.

EC_3 also contained two Ecological Systems in greater proportions than the ecoregion model (Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland and Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland), probably because these were relatively abundant in the local sample.

Comparison

The stronger presence of imagery variables in the local models (often) yielded maps with more fine scale spatial pattern.

Local sampling sometimes led to the loss of some ecological systems (Columbia Plateau Western Juniper Woodland in EC_2), or gains in others (e.g., the landslide type in CR_3).

The fact that imagery variables were unimportant at the ecoregional scale in the coast range, but were important in the east cascades may relate to differences in the variability in these data between the regions. The coast range is uniformly dark green and spectral reflectance is only weakly correlated with forest composition at ecoregional scales (Ohmann and Gregory 2002).

Conclusions

Observational scale affects model structure and spatial predictions (sometimes strongly).

Spatial patterns in vegetation types that correlate with imagery are (often) best modeled locally.

Spatial patterns in vegetation types relating to climate are more easily observed at ecoregional scales.

Different variables emerge in each model.

Climate (L)

ANNFROST	Mean number of days/yr when daily minimum temperature <=0.0 °C
ANNHDD	Annual heating degree days
ANNPRE	Annual precipitation
ANNSWRAD	Annual sum of total daily incident shortwave radiative flux
ANNVP	Annual vapor pressure
AUGMAXT	Mean August maximum temperature
CONTPRE	Percentage of annual precipitation falling in June-August
CVPRE	Coefficient of variation of mean monthly precipitation of December and July
DECMINT	Mean December minimum temperature
DIFTMP	Difference between AUGMAXT and DECMINT
FOG	visibility <1.6 km.
SMRPRE	Mean precipitation from May-September
SMRTMP	Mean temperature from May-September
SMRTP	September)
STRATUS	visibility <8 m.

Soil (S)

LACUSTRINE	Soil parent material contains sediments that were deposited in lakes
LANDSLIDE	Soil parent material contains unconsolidated material, from mass movement
ORGANIC	Soil parent material high in organic content
SEDIMENTARY	Soil parent material contains sedimentary rocks

Topography (T)

DEM	Elevation
SLPPCT	Slope (percent)

Disturbance (D)

IDSURVEY	Cumulative insect and disease mortality density based on aerial detection survey

Imagery (I)

TM500	TM band 5
TM700	TM band 7
R5400	Ratio of TM band 5 to TM band 4
MTM400	Median-filtered, TM band 4
MTM500	Median-filtered, TM band 5
MTM700	Median-filtered, TM band 7
MR4300	Median-filtered, ratio of TM band 4 to TM band 3
MR5400	Median-filtered, ratio of TM band 5 to TM band 4
MR5700	Median-filtered, ratio of TM band 5 to TM band 7
TC300	Tasseled-cap transformation axis 3
TC400	Tasseled-cap transformation axis 4
ADTM500	Absolute difference texture measure of TM500
MTC200	Median-filtered, tasseled-cap transformation axis 2
MTC300	Median-filtered, tasseled-cap transformation axis 3
MTC400	Median-filtered, tasseled-cap transformation axis 4
MTC600	Median-filtered, tasseled-cap transformation axis 6
ADR5400	Absolute difference texture measure of R5400
ADTC100	Absolute difference texture measure of TC100
ADTM400	Absolute difference texture measure of TM400
STDR4300	Standard deviation texture measure of R4300
STDTC100	Standard deviation texture measure of TC100
STDTC200	Standard deviation texture measure of TC200
STDTC300	Standard deviation texture measure of TC300
STDTC500	Standard deviation texture measure of TC500
STDTM200	Standard deviation texture measure of TM200
STDTM400	Standard deviation texture measure of TM400
CANOPY	Total tree canopy cover, from NLCD 2001

Location (L)

X	West - East
Y	North - South

Acknowledgements

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