Accuracy assessment

We took a three-pronged approach to assessing accuracy of the PNV map using the “nearest Neighbor” concepts from Gradient Nearest Neighbor (GNN) work:

- **Model stability/uncertainty** – check the similarity among vegetation (veg) zone/subzone rasters using the second, third, etc. neighbors rather than the first neighbor.
- **Local scale accuracy** - Observed vs. predicted veg zone/subzone by location
- **Area based regional accuracy** - Design-based (plot) vs. model-based (GNN) area estimates

Model stability/uncertainty

We compared veg zone/subzone-only realizations using the second, third, fourth and fifth nearest neighbors (k=2, 3, 4, 5) to the observed subzone (first nearest neighbor (k=1)) to assess how stable the model was. We created maps using the other neighbors for each year in the 1986-2017 temporal stack and followed the same rules in our methods section to create a single subzone raster for each of the neighbors. In general, exact matches to our PNV map (k=1) decline when using the other nearest neighbors. The comparisons vary by subzone, but typical declines in accuracy from k1k2 to k1k5 are 10-30% with an average decline in overall accuracy of 19%.

We also used the cell statistics tool in ArcGIS 10.5 to evaluate map stability by looking at the cell majority (the value most common when looking across all the temporal maps), cell variety (how many different subzone calls were made for a pixel over the temporal maps), and min-rank (the vegzone call that was the highest in the rule hierarchy) for each 30-meter cell across all the five nearest neighbor subzone maps. We then combined the k1, cell majority, cell variety, and min-rank layers into a single multiband raster (f_k1_k1k5_comb). We used the cell variety raster to look at agreement across all k1-k5 realizations. Variety values 1-2 (i.e., 1 – 2 distinct subzones predicted across five realizations) (78%) have good agreement across all k1-k5 rasters while values 3-4 (22%) demonstrate areas in the map where the modeled subzone is more uncertain. The uncertain areas appear to be a combination of disturbed areas and transitional areas from one veg zone to another.

Two additional rasters were built from the f_k1_k1k5_comb raster and each was evaluated for exact and fuzzy match. The first raster compared k1 subzone to k1k5 subzone majority, the second raster compared k1 to k1k5 subzone majority for k1k5 variety 1-2 and k1k5 subzone minimum rank for k1k5 variety 3-4. The second k1k5 comparison was built to emulate the subzone aggregation logic which utilizes the minimum ranked subzone in areas where there is higher uncertainty. The k1 to k1k5 majority raster and the k1 to k1k5 majority/minimum rank raster have similar exact match and fuzzy match agreements, however the k1 to k1k5 majority raster has 4-5% higher agreement (Figure 1). The highest exact match that we could expect across the whole map area is around 68% (fuzzy is 90%), partially due to small sample sizes associated with some subzones.

Figure 1 – Comparison of exact and fuzzy matches between subzone (k1) to k1_k1k5_maj and k1_k1k5_majmin rasters

	k1_k1k5_maj	K1_k1k5_majmin
Exact Match	68%	63%
Fuzzy Match	90%	86%

Local scale accuracy

We used a “nearest-independent neighbor” approach to assess accuracy of the new map for both vegzone and subzone (Ohmann and Gregory, 2002.). The nearest-independent neighbor approach allows us to generate a model validation dataset that behaves similarly to an independent validation dataset from the same forest inventory data used to develop GNN maps, thus providing a more reliable assessment of PNV map accuracy. For each inventory plot location used in producing the GNN dataset, the nearest neighbor plots in gradient space that are not measured at the same physical location were selected for the nine 30 X 30-meter pixels that comprise the areal extent of the plot’s sample area. In this way we produced a time-series of 32 (1986-2017) nearest-neighbor inventory plots for each pixel in a target-plot footprint. These plots were all assigned a subzone using the same logic as for the new PNV map. To get to a single subzone assignment for each pixel, we evaluated the majority (mode) subzone across all 32 observations and the number of distinct subzone assignments across all 32 observations. When the number of distinct subzone assignments was <=4, we assigned the majority subclass. Otherwise, we assigned the subzone the highest hierarchical rank, or minimum rank. Finally, we took the majority (mode) across all nine pixels in the location footprint to represent the predicted subzone. To assign predicted vegetation zones, we applied the vegetation zone associated with each predicted subzone.

For both vegetation zones and subzones, we performed both a “strict” and “fuzzy” version of the accuracy assessment. In the strict version, an assignment was recorded as correct if there was an exact match between the original assignment and the predicted assignment using the nearest-independent neighbor method. To carry out the fuzzy version, we constructed lists for each subzone of other subzones sufficiently similar in their environmental relationships and floristic composition that interpretation of the map would not significantly suffer if the assignments were swapped. For example, for the vegetation zone represented by the largest number of unique inventory plot locations (White Fir-Grand Fir), there were 11 vegetation zones that we judged to constitute a fuzzy match: Lodgepole Pine, Ponderosa Pine, Jeffrey Pine-Knobcone Pine, Douglas-Fir, Giant Sequoia, Western Hemlock, Western Red Cedar, California Red Fir-Shasta Red Fir, Pacific Silver Fir, Mountain Hemlock, and Subalpine Fir-Engelmann Spruce. The strict producer’s accuracy (i.e., percentage of plots in the zone that were mapped correctly) for the White Fir-Grand Fir Vegzone was 71%, whereas the fuzzy producer’s accuracy was 99%. The strict user’s accuracy (i.e., percentage of the plots mapped as the zone that were observed in that zone) for the White Fir-Grand Fir zone was 71%, whereas the fuzzy user’s accuracy was 98%.

For vegetation zones, the overall strict accuracy was 65% and the overall fuzzy accuracy was 97%. For individual zones, strict producer’s accuracy ranged from 0% to 89% and fuzzy producer’s accuracy ranged from 0% to 100%, while strict user’s accuracy ranged from 0% to 78% and fuzzy user’s accuracy ranged from 0% to 100%. The lower values are mostly associated with very minimally represented zones (i.e., Port Orford Cedar, Giant Sequoia, Grasslands-Meadows, and Shrublands, each of which accounted for at most 0.1% of the map). For the 10 most common vegetation zones, which together accounted for 87% of the map (White Fir - Grand Fir, Western Hemlock, Douglas-Fir, Ponderosa Pine, Pacific Silver Fir, Pinyon-Juniper-Cypress, Mountain Hemlock, Hardwoods, Subalpine Fir - Engelmann Spruce, and Tanoak), strict producer’s accuracy ranged from 56% to 82% and fuzzy producer’s accuracy ranged from 90% to 99%, while strict user’s accuracy ranged from 51% to 78% and fuzzy user’s accuracy ranged from 92% to 100%. For subzones, the overall strict accuracy was 42% and the overall fuzzy accuracy was 85%. For individual subzones, strict producer’s accuracy ranged from 0% to 88% and fuzzy producer’s accuracy ranged from 0% to 100%, while both strict and fuzzy user’s accuracy ranged from 0% to 100%.

The lower values are associated with very minimally represented subzones (i.e., Moist Western Hemlock, Limber Pine Parklands, Cool Western Red Cedar, White Bark Pine Parklands, and the one Giant Sequoia subzone, each of which accounted for at most 0.2% of the map). For the Western Hemlock VeryMoist Subzone, the most common subzone, strict producer’s accuracy was 71%, fuzzy producer’s accuracy was 94%, strict user’s accuracy 63%, and fuzzy user’s accuracy was 91%.

Area based regional accuracy

We compared designed-based (FIA inventory plots) and model-based (using GNN) area estimates for each vegzone and subzone. We used the error matrix from the local scale accuracy test to adjust model-based (GNN) area estimates and generate adjusted area estimates plus 95% confidence intervals based on methods described by Olofsson et al., 2013.

To determine agreement between the two area estimates, we employed the following methods. For design-based estimates we used species composition from the 2016 FIA annual inventory to determine both subzone and vegzone. Design-based plots were expanded by their expansion factors. For GNN, we do this in a much simpler way than official FIA methods. We simply use the number of plots in each of our strata (Washington, Oregon, California federal lands, California non-federal lands) and divide total area by this number. This is done for forested and non-forested plots together for Oregon and Washington. Furthermore, each plot's area expansion factor is multiplied by the proportion of forest/non-forest/non-sampled on that plot such that it is divided proportionally on multi-condition-class plots. Plots were then grouped by like vegzone and subzone and area represented by the plots in each classification unit were summarized. For model-based estimates we summarized the pixels in each vegzone and subzone from our final map product. We calculated the error-adjusted area estimates by using the error matrix from the observed/predicted local scale assessment to adjust map-based areas toward plot-based proportions. For example, assume we have a large over-prediction of a certain GNN class relative to what shows up in the design-based sample. Only if the error matrix shows this large proportional over-prediction (i.e., commission) will the Olofsson area-estimate be adjusted to a lower area estimate. If errors are proportionally balanced in the error matrix, the corrected area estimate will be roughly the same as the mapped estimate as we are assuming that the errors, which we see at plots, apply everywhere.

The error correction highlights which classification units were over predicted or under predicted. Results indicated a general close match between design and model-based estimates for vegzone.

53% of the individual vegzones were within the Olofsson 95% confidence interval. Modeled area estimates averaged 96% within the Olofsson 95% confidence interval of the design-based area estimate and ranged from 86 – 100% for individual vegzones. The following vegzones model-based area were overestimated: Pinyon-Juniper-Cypress, Foothill Pine-Coulter Pine, Sitka Spruce, Redwood, Western Hemlock, and Mountain Hemlock, while the following vegzones model-based area were underestimated: Lodgepole Pine, Ponderosa Pine, Douglas-fir, and Parklands.

Subzone results were similar to the vegzone results indicating a general close match between design and model-based estimates. 71% of the individual subzones were within the Olofsson 95% confidence interval. Modeled area estimates averaged 97% within the Olofsson 95% confidence interval of the design-based area estimate and ranged from 56 – 100% for individual subzones. The following subzones model-based area were overestimated: Oak Woodlands, Juniper Woodlands, Foothill Pine-Oak, VeryWet Sitka Spruce, VeryMoist Redwood, VeryMoist Western Hemlock, CoolWet Mountain Hemlock, and Subalpine Larch Parklands, while the following subzones model-based area were underestimated: Riparian Hardwood Forest, Other Hardwoods, CoolDry Lodgepole Pine, WarmXeric Ponderosa Pine, VeryWarmDry Douglas-fir, WarmDry Douglas-fir, VeryWarmMoist Douglas-fir, CoolMoist White Fir-Grand Fir, Moist Western Hemlock, and Whitebark Pine Parklands.