Southeast Oregon NN Vegetation Composition Map Accuracy Report – 2018-20 Landsat Imagery Year/2016NaipYear

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Introduction

This report contains information detailing the model used to build the imputed vegetation map for southeastern Oregon. It contains only information that can be calculated from species x cover vegetation survey plot data records. All attributes distributed with the raster data layer have been assessed for accuracy here.

This document was originally written as a reference for vegetation maps showing arid vegetation across Arizona and New Mexico. It has been modified to apply to this mapping region as needed.

Package Contents

Selected individual map indicators can be viewed and downloaded via a web map from https://tools.oregonexplorer.info/OE_HtmlViewer/index.html?viewer=sagegrouse.

The full version of this map can be downloaded from: https://oe.oregonexplorer.info/externalcontent/sagecon/datafordownload/SoutheastOregon_Vegetation_2020.zip.

The zip file with the full version contains two subfolders: one named “Documentation”, and another labeled “GIS Data”. The Documentation subfolder contains a copy of this document, as well as a supplemental excel file describing accuracy for one categorical variable with too many categories to display within a word document (referenced below in the text). The “GIS Data” subfolder contains a geodatabase which houses four tables, and three raster data layers. The tables hold vegetation descriptor attributes that can be joined to the “nn1_VegComp” raster layer for display on the field named ‘Value_’. The table named ‘All’ contains all variables that are described in this document, while the other tables contain subsets of these variables. They are included for ease of display, as most users will find the ‘All’ table unwieldy. The supplemental grids ‘nn1_dist’, and ‘nn1_edst’ are different mapped indicators of model confidence, and are described fully under the Methods/Map assessment/Supplemental data layers’ section.

Download options for the maps are under revision as of 03-13-2025. Contact emilie.henderson@oregonstate.edu with further questions

Additional Notes

In the discussion section, we address the implications of some of the accuracy assessments for different data uses. For further discussion on the use of this type of vegetation map for different applications, please see Henderson (2019) in the reference section.

Methods

This report references the Southeast Oregon modeling region, indicated in blue in Panel a (Figure 1). Panels b, c, and d show hexagons used for multi-scaled accuracy assessments. Hexagon sizes are 50,000ha for the Hex1 scale, 100,000ha for the Hex2 scale, and 200,000ha in size for the Hex3 scale.

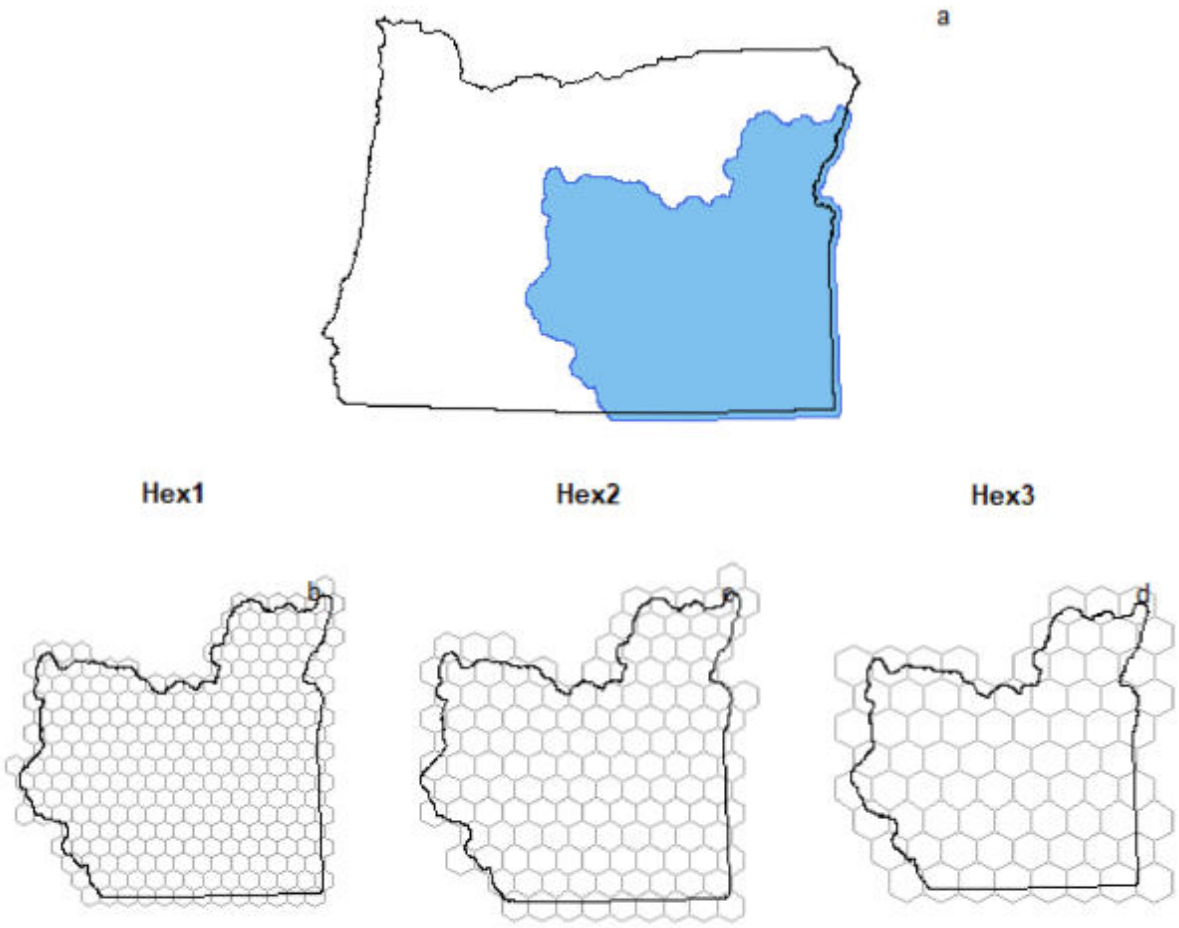

Figure 1: Southeast Oregon model region and hexagons used for accuracy assessment. Note that the plot data sample is uneven. Only those hexagons shown here contain enough sample plots to support hex-based assessments.

Data

Plot

We used 3,944 vegetation plots data from 32 data sources (Table 1), which contained species-cover information. Most plots were surveyed between 2011 and 2017, but a few were drawn from earlier dates. These older vegetation survey plots were added to represent portions of the landscape with trees, because the more recent plots under-represent this portion of the landscape.

Table 1: Data used for input plot data sample.

	2001	2002	2003	2004	2011	2012	2013	2014	2015	2016	2017	2018	2020	Total
AIM-NA	0	0	0	0	0	1	0	0	0	552	0	0	0	553
AIM-OR_BakerFO_LUP_2017_5-2a_01.mdb	0	0	0	0	0	0	0	0	0	0	7	0	0	7
AIM-OR_BurnsDO_LUP_2017_5-2_02.mdb	0	0	0	0	0	0	0	0	0	0	44	0	0	44
AIM-OR_BurnsDO_LUP_2018_5-3b_05.mdb	0	0	0	0	0	0	0	0	0	0	0	50	0	50
AIM-OR_DryValleyJackMtn_PAC_2018_5-3b_03.mdb	0	0	0	0	0	0	0	0	0	0	0	48	0	48
AIM-OR_HTP17_PAC_2017_5-3b_04.mdb	0	0	0	0	0	0	0	0	0	0	0	128	0	128
AIM-OR_HTP18_PAC_2018_5-3b_04.mdb	0	0	0	0	0	0	0	0	0	0	0	94	0	94
AIM-OR_LakeviewDO_LUP_2017_5-2_01.mdb	0	0	0	0	0	0	0	0	0	0	46	0	0	46
AIM-OR_LakeviewDO_LUP_2018_5-3b_02.mdb	0	0	0	0	0	0	0	0	0	0	0	76	0	76
AIM-OR_OregonSO_BeattyButteGRSG_2017_5-2_01.mdb	0	0	0	0	0	0	0	0	0	0	46	0	0	46
AIM-OR_OregonSO_GRSGDryValleyPAC_2017_5-2_01.mdb	0	0	0	0	0	0	0	0	0	0	47	0	0	47
AIM-OR_OregonSO_SFAGRSG_2017_5-2_01.mdb	0	0	0	0	0	0	0	0	0	0	123	0	0	123
AIM-OR_OregonStateOffice_PACGRSG_2017_5-2_01.mdb	0	0	0	0	0	0	0	0	1	0	134	0	0	135
AIM-OR_PrinevilleDO_LUP_2017_5-2a_01.mdb	0	0	0	0	0	0	0	0	0	0	56	0	0	56
AIM-OR_PrinevilleDO_LUP_2018_5-3b_03.mdb	0	0	0	0	0	0	0	0	0	0	0	61	0	61
AIM-OR_State_SFA_2016_5-3b_04.mdb	0	0	0	0	0	0	0	0	0	29	0	0	0	29
AIM-OR_State_SFA_2018_5-3b_03.mdb	0	0	0	0	0	0	0	0	0	0	0	112	0	112
AIM-OR_ValeDO_ESR_2017_5-2_01.mdb	0	0	0	0	0	0	0	0	0	0	38	0	0	38
AIM-OR_ValeDO_LUP_2017_5-2_01.mdb	0	0	0	0	0	0	0	0	0	0	49	0	0	49
AIM-OR_ValeDO_LUP_2018_5-3b_03.mdb	0	0	0	0	0	0	0	0	0	0	0	46	0	46
BakerMesicPlots_2020	0	0	0	0	0	0	0	0	0	0	0	0	55	55
BLM Vale	0	0	0	0	0	311	0	0	0	0	0	0	0	311
BLM_AIM_2015AndEarlier	0	0	0	0	0	1	0	0	3	0	0	0	0	4
BLM_LMF	0	0	0	0	79	297	0	267	254	0	0	0	0	897
Christy	0	0	0	0	0	11	2	0	0	0	0	0	0	13
Emilie	0	0	0	0	0	0	0	0	10	0	0	0	0	10
Jimmy	0	0	0	0	0	0	0	0	20	0	0	0	0	20
Landfire	1	1	3	0	0	0	0	0	0	0	0	0	0	5
MalheurVeg_2015	0	0	0	0	0	0	0	0	77	0	0	0	0	77
Mike-EOR-EcoPlots	0	0	1	2	0	0	0	0	0	0	0	0	0	3
Newhouse	0	0	0	0	0	3	0	0	0	0	0	0	0	3
Plot Data	0	0	0	0	111	45	602	0	0	0	0	0	0	758
Total	1	1	4	2	190	669	604	267	365	581	590	615	55	3944

Spatial

Raster explanatory variables included variables representing topography (extracted from national elevation dataset, Gesch et al. 2002), climate (derivatives of PRISM climate 30 year normal, Daly et al. 2008), soil (principal components analysis (PCA) summaries of POLARIS soil properties, Ramcharan et al. 2018)), and remote sensing imagery information. Remote sensing information was extracted from a LANDSAT mosaic showing median reflectance values from spring imagery illustrating 2018 to 2020, and summer imagery illustrating the same years (median extraction methods derived from script shared by Matthew Gregory in 2021, working through Google Earth Engine). In addition to the landsat imagery, we used PCA summaries of image texture metrics (Nielsen and Noone 2014) extracted from 2016 airphotos taken for the national airphoto inventory program. Variables selected for modeling vegetation described by this map are described in detail in Appendix 1a.

Imputation model

Background on imputation

The model used to create the map is a member of a family of methods called imputation. Imputation refers to a procedure using observations that have a full suite of variables to inform predictions of missing values for observations that contain only some of the variables (Eskelson et al. 2009). It is a particularly useful technique for mapping multiple, co-varying response variables (Henderson et al. 2014), and is often used in to inform landscape management questions that require multivariate information (Ohmann et al. 2011). In our application, vegetation plot data contain a full suite of information on vegetation, and also a full suite of information from raster data describing the environment, such as topography and remote sensing. Mapped pixels contain a partial suite of information, just the raster data describing environment, and the imputation model estimates vegetation from those ancillary variables.

The root of the imputation procedure uses a distance metric to identify one or more plot observations that are close matches to the conditions in the target pixel. In our application, we simply choose the closest match. All values from the chosen plot are mapped to the predicted pixel via the plot identifier. This approach has the advantage of maintaining the covariance structure of the vegetation information embodied in the original input data, rendering our maps appropriate for more flexible summary variable configurations. Map attributes that are derived from multiple plot variables (e.g., proportion of all grasses that are non-native) can be calculated and displayed in the map without creating a new model.

There are many variants of imputation that have been used in mapping forest inventory information (e.g., kNN: Tomppo and Katila 1991), MSN:, Moeur and Stage (1995), GNN:, Ohmann and Gregory (2002), and RFNN: Crookston and Finley (2008)]. We rely on the RFNN procedure here, which uses information from internal random forest models to calculate the neighbor-distance metric used to identify plots for new predictions.

Imputation modeling has a shorter history as a tool for mapping the arid portion of the landscape, but see (Creutzburg, Henderson, and Conklin 2015) for an example of its use.

Y variables to structure the imputation model

The *yaImpute* imputation algorithm in R (Crookston and Finley 2008), builds one random forest model for each response variable. We calculated three categorical response variables for this purpose, one categorization based on species composition, one based on the relative abundance (cover) of life forms within the vegetation (e.g., trees, shrubs, grasses, and forbs and herbs), and one based on a suite of variables designed to indicate landscape condition (See Appendix 1b. Variables with a prefix of “Ind” were used to build the third classified y-variable). We generated the categories based on a hierarchical clustering algorithm and Ward’s linkage method. We used our judgement to cut the hierarchical cluster object, aiming each time to obtain 30 or fewer categories to illustrate the range of variability in the data. Categorizations with fewer than 30 variables were used when the classification contained more than two categories whose size was prohibitively small (< 5).

Our final modeling y-variables included 30 species composition categories, and 30 structural categories, 30 indicator categories, and a binary variable describing *Juniperus occidentalis* presence and absence, and a categorization of cover for obligate and facultative wetland species (four categories).

Explanatory variable selection

Due to the large initial list of possible explanatory variables (127), we reduced our variables through a two-phase process. First, we extracted the primary information from the largest groups of variables (soil, and airphoto) into axes of variation with principal components analysis. This reduced the lists from 60 soil variables and 98 airphoto variables to 18 soil summaries and 37 airphoto texture summaries.

Once the initial phase of variable reduction was complete, we developed a two-step approach for variable selection, roughly following Tomppo and Halme (2004), and selected five sets of variables, one set for each y-variable. The first step of this phase involved building one large random forest model for a single y-variable, tallying variable importance (both GINI, and Mean Decrease Accuracy measures) and eliminating approximately 10-20% of the variables that were least important in that large model. Then, with the reduced list of variables, we used a genetic-evolution based algorithm to select a smaller suite of un-correlated variables that performed well together. The selection criterion for each 'generation' of models emphasized model accuracy at predicting the y-variable categories (Kappa,(Cohen 1960)), balanced with a penalty factor that reduced each model's score according to the proportion of variables used that were tightly-correlated with each other.

Our final variable list of 44 variables to use for imputation included all variables selected for the species-group, structure-group, indicator-group, and binary juniper sub-models. These variables are listed and described in Appendix 1.

Model assessment

Variable importance

We show the relative importance of each variable for predicting each categorical y-variable (species composition, and structure groups), extracting two variable importance measures, the GINI index, which indicates each variable's contribution to reducing the class impurity in the model prediction, and also the mean decrease accuracy measure, which indicates the reduction in model accuracy for the y-variable that results from randomly permuting the values in each explanatory variable, one at a time. We report both metrics because they are complementary in their information content.

Accuracy for response variables

We assess the model's capacity to predict several variables of three different types. For species-cover model predictions, we assess the model's capacity to predict range on a binary transformation of species cover using the kappa statistic (Cohen 1960). For continuous variables describing community-level cover summaries (e.g., shrub cover, tree cover, % cover of exotic annual grasses), we report a regression-based analysis of model accuracy (Riemann et al. 2010).

Riemann's protocol involves three regression-based statistics that report on a regression model of observed and predicted values. The Systematic Agreement Coefficient (AC_sys), indicates how well the regression line matches a 1:1 line (values less than 1 indicate that the regression line differs from 1:1, highlighting bias in the model prediction). The Unsystematic Agreement Coefficient (AC_uns) indicates the degree of scatter around that regression line, or model precision. AC_uns values less than 1 indicate more scatter around the regression line. This statistic is analogous to an R^2 value. The overall Agreement Coefficient (AC) merges

information from both AC_sys and AC_uns to give an indication of overall model performance in terms of both precision and bias.

We also calculate the Kolmogorov-smirnoff statistic for continuous variables to indicate how well the model prediction's statistical distribution matched that for relationship with the distribution of observed values (Lopes, Reid, and Hobbes 2007). For categorical variables, we report overall and class-level statistics (kappa and % accuracy). We also provide error matrices to allow map users to evaluate each categorical variable's fitness to provide information to their current project when a particular category is of primary importance.

Vegetation summary variables that are included with the distributed maps are described in Appendix 1b. A subset of illustrative variables are illustrated graphically within the results section.

Mapping

The final imputation model was used to generate a prediction of the nearest neighbor plot for all pixels in the area of interest. This raw grid was converted to an integer, and areas that were outside of the scope of our model were masked using three ancillary data sources. Developed areas, cultivated crops, and water were masked from information in the National Land Cover Datasest (NLCD, Homer et al. 2015). Forested areas were masked from information in the USGS Gap Analysis Program's landcover layer (GAP, Gap Analysis Program 2011). A supplemental local mask was also developed from airphoto interpreted points to supplement NLCD's information cultivated crops and water, as well as estimate and barren lands with no vegetation. This local map was build using a random forest (classification mode) model. These three data sources were combined in to a mask that is applied to the distributed grid.

Attributes describing vegetation are contained in three tables in the file geodatabase. They may be joined to the final raster grid using the 'Value' field, and displayed in a GIS.

Map assessment

Map Review

In the drafting process, we assessed the map's congruence with local expert knowledge through a series of online meetings. Over the course of these meetings, some fixable problems were identified (and corrected for this final map draft), and others were noted for future reference. Fixable problems included errors in summarizing plot data, and missing but needed explanatory data layers.

Plot data summary errors were simply corrected for the final draft.

Missing explanatory raster data layers were, if they were available, added in to the final model. The automated variable selection process contains some uncertainties, and the random forest algorithm can effectively handle some irrelevant variables without drastically altering model predictions. Because of both of these factors, we felt comfortable adding one variable describing fire history, and also one topography variable to the final model shown here (years since last fire, and aspect).

Another class of problem was also identified during the expert review process, which includes problems that are unfixable at this time. These are documented within the results and discussion

section. Some of the currently-unfixable problems may be resolved in future drafts with additional plot data, and others may require a stronger suite of imagery variables to improve.

Supplemental data layers

As well as providing a raster data layer containing vegetation attributes, we provide two additional layers that depict two other aspects of map quality: nearest neighbor distances and euclidean environmental distances (named “nn1_dst”“, and”nn1_edst"" respectively in the geodatabase).

The nearest neighbor distance map indicates the distance between each pixel, and the plot imputed to that pixel within the space defined by the imputation model. In some imputation variants, this distance is analogous to environmental distance, but in random forest nearest neighbor imputation, it is not. The random forest nearest neighbor-based distance metric calculates imputation distances based on how plots are sorted by the classification trees that comprise the two random forest models. The space defined by this distance metric is nonlinear, and also non-euclidean, but it can be interpreted as an index of model certainty. When imputation distances are shorter, the imputation model has a clearer choice of the best plot match. Longer imputation distances indicate less certainty about the optimal plot choice. Short imputation distances often arise in areas of the landscape that are less well-sampled because it is more likely that only one plot is a reasonable choice. In portions of the landscape that are well-described by the plot data sample, imputation distances are often longer because the identity of the best possible plot is less clear when there are many good choices. Confoundingly, in portions of the landscape that are poorly-described by the plot data, it is also possible to have long imputation distances when the model is choosing from several equally poor plot choices.

Because the imputation distance metric is uninformative about how closely a given plot is matched to each pixel, we also provide a euclidean distance map that shows the euclidean distance between each pixel’s native values in the explanatory variables, and the explanatory data values associated with the plot imputed to that pixel. This environmental distance map helps illustrate areas in the map that are less well-described by the plot data sample. To calculate our environmental distance metric, we normalized all explanatory variables to range from zero to one. In future drafts, we are considering weighting the normalization to reflect variable importance, but as this has not yet been tested we have mapped values from the former calculation for this project.

Results

Variable importance

For the structure-group y-variable, climate, soil and imagery variables were selected. Three climate variables (growing season temperature, average annual temperature and the seasonal continuity of precipitation) were the strongest variables for predicting the structure-groups. Landsat imagery variables, were important, and airphoto and soil summaries were also included (Figure 2a).

For the species-group y-variable, elevation was the most important predictor variable. Summer temperatures were also important (growing season temperatures, and august maximum temp). Elevation was also an important predictor of the species-groups. Landsat and soil variables were somewhat important, and one airphoto variable was included in the random forest model for this y-variable (Figure 2b). The most important variables for the indicator-group y-variable included imagery (naip), elevation, landsat, and climate (summer temperature) (Figure 2c). The binary juniper variable relied on topography and climate more strongly than did the other variables, as well as imagery (Figure 2d).

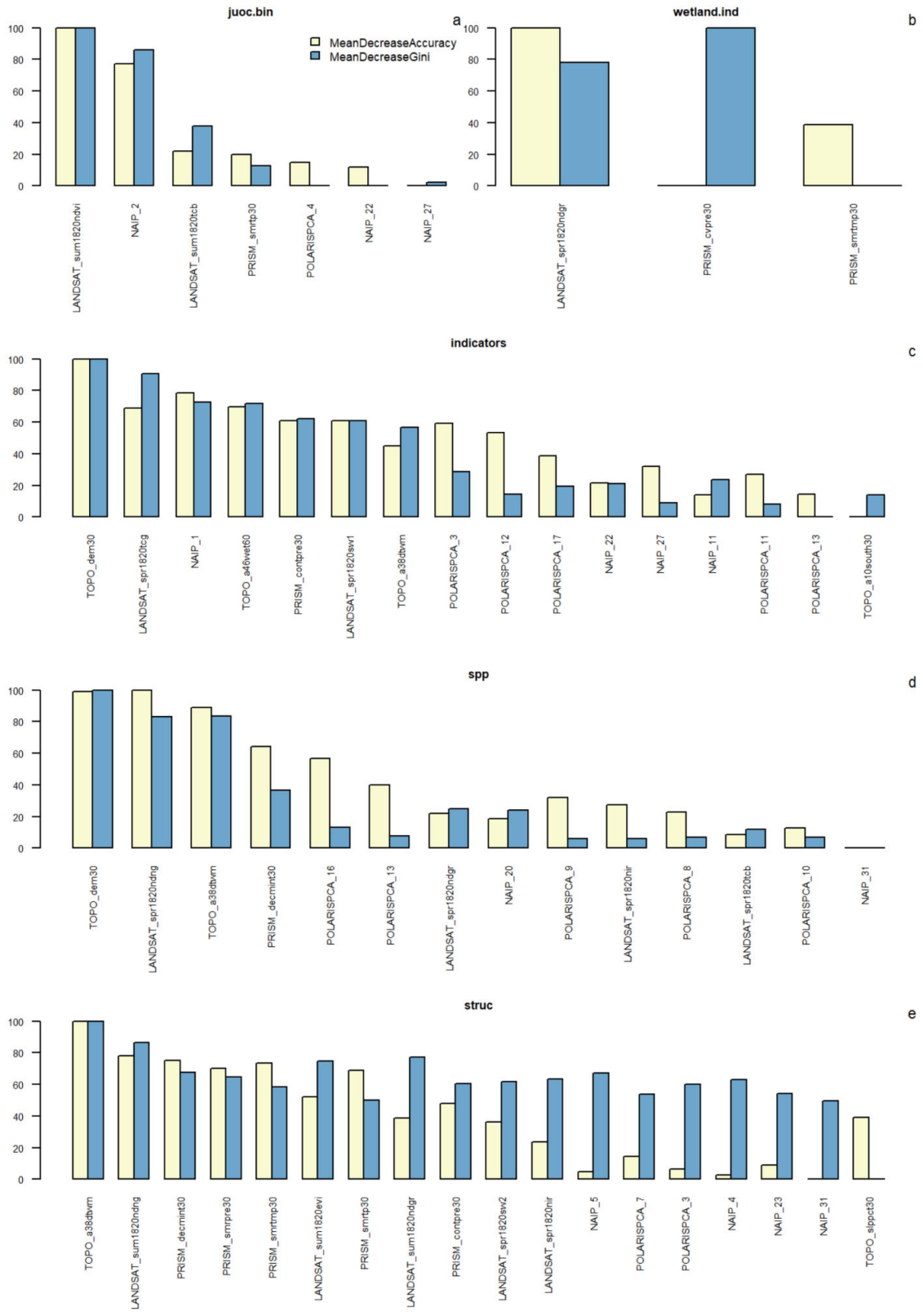

Figure 2: Variable importance metrics for each y-variable. The order of variables corresponds to the combined ranking of both metrics.

Species range

At the plot scale, 44% of range predictions for the common species shown in Table 2 had kappa statistics of greater than 0.4. This generally improved at the broader scales of summary, with 78, 61 and 39% of these species surpassing this threshold at the Hex1, Hex2 and Hex3 scales, respectively. Species range accuracy was most often at its' peak at the Hex1 scale.

Additional details on the accuracy of model predictions for all 51 species present in more than 5% of the input plot data for this model are shown in Appendix 2 (range), and 3 (cover).

Table 2: Kappa Statistics for all species that are present in more than 10% of the input plot data. Kappa values of 0.4, a cutoff that suggests that species range predictions are accurate enough to provide useful information. Standard error of the kappa statistic is shown in parentheses.

	Scientific.Name	Count	Plot	Hex1	Hex2	Hex3
ACTH7	*Achnatherum thurberianum*	1228	0.36 *(0.02)*	0.56 *(0.15)*	0.48 *(0.22)*	0.00 *(0.00)*
AGCR	*Agropyron cristatum*	406	0.52 *(0.02)*	0.56 *(0.07)*	0.44 *(0.10)*	0.61 *(0.13)*
ARAR8	*Artemisia arbuscula*	907	0.47 *(0.02)*	0.64 *(0.07)*	0.33 *(0.12)*	0.29 *(0.16)*
ARTRT	*Artemisia tridentata ssp. tridentata*	775	0.39 *(0.02)*	0.52 *(0.09)*	0.44 *(0.15)*	0.30 *(0.25)*
ARTRW8	*Artemisia tridentata ssp. wyomingensis*	1882	0.42 *(0.01)*	0.32 *(0.15)*	0.26 *(0.22)*	0.00 *(0.00)*
BRTE	*Bromus tectorum*	2762	0.52 *(0.01)*	-0.01 *(0.01)*	0.00 *(0.00)*	0.00 *(0.00)*
CHVI8	*Chrysothamnus viscidiflorus*	1253	0.39 *(0.02)*	0.23 *(0.12)*	0.55 *(0.23)*	1.00 *(0.00)*
COPA3	*Collinsia parviflora*	664	0.26 *(0.02)*	0.47 *(0.09)*	0.43 *(0.13)*	0.37 *(0.28)*
CRAC2	*Crepis acuminata*	736	0.30 *(0.02)*	0.66 *(0.07)*	0.45 *(0.14)*	0.41 *(0.20)*
ELEL5	*Elymus elymoides*	2294	0.31 *(0.02)*	0.49 *(0.22)*	-0.03 *(0.01)*	0.00 *(0.00)*
ERNA10	*Ericameria nauseosa*	775	0.34 *(0.02)*	0.44 *(0.12)*	0.43 *(0.17)*	0.00 *(0.00)*
FEID	*Festuca idahoensis*	1050	0.50 *(0.02)*	0.76 *(0.07)*	0.66 *(0.13)*	0.00 *(0.00)*
JUOC	*Juniperus occidentalis*	401	0.71 *(0.02)*	0.83 *(0.05)*	0.79 *(0.07)*	0.61 *(0.12)*
MIGR	*Microsteris gracilis*	544	0.23 *(0.02)*	0.57 *(0.08)*	0.59 *(0.11)*	0.64 *(0.19)*
PHLO2	*Phlox longifolia*	739	0.28 *(0.02)*	0.41 *(0.08)*	0.37 *(0.11)*	0.44 *(0.19)*
POSE	*Poa secunda*	3025	0.50 *(0.02)*	-0.01 *(0.01)*	0.00 *(0.00)*	0.00 *(0.00)*
PSSP6	*Pseudoroegneria spicata*	1770	0.43 *(0.01)*	0.51 *(0.13)*	0.00 *(0.00)*	0.00 *(0.00)*
SIAL2	*Sisymbrium altissimum*	403	0.29 *(0.02)*	0.52 *(0.07)*	0.60 *(0.09)*	0.63 *(0.14)*

Continuous variables

We report in detail for three continuous variables here: Juniper, *Artemisia tridentata*, *Artemisia arbuscula* and Invasive Annual Grass. For assessments of all continuous, summarized variables available in the map, see Appendix 3.

Juniper

The variable showing the percent cover of Juniper performed well overall. At the plot scale, the model prediction was unbiased, although not very precise (AC_sys = 0.99, AC_uns = 0.17, Figure 3a). At broader scales of summary, the model's precision improved, and remained unbiased (AC_sys = 0.99, 1, 0.99, and AC_uns = 0.84, 0.91, 0.92 for Hex1, Hex2, and Hex3 scales respectively, Figure 3b, c and d).

The model prediction reproduced the distribution of values in the observations for AllJuniper quite consistently across all spatial scales (Figure 4).

The spatial patterns of prediction errors appear well-dispersed throughout the sampled portion of the modeling region on visual inspection (5c, f and i).

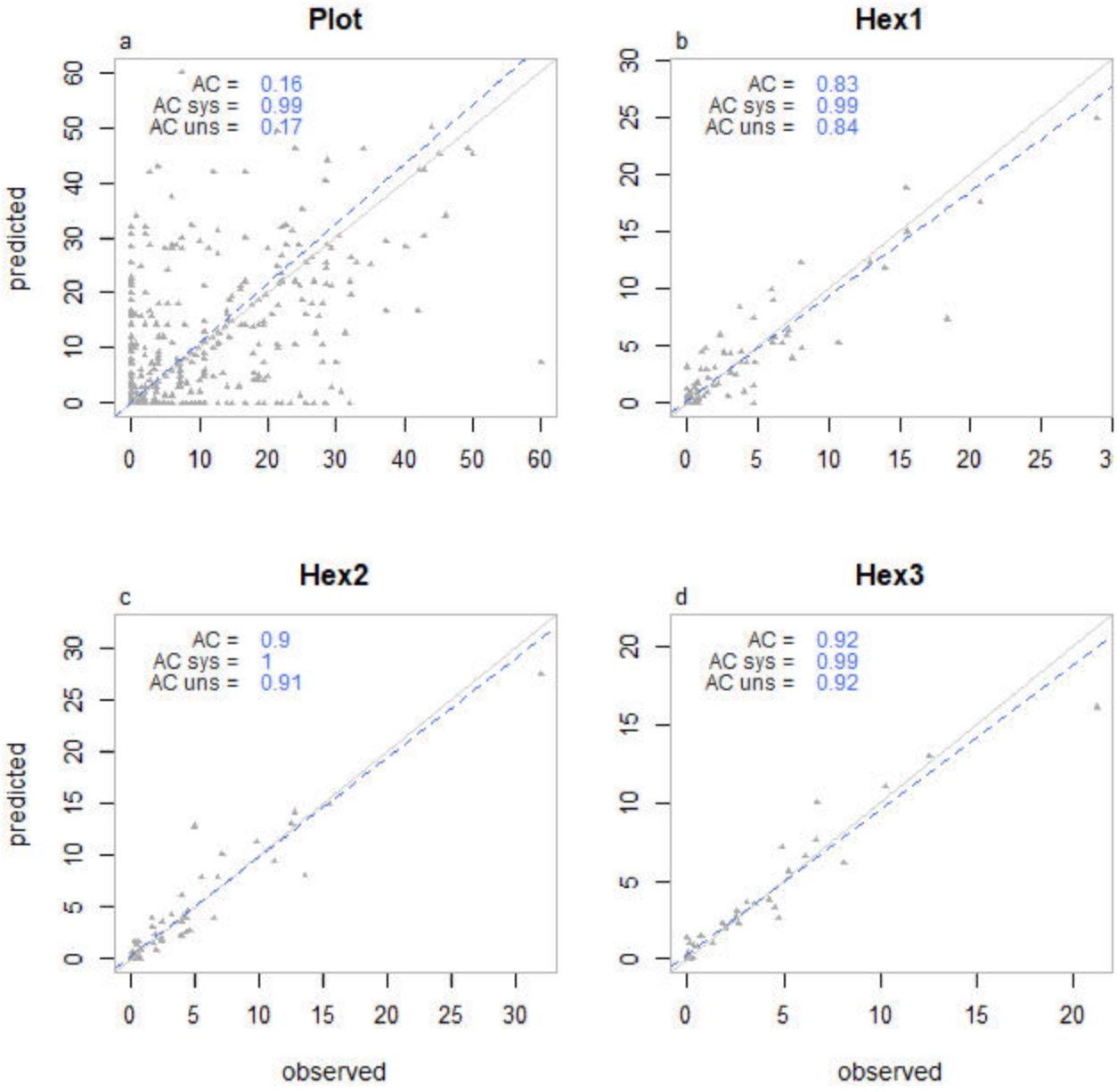

Figure 3: GMFR-based accuracy statistics for AllJuniper variable, at Plot, Hex 1, Hex 2, and Hex 3 scales of summary (Panels a,b,c and d respectively). AC_sys = 'Systematic Agreement Coefficient', and indicates how well the regression line matches a 1:1 line. AC_uns = 'Unsystematic Agreement Coefficient' indicates scatter around the regression line. AC = 'Agreement Coefficient', integrates the two components of accuracy and indictes overall fit. All 3 statistics indicate good fit as they approach 1.

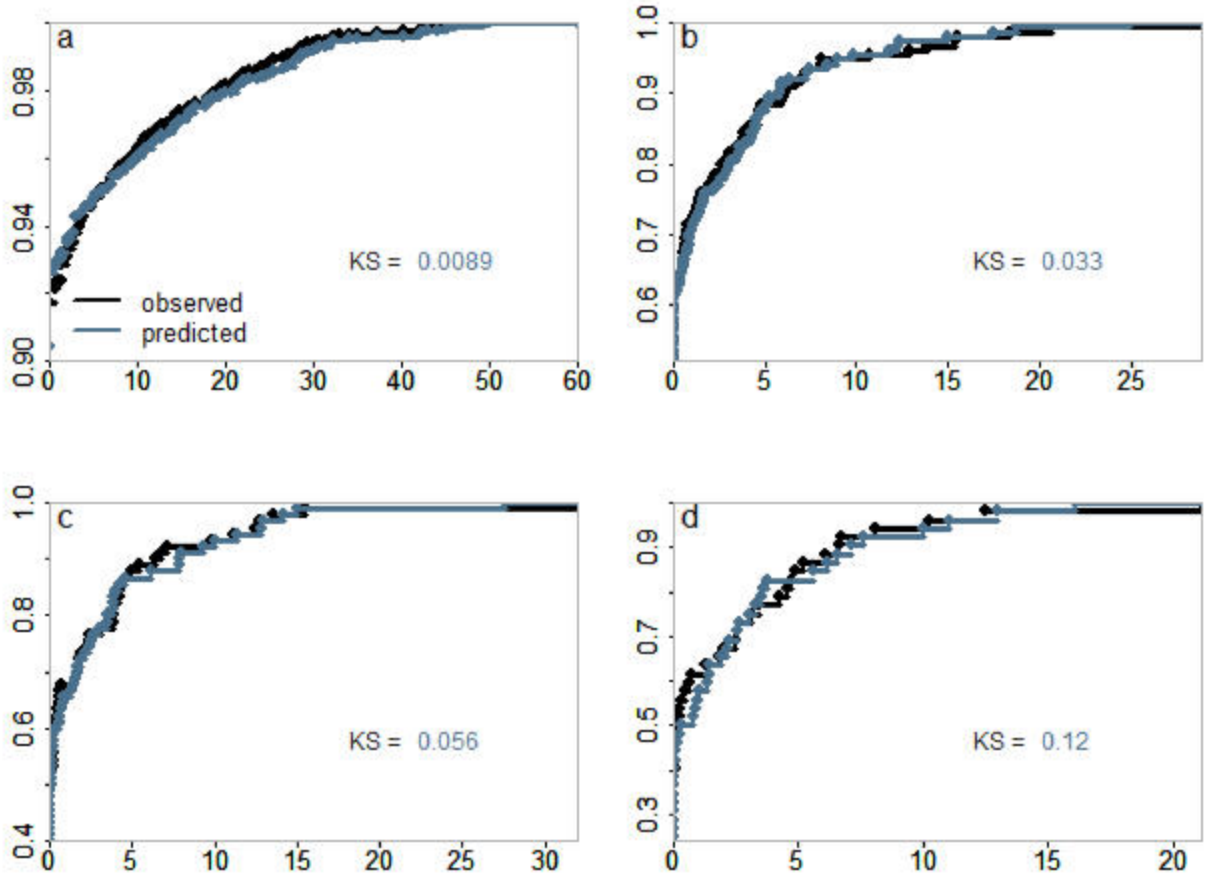

Figure 4: Distributional accuracy for AllJuniper variable, at Plot, Hex 1, Hex 2, and Hex 3 scales of summary (Panels a,b,c and d respectively). When the two lines are closely matched, the statistical distribution of values contained in the observations and predictions are similar.

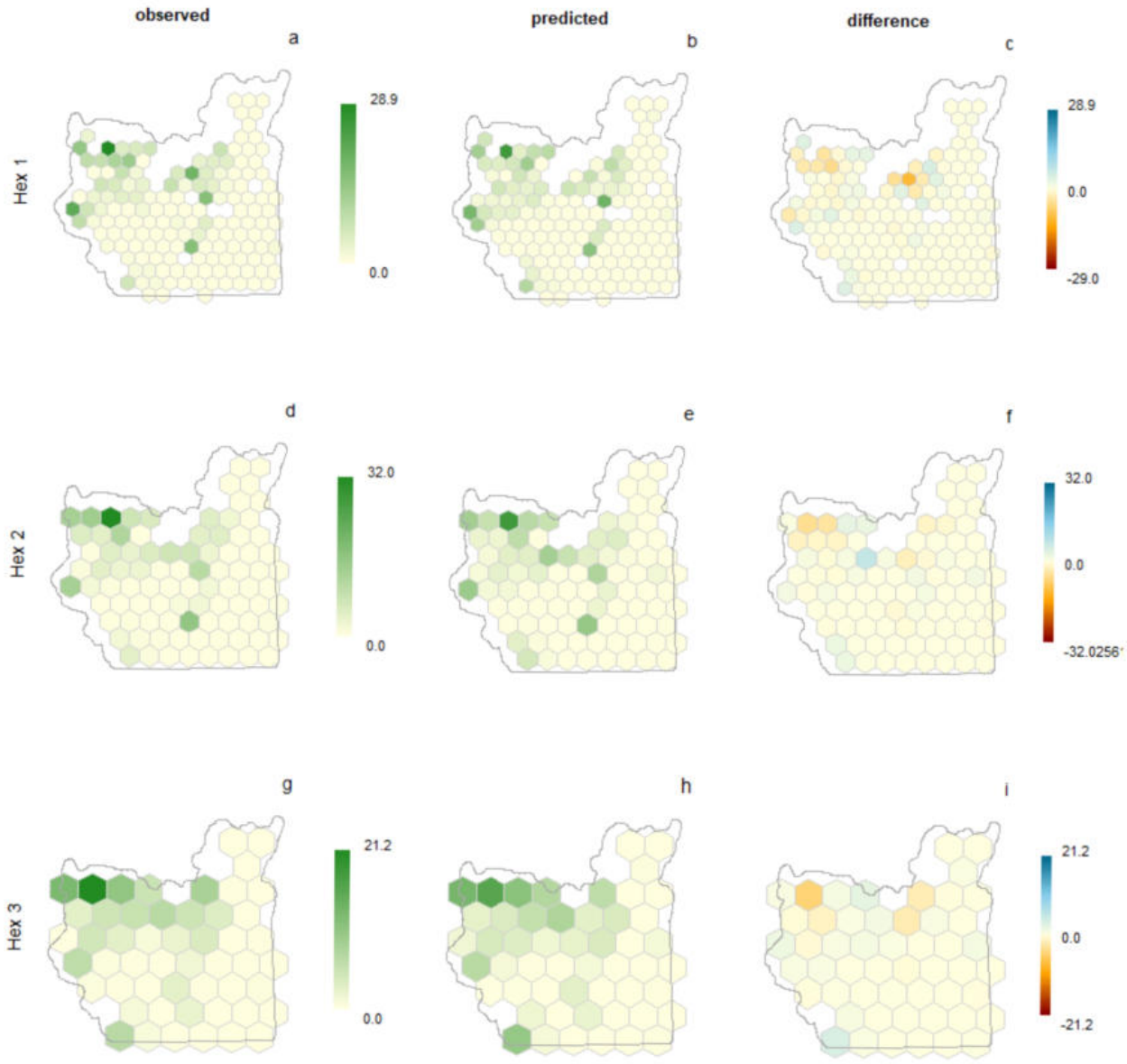

Figure 5: Model observations, predictions for AllJuniper and the difference between the two, summarized at Hex 1, Hex 2, and Hex 3 scales of summary.

Artemisia tridentata

The variable showing the percent cover of *Artemisia tridentata* performed well overall. At the plot scale, the model prediction was unbiased, although not very precise (AC_sys = 1, AC_uns = -0.39, Figure 6a). At broader scales of summary, the model's precision improved, and remained unbiased (AC_sys = 0.97, 0.96, 0.97, and AC_uns = 0.75, 0.78, 0.8 for Hex1, Hex2, and Hex3 scales respectively, Figure 6b, c and d).

The model prediction reproduced the distribution of values in the observations for SageTridentata quite consistently across all spatial scales (Figure 7).

The spatial patterns of prediction errors appear well-dispersed throughout the sampled portion of the modeling region on visual inspection (8c, f and i).

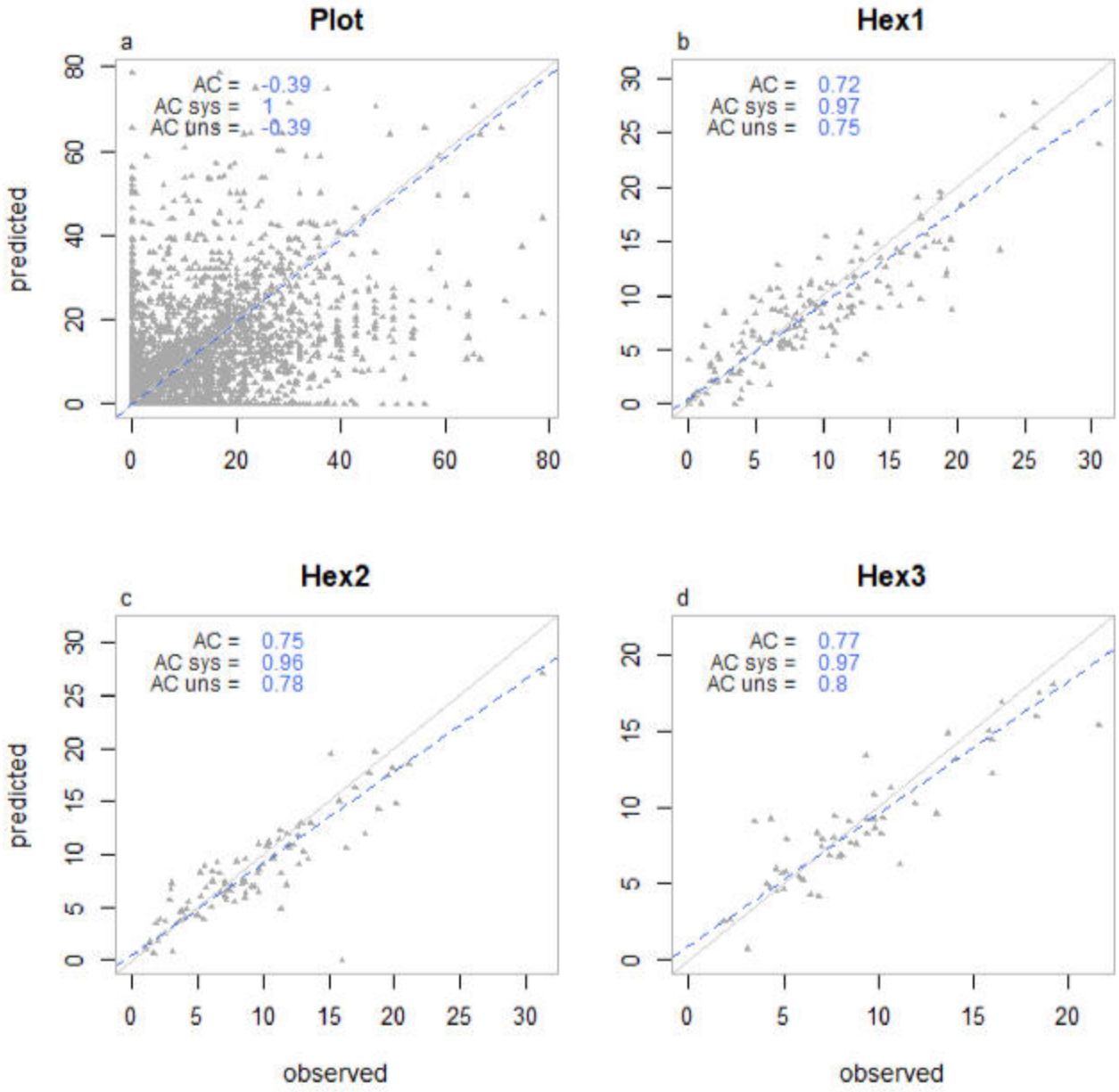

Figure 6: GMFR-based accuracy statistics for SageTridentata variable, at Plot, Hex 1, Hex 2, and Hex 3 scales of summary (Panels a,b,c and d respectively). AC_sys = 'Systematic Agreement Coefficient', and indicates how well the regression line matches a 1:1 line. AC_uns = 'Unsystematic Agreement Coefficient' indicates scatter around the regression line. AC = 'Agreement Coefficient', integrates the two components of accuracy and indictes overall fit. All 3 statistics indicate good fit as they approach 1.

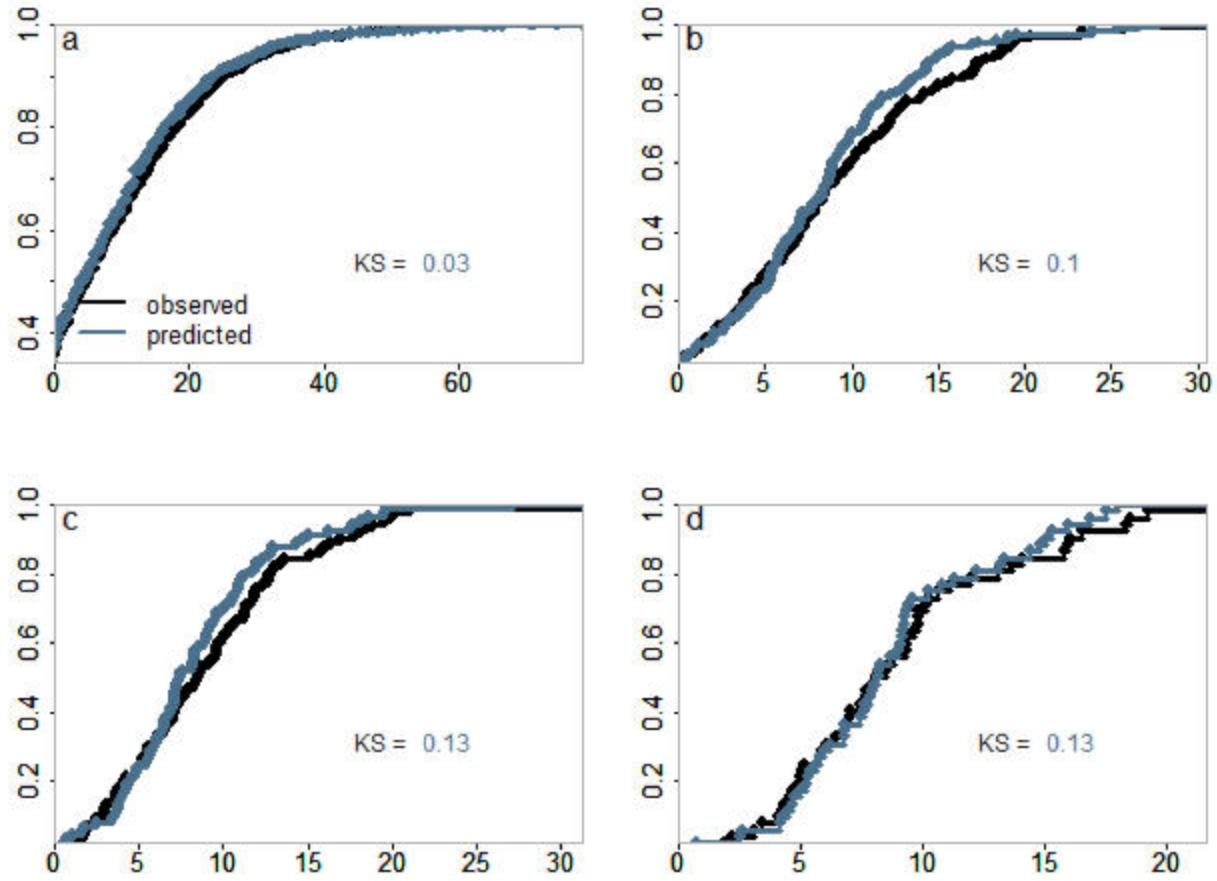

Figure 7: Distributional accuracy for SageTridentata variable, at Plot, Hex 1, Hex 2, and Hex 3 scales of summary (Panels a,b,c and d respectively). When the two lines are closely matched, the statistical distribution of values contained in the observations and predictions are similar.

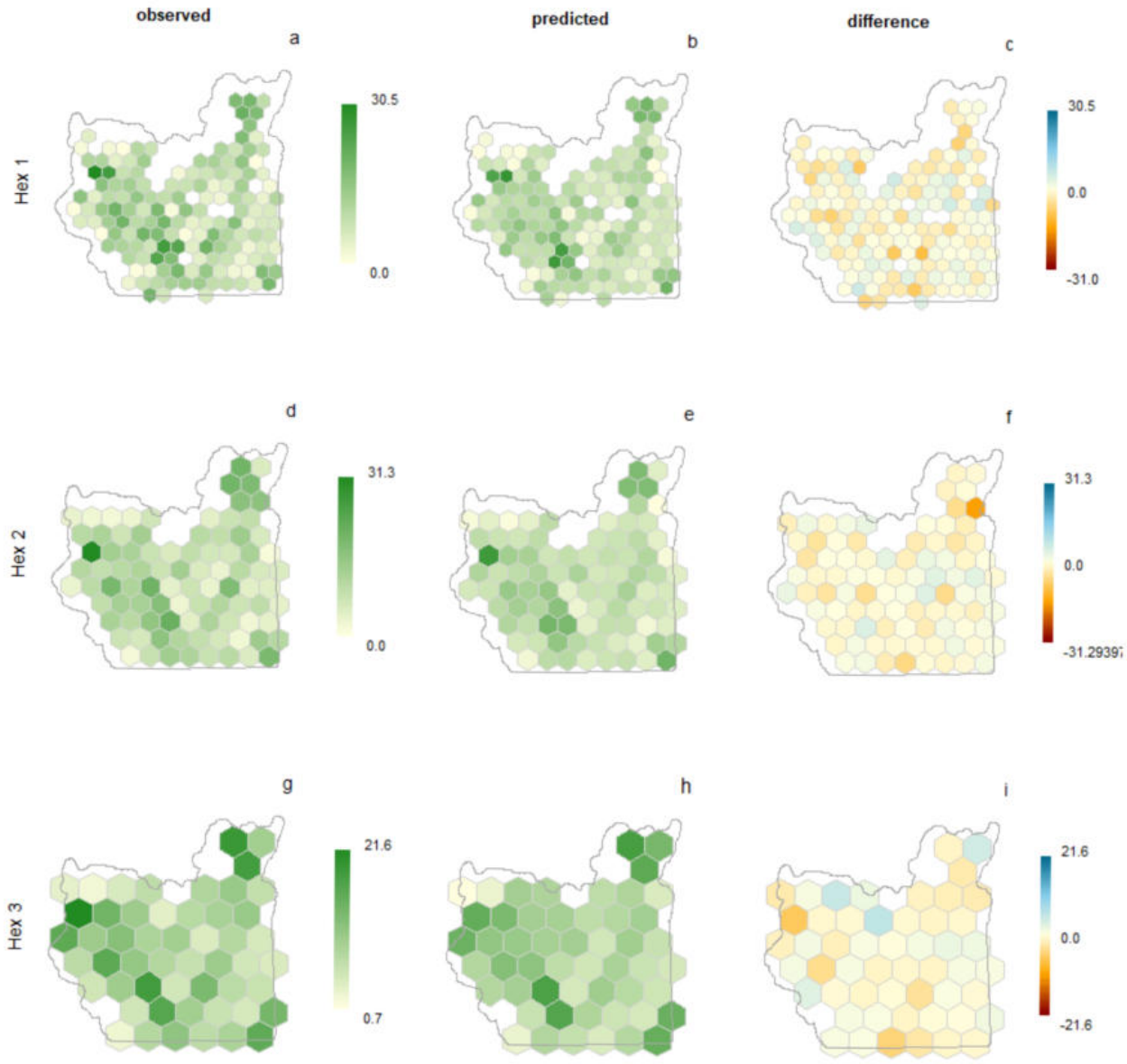

Figure 8: Model observations, predictions for SageTridentata and the difference between the two, summarized at Hex 1, Hex 2, and Hex 3 scales of summary.

Artemisia arbuscula

The variable showing the percent cover of *Artemisia arbuscula* performed well overall. At the plot scale, the model prediction was unbiased, although not very precise (AC_sys = 0.99, AC_uns = -0.7, Figure 9a). At broader scales of summary, the model's precision improved, and remained unbiased (AC_sys = 1, 0.95, 0.99, and AC_uns = 0.32, 0.57, 0.74 for Hex1, Hex2, and Hex3 scales respectively, Figure 9b, c and d).

The model prediction reproduced the distribution of values in the observations for ARAR8 quite consistently across all spatial scales (Figure 10).

The spatial patterns of prediction errors appear well-dispersed throughout the sampled portion of the modeling region on visual inspection (11c, f and i).

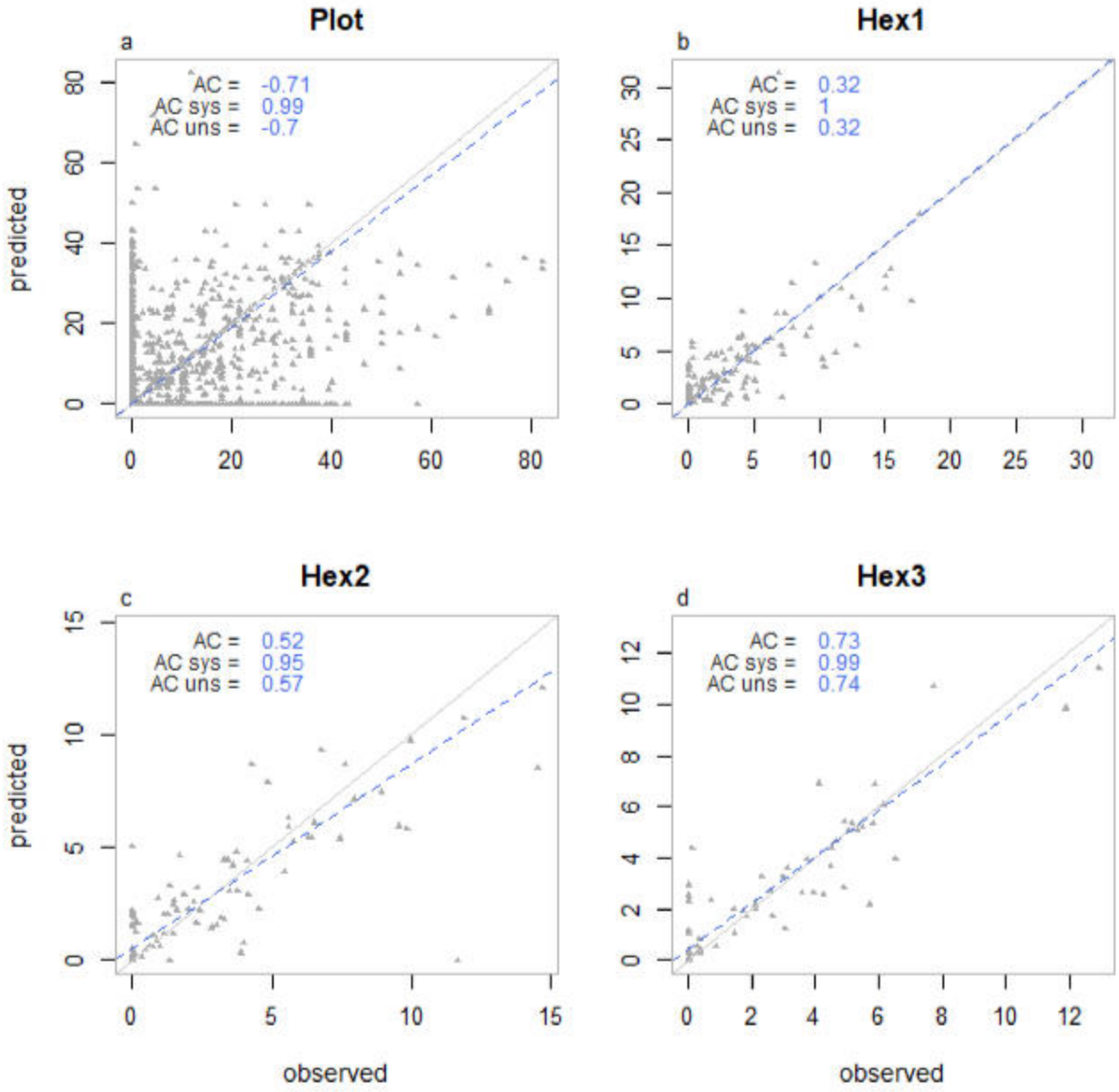

Figure 9: GMFR-based accuracy statistics for ARAR8 variable, at Plot, Hex 1, Hex 2, and Hex 3 scales of summary (Panels a,b,c and d respectively). AC_sys = 'Systematic Agreement Coefficient', and indicates how well the regression line matches a 1:1 line. AC_uns = 'Unsystematic Agreement Coefficient' indicates scatter around the regression line. AC = 'Agreement Coefficient', integrates the two components of accuracy and indictes overall fit. All 3 statistics indicate good fit as they approach 1.

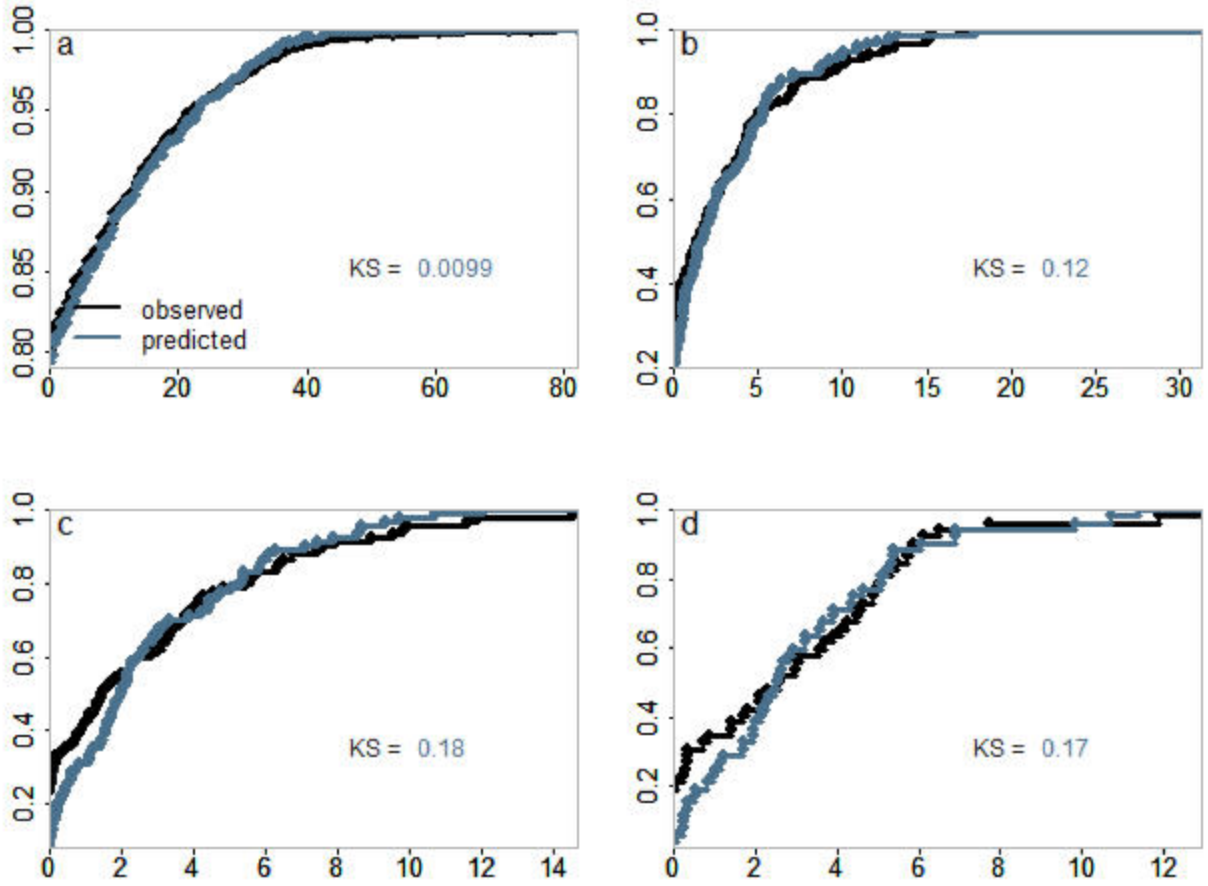

Figure 10: Distributional accuracy for ARAR8 variable, at Plot, Hex 1, Hex 2, and Hex 3 scales of summary (Panels a,b,c and d respectively). When the two lines are closely matched, the statistical distribution of values contained in the observations and predictions are similar.

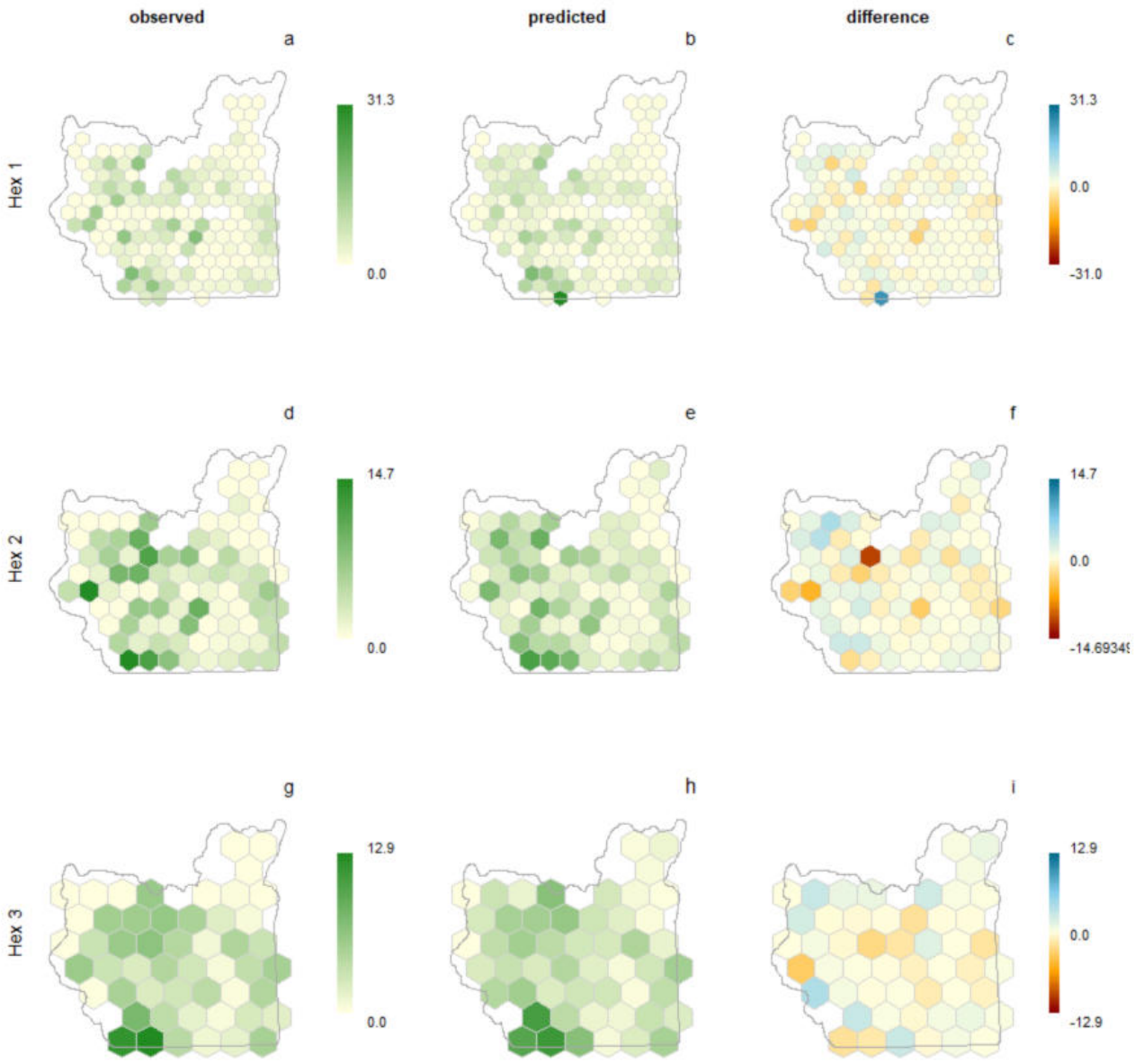

Figure 11: Model observations, predictions for ARAR8 and the difference between the two, summarized at Hex 1, Hex 2, and Hex 3 scales of summary.

Invasive Annual Grass

The variable showing the percent cover of Invasive Annual Grass performed well overall. At the plot scale, the model prediction was unbiased, although not very precise (AC_sys = 0.99, AC_uns = -0.47, Figure 12a). At broader scales of summary, the model's precision improved, and remained unbiased (AC_sys = 0.96, 0.96, 0.92, and AC_uns = 0.69, 0.87, 0.79 for Hex1, Hex2, and Hex3 scales respectively, Figure 12b, c and d).

The model prediction reproduced the distribution of values in the observations for InvasiveAnnualGrass quite consistently across all spatial scales (Figure 13).

The spatial patterns of prediction errors appear well-dispersed throughout the sampled portion of the modeling region on visual inspection (14c, f and i).

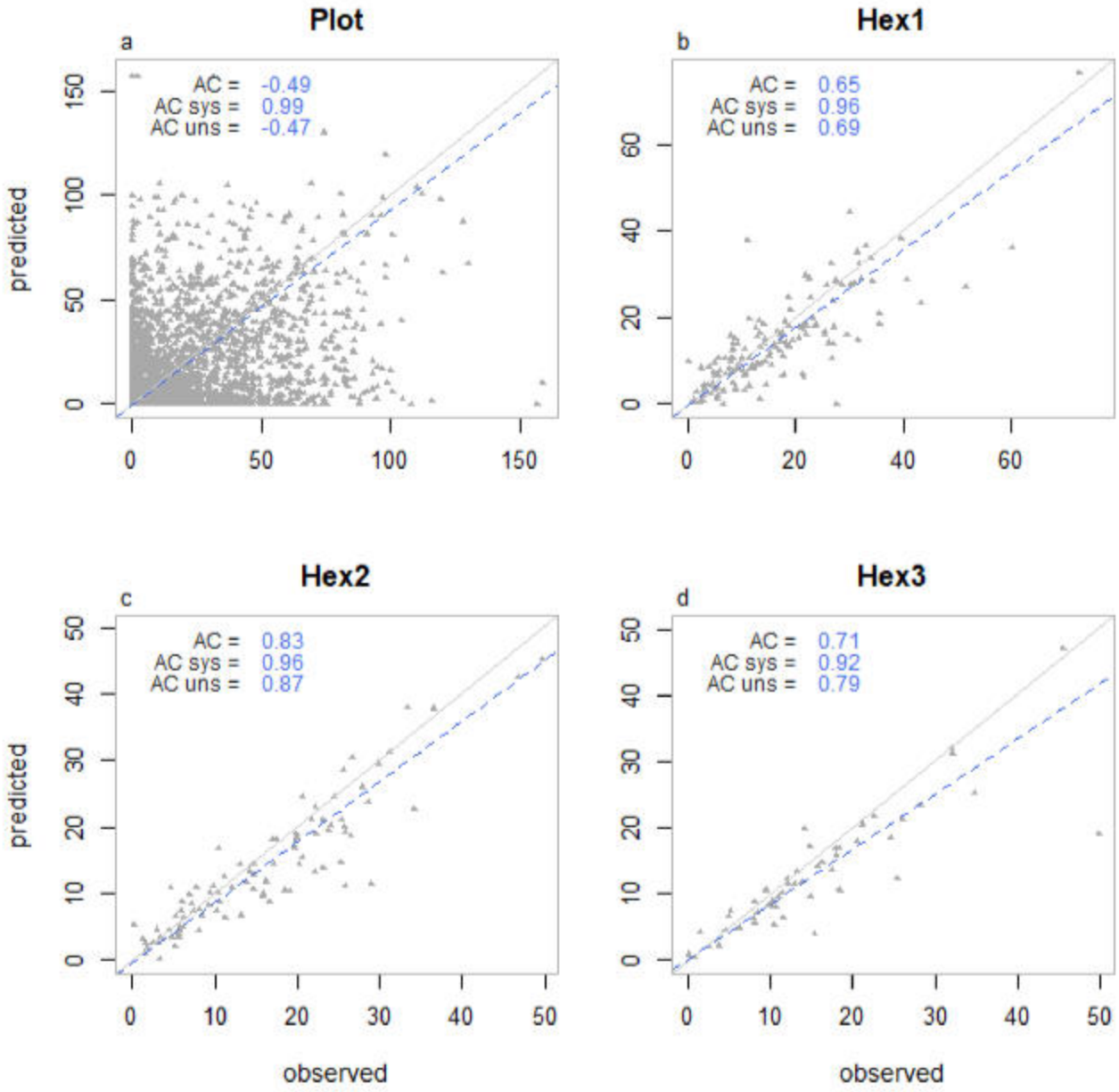

Figure 12: GMFR-based accuracy statistics for InvasiveAnnualGrass variable, at Plot, Hex 1, Hex 2, and Hex 3 scales of summary (Panels a,b,c and d respectively). AC_sys = 'Systematic Agreement Coefficient', and indicates how well the regression line matches a 1:1 line. AC_uns = 'Unsystematic Agreement Coefficient' indicates scatter around the regression line. AC = 'Agreement Coefficient', integrates the two components of accuracy and indictes overall fit. All 3 statistics indicate good fit as they approach 1.

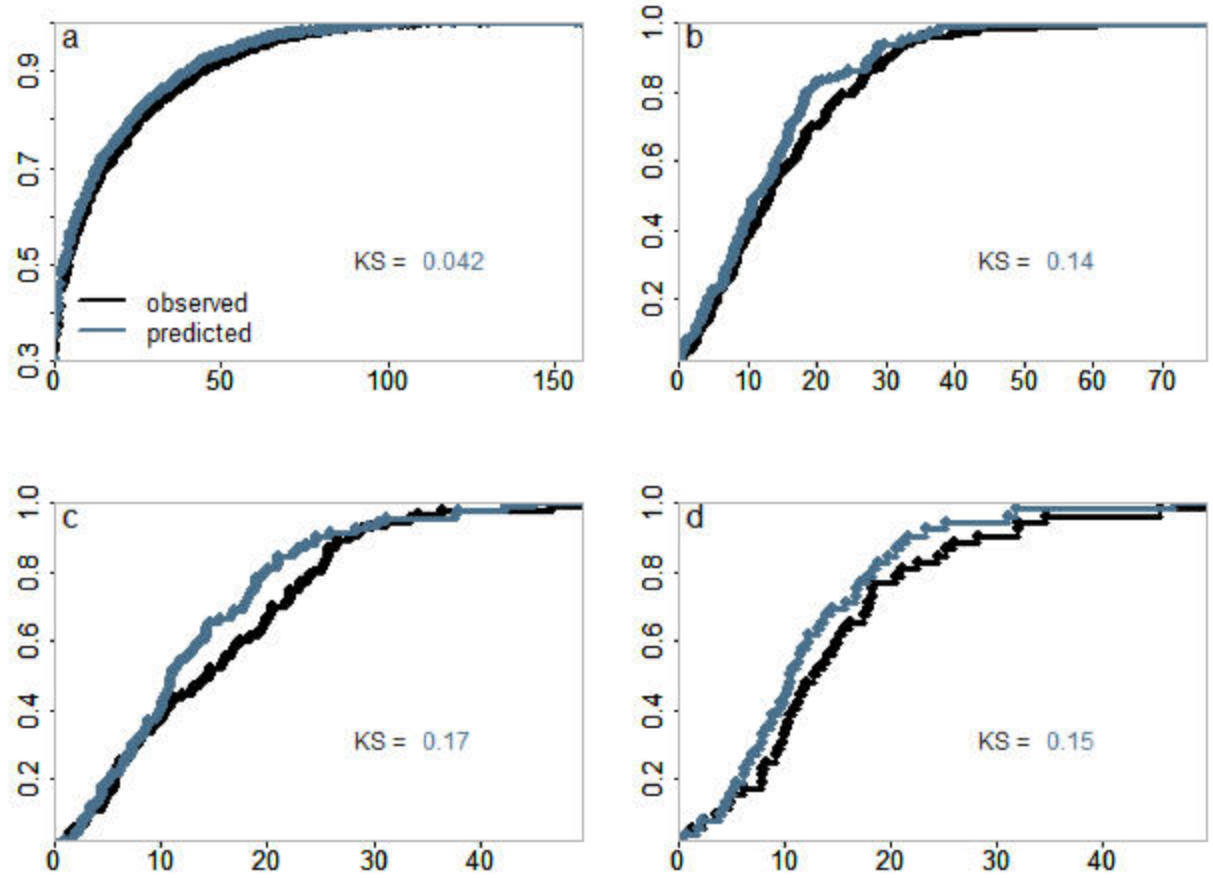

Figure 13: Distributional accuracy for InvasiveAnnualGrass variable, at Plot, Hex 1, Hex 2, and Hex 3 scales of summary (Panels a,b,c and d respectively). When the two lines are closely matched, the statistical distribution of values contained in the observations and predictions are similar.

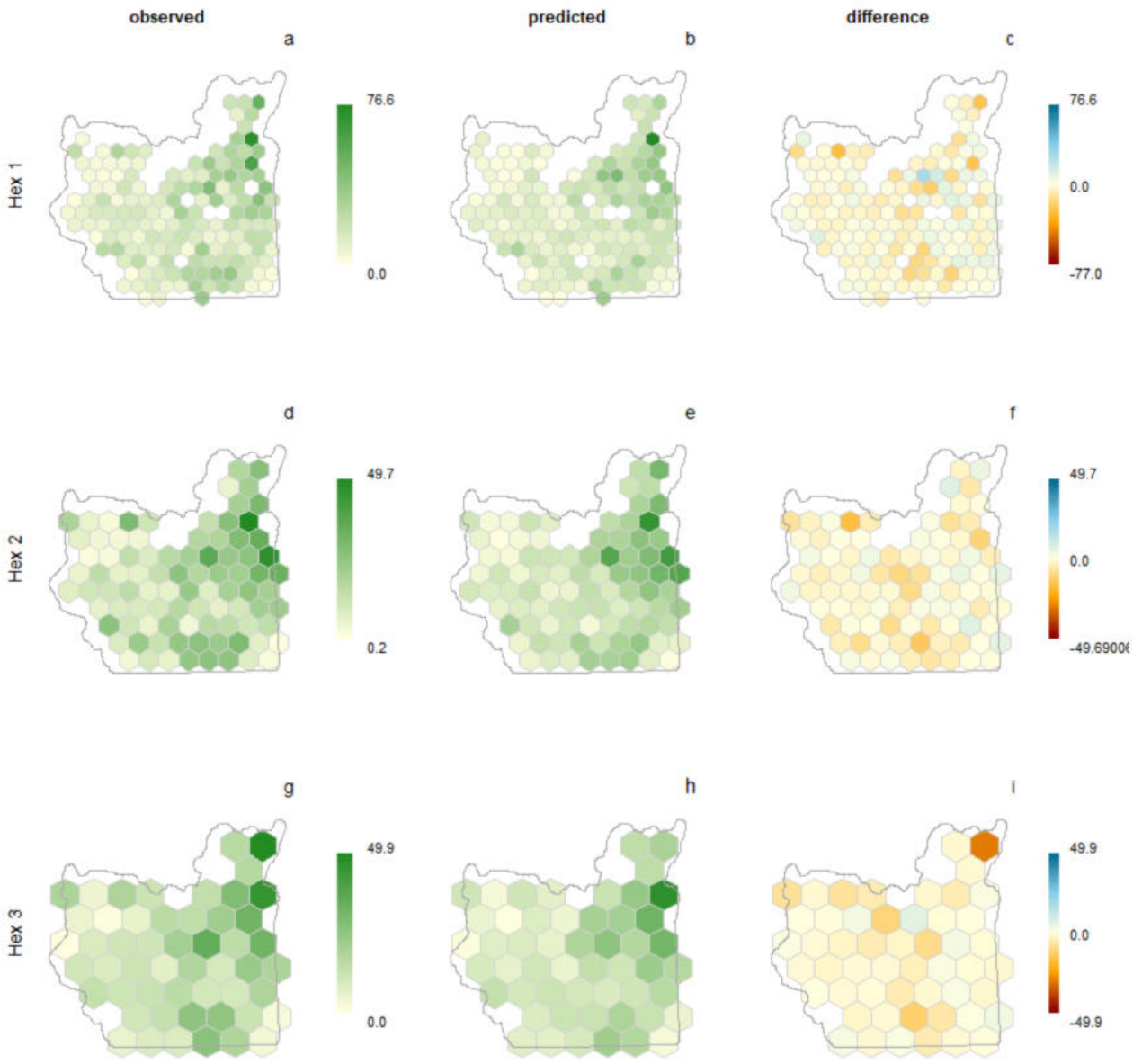

Figure 14: Model observations, predictions for InvasiveAnnualGrass and the difference between the two, summarized at Hex 1, Hex 2, and Hex 3 scales of summary.

Categorical variables

Sagebrush Class

Overall, the model was marginal at identifying the most common species in its predictions (Overall Kappa: 0.293). The accuracy for any individual species was frequently low, but category 1 performed well. Class-level statistics ranged from 0.237 to 0.46. Although the overall Kappa statistic was fairly low, we note that most of the confusion is constrained to adjacent classes (see Table 3). Class 3 is primarily confused with classes 2 and 4, and only sometimes confused with classes 1 and 5.

Table 3: Error matrix for Sagebrush_Class.

	> 25	0	0.01 to 5	15.01 to 25	5.01 to 15	Row_Accuracy	*Kappa*	*ASE*
> 25	271	37	36	162	98	*44.9%*	0.303	0.019
0	41	400	95	55	107	*57.3%*	0.460	0.018
0.01 to 5	25	146	232	66	177	*35.9%*	0.251	0.020
15.01 to 25	219	46	46	327	174	*40.3%*	0.237	0.018
5.01 to 15	140	106	199	228	511	*43.2%*	0.237	0.017
Column_Accuracy	*38.9%*	*54.4%*	*38.2%*	*39.0%*	*47.9%*	*44.1%*	0.293	0.010

Ecological State - Detailed

Overall, the model was marginal at identifying the most likely Ecological State, as described by a cover categorization and a grade based on understory condition (Overall Kappa: 0.374). The accuracy for any individual category was often low, but a few categories performed well. Class-level statistics ranged from 0 to 0.559.

Error matrix and class-level kappa statistics are available in: `ErrorMatrix_Ecological_State_Detail.csv' (Contact emilie.henderson@oregonstate.edu if needed)

Table 4: Class-level kappa statistics for Ecological_State_Detail. Overall Kappa Statistic: 0.374, ase =0.01.

	Kappa	ASE
A-: Potentially Good Condition Sagebrush	0.168	0.028
A: Good Condition Sagebrush	0.445	0.015
B-: Potentially Good Condition Grassland	0.274	0.029
B: Good Condition Grassland	0.347	0.017
C1: Poor Condition Sagebrush	0.320	0.029
C2: Early Juniper Encroachment with Good Condition	0.559	0.031
C3: Mid Juniper Encroachment with Good Condition	0.498	0.051
D1: Poor Condition Grassland	0.284	0.027
D2: Early Juniper Encroachment with Poor Condition	0.363	0.186
D3: Mid Juniper Encroachment with Poor Condition	0.000	0.000
D4: Late Juniper Encroachment	0.356	0.099
N/A	0.471	0.040
Overall	0.374	0.010

Ecological State: Juniper Phase

Overall, the model was acceptable at identifying the cover component of Ecological State (Overall Kappa: 0.474). The accuracy for any individual category was often low, but a few categories performed well. Class-level statistics ranged from 0.356 to 0.563.

Table 5: Error matrix for JuniperPhase.

	Grassland	Juniper_I	Juniper_II	Juniper_III	NA	Sage	Row_Accuracy	*Kappa*	*ASE*
Grassland	1068	25	6	0	43	479	*65.9%*	0.460	0.014
Juniper_I	11	117	13	1	1	34	*66.1%*	0.563	0.030
Juniper_II	3	27	37	9	5	4	*43.5%*	0.477	0.050
Juniper_III	1	4	6	7	0	2	*35.0%*	0.356	0.099
NA	31	3	2	0	60	19	*52.2%*	0.471	0.040
Sage	425	47	3	2	22	1427	*74.1%*	0.474	0.014
Column_Accuracy	*69.4%*	*52.5%*	*55.2%*	*36.8%*	*45.8%*	*72.6%*	*68.9%*	0.474	0.012

Ecological State: Summary Grade

Overall, the model was acceptable at predicting the grade component of Ecological State (Overall Kappa: 0.429). The accuracy for any individual category was often low, but a few categories performed well. Class-level statistics ranged from 0.281 to 0.477.

Table 6: Error matrix for Ecological_State_Summary.

	A	B	C	D	N/A	Row_Accuracy	*Kappa*	*ASE*
A	1198	311	117	56	16	*70.6%*	0.474	0.014
B	352	771	72	105	38	*57.6%*	0.398	0.015
C	108	41	275	50	12	*56.6%*	0.477	0.021
D	45	100	51	106	5	*34.5%*	0.281	0.026
N/A	14	28	10	3	60	*52.2%*	0.471	0.040
Column_Accuracy	*69.8%*	*61.6%*	*52.4%*	*33.1%*	*45.8%*	*61.1%*	0.429	0.011

Expert map reviews

Expert reviews of this map suggest some remaining issues beyond the fine-scale noise that is attributable to our statistical technique.

The first involves the mapping of western juniper. Although our model assessments indicate that this was a particularly robust variable, it is also a variable of critical concern in the area, and hence we attach greater importance to its' accuracy. While our map is fairly good at indicating the abundance of juniper, especially at broader spatial scales, we sometimes fail to adequately represent the range of juniper in this part of the state. For example, each expert reviewer confirmed that there is currently no juniper growing in the trout creek mountains, near the southeast corner of the map. However, our map places some small patches of juniper, mostly on hillslopes, and near streams. Reviewers suggested that these areas were more likely other trees, such as aspen (streamsides), and mountain mahogany (hilltops) in the area. It is possible that extra plot data describing these types of areas in the trout creek range could improve the model's performance in this respect. Given the need to understand the process of juniper expansion in the sage-steppe, improving this aspect of map performance may be worthwhile. In other portions of the landscape (especially along the margins of areas with heavier juniper cover in the northwest quadrant of the map), there are extensive areas mapped as showing a 'trace' of juniper, when investigation of airphotos indicates that juniper is absent. It is possible that these areas may contain very small numbers of very young junipers currently. It is also possible that the model maps this category with poor precision since juniper at such a low coverage level will not strongly affect the landsat spectral reflectance, or image texture remotely sensed imagery resources that we are using. This issue is compounded in the northwestern corner of the map due to a dearth of recent plot data describing the juniper woodlands. Additions of more plots arrayed to describe the full plant compositional gradient from sage-steppe to juniper woodlands would likely improve model performance in this area.

Three of our expert reviewers noted that low sagebrush cover in the Beatys PAC area seemed a bit high. Some of this impression may stem from viewing a single-variable illustration of low sagebrush. It often mixes with other species, and is not the dominant sagebrush species in the area of concern. However, there is a zone within the PAC, within Hart Mountain Wildlife Refuge, where plot data are very sparse. The question of whether low sagebrush cover is mapping appropriately in the area could be better addressed were there additional plots in the

area. Older vegetation survey plots from the area may contain useful information, so long as they fall outside of areas affected by recent fires.

The third area of concern that was highlighted in the map review process is the performance of the variable describing deep-rooted perennial grasses, near in the northeastern corner of the map within the Baker Priority Area for Conservation. This variable showed considerably higher values in this area than in others, and as such was chosen for a focused review. The targeted review in the Baker area revealed that this variable was not performing well in concert with the two summaries of introduced species, invasive annual grasses, and undesirable annual forbs, especially around the area of the 2012 Sardine fire. An additional summary variable tallying the cover of noxious weeds listed by counties was added to the map to assist in evaluating the model's performance with respect to fire's effects on species invasions.

Further exploration of the relationship between our mapped variables and known recent fire data (from Monitoring Trends in Burn Severity) indicated that while some variables appeared to reflect recent fire history in a model with only imagery (shrub species abundances), other fire-related vegetation changes did not. This is unsurprising as the transition from native grasslands to non-native grasslandsis unlikely to show up in either landsat spectral reflectance, or in airphoto-based texture summaries. Because fire-related transitions from native-dominated to invasive-dominated communities are of particular interest in the area, we concluded that adding a fire history variable to the model was merited. We considered using fire intensity from the Monitoring Trends in Burn Severitiy data, but due to the mapping artifacts from the failure of the landsat 7 sensor in 2012, we concluded that this variable was not of adequate quality for use in modeling, and selected simply years since fire for our fire history response variable. During this same review session, we also observed that known vegetation transitions from north to south sloping aspects were not illustrated in the model. Because of this, we chose to reintroduce the raster variable describing aspect in to our final model. These variable re-introductions had very small effects on the resultant maps (most of the problems documented here remain in the final map), and almost no effects on model accuracy statistics.

Discussion

Overall map assessment

For most of the southwest Oregon modeling region, this map contains information that is accurate enough to inform management planning processes that encompass larger areas.

For some variables, it may be useful at finer scales as well. For uses that require precise information at fine spatial scales, field visits or other local data sources are highly recommended for all variables. This map is best-suited for providing a broader-context background in which to frame information at finer spatial scales.

Despite the issues discussed above under 'expert review', most of the review sessions confirm the findings from the formal accuracy assessments. Despite the fine-scale noise, the map is robust enough to provide broad overviews of vegetation patterns across the landscape for a variety of summary variables. Although many single-species predictions variables are problematic, most of the summarized variables that aggregate the cover of many species contain meaningful information.

Scale and accuracy

For both binary (species presence-absence) and continuous variables, we have assessed model accuracy at multiple scales. For continuous variables, model precision improves with summaries over larger areas. For species presence-absence, model predictions are strongest at intermediate scales. The latter pattern often emerges from a failure to predict species absences (low specificity) at broad scales of summary. In other words, infrequent plot-level false positive predictions yield errors over the largest hexagons used for summary.

We do not assess model accuracy at broader spatial scales for multi-category response variables. This is not because the assessment is not useful, but rather because we still lack an appropriate tool for multi-scale accuracy assessment of multi-category variables. Research into appropriate methods to do so is a priority for future work.

Monitoring context: change detection

This map is the fourth in a series of similar maps for the area. The first was completed in 2010 (imagery date 2006) for the Integrated Landscape Assessment Project. The second was completed in 2011 (2011 imagery), in support of the Climate-Management-Habitat, USGS-funded project. The second map was updated shortly thereafter (2013, imagery date 2011, with 2013 imagery in areas burned in 2012) in support of greater sage-grouse management planning. While there is a need for illustrating change across the landscape, we caution users against using this suite of maps specifically for change detection because none of them were created to support that application. Real landscape changes are confounded among these maps with an array of technical differences. Data availability in terms of both plot and raster data have improved since the first version. In the most recent draft, significant improvements to both imagery data (especially handling of NAIP NTMs), and soil data have yielded marked improvements to map quality. In addition, we have made improvements to our modeling process in terms of y-variable configurations, and also the explanatory variable selection process. Taken together these changes are a net positive for each map as accuracy improves, but they also confound the process of change detection. It is possible to build a framework for change detection and monitoring with

imputation mapping (see Ohmann et al. 2012; Kennedy et al. 2018 for examples in forests), but this requires a platform for maximizing methodological consistency between the maps that are to be compared.

Acknowledgements

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We very much appreciate the time donated by our expert map reviewers: Jaqueline Cupples adn Angela Sitz (US Fisheries and Wildlife Service), John Owens, (US Bureau of Land Management), and Lee Foster (Oregon Department of Fisheries and Wildlife). This map was greatly improved from its earliest drafts because of the feedback that they provided.

Appendices

Appendix 1a: Variables selected for final model

Variable Name	Description
NAIP_1	Principal component axis from NAIP NTMs - 1
NAIP_2	Principal component axis from NAIP NTMs - 2
NAIP_4	Principal component axis from NAIP NTMs - 4
NAIP_5	Principal component axis from NAIP NTMs - 5
NAIP_11	Principal component axis from NAIP NTMs - 11
NAIP_20	Principal component axis from NAIP NTMs - 20
NAIP_22	Principal component axis from NAIP NTMs - 22
NAIP_23	Principal component axis from NAIP NTMs - 23
NAIP_27	Principal component axis from NAIP NTMs - 27
NAIP_31	Principal component axis from NAIP NTMs - 31
POLARISPCA_3	Principal component axis from POLARIS soil data layers - 3
POLARISPCA_4	Principal component axis from POLARIS soil data layers - 4
POLARISPCA_7	Principal component axis from POLARIS soil data layers - 7
POLARISPCA_8	Principal component axis from POLARIS soil data layers - 8
POLARISPCA_9	Principal component axis from POLARIS soil data layers - 9
POLARISPCA_10	Principal component axis from POLARIS soil data layers - 10
POLARISPCA_11	Principal component axis from POLARIS soil data layers - 11
POLARISPCA_12	Principal component axis from POLARIS soil data layers - 12
POLARISPCA_13	Principal component axis from POLARIS soil data layers - 13
POLARISPCA_16	Principal component axis from POLARIS soil data layers - 16
POLARISPCA_17	Principal component axis from POLARIS soil data layers - 17
PRISM_contpre30	Continuity of Precipitation
PRISM_cvpre30	Coefficient of variation of precipitation
PRISM_decmint30	December Minimum Temperature
PRISM_smrpre30	Growing Season Precipitation (JJA)
PRISM_smrtmp30	Growing Season Temperature(JJA)
PRISM_smrtp30	Growing Season Drought Index (JJA)
TOPO_dem30	Elevation
TOPO_slppct30	Percent slope
TOPO_a10south30	Southness component of aspect, scaled 1-100
TOPO_a38dtwm	XX
TOPO_a46wet60	Nielsen. SAGA wetness index (Conrad et al. 2015), closely related to Compound Topographic Index (Moore 1991)
LANDSAT_spr1820ndgr	Landsat 8 mediod. April - June 2018-2020. NDGR Normailzed Difference Green:Red
LANDSAT_spr1820ndng	Landsat 8 mediod. April - June 2018-2020. NDNG Normailzied Difference Near Infrared: Green
LANDSAT_spr1820nir	Landsat 8 mediod. April - June 2018-2020. Band 5. Near Infrared.
LANDSAT_spr1820sw1	Landsat 8 mediod. April - June 2018-2020. Band 6. Short wave Infrared 1
LANDSAT_spr1820sw2	Landsat 8 mediod. April - June 2018-2020. Band 7. Short wave Infrared 7
LANDSAT_spr1820tcb	Landsat 8 mediod. April - June 2018-2020. Tassled Cap Brightness
LANDSAT_spr1820tcg	Landsat 8 mediod. April - June 2018-2020. Tassled Cap Greenness
LANDSAT_sum1820evi	Landsat 8 mediod. July - September 2018-2020. EVI Enhanced Vegetation Index
LANDSAT_sum1820ndgr	Landsat 8 mediod. July - September 2018-2020. NDGR Normailzed Difference Green:Red
LANDSAT_sum1820ndng	Landsat 8 mediod. July - September 2018-2020. NDNG Normailzied Difference Near Infrared: Green
LANDSAT_sum1820ndvi	Landsat 8 mediod. July - September 2018-2020. NDVI Normalized Difference Vegetation Index
LANDSAT_sum1820tcb	Landsat 8 mediod. July - September 2018-2020. Tassled Cap Brightness

Appendix 1b: Vegetation summary response variable definitions

Variable.Name	Description
TreeCov	Total cover of all tree species
ShrubCov	Total cover of all shrub species
GrassCov	Total cover of all grass species
ForbCov	Total cover of all forb and herb species
VineCov	Total cover of all vine species
NonvascularCov	Total cover of all nonvascular species
BareGround	Estimated bare ground from line-intercept data. When line-intercept is unavailable, estimated by subtracting total cover from 100
TotalCov	Total cover of all plants
SageGrousePreferredForbs_High	Total cover of perennial forbs with high value as GSG food.
SageGrousePreferredForbs_All	Total cover of perennial forbs with any value as GSG food.
AllSage	Total cover of all Artemisia species.
SageClass	Categorical variable relating to AllSage: 0%, trace - 5%, 5-15%,15-25%, and >25%
AllJuniper	Total cover of all members of the genus *Juniperus*
SageTridentata	Total cover of all subspecies of *Artemisia tridentata*
SageShallowSoil	Total cover of *Artemisia* species that indicate shallow soils
EarlySeralShrub	Total cover of early seral shrub species
DeepRootPerennialGrass	Total cover of perennial grass species with very deep roots (high potential for restoration).
SandbergBluegrass	Total cover of all *Poa secunda* and subspecies
SeededGrass	Total cover of grass species that are commonly seeded into pastures.
InvasiveAnnualGrass	Total cover of invasive annual grass species
UndesirableAnnualForbs	Total of all forbs labeled 'undesirable' as indicating degraded conditions.
EcologicalStateDetail	Classified variable describing Ecological State according to cover (grass/sage/juniper), understory condition, and an associated grade. Components are separated by ':' in this variable representation.
NoxiousWeeds	Total cover of all "A-level" noxious weeds listed for relevant counties.
JuniperPhase	Cover type for Ecological State (Shrub, Grassland, Juniper phase I, II or III)
WetlandIndicators	Total cover of all species listed as obligate or facultative wetland species by USDA, and DoD
Conifer	Total cover of all coniferous trees
EcologicalStateSummary	Grade assigned to ES_Cover and ES_Understory combination
PerennialGrass	Sum of cover of all perennial grasses (Used for calculating Juniper_Index, and other Ecological State-related variables)
Low_Black_Silver_Sage	Total cover of Artemisia arbuscula, Artemisia nova, and Artemisia cana
BigSage	Total cover of all subspecies of *Artemisia tridentata*
TallGrass	Total cover of all grasses flagged as having tall stature.
NonNativePerennialGrass	Total cover of non-native perennial grass species
ExoticAnnualGrass	Total cover of all exotic annual grasses
PristineGrass	Total cover of native bunchgrasses indicating undisturbed conditions.
NativeGrass	Total cover of all native grasses

Appendix 1c: Species lists for select summary response variables

PristineGrass

Component Species		
Achnatherum hymenoides	*Calamagrostis montanensis*	*Koeleria macrantha*
Achnatherum lemmonii	*Calamagrostis sesquiflora*	*Koeleria*
Achnatherum lettermanii	*Danthonia parryi*	*Kobresia simpliciuscula*
Achnatherum nelsonii	*Elymus trachycaulus*	*Leymus cinereus*

Component Species		
Achnatherum occidentale	*Festuca idahoensis*	*Schedonorus arundinaceus*
Achnatherum pinetorum	*Festuca viridula*	*Poa secunda*
Achnatherum richardsonii	*Glyceria borealis*	*Poa cusickii*
Achnatherum thurberianum	*Glyceria grandis*	*Pseudoroegneria spicata*
Achnatherum webberi	*Glyceria striata*	*Pseudoroegneria spicata ssp. spicata*
Carex filifolia	*Hesperostipa comata*	
Calamagrostis koelerioides	*Hordeum brachyantherum*	

ExoticAnnualGrass

Component Species		
Aegilops cylindrica	*Briza maxima*	*Polypogon monspeliensis*
Aira caryophyllea	*Bromus marginatus*	*Polypogon*
Avena fatua	*Briza minor*	*Sorghum bicolor*
Avena sativa	*Bromus tectorum*	*Taeniatherum caput-medusae*
Bromus japonicus	*Cynosurus echinatus*	*Ventenata dubia*
Bromus berteroanus	*Hordeum murinum*	*Ventenata*
Bromus briziformis	*Poa annua*	*Vulpia bromoides*

NonNativePerennialGrass

Component Species		
Agropyron cristatum	*Carex muricata*	*Panicum*
Agropyron desertorum	*Dactylis glomerata*	*Phalaris aquatica*
Agropyron fragile (Roth) P. Candargy	*Elymus repens*	*Phalaris arundinacea*
Agropyron	*Festuca brevipila*	*Phleum pratense*
Agrostis stolonifera	*Holcus lanatus*	*Poa bulbosa*
Alopecurus pratensis	*Schedonorus arundinaceus*	*Poa compressa*
Ammophila arenaria	*Lolium*	*Poa pratensis*
Anthoxanthum odoratum	*Lolium perenne*	*Poa trivialis*
Arrhenatherum elatius	*Schedonorus pratensis*	*Psathyrostachys juncea*
Bromus inermis	*Muhlenbergia cuspidata*	*Thinopyrum intermedium*

BigSage

Component Species
Artemisia tridentata
Artemisia tridentata ssp. spiciformis
Artemisia tridentata ssp. tridentata
Artemisia tridentata ssp. vaseyana
Artemisia tridentata ssp. wyomingensis

Low_Black_Silver_Sage

Component Species		
Artemisia cana	*Artemisia arbuscula Nutt. ssp. thermopola*	*Artemisia cana ssp. viscidula*
Artemisia arbuscula	*Artemisia cana ssp. bolanderi*	*Artemisia nova*

TallGrass

Component Species

Component Species		
Achnatherum hymenoides	*Carex obnupta*	*Juncus longistylis*
Achnatherum lemmonii	*Carex pachystachya*	*Juncus mertensianus*
Achnatherum lettermanii	*Carex petasata*	*Juncus nevadensis*
Achnatherum nelsonii	*Carex praegracilis*	*Juncus nodosus*
Achnatherum occidentale	*Carex praticola*	*Juncus parryi*
Achnatherum pinetorum	*Carex scirpoidea*	*Juncus tenuis*
Achnatherum richardsonii	*Carex raynoldsii*	*Leymus cinereus*
Achnatherum speciosum	*Carex rostrata*	*Leymus mollis*
Achnatherum thurberianum	*Calamagrostis rubescens*	*Leymus triticoides*
Achnatherum webberi	*Carex saxatilis*	*Schedonorus arundinaceus*
Agrostis capillaris	*Carex scopulorum*	*Lolium perenne*
Agropyron cristatum	*Carex simulata*	*Luzula parviflora*
Agropyron desertorum	*Carex stipata*	*Luzula spicata*
Agrostis pallens	*Carex utriculata*	*Melica bulbosa*
Agrostis exarata	*Carex vesicaria*	*Melica californica*
Agrostis gigantea	*Carex vulpinoidea*	*Melica montezumae*
Agrostis idahoensis	*Cinna latifolia*	*Melica spectabilis*
Agrostis stolonifera	*Cyperus acuminatus*	*Melica subulata*
Agrostis scabra	*Danthonia californica*	*Muhlenbergia asperifolia*
Alopecurus aequalis	*Dactylis glomerata*	*Muhlenbergia cuspidata*
Alopecurus carolinianus	*Danthonia intermedia*	*Muhlenbergia glomerata*
Alopecurus pratensis	*Danthonia unispicata*	*Muhlenbergia mexicana*
Ammophila arenaria	*Deschampsia cespitosa*	*Muhlenbergia racemosa*
Arrhenatherum elatius	*Deschampsia danthonioides*	*Nassella lepida*
Bouteloua gracilis	*Deschampsia elongata*	*Nassella viridula*
Bolboschoenus maritimus	*Dulichium arundinaceum*	*Phleum alpinum*
Bromus arvensis	*Eleocharis acicularis*	*Phalaris aquatica*
Bromus carinatus	*Elymus caninus*	*Phalaris arundinacea*
Bromus ciliatus	*Elymus canadensis*	*Phragmites australis*
Bromus inermis	*Elymus elymoides*	*Phleum pratense*
Bromus orcuttianus	*Eleocharis palustris*	*Poa arctica*
Bromus sitchensis	*Eleocharis rostellata*	*Poa secunda*
Bromus vulgaris	*Elymus glaucus*	*Poa bigelovii*
Carex aperta	*Elymus lanceolatus*	*Poa compressa*
Carex aquatilis	*Elymus macrourus ?? - nearest: AK*	*Poa cusickii*
Carex atherodes	*Eleocharis ovata*	*Poa fendleriana*
Carex athrostachya	*Elymus repens*	*Poa glauca*
Carex aurea	*Pascopyrum smithii*	*Poa leibergii*
Carex bebbii	*Elymus trachycaulus*	*Poa leptocoma*
Carex canescens	*Eriophorum angustifolium*	*Poa nervosa*
Carex capillaris	*Eriophorum gracile*	*Poa palustris*
Calamagrostis canadensis	*Festuca californica*	*Poa pratensis*
Carex comosa	*Festuca campestris*	*Poa trivialis*
Carex deweyana	*Festuca idahoensis*	*Poa wheeleri*
Carex diandra	*Festuca occidentalis*	*Pseudoroegneria spicata*
Carex disperma	*Festuca rubra*	*Pseudoroegneria spicata ssp. spicata*
Carex douglasii	*Festuca subulata*	*Schoenoplectus acutus*
Carex echinata	*Festuca viridula*	*Scirpus cyperinus*
Carex filifolia	*Glyceria borealis*	*Scirpus microcarpus*
Carex geyeri	*Glyceria striata*	*Scirpus pallidus*
Carex halliana	*Hesperostipa comata*	*Schoenoplectus tabernaemontani*
Carex hendersonii	*Hierochloe odorata*	*Secale cereale*
Carex hoodii	*Hordeum brachyantherum*	*Spartina gracilis*
Carex interior	*Hordeum jubatum*	*Sporobolus airoides*

Component Species		
Carex leptalea	*Holcus lanatus*	*Sporobolus compositus*
Carex lenticularis	*Hordeum vulgare*	*Sporobolus cryptandrus*
Carex livida	*Juncus acuminatus*	*Spartina patens*
Carex limosa	*Juncus articulatus*	*Thinopyrum intermedium*
Calamagrostis stricta	*Juncus bufonius*	*Thinopyrum ponticum*
Carex luzulina	*Juncus castaneus*	*Torreyochloa pallida*
Carex lyngbyei	*Juncus confusus*	*Triticum aestivum*
Carex mertensii	*Juncus drummondii*	*Trisetum canescens*
Carex microptera	*Juncus effusus*	*Trisetum spicatum*
Carex nebrascensis	*Juncus ensifolius*	*Trisetum wolfii*

SageTridentata

Component Species
Artemisia tridentata
Artemisia tridentata ssp. spiciformis
Artemisia tridentata ssp. tridentata
Artemisia tridentata ssp. vaseyana
Artemisia tridentata ssp. wyomingensis

SageShallowSoil

Component Species
Artemisia arbuscula
Artemisia arbuscula Nutt. ssp. thermopola
Artemisia nova
Artemisia rigida

EarlySeralShrub

Component Species		
Chrysothamnus depressus	*Ericameria nauseosa*	*Ericameria*
Chrysothamnus viscidiflorus	*Chrysothamnus*	*Gutierrezia sarothrae*

DeepRootPerennialGrass

Component Species		
Achnatherum hymenoides	*Deschampsia cespitosa*	*Leymus cinereus*
Achnatherum lemmonii	*Elymus elymoides*	*Leymus triticoides*
Achnatherum nelsonii	*Elymus glaucus*	*Poa cusickii*
Achnatherum occidentale	*Elymus lanceolatus*	*Pseudoroegneria spicata*
Achnatherum pinetorum	*Elymus trachycaulus*	*Pseudoroegneria spicata ssp. inermis*
Achnatherum speciosum	*Festuca idahoensis*	*Pseudoroegneria spicata ssp. spicata*
Achnatherum thurberianum	*Hesperostipa comata*	*Sporobolus cryptandrus*
Achnatherum webberi	*Koeleria macrantha*	
Danthonia californica	*Koeleria*	

SeededGrass

Component Species
Agropyron cristatum

Component Species
Agropyron desertorum
Agropyron
Thinopyrum intermedium

InvasiveAnnualGrass

Component Species		
Aegilops cylindrica	*Poa bulbosa*	*Ventenata dubia*
Bromus tectorum	*Taeniatherum caput-medusae*	*Ventenata*

SageGrousePreferredForbs_High

Component Species		
Phlox longifolia	*Crepis occidentalis*	*Navarretia divaricata*
Agoseris aurantiaca	*Erodium cicutarium*	*Nemophila pedunculata*
Agoseris glauca	*Eriastrum sparsiflorum*	*Phlox austromontana*
Agoseris grandiflora	*Eriastrum wilcoxii*	*Phacelia heterophylla*
Agoseris heterophylla	*Geum triflorum*	*Phlox hoodii*
Aliciella leptomeria	*Gilia brecciarum*	*Phacelia humilis*
Arenaria aculeata	*Navarretia capillaris*	*Phacelia linearis*
Arenaria capillaris	*Gilia inconspicua*	*Phlox*
Arenaria congesta	*Gilia sinuata*	*Plectritis macrocera*
Arenaria	*Holosteum umbellatum*	*Potentilla arguta*
Arenaria kingii	*Hydrophyllum capitatum*	*Potentilla glandulosa*
Astragalus atratus	*Lactuca serriola*	*Polemonium micranthum*
Astragalus conjunctus	*Lathyrus lanszwertii*	*Silene douglasii*
Astragalus convallarius	*Lathyrus rigidus*	*Silene menziesii*
Astragalus collinus	*Leptosiphon liniflorus*	*Sidalcea oregana*
Astragalus curvicarpus	*Linanthus pungens*	*Silene scaposa*
Astragalus filipes	*Lewisia rediviva*	*Sphaeralcea munroana*
Astragalus lentiginosus	*Leptosiphon septentrionalis*	*Sphaeralcea parvifolia*
Astragalus malacus	*Lithophragma glabrum*	*Stellaria nitens*
Astragalus mulfordiae	*Lithophragma parviflorum*	*Trifolium arvense*
Astragalus nuttallianus	*Lithophragma tenellum*	*Tragopogon dubius*
Astragalus obscurus	*Mentzelia albicaulis*	*Trifolium macrocephalum*
Astragalus purshii	*Mentzelia dispersa*	*Trifolium oliganthum*
Astragalus sclerocarpus	*Mentzelia veatchiana*	*Trifolium repens*
Astragalus	*Microsteris gracilis*	*Vicia americana*
Crepis modocensis	*Mimulus cusickii*	*Viola beckwithii*
Claytonia perfoliata	*Microseris laciniata*	*Viola nuttallii*
Collomia grandiflora	*Mimulus nanus*	*Viola praemorsa*
Collomia linearis	*Microseris nutans*	*Viola purpurea*
Crepis acuminata	*Nothocalais troximoides*	*Viola trinervata*
Crepis atribarba	*Montia linearis*	
Crepis intermedia	*Navarretia breweri*	

AllSage

Component Species		
Artemisia cana	*Artemisia papposa*	*Artemisia tridentata ssp. spiciformis*
Artemisia arbuscula	*Artemisia rigida*	*Artemisia tridentata ssp. tridentata*
Artemisia cana ssp. bolanderi	*Picrothamnus desertorum*	*Artemisia tridentata ssp. vaseyana*

Component Species		
Artemisia cana ssp. viscidula	*Artemisia tridentata*	*Artemisia tridentata ssp. wyomingensis*
Artemisia nova	*Artemisia tripartita*	

UndesirableAnnualForbs

Component Species		
Agrostemma githago	*Centaurea solstitialis*	*Sisymbrium altissimum*
Alyssum alyssoides	*Chorispora tenella*	*Sisymbrium loeselii*
Alyssum desertorum	*Descurainia sophia*	*Sisymbrium officinale*
Alyssum	*Erodium botrys*	*Sisymbrium*
Amsinckia lycopsoides	*Erodium cicutarium*	*Tragopogon*
Amsinckia menziesii	*Erodium*	*Tragopogon dubius*
Amsinckia	*Lactuca serriola*	*Tragopogon pratensis*
Amsinckia tessellata	*Salsola kali*	*Tragopogon miscellus*
Centaurea cyanus	*Salsola*	*Tragopogon porrifolius*
Centaurea diffusa	*Salsola tragus*	

SageGrousePreferredForbs_All

Component Species		
Phlox longifolia	*Delphinium andersonii*	*Lomatium nudicaule*
Abronia mellifera	*Delphinium bicolor*	*Lomatium packardiae*
Achillea millefolium	*Delphinium distichum*	*Lomatium tracyi*
Acroptilon repens	*Delphinium glareosum*	*Lomatium triternatum*
Agoseris aurantiaca	*Descurainia incana*	*Lomatium vaginatum*
Agoseris glauca	*Delphinium nuttallianum*	*Machaeranthera canescens*
Agoseris grandiflora	*Delphinium nuttallii*	*Madia citriodora*
Agoseris heterophylla	*Descurainia pinnata*	*Madia exigua*
Agastache urticifolia	*Descurainia sophia*	*Madia glomerata*
Allium acuminatum	*Dodecatheon pulchellum*	*Madia gracilis*
Alyssum alyssoides	*Draba verna*	*Madia sativa*
Alyssum desertorum	*Epilobium brachycarpum*	*Mentzelia albicaulis*
Allium douglasii	*Epilobium ciliatum*	*Mentzelia dispersa*
Allium fibrillum	*Epilobium glaberrimum*	*Mertensia longiflora*
Allium lemmonii	*Epilobium minutum*	*Mertensia oblongifolia*
Aliciella leptomeria	*Eriogonum alatum*	*Mentzelia veatchiana*
Allium nevadense	*Erigeron aphanactis*	*Microsteris gracilis*
Allium parvum	*Eriogonum baileyi*	*Mimulus cusickii*
Allium tolmiei	*Erigeron bloomeri*	*Microseris laciniata*
Amsinckia lycopsoides	*Ericameria bloomeri*	*Mimulus nanus*
Amsinckia menziesii	*Eriogonum brevicaule*	*Microseris nutans*
Amsinckia tessellata	*Eriogonum caespitosum*	*Nothocalais troximoides*
Antennaria corymbosa	*Erigeron chrysopsidis*	*Montia linearis*
Antennaria dimorpha	*Erodium cicutarium*	*Myosotis discolor*
Antennaria geyeri	*Eriogonum compositum*	*Navarretia breweri*
Antennaria luzuloides	*Eriogonum corymbosum*	*Navarretia divaricata*
Antennaria microphylla	*Erigeron corymbosus*	*Nemophila pedunculata*
Antennaria rosea	*Erigeron divergens*	*Orobanche corymbosa*
Antennaria stenophylla	*Eriogonum douglasii*	*Orthocarpus tenuifolius*
Antennaria umbrinella	*Erigeron filifolius*	*Packera cana*
Arenaria aculeata	*Erigeron foliosus*	*Perideridia bolanderi*
Arenaria capillaris	*Eriogonum heracleoides*	*Penstemon caespitosus*
Arabis cobrensis	*Eriogonum inflatum*	*Penstemon cusickii*

Component Species		
Arenaria congesta	*Erigeron jonesii*	*Penstemon cyananthus*
Arabis demissa	*Eriophyllum lanatum*	*Penstemon deustus*
Arabis drummondii	*Erigeron linearis*	*Penstemon gairdneri*
Arenaria	*Eriogonum microthecum*	*Penstemon humilis*
Arabis hirsuta	*Eriogonum niveum*	*Penstemon laetus*
Arabis holboellii	*Eriogonum ovalifolium*	*Perideridia oregana*
Arenaria kingii	*Erigeron poliospermus*	*Pectis papposa*
Arnica rydbergii	*Erigeron pumilus*	*Penstemon seorsus*
Arnica sororia	*Eriogonum racemosum*	*Penstemon watsonii*
Astragalus atratus	*Erigeron simplex*	*Phlox austromontana*
Astragalus conjunctus	*Eriastrum sparsiflorum*	*Phoenicaulis cheiranthoides*
Astragalus convallarius	*Eriogonum sphaerocephalum*	*Phacelia heterophylla*
Astragalus collinus	*Eriogonum strictum*	*Phlox hoodii*
Astragalus curvicarpus	*Eriogonum thymoides*	*Phacelia humilis*
Asclepias fascicularis	*Eriogonum umbellatum*	*Phacelia linearis*
Astragalus filipes	*Eriogonum vimineum*	*Phlox*
Astragalus lentiginosus	*Eriastrum wilcoxii*	*Plectritis macrocera*
Astragalus malacus	*Fritillaria pudica*	*Plagiobothrys tenellus*
Astragalus mulfordiae	*Galium ambiguum*	*Potentilla arguta*
Astragalus nuttallianus	*Galium aparine*	*Polygonum douglasii*
Astragalus obscurus	*Gayophytum diffusum*	*Potentilla glandulosa*
Astragalus purshii	*Galium glabrescens*	*Polemonium micranthum*
Astragalus sclerocarpus	*Gayophytum heterozygum*	*Polygonum parryi*
Astragalus	*Galium parisiense*	*Polygonum polygaloides*
Balsamorhiza hookeri	*Gayophytum racemosum*	*Polygonum ramosissimum*
Balsamorhiza incana	*Gayophytum ramosissimum*	*Ranunculus glaberrimus*
Balsamorhiza sagittata	*Galium tricornutum*	*Salvia aethiopis*
Balsamorhiza serrata	*Geum triflorum*	*Salvia dorrii*
Balsamorhiza sericea	*Gilia brecciarum*	*Salsola kali*
Blepharipappus scaber	*Navarretia capillaris*	*Salsola tragus*
Crepis modocensis	*Gilia inconspicua*	*Scutellaria angustifolia*
Castilleja angustifolia	*Gilia sinuata*	*Scutellaria antirrhinoides*
Castilleja linariifolia	*Gutierrezia sarothrae*	*Scutellaria nana*
Calochortus	*Hackelia cusickii*	*Senecio crassulus*
Calochortus macrocarpus	*Hieracium cynoglossoides*	*Senecio integerrimus*
Castilleja miniata	*Hieracium longiberbe*	*Senecio spartioides*
Castilleja pilosa	*Hieracium scouleri*	*Senecio vulgaris*
Castilleja	*Holosteum umbellatum*	*Sisymbrium altissimum*
Camissonia tanacetifolia	*Hydrophyllum capitatum*	*Silene douglasii*
Ceratocephala testiculata	*Idahoa scapigera*	*Silene menziesii*
Chenopodium leptophyllum	*Iva axillaris*	*Sidalcea oregana*
Ericameria nauseosa	*Lactuca serriola*	*Silene scaposa*
Cirsium canovirens	*Layia glandulosa*	*Sphaeralcea munroana*
Cirsium vulgare	*Lathyrus lanszwertii*	*Sphaeralcea parvifolia*
Cirsium undulatum	*Lagophylla ramosissima*	*Stenotus acaulis*
Clarkia gracilis	*Lathyrus rigidus*	*Stellaria nitens*
Claytonia perfoliata	*Lepidium lasiocarpum*	*Tetradymia canescens*
Cordylanthus capitatus	*Leptosiphon liniflorus*	*Tetradymia glabrata*
Collomia grandiflora	*Leucocrinum montanum*	*Tetradymia spinosa*
Collinsia grandiflora	*Lepidium oblongum*	*Trifolium arvense*
Collomia linearis	*Lepidium perfoliatum*	*Tragopogon dubius*
Collinsia parviflora	*Linanthus pungens*	*Trifolium macrocephalum*
Cordylanthus ramosus	*Lewisia rediviva*	*Trifolium oliganthum*
Crepis acuminata	*Leptosiphon septentrionalis*	*Trifolium repens*

Component Species		
Cryptantha affinis	*Lithophragma glabrum*	*Verbascum thapsus*
Cryptantha ambigua	*Lithophragma parviflorum*	*Vicia americana*
Crepis atribarba	*Lithophragma tenellum*	*Viola beckwithii*
Cryptantha circumscissa	*Lithospermum ruderale*	*Viola nuttallii*
Cryptantha flaccida	*Lomatium canbyi*	*Viola praemorsa*
Cryptantha gracilis	*Lomatium cous*	*Viola purpurea*
Crepis intermedia	*Lomatium dissectum*	*Viola trinervata*
Cryptantha intermedia	*Lomatium donnellii*	*Wyethia mollis*
Cryptantha interrupta	*Lomatium grayi*	*Zigadenus*
Crepis occidentalis	*Lomatium macrocarpum*	*Zigadenus paniculatus*
Cryptantha torreyana	*Lomatium*	*Zigadenus venenosus*
Cryptantha watsonii	*Lomatium nevadense*	

SandbergBluegrass

Component Species
Poa secunda

NoxiousWeeds

Component Species		
Acroptilon repens	*Centaurea solstitialis*	*Onopordum acanthium*
Aegilops cylindrica	*Chondrilla juncea*	*Onopordum acaulon*
Agrostemma githago	*Crupina vulgaris*	*Polygonum cuspidatum*
Alhagi maurorum	*Cynoglossum officinale*	*Potentilla recta*
Berteroa incana	*Cytisus scoparius*	*Salvia aethiopis*
Brachypodium sylvaticum	*Daucus carota*	*Senecio jacobaea*
Carduus nutans	*Euphorbia esula*	*Silybum marianum*
Carduus	*Hieracium aurantiacum*	*Solanum rostratum*
Centaurea calcitrapa	*Linaria dalmatica*	*Taeniatherum caput-medusae*
Centaurea diffusa	*Linaria vulgaris*	*Ventenata dubia*
Centaurea macrocephala	*Ludwigia palustris*	*Xanthium spinosum*

WetlandIndicators

Component Species		
Acorus calamus	*Navarretia capillaris*	*Poa palustris*
Acer circinatum	*Glyceria borealis*	*Polygonum parryi*
Aconitum columbianum	*Glyceria grandis*	*Polygonum polygaloides*
Acer glabrum	*Glycyrrhiza lepidota*	*Poa pratensis*
Actaea laciniata	*Glyceria striata*	*Polygonum ramosissimum*
Acer macrophyllum	*Gnaphalium palustre*	*Poa reflexa*
Acer negundo	*Grindelia nana*	*Potentilla rivalis*
Actaea rubra	*Gratiola neglecta*	*Poa trivialis*
Adiantum aleuticum	*Grindelia stricta*	*Prunus virginiana*
Agoseris aurantiaca	*Gymnocarpium dryopteris*	*Psilocarphus brevissimus*
Agrostis capillaris	*Gymnosteris parvula*	*Psilocarphus oregonus*
Agrostis exarata	*Hastingsia alba*	*Pseudognaphalium stramineum*
Agrostis gigantea	*Heliotropium curassavicum*	*Puccinellia lemmonii*
Agoseris glauca	*Heracleum maximum*	*Puccinellia nuttalliana*
Agrostis hendersonii	*Helianthus nuttallii*	*Pyrola asarifolia*
Agrostis idahoensis	*Hesperochiron pumilus*	*Pyrola chlorantha*
Agrostis oregonensis	*Heterocodon rariflorum*	*Pyrrocoma hirta*

Component Species		
Agrostis stolonifera	*Heracleum sphondylium*	*Pyrrocoma lanceolata*
Agrostis scabra	*Hippuris vulgaris*	*Pyrrocoma racemosa*
Alopecurus aequalis	*Howellia aquatilis*	*Pyrrocoma uniflora*
Allium bisceptrum	*Hordeum brachyantherum*	*Ranunculus acriformis*
Alopecurus carolinianus	*Hordeum depressum*	*Ranunculus acris*
Allium douglasii	*Hordeum jubatum*	*Ranunculus alismifolius*
Alopecurus geniculatus	*Holcus lanatus*	*Ranunculus aquatilis*
Allophyllum gilioides	*Hordeum murinum*	*Ranunculus eschscholtzii*
Alnus incana	*Hornungia procumbens*	*Ranunculus flammula*
Alisma triviale	*Hypericum anagalloides*	*Ranunculus glaberrimus*
Allium madidum	*Hydrophyllum fendleri*	*Ranunculus gmelinii*
Allenrolfea occidentalis	*Hymenoxys hoopesii*	*Ranunculus macounii*
Alopecurus pratensis	*Hypericum majus*	*Ranunculus muricatus*
Alnus rhombifolia	*Hydrophyllum occidentale*	*Ranunculus occidentalis*
Alnus rubra	*Hypericum scouleri*	*Ranunculus orthorhynchus*
Allium schoenoprasum	*Hydrophyllum tenuipes*	*Ranunculus parviflorus*
Allium validum	*Iliamna rivularis*	*Ranunculus populago*
Alnus viridis	*Impatiens ecalcarata*	*Ranunculus repens*
Amaranthus blitoides	*Iris missouriensis*	*Ranunculus sceleratus*
Scirpus nevadensis	*Isoetes bolanderi*	*Ranunculus uncinatus*
Angelica arguta	*Juncus acuminatus*	*Rhamnus alnifolia*
Antennaria corymbosa	*Juncus alpinoarticulatus*	*Rhododendron occidentale*
Androsace filiformis	*Juncus arcticus*	*Ribes aureum*
Angelica genuflexa	*Juncus articulatus*	*Ribes bracteosum*
Antennaria media	*Juncus arcticus var. littoralis*	*Ribes divaricatum*
Anthoxanthum odoratum	*Juncus balticus*	*Ribes hudsonianum*
Anemone parviflora	*Juncus brachyphyllus*	*Ribes inerme*
Apocynum cannabinum	*Juncus bufonius*	*Ribes lacustre*
Aquilegia formosa	*Juncus capillaris*	*Ribes oxyacanthoides*
Aralia californica	*Juncus castaneus*	*Ribes triste*
Arnica chamissonis	*Juncus compressus*	*Ribes viscosissimum*
Arabis crucisetosa	*Juncus confusus*	*Ribes wolfii*
Artemisia douglasiana	*Juncus drummondii*	*Romanzoffia californica*
Arnica longifolia	*Juncus dudleyi*	*Rorippa columbiae*
Arnica latifolia	*Juncus effusus*	*Rorippa curvisiliqua*
Armeria maritima	*Juncus ensifolius*	*Rorippa curvipes*
Arnica mollis	*Juncus falcatus*	*Rosa nutkana*
Astragalus agrestis	*Juncus filiformis*	*Rorippa palustris*
Astragalus alpinus	*Juncus hallii*	*Rosa pisocarpa*
Astragalus canadensis	*Juncus hemiendytus*	*Romanzoffia sitchensis*
Asarum caudatum	*Juncus howellii*	*Rorippa sphaerocarpa*
Asclepias fascicularis	*Juncus lesueurii*	*Rumex acetosa*
Astragalus lemmonii	*Juncus longistylis*	*Rubus arcticus*
Symphyotrichum spathulatum	*Juncus mertensianus*	*Rubus armeniacus*
Astragalus robbinsii	*Juncus*	*Rubus bartonianus*
Asclepias speciosa	*Juncus nevadensis*	*Ruppia cirrhosa*
Asplenium trichomanes	*Juncus nodosus*	*Rumex crispus*
Athyrium americanum	*Juncus occidentalis*	*Rumex obtusifolius*
Atriplex patula	*Juncus orthophyllus*	*Rudbeckia occidentalis*
Barbarea orthoceras	*Juncus oxymeris*	*Rubus parviflorus*
Bassia scoparia	*Juncus parryi*	*Rumex paucifolius*
Barbarea vulgaris	*Juncus patens*	*Rubus pubescens*
Beckmannia syzigachne	*Juncus regelii*	*Rumex salicifolius*
Betula occidentalis	*Juncus saximontanus*	*Rubus spectabilis*

Component Species		
Betula papyrifera	*Juncus tenuis*	*Rubus ursinus*
Betula pumila	*Juncus tracyi*	*Saxifraga adscendens*
Blechnum spicant	*Kalmia microphylla*	*Salix amygdaloides*
Botrychium crenulatum	*Kobresia myosuroides*	*Saussurea americana*
Botrychium lanceolatum	*Kobresia simpliciuscula*	*Salix barclayi*
Bolboschoenus maritimus	*Lactuca biennis*	*Salix bebbiana*
Botrychium lunaria	*Lapsana communis*	*Salix boothii*
Boykinia major	*Lasthenia glaberrima*	*Salix brachycarpa*
Boykinia occidentalis	*Lactuca ludoviciana*	*Sanguisorba canadensis*
Bolandra oregana	*Lathyrus palustris*	*Sagittaria calycina*
Botrychium simplex	*Lathyrus sphaericus*	*Saxifraga caespitosa*
Bromus ciliatus	*Lactuca tatarica*	*Salix commutata*
Brodiaea coronaria	*Leymus cinereus*	*Sagittaria cuneata*
Briza minor	*Leucothoe davisiae*	*Salicornia depressa*
Schoenoplectus pungens	*Lepidium dictyotum*	*Salix drummondiana*
Cardamine angulata	*Lepidium latifolium*	*Salix eastwoodiae*
Catabrosa aquatica	*Lemna minor*	*Salix exigua*
Cardamine breweri	*Leptarrhena pyrolifolia*	*Salix farriae*
Calypso bulbosa	*Lemna trisulca*	*Salix geyeriana*
Cabomba caroliniana	*Leymus triticoides*	*Salix glauca*
Calamagrostis canadensis	*Limosella acaulis*	*Sagittaria latifolia*
Cardamine cordifolia	*Lilium bolanderi*	*Salix hookeriana*
Carex douglasii	*Ligusticum canbyi*	*Salix lasiolepis*
Carex filifolia	*Ligusticum grayi*	*Salix lemmonii*
Callitriche heterophylla	*Lilium kelloggii*	*Salicornia rubra*
Caltha leptosepala	*Lilium pardalinum*	*Salix lutea*
Camassia leichtlinii	*Ligusticum tenuifolium*	*Salix melanopsis*
Calochortus longebarbatus	*Schedonorus arundinaceus*	*Saxifraga mertensiana*
Calamagrostis stricta	*Lomatium bradshawii*	*Sambucus nigra*
Cakile maritima	*Lonicera conjugialis*	*Salix nivalis*
Callitriche marginata	*Lotus corniculatus*	*Salix planifolia*
Castilleja miniata	*Lonicera involucrata*	*Sagina procumbens*
Castilleja minor	*Lolium perenne*	*Salix prolixa*
Canadanthus modestus	*Lonicera utahensis*	*Sagina saginoides*
Callitropsis nootkatensis	*Luzula comosa*	*Salix scouleriana*
Calamagrostis nutkaensis	*Lupinus latifolius*	*Salix sitchensis*
Cardamine nuttallii	*Ludwigia palustris*	*Salix tracyi*
Calochortus nudus	*Luzula parviflora*	*Salix vestita*
Cardamine occidentalis	*Lupinus polyphyllus*	*Salix wolfii*
Cardamine oligosperma	*Lupinus rivularis*	*Schoenoplectus acutus*
Cardamine parviflora	*Lycopus americanus*	*Schoenoplectus americanus*
Castilleja parviflora	*Lysichiton americanus*	*Scirpus congdonii*
Caltha palustris	*Lycopus asper*	*Scirpus cyperinus*
Cardamine penduliflora	*Lysimachia ciliata*	*Sclerolinon digynum*
Cardamine pensylvanica	*Lycopodium clavatum*	*Scutellaria galericulata*
Carex petasata	*Lycopodiella inundata*	*Schoenoplectus*
Camassia quamash	*Lythrum salicaria*	*Scirpus*
Castilleja rhexiifolia	*Lysimachia thyrsiflora*	*Scrophularia lanceolata*
Carex rossii	*Lycopus uniflorus*	*Scirpus microcarpus*
Callitriche stagnalis	*Maianthemum dilatatum*	*Scheuchzeria palustris*
Castilleja suksdorfii	*Malus fusca*	*Scirpus pallidus*
Castilleja tenuis	*Maianthemum racemosum*	*Schoenoplectus subterminalis*
Carex vallicola	*Maianthemum stellatum*	*Schoenoplectus tabernaemontani*
Centaurium erythraea	*Mentha arvensis*	*Senecio hydrophiloides*

Component Species		
Chrysosplenium glechomifolium	*Mertensia bella*	*Senecio hydrophilus*
Chenopodium rubrum	*Mertensia ciliata*	*Senecio sphaerocephalus*
Circaea alpina	*Medicago lupulina*	*Senecio triangularis*
Cirsium arvense	*Mertensia oblongifolia*	*Sinapis alba*
Cicuta bulbifera	*Mertensia paniculata*	*Sisyrinchium bellum*
Cicuta douglasii	*Melica spectabilis*	*Sidalcea cusickii*
Cirsium edule	*Mentha spicata*	*Sisyrinchium halophilum*
Cinna latifolia	*Menyanthes trifoliata*	*Sisyrinchium idahoense*
Cirsium scariosum	*Mimulus alsinoides*	*Sidalcea malviflora*
Claytonia cordifolia	*Mimulus breviflorus*	*Silene menziesii*
Claytonia lanceolata	*Mimulus cardinalis*	*Sidalcea neomexicana*
Clematis ligusticifolia	*Mimulus dentatus*	*Sidalcea oregana*
Claytonia perfoliata	*Mimulus floribundus*	*Sium suave*
Cleomella plocasperma	*Mimulus lewisii*	*Sonchus asper*
Claytonia sibirica	*Mimulus moschatus*	*Solanum dulcamara*
Corydalis caseana	*Mimulus primuloides*	*Sorbus sitchensis*
Cornus glabrata	*Mitella stauropetala*	*Sparganium eurycarpum*
Coptis laciniata	*Mimulus tilingii*	*Spartina gracilis*
Conium maculatum	*Mimulus tricolor*	*Sporobolus airoides*
Comarum palustre	*Mimulus washingtonensis*	*Sparganium angustifolium*
Cordylanthus ramosus	*Morella californica*	*Sphenosciadium capitellatum*
Corydalis scouleri	*Montia chamissoi*	*Spiraea douglasii*
Corallorhiza trifida	*Montia dichotoma*	*Sparganium emersum*
Crataegus douglasii	*Montia fontana*	*Sphenopholis obtusata*
Cyperus acuminatus	*Moehringia lateriflora*	*Sparganium natans*
Cyperus	*Montia linearis*	*Spartina patens*
Damasonium californicum	*Moehringia macrophylla*	*Spiranthes romanzoffiana*
Danthonia californica	*Monolepis nuttalliana*	*Spergularia rubra*
Darlingtonia californica	*Montia parvifolia*	*Streptopus amplexifolius*
Dasiphora fruticosa	*Muhlenbergia andina*	*Stellaria borealis*
Deschampsia danthonioides	*Muhlenbergia asperifolia*	*Stellaria calycantha*
Deschampsia elongata	*Muhlenbergia filiformis*	*Stachys chamissonis*
Delphinium glaucum	*Muhlenbergia glomerata*	*Stellaria crispa*
Delphinium nuttallianum	*Muhlenbergia mexicana*	*Streptopus lanceolatus*
Dichanthelium acuminatum	*Muhlenbergia minutissima*	*Stellaria longifolia*
Dipsacus fullonum	*Muhlenbergia racemosa*	*Stellaria longipes*
Distichlis spicata	*Muhlenbergia richardsonis*	*Stellaria longipes ssp. longipes*
Dodecatheon alpinum	*Myosurus apetalus*	*Stachys mexicana*
Downingia bacigalupii	*Myriophyllum aquaticum*	*Stellaria obtusa*
Downingia bicornuta	*Myosotis arvensis*	*Stachys pilosa*
Dodecatheon dentatum	*Myosotis discolor*	*Stachys rigida*
Downingia elegans	*Myosotis laxa*	*Streptopus streptopoides*
Dodecatheon jeffreyi	*Myosurus minimus*	*Stellaria umbellata*
Downingia laeta	*Myosotis scorpioides*	*Suaeda calceoliformis*
Dodecatheon pulchellum	*Myriophyllum sibiricum*	*Swertia perennis*
Downingia yina	*Myosotis sylvatica*	*Symphytum asperum*
Draba albertina	*Myosotis verna*	*Symphyotrichum ascendens*
Drosera anglica	*Navarretia breweri*	*Symphyotrichum chilense*
Dryopteris carthusiana	*Navarretia intertexta*	*Symphyotrichum ericoides*
Dryopteris expansa	*Navarretia leucocephala*	*Symphyotrichum frondosum*
Drosera rotundifolia	*Nasturtium officinale*	*Symphyotrichum subspicatum*
Dulichium arundinaceum	*Nemophila pedunculata*	*Teucrium canadense*
Eleocharis acicularis	*Nitrophila occidentalis*	*Thalictrum alpinum*
Eleocharis bella	*Oenothera elata*	*Thelypodium integrifolium*

Component Species		
Eleocharis bolanderi	*Oenothera flava*	*Thalictrum fendleri*
Elymus canadensis	*Oenanthe sarmentosa*	*Thermopsis montana*
Elodea canadensis	*Oenothera villosa*	*Thuja plicata*
Elatine chilensis	*Oplopanax horridus*	*Thelypodium sagittatum*
Eleocharis elliptica	*Oreostemma alpigenum*	*Thalictrum sparsiflorum*
Eleocharis	*Orthocarpus bracteosus*	*Thalictrum venulosum*
Eleocharis palustris	*Orogenia fusiformis*	*Tiarella trifoliata*
Eleocharis rostellata	*Osmorhiza purpurea*	*Toxicodendron diversilobum*
Eleocharis macrostachya	*Packera bolanderi*	*Triantha glutinosa*
Elodea nuttallii	*Panicum capillare*	*Tolmiea menziesii*
Eleocharis ovata	*Packera dimorphophylla*	*Torreyochloa pallida*
Eleocharis quinqueflora	*Parnassia fimbriata*	*Trautvetteria caroliniensis*
Elymus repens	*Packera indecora*	*Trifolium cyathiferum*
Pascopyrum smithii	*Packera paupercula*	*Trifolium douglasii*
Elymus trachycaulus	*Parnassia palustris*	*Trifolium eriocephalum*
Empetrum nigrum	*Packera pseudaurea*	*Trientalis europaea*
Epilobium brachycarpum	*Parentucellia viscosa*	*Trifolium fragiferum*
Epilobium ciliatum	*Petasites frigidus*	*Trifolium howellii*
Epilobium densiflorum	*Perideridia gairdneri*	*Trifolium hybridum*
Epipactis gigantea	*Penstemon globosus*	*Triteleia hyacinthina*
Epilobium glaberrimum	*Pedicularis groenlandica*	*Triglochin maritima*
Epilobium hirsutum	*Penstemon procerus*	*Trifolium variegatum*
Epilobium hornemannii	*Phleum alpinum*	*Trifolium wormskioldii*
Epilobium lactiflorum	*Phalaris arundinacea*	*Trollius laxus*
Epilobium luteum	*Phragmites australis*	*Trifolium longipes*
Epilobium oregonense	*Physocarpus capitatus*	*Trifolium microcephalum*
Epilobium palustre	*Phacelia inundata*	*Triglochin palustris*
Epilobium pallidum	*Phalaris paradoxa*	*Trifolium productum*
Epilobium saximontanum	*Phacelia procera*	*Trifolium repens*
Equisetum arvense	*Phleum pratense*	*Typha angustifolia*
Equisetum fluviatile	*Phacelia tetramera*	*Typha latifolia*
Equisetum hyemale	*Pinus contorta*	*Umbellularia californica*
Equisetum laevigatum	*Picea engelmannii*	*Urtica dioica*
Equisetum palustre	*Picea sitchensis*	*Utricularia intermedia*
Equisetum telmateia	*Plagiobothrys figuratus*	*Utricularia macrorhiza*
Equisetum variegatum	*Plantago lanceolata*	*Utricularia minor*
Eriophorum angustifolium	*Plagiobothrys leptocladus*	*Vahlodea atropurpurea*
Eriophorum chamissonis	*Plantago macrocarpa*	*Valeriana edulis*
Erigeron coulteri	*Plantago major*	*Vaccinium macrocarpon*
Eriophorum gracile	*Plantago maritima*	*Valeriana occidentalis*
Erigeron howellii	*Plagiobothrys mollis*	*Vaccinium parvifolium*
Eragrostis hypnoides	*Plagiobothrys nothofulvus*	*Valeriana scouleri*
Erigeron lonchophyllus	*Platanthera obtusata*	*Valeriana sitchensis*
Eragrostis mexicana	*Pleuropogon refractus*	*Vaccinium uliginosum*
Eragrostis pectinacea	*Plagiobothrys salsus*	*Veronica americana*
Erigeron peregrinus	*Plagiobothrys scouleri*	*Veronica anagallis-aquatica*
Erythronium revolutum	*Platanthera sparsiflora*	*Verbena bracteata*
Mimulus guttatus	*Platanthera stricta*	*Veratrum californicum*
Euthamia occidentalis	*Plagiobothrys tenellus*	*Veronica cusickii*
Euonymus occidentalis	*Poa alpina*	*Verbena lasiostachys*
Euphorbia spathulata	*Poa annua*	*Veronica peregrina*
Festuca rubra	*Populus angustifolia*	*Veronica scutellata*
Floerkea proserpinacoides	*Polygonum aviculare*	*Veronica serpyllifolia*
Fraxinus latifolia	*Populus balsamifera*	*Veratrum viride*

Component Species		
Frangula purshiana	*Potentilla biennis*	*Veronica wormskjoldii*
Gaultheria humifusa	*Porterella carnosula*	*Viola adunca*
Gayophytum humile	*Potamogeton crispus*	*Vicia americana*
Galium mexicanum	*Potamogeton diversifolius*	*Viburnum edule*
Gaultheria ovatifolia	*Potentilla drummondii*	*Viola glabella*
Galium palustre	*Potentilla flabellifolia*	*Viola hallii*
Gayophytum racemosum	*Polyctenium fremontii*	*Viola macloskeyi*
Galium trifidum	*Potentilla gracilis*	*Viola nephrophylla*
Geum aleppicum	*Potamogeton gramineus*	*Viola palustris*
Gentianella amarella	*Poa leptocoma*	*Vulpia bromoides*
Gentiana calycosa	*Polypogon monspeliensis*	*Woodwardia fimbriata*
Geum macrophyllum	*Poa marcida*	*Wyethia amplexicaulis*
Gentiana prostrata	*Potamogeton natans*	*Wyethia helianthoides*
Gentianella propinqua	*Poa nemoralis*	*Xanthium strumarium*
Geranium richardsonii	*Potentilla newberryi*	*Zizia aptera*
Gentiana sceptrum	*Potentilla norvegica*	*Zizania palustris*
Gentianopsis simplex	*Polemonium occidentale*	
Geranium viscosissimum	*Portulaca oleracea*	

Conifer

Component Species		
Unknown Conifer Tree	*Juniperus osteosperma*	*Pinus monophylla*
Abies amabilis	*Juniperus scopulorum*	*Pinus monticola*
Abies bracteata	*Larix lyallii*	*Pinus*
Abies concolor	*Larix occidentalis*	*Pinus ponderosa*
Abies	*Larix*	*Picea pungens*
Abies grandis	*Pinus albicaulis*	*Picea sitchensis*
Abies lasiocarpa	*Pinus attenuata*	*Pseudotsuga*
Abies magnifica	*Picea breweriana*	*Pseudotsuga menziesii*
Abies magnifica var. shastensis	*Picea*	*Sequoia sempervirens*
Abies procera	*Pinus contorta*	*Taxus brevifolia*
Calocedrus decurrens	*Pinus edulis*	*Taxus*
Callitropsis nootkatensis	*Picea engelmannii*	*Thuja plicata*
Chamaecyparis lawsoniana	*Pinus flexilis*	*Tsuga heterophylla*
Juniperus communis	*Picea glauca*	*Tsuga mertensiana*
Juniperus horizontalis	*Pinus jeffreyi*	
Juniperus occidentalis	*Pinus lambertiana*	

Appendix 2: Species range accuracy

Accuracy for the prediction of the range of all species that appear in > 5% of the observations.

	Scientific.Name	Count	Plot	Hex1	Hex2	Hex3
ACMI2	*Achillea millefolium*	2910	0.35 *(0.03)*	0.58 *(0.07)*	0.55 *(0.10)*	0.25 *(0.19)*
ACHY	*Achnatherum hymenoides*	2790	0.37 *(0.03)*	0.59 *(0.07)*	0.57 *(0.09)*	0.57 *(0.14)*
ACTH7	*Achnatherum thurberianum*	12280	0.36 *(0.02)*	0.56 *(0.15)*	0.48 *(0.22)*	0.00 *(0.00)*
AGCR	*Agropyron cristatum*	4060	0.52 *(0.02)*	0.56 *(0.07)*	0.44 *(0.10)*	0.61 *(0.13)*
ARAR8	*Artemisia arbuscula*	9070	0.51 *(0.02)*	0.61 *(0.07)*	0.29 *(0.12)*	0.13 *(0.15)*
ARTRT	*Artemisia tridentata ssp. tridentata*	7750	0.39 *(0.02)*	0.52 *(0.09)*	0.44 *(0.15)*	0.30 *(0.25)*
ARTRV	*Artemisia tridentata ssp. vaseyana*	2770	0.54 *(0.03)*	0.59 *(0.06)*	0.56 *(0.09)*	0.41 *(0.17)*
ARTRW8	*Artemisia tridentata ssp. wyomingensis*	18820	0.42 *(0.01)*	0.32 *(0.15)*	0.26 *(0.22)*	0.00 *(0.00)*

ATCO	*Atriplex confertifolia*	2240.63 *(0.03)*	0.57 *(0.07)*	0.68 *(0.08)*	0.52 *(0.11)*
BRHO2	*Bromus hordeaceus*	2010.30 *(0.03)*	0.56 *(0.07)*	0.48 *(0.09)*	0.54 *(0.11)*
BRTE	*Bromus tectorum*	27620.52 *(0.01)*	-0.01 *(0.01)*	0.00 *(0.00)*	0.00 *(0.00)*
CETE5	*Ceratocephala testiculata*	3070.24 *(0.03)*	0.52 *(0.07)*	0.55 *(0.09)*	0.63 *(0.11)*
CHVI8	*Chrysothamnus viscidiflorus*	12530.39 *(0.02)*	0.23 *(0.12)*	0.55 *(0.23)*	1.00 *(0.00)*
COPA3	*Collinsia parviflora*	6640.26 *(0.02)*	0.47 *(0.09)*	0.43 *(0.13)*	0.37 *(0.28)*
CRAC2	*Crepis acuminata*	7360.30 *(0.02)*	0.66 *(0.07)*	0.45 *(0.14)*	0.41 *(0.20)*
CROC	*Crepis occidentalis*	1990.11 *(0.03)*	0.55 *(0.07)*	0.62 *(0.08)*	0.64 *(0.12)*
DRVE2	*Draba verna*	3690.23 *(0.02)*	0.49 *(0.07)*	0.59 *(0.09)*	0.46 *(0.14)*
ELEL5	*Elymus elymoides*	22940.31 *(0.02)*	0.49 *(0.22)*	-0.03 *(0.01)*	0.00 *(0.00)*
EPMI	*Epilobium minutum*	2590.16 *(0.03)*	0.52 *(0.07)*	0.49 *(0.09)*	0.62 *(0.11)*
ERNA10	*Ericameria nauseosa*	7750.34 *(0.02)*	0.44 *(0.12)*	0.43 *(0.17)*	0.00 *(0.00)*
ERTE18	*Ericameria teretifolia*	2080.51 *(0.03)*	0.65 *(0.06)*	0.73 *(0.07)*	0.66 *(0.11)*
FEID	*Festuca idahoensis*	10500.50 *(0.02)*	0.76 *(0.07)*	0.66 *(0.13)*	0.00 *(0.00)*
GRSP	*Grayia spinosa*	3670.57 *(0.02)*	0.67 *(0.06)*	0.61 *(0.08)*	0.58 *(0.11)*
GUSA2	*Gutierrezia sarothrae*	2040.46 *(0.03)*	0.58 *(0.07)*	0.60 *(0.08)*	0.53 *(0.11)*
HOUM	*Holosteum umbellatum*	2600.29 *(0.03)*	0.44 *(0.07)*	0.49 *(0.09)*	0.54 *(0.12)*
JUOC	*Juniperus occidentalis*	4010.71 *(0.02)*	0.83 *(0.05)*	0.79 *(0.07)*	0.61 *(0.12)*
KOMA	*Koeleria macrantha*	2670.39 *(0.03)*	0.73 *(0.05)*	0.75 *(0.07)*	0.65 *(0.13)*
LEPE2	*Lepidium perfoliatum*	3370.31 *(0.03)*	0.41 *(0.07)*	0.47 *(0.09)*	0.66 *(0.11)*
LECI4	*Leymus cinereus*	3600.32 *(0.02)*	0.41 *(0.07)*	0.45 *(0.10)*	0.71 *(0.14)*
LIPU11	*Linanthus pungens*	2590.34 *(0.03)*	0.55 *(0.07)*	0.46 *(0.10)*	0.39 *(0.16)*
LUCA	*Lupinus caudatus*	1990.28 *(0.03)*	0.66 *(0.06)*	0.62 *(0.08)*	0.45 *(0.13)*
MIGR	*Microsteris gracilis*	5440.23 *(0.02)*	0.57 *(0.08)*	0.59 *(0.11)*	0.64 *(0.19)*
PHHO	*Phlox hoodii*	3800.30 *(0.02)*	0.45 *(0.08)*	0.58 *(0.10)*	0.24 *(0.23)*
PHLO2	*Phlox longifolia*	7390.28 *(0.02)*	0.41 *(0.08)*	0.37 *(0.11)*	0.44 *(0.19)*
POBU	*Poa bulbosa*	2470.34 *(0.03)*	0.58 *(0.07)*	0.57 *(0.09)*	0.62 *(0.11)*
POSE	*Poa secunda*	30250.50 *(0.02)*	-0.01 *(0.01)*	0.00 *(0.00)*	0.00 *(0.00)*
PSSP6	*Pseudoroegneria spicata*	17700.43 *(0.01)*	0.51 *(0.13)*	0.00 *(0.00)*	0.00 *(0.00)*
PUTR2	*Purshia tridentata*	2550.36 *(0.03)*	0.60 *(0.06)*	0.63 *(0.08)*	0.54 *(0.14)*
SIAL2	*Sisymbrium altissimum*	4030.29 *(0.02)*	0.52 *(0.07)*	0.60 *(0.09)*	0.63 *(0.14)*
TACA8	*Taeniatherum caput-medusae*	3010.40 *(0.03)*	0.58 *(0.07)*	0.34 *(0.09)*	0.51 *(0.11)*
TEGL	*Tetradymia glabrata*	2210.36 *(0.03)*	0.57 *(0.07)*	0.52 *(0.09)*	0.59 *(0.12)*

Appendix 3: Species cover accuracy

Accuracy statistics for species cover predictions (only those that appear in more than 5% of all observations). '.' indicates that gmfr statistics are unavailable for the species (species not present in plot-level/hexagon-level prediction summaries).

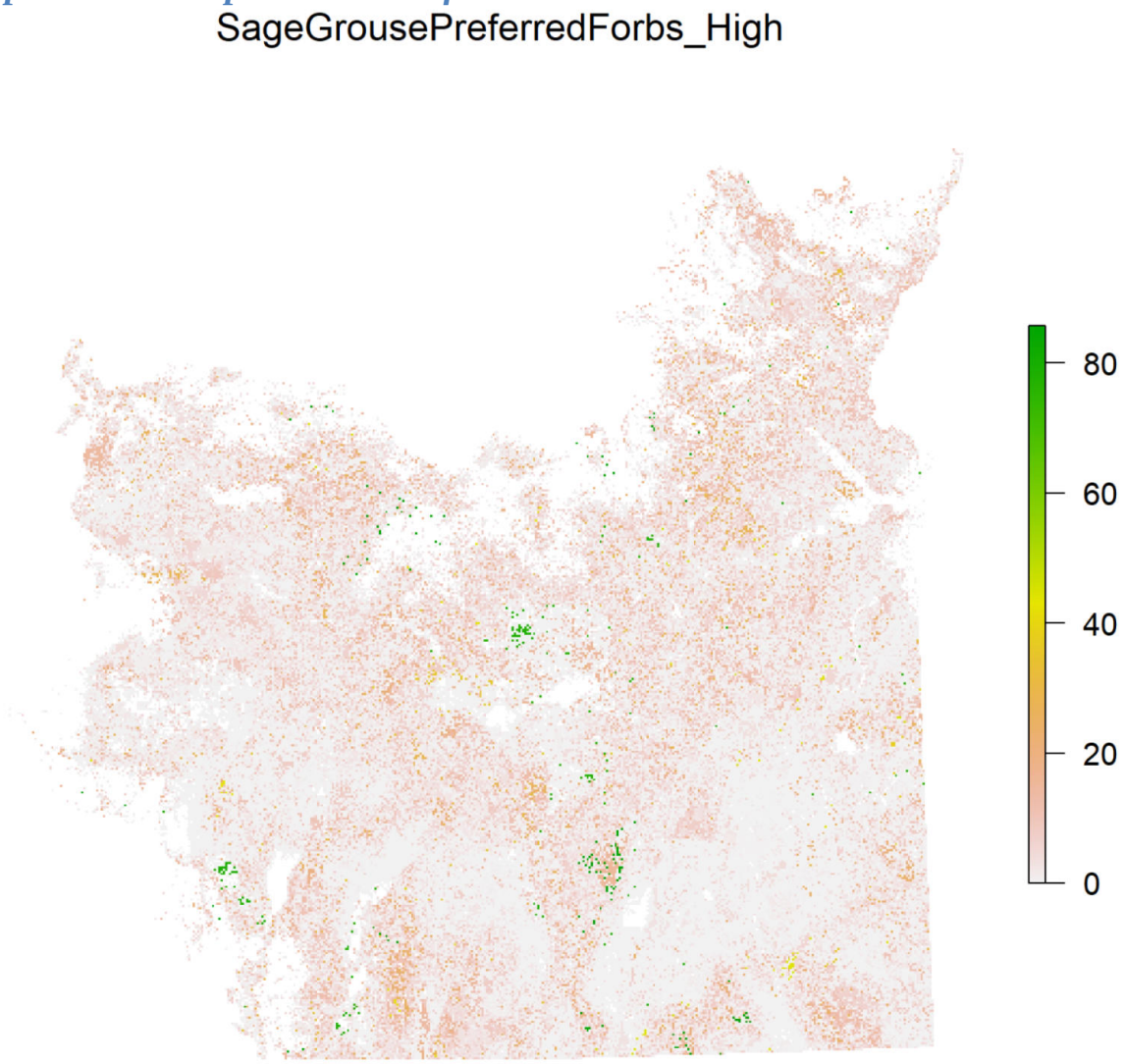
	AC	***Plot*** AC_sys	AC_uns	AC	***Hex1*** AC_sys	AC_uns	AC	***Hex2*** AC_sys	AC_uns	AC	***Hex3*** AC_sys	AC_uns
ACHY	-1.69	1.00	-1.69	-0.24	1.00	-0.24	0.43	0.96	0.47	-0.04	0.97	-0.01
ACMI2	-1.85	0.93	-1.79	0.04	0.99	0.05	0.61	0.97	0.64	0.37	0.93	0.44
ACTH7	-1.96	0.94	-1.90	0.19	0.96	0.23	0.50	0.96	0.54	0.77	0.96	0.81
AGCR	-1.69	0.94	-1.63	0.36	0.83	0.53	0.54	0.93	0.61	0.57	0.88	0.70
ARAR8	-0.46	0.99	-0.46	0.60	1.00	0.60	0.65	0.98	0.67	0.78	0.99	0.79
ARTRT	-1.64	0.95	-1.59	0.43	0.91	0.52	0.34	0.91	0.42	0.62	0.88	0.74
ARTRV	-0.96	0.96	-0.92	0.45	0.86	0.60	0.39	0.81	0.59	0.62	0.79	0.83
ARTRW8	-0.40	1.00	-0.40	0.72	0.97	0.75	0.69	0.98	0.71	0.73	1.00	0.73
ATCO	-1.65	0.99	-1.64	0.59	0.89	0.70	0.74	0.93	0.81	0.65	0.94	0.71
BRHO2	-6.81	0.97	-6.78	-0.47	0.96	-0.43	-2.36	0.65	-2.02	0.39	0.99	0.40
BRTE	-0.54	0.98	-0.53	0.59	0.96	0.63	0.76	0.96	0.80	0.72	0.94	0.78
CETE5	-3.62	0.99	-3.61	-1.53	0.32	-0.85	0.45	0.97	0.48	0.41	0.98	0.43
CHVI8	-1.04	0.92	-0.96	0.41	0.86	0.55	0.41	0.90	0.51	0.62	0.84	0.78
COPA3	-3.61	1.00	-3.61	-0.51	0.97	-0.48	0.35	0.99	0.36	0.31	0.90	0.41
CRAC2	-3.61	1.00	-3.61	0.01	1.00	0.01	-0.06	0.98	-0.04	0.43	0.97	0.45
CROC	-7.18	0.97	-7.14	-0.20	1.00	-0.20	0.29	1.00	0.29	0.28	1.00	0.28

DRVE2	-4.98	0.92	-4.90	-0.05	0.77	0.17	0.07	0.62	0.44	0.14	0.46	0.68
ELEL5	-2.42	1.00	-2.42	0.06	0.95	0.12	0.02	0.93	0.08	0.32	0.92	0.41
EPMI	-11.33	1.00	-11.32	-0.70	0.84	-0.54	0.31	0.92	0.40	-0.04	0.93	0.03
ERNA10	-1.43	0.92	-1.35	0.54	0.91	0.63	0.72	0.85	0.87	0.90	0.94	0.96
ERTE18	-1.10	0.86	-0.96	0.54	0.92	0.62	0.79	0.98	0.81	0.72	0.94	0.78
FEID	-0.78	0.97	-0.75	0.67	0.94	0.73	0.72	0.94	0.78	0.48	0.97	0.50
GRSP	-1.60	0.95	-1.55	0.69	0.98	0.71	0.62	0.91	0.71	0.82	0.98	0.84
GUSA2	-0.96	1.00	-0.96	0.34	0.99	0.35	0.42	0.96	0.45	0.41	0.98	0.42
HOUM	-4.30	0.70	-4.00	-0.57	0.92	-0.48	0.23	0.77	0.46	0.33	0.73	0.60
JUOC	0.16	0.99	0.17	0.83	0.99	0.84	0.90	1.00	0.91	0.92	0.99	0.92
KOMA	-3.70	0.83	-3.53	0.36	0.85	0.51	0.26	0.90	0.36	0.66	0.85	0.81
LECI4	-3.85	0.96	-3.81	-0.66	0.92	-0.58	0.28	0.95	0.32	-0.19	0.75	0.06
LEPE2	-6.25	0.81	-6.06	-0.75	0.97	-0.72	0.07	0.94	0.13	0.65	0.96	0.69
LIPU11	-2.28	0.99	-2.27	-0.74	0.99	-0.73	0.65	0.98	0.67	0.73	0.95	0.78
LUCA	-6.97	0.96	-6.94	0.11	1.00	0.11	0.21	0.99	0.21	-0.13	0.94	-0.07
MIGR	-5.01	0.99	-5.01	-0.96	0.94	-0.90	0.25	0.86	0.39	0.03	0.49	0.54
PHHO	-2.30	1.00	-2.30	-0.08	0.98	-0.06	0.14	0.90	0.24	0.46	1.00	0.46
PHLO2	-3.76	0.88	-3.64	0.11	1.00	0.11	0.32	0.97	0.35	0.41	1.00	0.42
POBU	-4.19	0.86	-4.05	0.34	0.81	0.54	0.70	0.98	0.72	0.45	0.73	0.72
POSE	-0.75	0.98	-0.73	0.50	0.97	0.53	0.54	0.96	0.57	0.58	0.98	0.60
PSSP6	-1.45	1.00	-1.45	0.63	0.99	0.65	0.53	0.97	0.56	0.73	0.98	0.75
PUTR2	-2.87	0.85	-2.72	0.13	0.72	0.41	0.04	0.75	0.30	0.32	0.81	0.52
SIAL2	-5.19	0.96	-5.14	-0.25	0.96	-0.21	-0.14	0.95	-0.09	-0.01	0.61	0.38
TACA8	-1.90	1.00	-1.90	-0.12	0.95	-0.07	0.47	0.97	0.50	0.68	0.86	0.82
TEGL	-3.81	0.98	-3.78	0.40	0.97	0.44	-0.81	0.55	-0.36	0.25	0.80	0.45

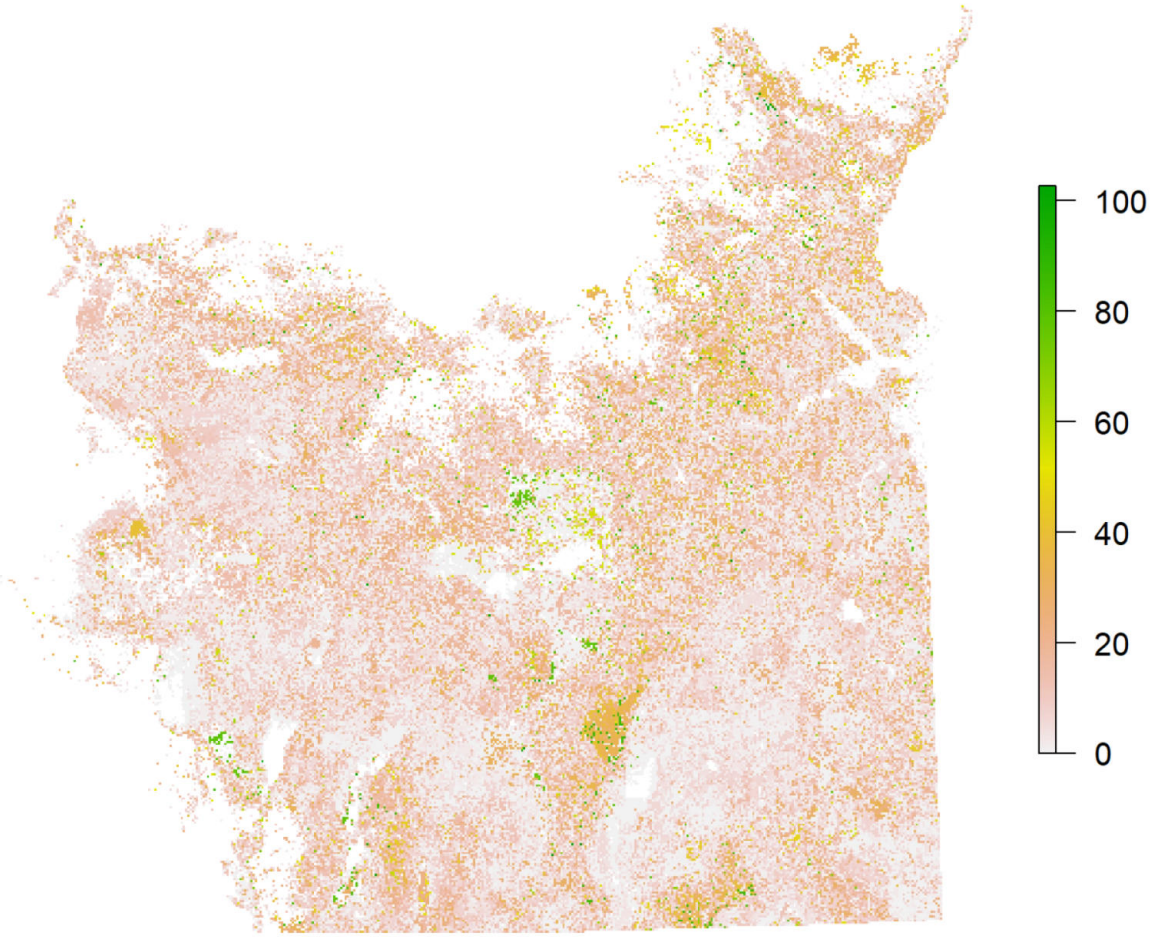
Appendix 4: Accuracy statistics for all continuous, summarized variables

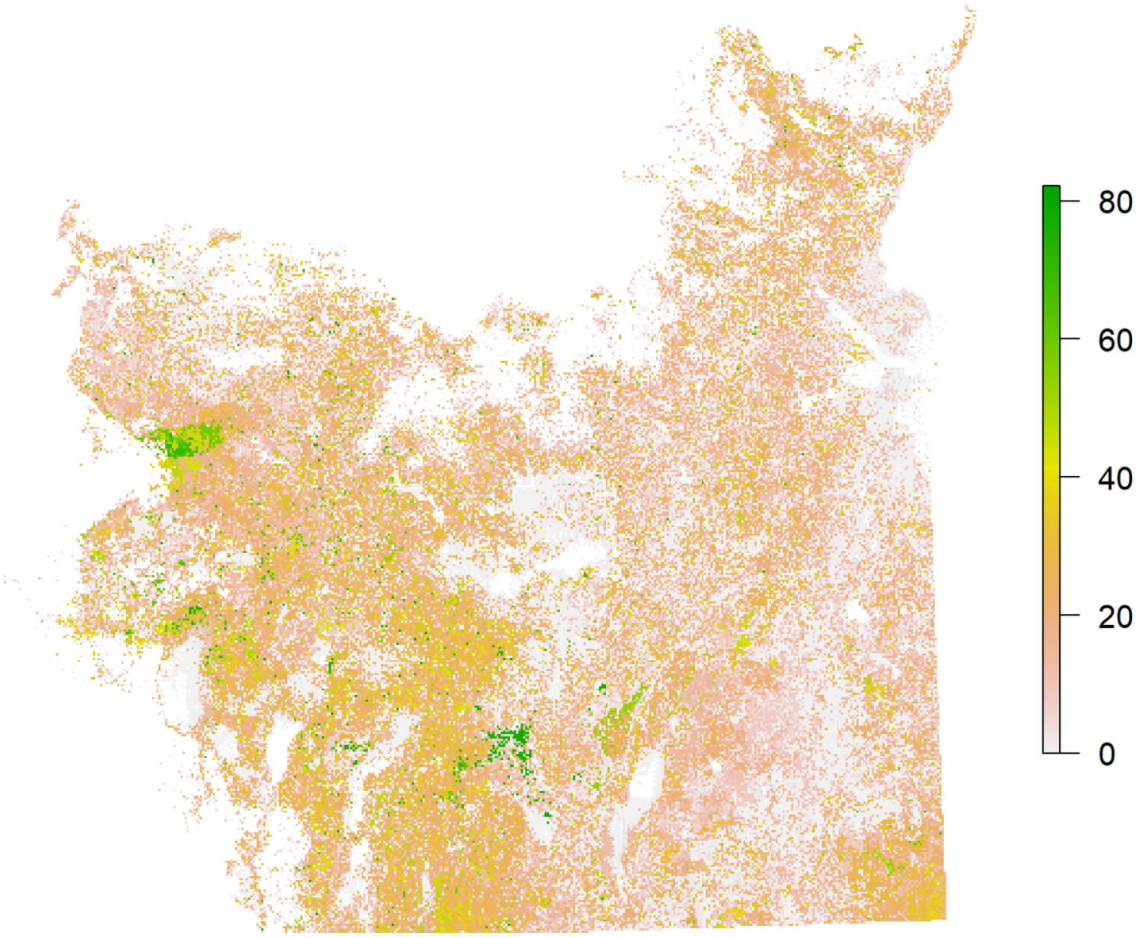
	Plot			***Hex1***			***Hex2***			***Hex3***	
	AC	AC_sys	AC_uns	AC	AC_sys	AC_uns	AC	AC_sys	AC_uns	AC	AC_sys	AC_uns
BareGround	-0.31	0.98	-0.29	0.59	0.93	0.67	0.73	0.91	0.82	0.73	0.90	0.83
ForbCov	-0.72	1.00	-0.72	0.54	0.99	0.55	0.57	0.99	0.58	0.63	0.94	0.69
GrassCov	-0.31	0.98	-0.29	0.66	0.96	0.70	0.66	0.95	0.71	0.80	0.95	0.85
NonvascularCov	-537.54	-6.53	-530.01	0.20	0.73	0.46	-2.35	0.75	-2.10	-1.48	0.93	-1.41
ShrubCov	-0.25	0.99	-0.24	0.69	0.96	0.74	0.74	0.94	0.80	0.73	0.94	0.79
TreeCov	0.29	0.99	0.29	0.88	0.99	0.88	0.92	0.99	0.93	0.87	0.99	0.89
TotalCov	-0.34	0.98	-0.31	0.64	0.94	0.70	0.66	0.93	0.74	0.79	0.92	0.87
NativeGrass	-0.60	0.98	-0.58	0.49	0.95	0.54	0.46	0.96	0.50	0.53	0.98	0.56
PristineGrass	-0.55	0.98	-0.53	0.53	0.96	0.57	0.57	0.96	0.61	0.56	0.98	0.58
ExoticAnnualGrass	-0.50	0.99	-0.48	0.59	0.96	0.64	0.80	0.96	0.85	0.73	0.93	0.80
EarlySeralShrub	-0.71	0.94	-0.65	0.55	0.89	0.66	0.53	0.92	0.61	0.83	0.90	0.94
NonNativePerennialGrass	-1.66	0.92	-1.59	0.32	0.82	0.51	0.61	0.94	0.66	0.49	0.80	0.69
BigSage	-0.39	1.00	-0.39	0.72	0.97	0.75	0.75	0.96	0.78	0.77	0.97	0.80
Low_Black_Silver_Sage	-0.45	0.99	-0.45	0.64	1.00	0.64	0.64	0.98	0.67	0.78	0.99	0.79
TallGrass	-0.68	0.98	-0.66	0.52	0.96	0.56	0.43	0.96	0.47	0.55	0.97	0.58
SageTridentata	-0.39	1.00	-0.39	0.72	0.97	0.75	0.75	0.96	0.78	0.77	0.97	0.80
SageShallowSoil	-0.44	0.99	-0.44	0.62	1.00	0.63	0.67	0.98	0.69	0.79	0.99	0.79
InvasiveAnnualGrass	-0.49	0.99	-0.47	0.65	0.96	0.69	0.83	0.96	0.87	0.71	0.92	0.79
DeepRootPerennialGrass	-0.81	0.99	-0.80	0.56	0.96	0.60	0.59	0.94	0.64	0.66	0.95	0.70
SeededGrass	-1.70	0.94	-1.63	0.35	0.83	0.51	0.54	0.93	0.61	0.57	0.88	0.69
SandbergBluegrass	-0.75	0.98	-0.73	0.50	0.97	0.53	0.54	0.96	0.57	0.58	0.98	0.60
AllJuniper	0.16	0.99	0.17	0.83	0.99	0.84	0.90	1.00	0.91	0.92	0.99	0.92
UndesirableAnnualForbs	-4.04	0.94	-3.98	0.25	1.00	0.25	0.39	0.99	0.40	0.34	0.93	0.41
AllSage	-0.28	0.99	-0.28	0.70	0.98	0.73	0.78	0.97	0.81	0.76	0.99	0.78
SageGrousePreferredForbs_High	-1.68	0.98	-1.67	0.03	1.00	0.03	0.41	0.99	0.42	0.34	0.92	0.42
SageGrousePreferredForbs_All	-0.91	0.99	-0.90	0.42	0.97	0.45	0.60	0.97	0.62	0.64	0.90	0.74
PerennialGrass	-0.57	0.98	-0.55	0.58	0.96	0.62	0.47	0.96	0.51	0.70	0.96	0.74
NoxiousWeeds	-1.74	1.00	-1.73	-0.13	0.92	-0.05	0.31	0.94	0.36	0.54	0.84	0.70
Conifer	0.20	1.00	0.20	0.88	0.99	0.88	0.88	1.00	0.89	0.88	0.98	0.90
WetlandIndicators	0.38	0.99	0.38	0.89	0.99	0.90	0.88	0.99	0.89	0.86	0.98	0.88

Appendix 5a: Map illustrations for variables.

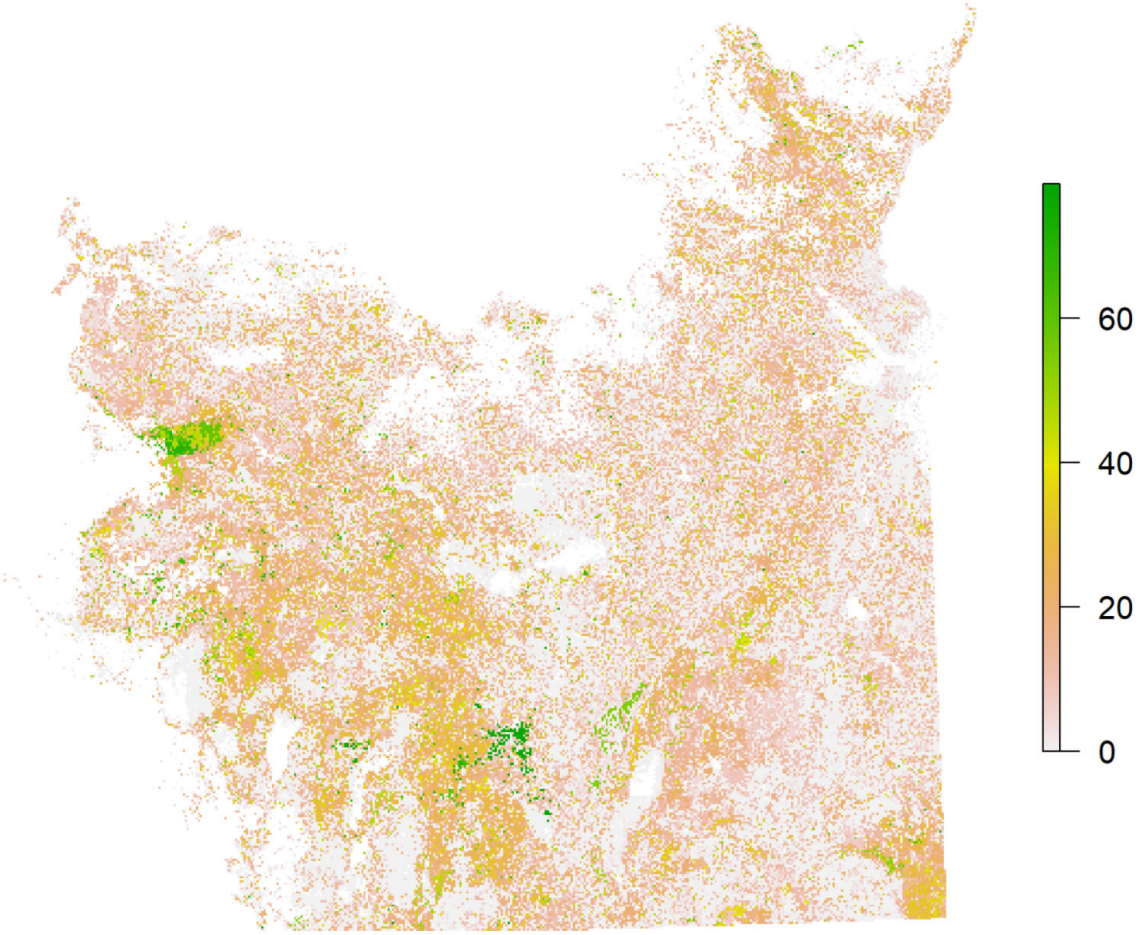


SageGrousePreferredForbs_All



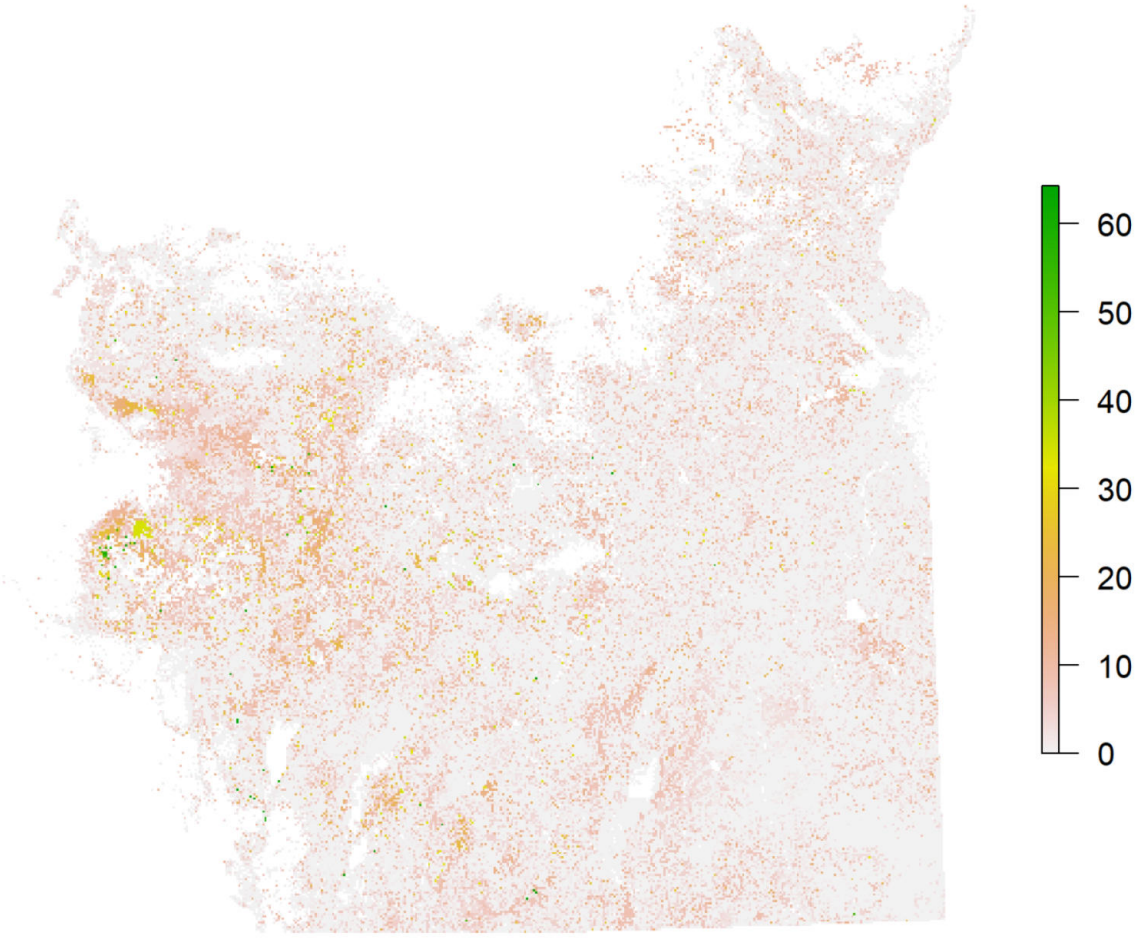

AllSage
80
60
40
20
0

SageTridentata

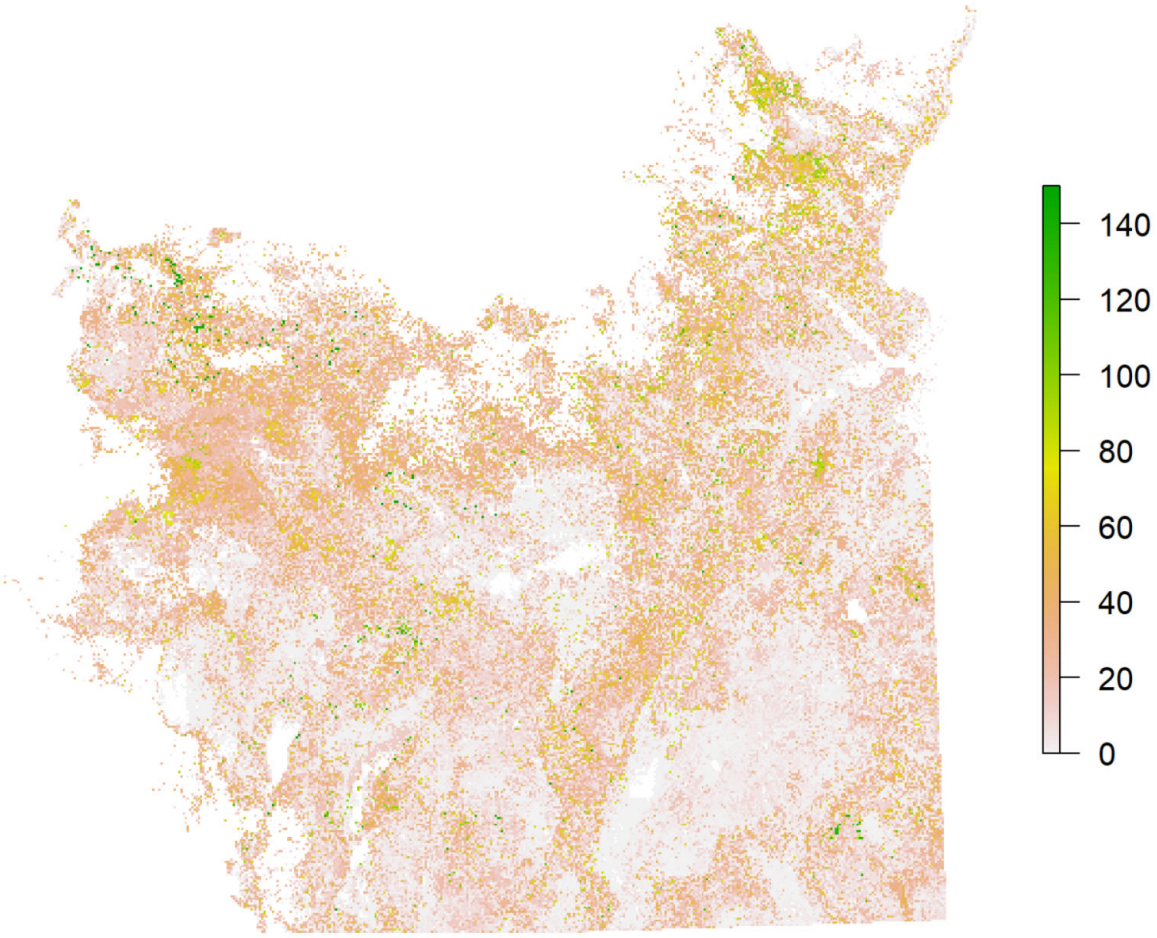


SageShallowSoil

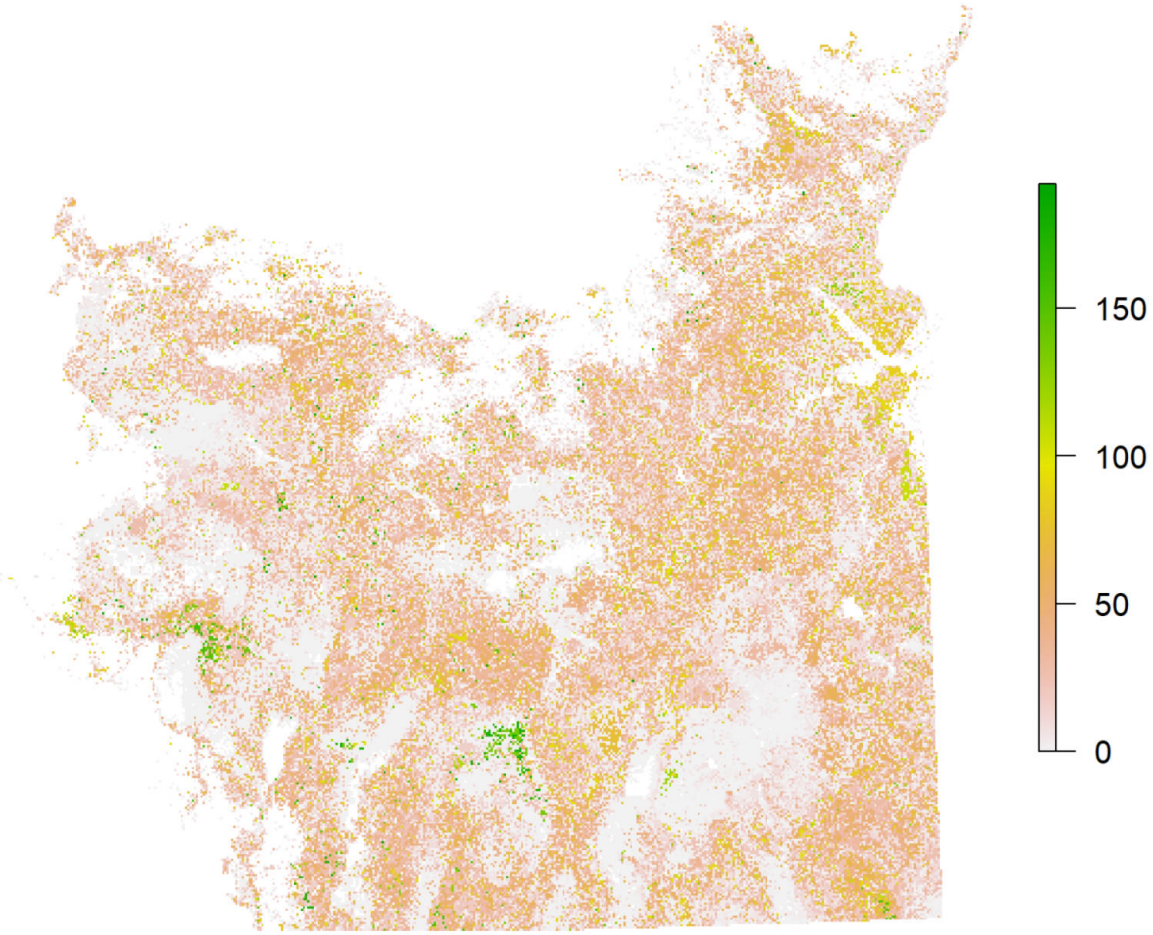
EarlySeralShrub

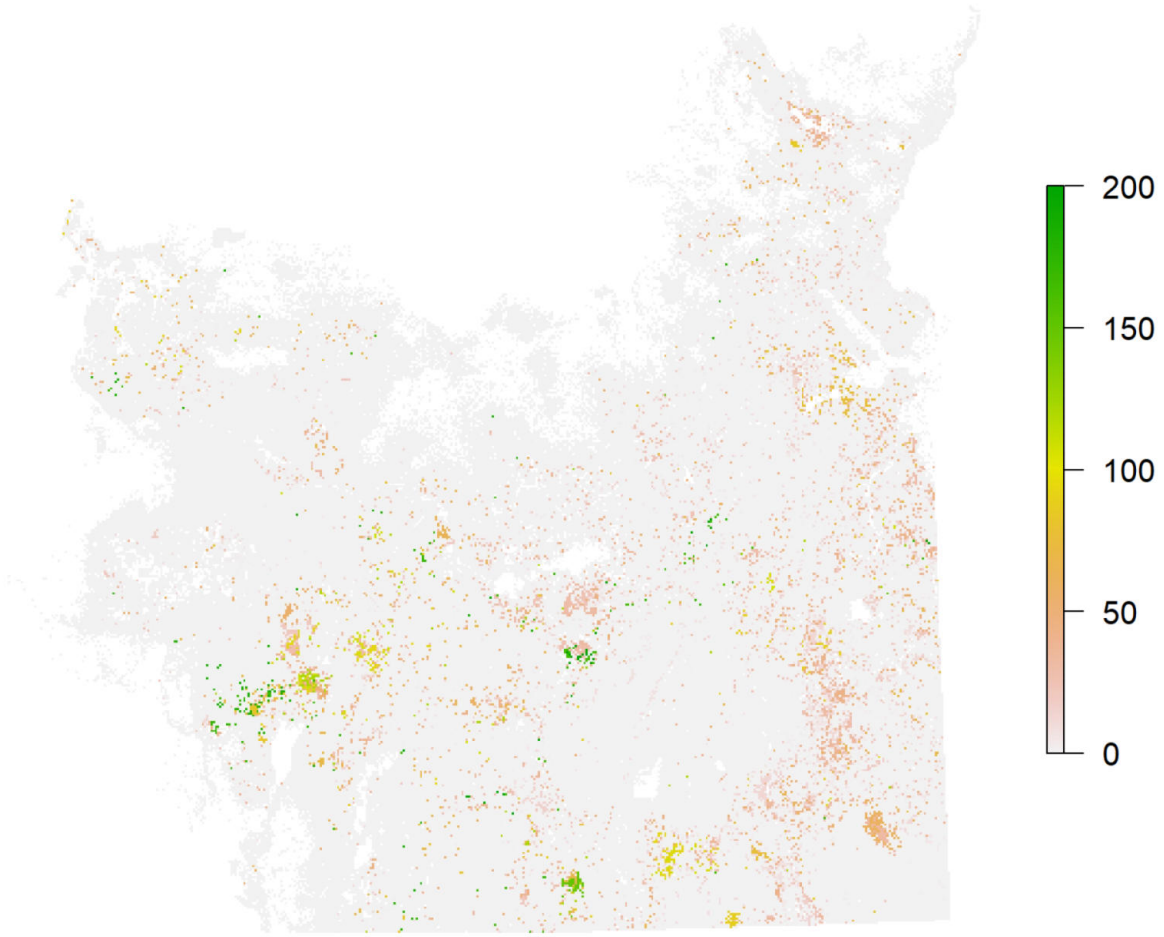


DeepRootPerennialGrass



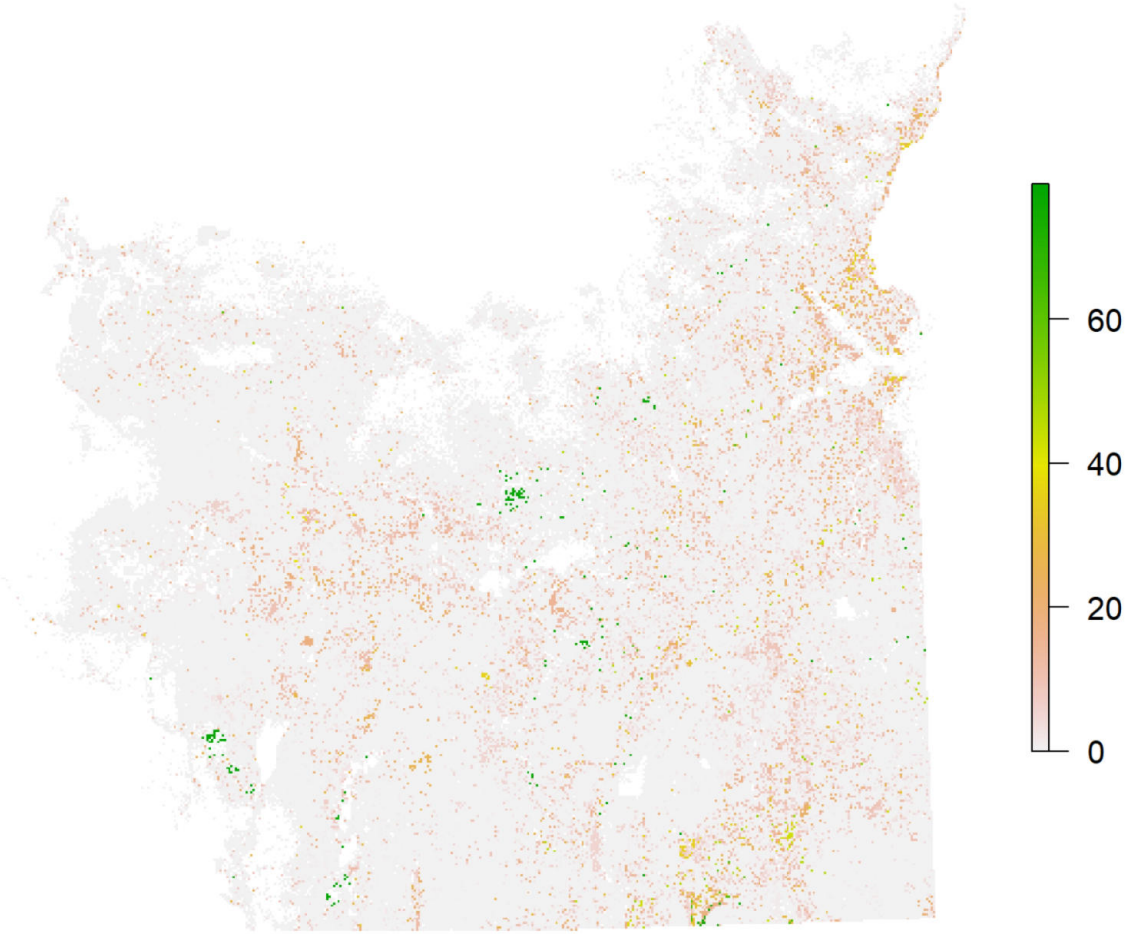
SandbergBluegrass

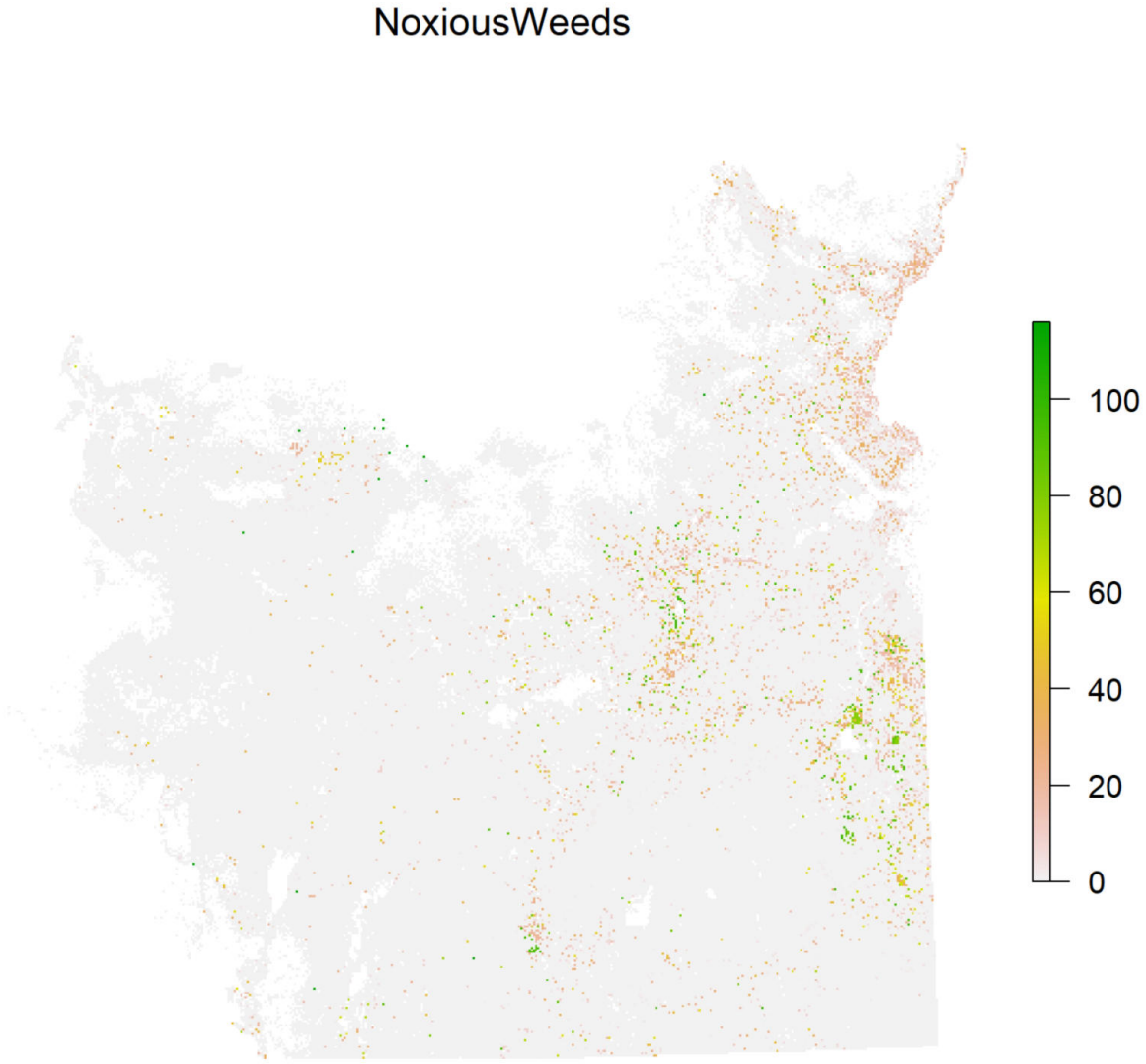


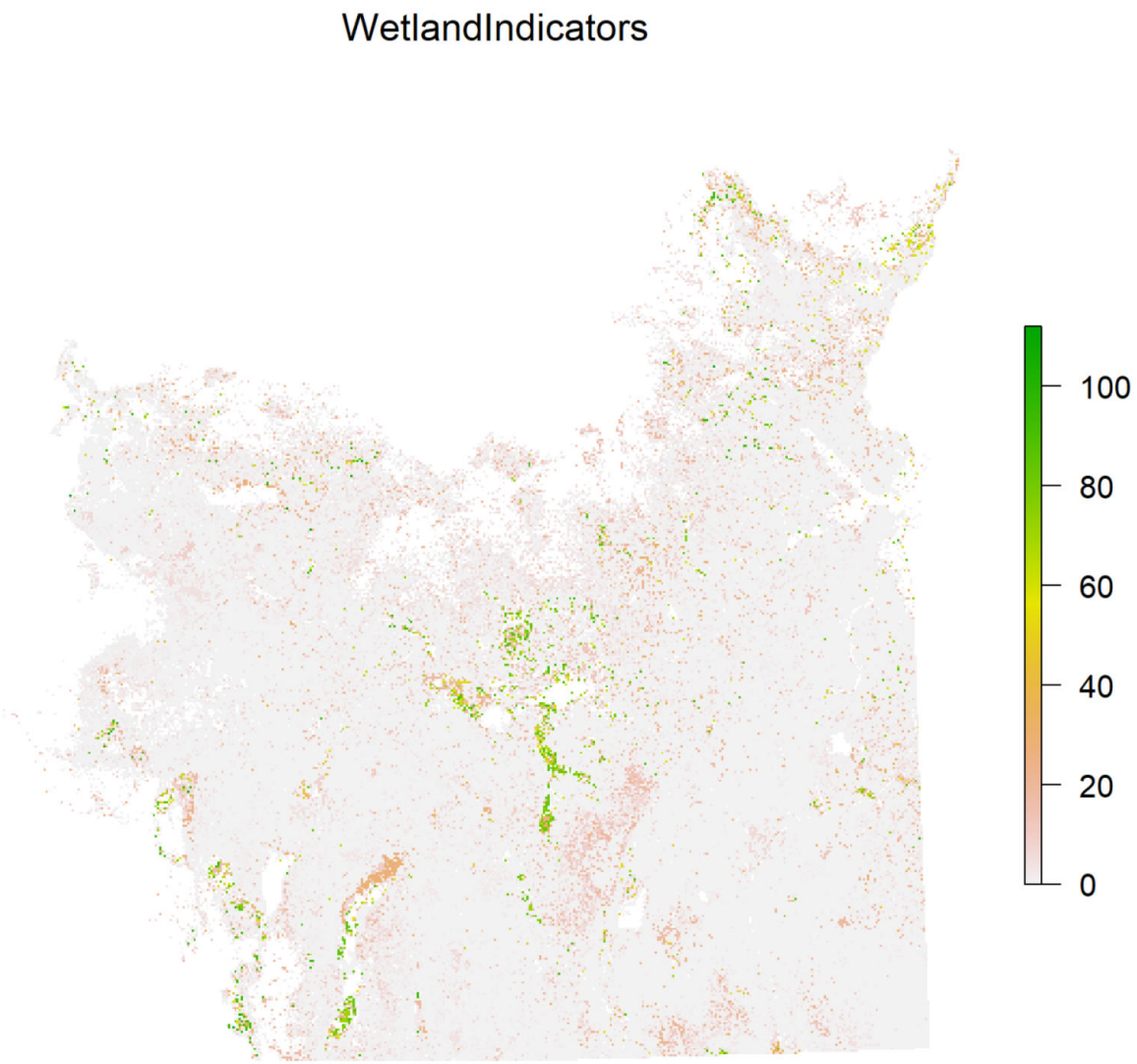

SeededGrass
200
150
100
50
0

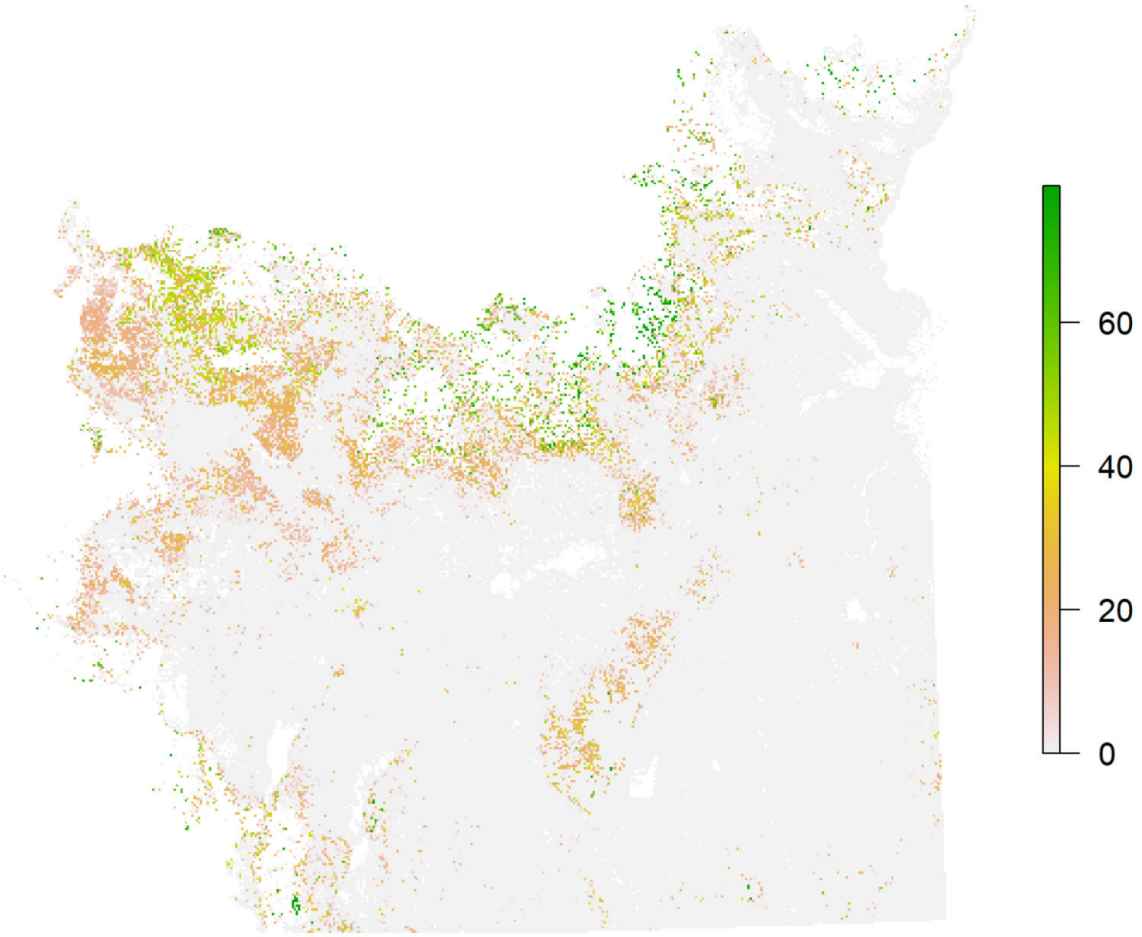

InvasiveAnnualGrass
150
100
50
0

UndesirableAnnualForbs



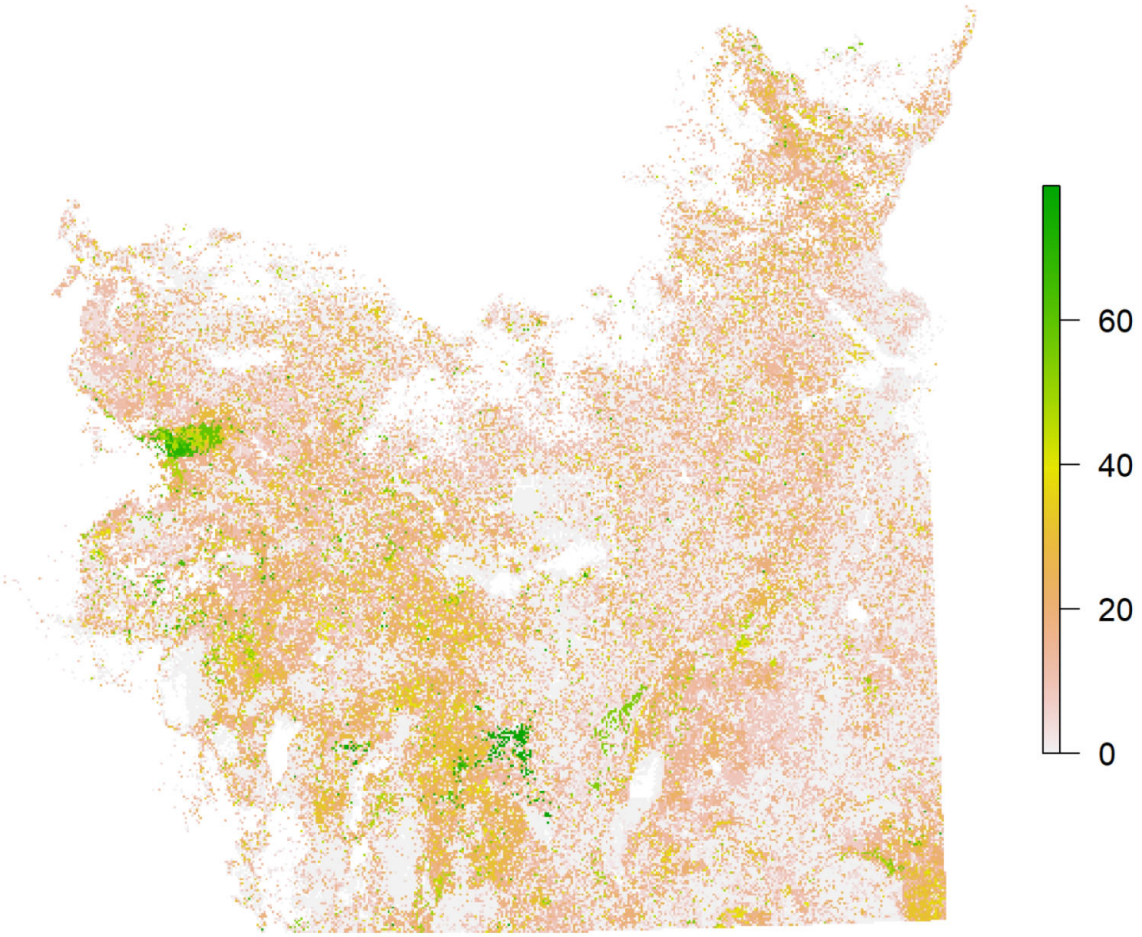

NoxiousWeeds
100
80
60
40
20
0

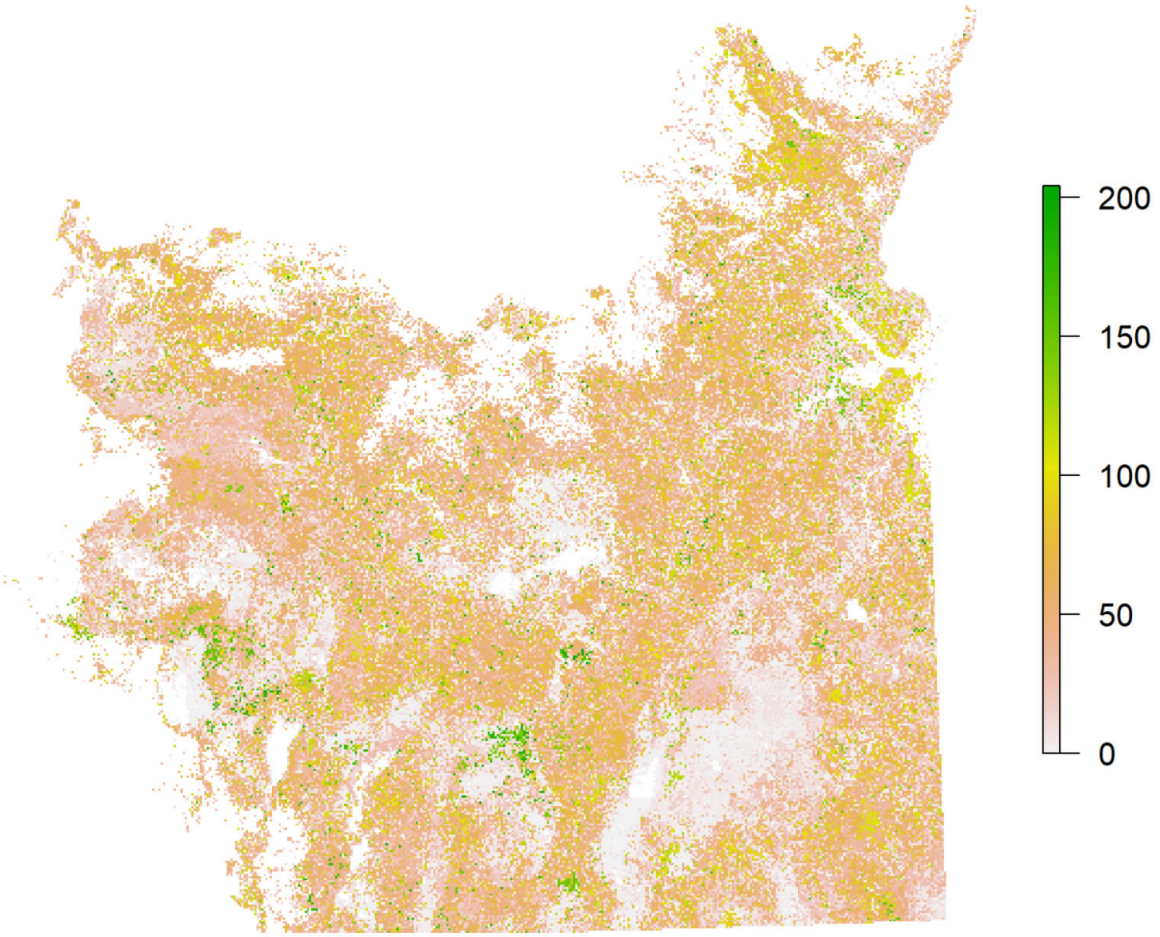

WetlandIndicators
100
80
60
40
20
0


Conifer
60
40
20
0

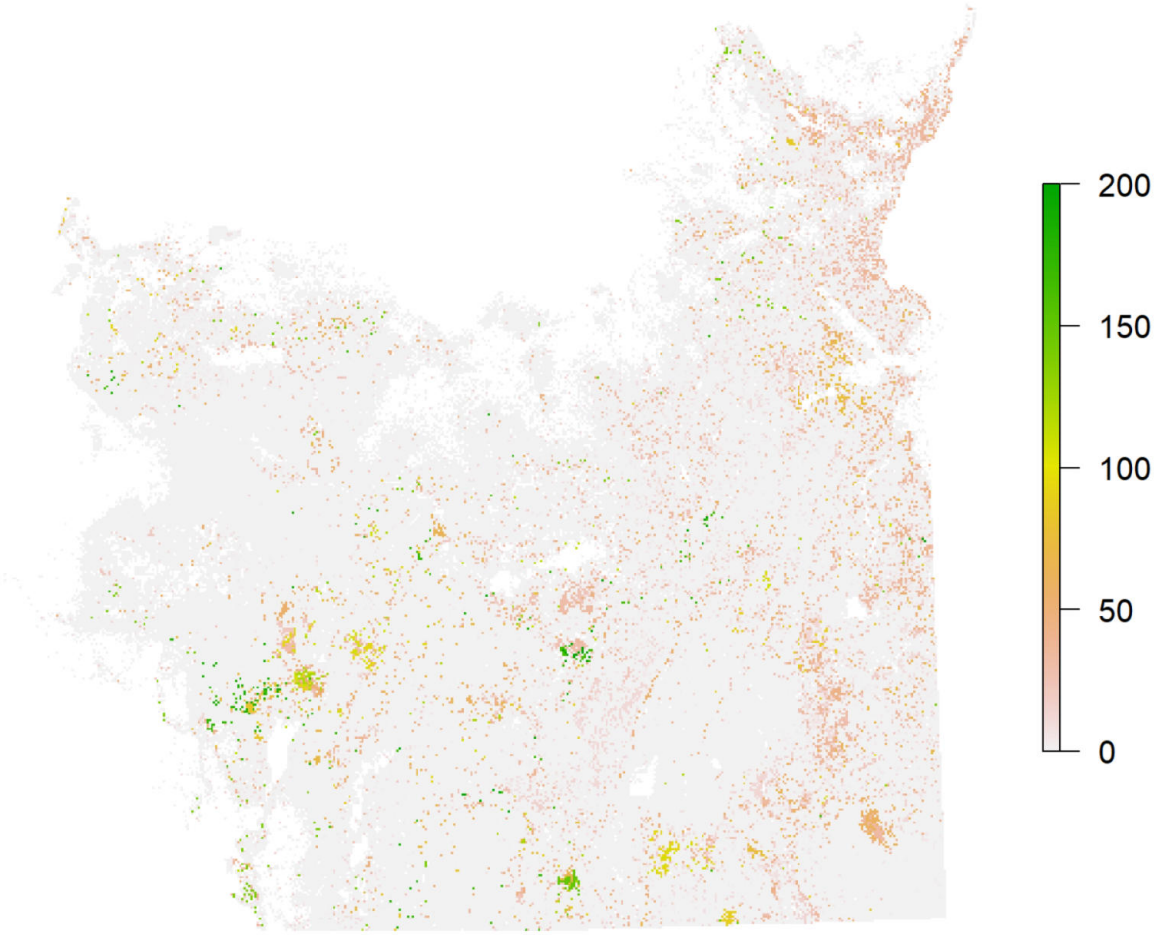
Low_Black_Silver_Sage

BigSage



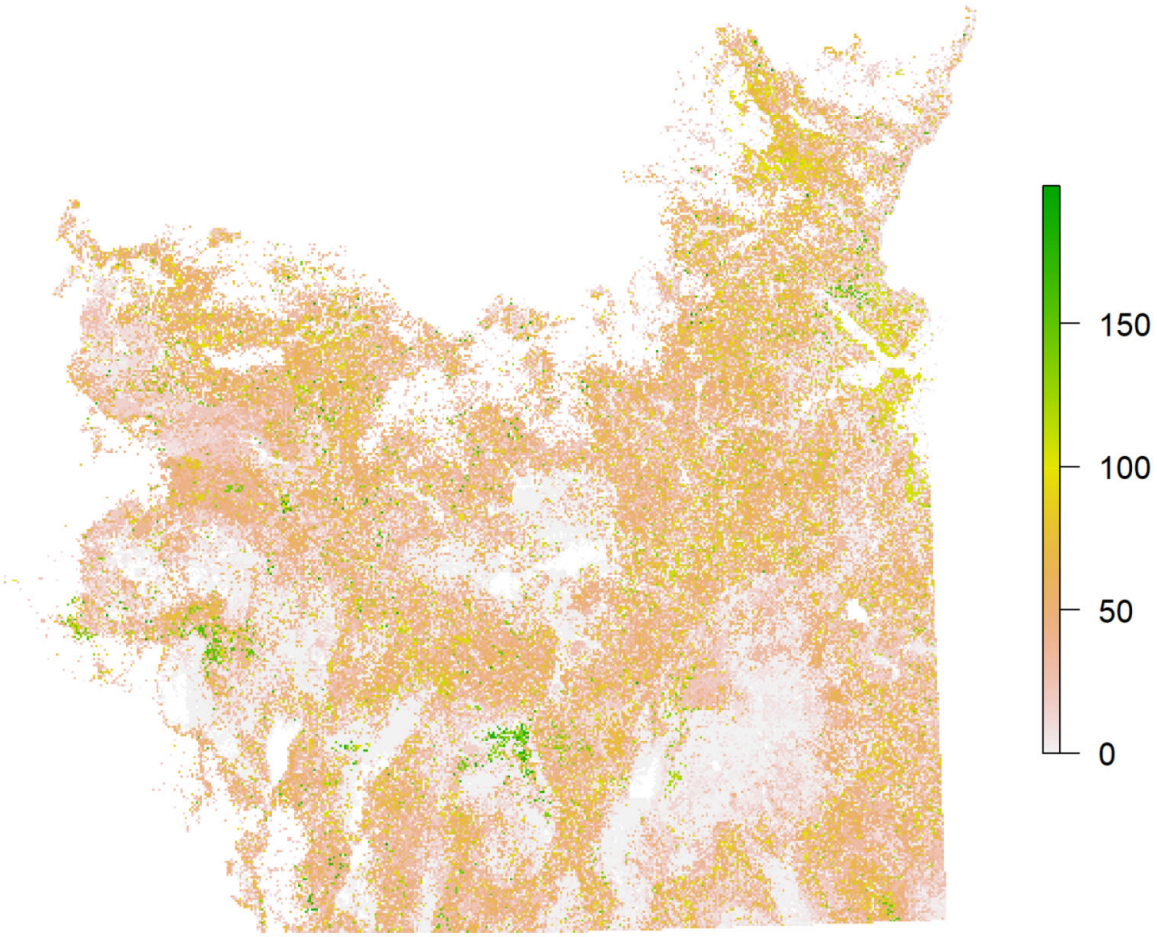

TallGrass
200
150
100
50
0

NonNativePerennialGrass



ExoticAnnualGrass

PristineGrass



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