PNNL-17209

Landscape Measures of Rangeland Condition in the Bureau of Land Management Owyhee Pilot Project: Shrub Canopy Mapping, Vegetation Classification, and Detection of Anomalous Land Areas

J. D. Tagestad
J. L. Downs

December 2007

Prepared for the U.S. Department of Interior
Bureau of Land Management
under a Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161
ph: (800) 553-6847
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

This document was printed on recycled paper.

PNNL-17209

Landscape Measures of Rangeland Condition in the BLM Owyhee Pilot Project: Shrub Canopy Mapping, Vegetation Classification, and Detection of Anomalous Land Areas

J. D. Tagestad
J. L. Downs

December 2007

Prepared for the U.S. Department of Interior
Bureau of Land Management
under a Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

In 2006, the Bureau of Land Management (BLM) Idaho office tasked the Pacific Northwest National Laboratory (PNNL) to collaborate in research being conducted under the BLM Owyhee Uplands Pilot Project to assess rangeland condition. The objective of this effort was to provide a sophisticated suite of data and tools to assist the BLM in evaluating the health and condition of the Owyhee Uplands study area. in this work, PNNL researchers focused on three technical tasks. The first involved enhancing existing algorithms to estimate shrub canopy cover in the lower Reynolds Creek watershed. The second task involved developing and applying a strategy to assess and compare three vegetation map products for the Idaho portion of the Owyhee study area. In the third task, PNNL developed techniques and data that can be used to identify areas exhibiting anomalous rangeland conditions such as exotic plants or excessive bare soil exposure.

Results of shrub canopy mapping for the lower Reynolds Creek watershed in Owyhee County in Idaho compare favorably with field validation data, except for predictions for areas with extremely rocky surfaces and areas with extremely dense shrub cover. The influence of rocky outcrops results in overestimation of shrubs in these areas, whereas extremely dense canopy cover sites (>50% canopy) were underestimated. Low sagebrush (*Artemisia arbuscula*) canopy cover is underestimated with the 1-m aerial photography used. The fit between independent, measured, and modeled data is $R^2 = 0.68$, with a root mean square error of 7.9% when rocky and extremely dense sites are ignored.

Vegetation map products for the Owyhee study area were compared and contrasted through a series of analyses. The LANDFIRE, SAGEMAP, and PNNL vegetation maps were acquired for the study area and were cross walked to the same set of vegetation categories. The map products were then compared directly to one another and assessed to determine accuracy using a set of 731 ground-truth observations. Comparisons of the three classifications by the potential vegetation types identified by the soil survey data for ecological sites for the sagebrush-dominated ecological site types in the study area indicate that the extent and distribution of vegetation classes dominated by big sagebrush (*Artemisia tridentata*) may be overestimated throughout the study area. Native perennial grasslands, invasive annual grasslands, and introduced grasslands may be underestimated. In general, the absolute accuracy of the PNNL product was slightly higher than the other two map products, but the agreement was less than 50% in all cases.

Analyses identifying areas of anomalous rangeland condition relied on soils survey ecological site data polygons and multidate Landsat information. The extreme spectral values derived from Landsat data for each ecological site type were used to identify areas of concern. We verified the anomalous area mapping by evaluating aerial photography and collecting ground-truth field data. Three potential rangeland issues were assessed using this technique: 1) juniper encroachment into sagebrush areas, 2) exotic annual grass infestation, and 3) excessive amounts of exposed soils. In general, results indicated that this method identifies areas with a high probability of exhibiting conditions of rangeland management concern.

These results and the landscape evaluation methods described here can be applied to further characterize the Owyhee study area to improve baseline and monitoring data for BLM's rangeland assessments. The shrub canopy cover mapping methods and the techniques for identifying anomalous areas provide promising tools to aid in assessing and monitoring the condition of BLM's western rangelands.

Abbreviations and Acronyms

ARS	Agricultural Research Service
BLM	Bureau of Land Management
GIS	geographic information system
GPS	Global Positioning System
LANDFIRE	Landscape Fire and Resource Management Planning Tools Project
m	meter
NAIP	National Agricultural Imagery Program
NDVI	Normalized Difference Vegetation Index
NVCS	National Vegetation Classification System
PNNL	Pacific Northwest National Laboratory
SAGEMAP	GIS database for sage grouse and shrub-steppe management in the intermountain west
SSURGO	Soil Survey Geographic (database)
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

Contents

Summary iii
Abbreviations and Acronyms v
1.0 Introduction 1.1
2.0 Quantifying Sagebrush Canopy Cover: Canopy Map Development Using Fine-Scale Imagery and Field Measurement 2.1
2.1 Methods 2.1
2.1.1 Field Data Collection 2.1
2.1.2 Image Data 2.3
2.1.3 Analysis of Image Texture 2.3
2.1.4 Regression Model for Field Plot Data and Texture Data 2.4
2.2 Results and Summary 2.5
3.0 Evaluation of Vegetation Classification Data Products 3.1
3.1 Evaluation Methods 3.2
3.2 Evaluation of Classifications 3.6
4.0 Anomaly Analysis 4.1
4.1 Juniper Anomalies 4.1
4.2 Bare Soil and Invasive Species Anomalies 4.4
5.0 References 5.1

Appendix A – Description of Final Vegetation Cover Types and Plant Codes Used in the PNNL Classification of Vegetation in the Snake River Study Area A.1
Appendix B – Evaluation of Accuracy of Vegetation Classifications Using Ground-Truth Data B.1

Figures

2.1 Example of a 10-m by 10-m Field Plot in a Wyoming Big Sagebrush Stand 2.2

2.2 Panchromatic Image of an Area of Variable Shrub Cover 2.3

2.3 Texture Image of an Area of Variable Shrub Cover.. 2.4

2.4 Relationship Between Image Texture and Field-Measured Shrub Canopy Cover 2.5

2.5 Results of Single Variable Nonlinear Model With All Data Shown for Measured vs. Modeled Shrub Canopy Cover 2.6

2.6 Results of Multivariable Linear Non-conditional Model with All Data Shown..................... 2.7

2.7 Results of Single Variable Nonlinear Model without Values from Rocky Plots or from Plots with Canopy >50% 2.7

2.8 Results of Multivariable Linear Non-conditional Model with Data from Rocky Plots and Canopy >50% Removed 2.8

2.9 Modeled Shrub Canopy Cover for Lower Reynolds Creek Watershed Using NAIP Imagery 2.10

3.1 Location and Extent of Overlap Between the PNNL Vegetation Classification and the Owyhee Study Area Boundaries 3.1

3.2 Example at Two Scales Showing Areas of Agreement and Disagreement Between the PNNL Vegetation Classification and SAGEMAP for the Owyhee Uplands...... 3.8

3.3 Proportion of Mapped Vegetation Classes in the PNNL Vegetation Classification 3.13

3.4 Proportion of Mapped Vegetation Classes in the SAGEMAP Vegetation Classification....... 3.14

3.5 Proportion of Mapped Vegetation Classes in the LANDFIRE Vegetation Classification 3.15

3.6 Potential Vegetation Types as Indicated by Dominant Ecological Site for Soil Survey Polygons in Majority of the Idaho Study Region 3.16

3.7 Comparison of the Three Vegetation Classification Map Products for the Ecological Sites Dominated by Big Sagebrush Community Types 3.17

3.8 Comparison of the Three Vegetation Classification Map Products for the Ecological Sites Dominated by Low Sagebrush Community Types 3.18

3.9 Comparison of the Three Vegetation Classification Map Products for the Ecological Sites Dominated by Mountain Sagebrush Community Types... 3.19

3.10 Comparison of the Three Vegetation Classification Map Products for the Ecological Sites Dominated by Intermountain Basins Mixed Salt Desert Scrub Community Types 3.20

4.1 Identifying Anomalous Pixels Within a Landscape Unit by Isolating NDVI Values at the Extreme of the Distribution for That Unit 4.1

4.2 Results of High NDVI Anomaly Mapping with Landsat and MODIS Imagery Showing Juniper Encroachment into a Shallow Claypan 12-16 Ecological Site 4.2

4.3 Number of Juniper Trees Identified Within in 30-m Radius of Random Points in High and Median NDVI Anomalies 4.4

4.4 High May NDVI Anomalies in Loamy 7-10 Ecological Site, Potentially Indicating Exotic Annual Weed Infestation 4.5

4.5 Measured Canopy Cover for Vegetation and Ground Condition Within Low, Median, and High Anomalous Areas Based on May 2006 NDVI Values 4.6

4.6 Measured Canopy Cover for Vegetation and Ground Condition Within Low, Median, and High Anomalous Areas Based on June 2006 Brightness Values 4.7

Tables

2.1 Number of Canopy Cover Plots Placed in Representative Plant Communities in the Reynolds Creek Experimental Watershed 2.2

3.1 Assignment of PNNL Vegetation Cover Types to the National Vegetation Classification System Used in the SAGEMAP Classification 3.3

3.2 Ecological Systems Classification Aggregated to General Vegetation Classes for the SAGEMAP Classification 3.5

3.3 LANDFIRE Vegetation Classification Aggregated to General Vegetation Classes 3.7

3.4 Overall Agreement Between Ground-Truth Data and Three Vegetation Classifications Based on Remotely Sensed Imagery 3.9

3.5. Comparison of Expected Vegetation Types to Actual Mapped Vegetation Types 3.10

3.6 Potential Dominant Vegetation for Soil Ecological Sites Found in the Owyhee Study Area 3.11

4.1 Summary of Juniper Count Samples in High and Median Normalized Difference Vegetation Index Anomalous Areas 4.3

4.2 Number of Field Sites in Big Sagebrush-Dominated Ecological Sites 4.5

1.0 Introduction

The Pacific Northwest National Laboratory (PNNL) has adapted and developed remote sensing tools to address the needs of the Bureau of Land Management (BLM) and other federal agencies in evaluating rangelands in the western United States. PNNL has tested and applied several of these methodologies to southern Idaho rangelands that will significantly improve mapping capabilities for these areas. Specific issues that can be addressed using remote sensing data include the type, distribution, and quality of vegetation cover on large landscape areas. Remote sensing imagery also can be used with ground data and spatial geographic information systems to monitor changes in the type and quality of vegetation.

This report provides preliminary information on three tasks that PNNL is conducting in support of the Owyhee Rangelands Pilot Project Section 2 describes PNNL research conducted to develop and apply site-specific data and algorithms to estimate shrub canopy cover in the Reynolds Creek watershed in southern Idaho—part of the Owyhee study area. In Section 3, the work completed to assess and compare three vegetation map products for the Idaho portion of the Owyhee study area is described. Section 4 documents techniques and data that can be used to identify areas with anomalous vegetation—those areas in which the vegetation cover type and distribution do not agree with the vegetation expected for a specific landscape unit based on soils, elevation and topography. Sources cited in this report are listed in Section 5. Appendixes provide descriptions of vegetation classes and plant codes used for the mapping projects.

2.0 Quantifying Sagebrush Canopy Cover: Canopy Map Development Using Fine-Scale Imagery and Field Measurement

The relative amount and distribution of shrub canopy cover in rangelands is critical information for land managers, fire modelers, wildlife biologists, and ecologists, but determining the spatial extent and relative quantity of shrublands across the landscape can be very difficult. The specific purpose of this study was to test automated methods for characterizing shrub canopy cover (distribution and density) using several types of fine-scale image data. PNNL assessed methods using shrub canopy field measurements with high-resolution land imagery to produce a map layer quantifying shrub canopy cover over a large area (>50,000 acres).

Developing capabilities to map shrub canopy cover in the shrub-steppe has been a challenge for the remote sensing community. Current methods for measuring shrub canopy cover require intensive field measurements. Sampling transects or plots for canopy cover can provide useful data from discrete locations but is insufficient for developing a landscape-level understanding of shrub cover and distribution. In addition, the patterns of shrub canopy cover and distribution are more easily discerned from above than on the ground. Large area canopy analysis generally has required field data, local knowledge, and photo interpretation. In contrast, PNNL used limited field data with high-resolution aerial or satellite imagery and geographic information system (GIS) technology to develop and apply methods to create fine-scale shrub canopy maps.

2.1 Methods

The main study area for collecting data for developing the canopy cover model was within the Reynolds Creek Experimental Watershed in Owyhee County in southern Idaho. The Reynolds Creek Experimental Watershed is operated through the U.S. Department of Agriculture-Agricultural Research Service Northwest Watershed Research Center in Boise, Idaho. Field Data

2.1.1 Field Data Collection

To measure shrub canopy cover, PNNL researchers located field plots within the Reynolds Creek watershed using a stratified approach to reflect the variability in shrub canopy cover and plant associations across the study area (Table 2.1). Field data for canopy model development (June 2006) and verification of results (June 2007) were collected using the same methods.

Plots were placed in selected cover types that represented the local variation in canopy, from sparse to dense cover. Field plots were laid out with one axis oriented to true north. Within each 10-m- x 10-m-square plot, PNNL measured shrub height, the widest canopy diameter, and the canopy diameter perpendicular to the first. We recorded information to the nearest decimeter for each shrub rooted within the plot. Ocular estimates of the percentage of live foliar canopy and percentage of dead foliar canopy also were recorded. The canopy cover was calculated by summing the oval areas based on perpendicular diameters for each rooted shrub and any canopy of shrubs not rooted in the plot that extended over the boundary into the plot. The total is expressed as a proportion of the 100-m^2 plot area (percentage) and adjusted for the amount of dead foliar canopy. Digital photographs were taken of the plot from the southeast corner to the west, the northeast corner to the west, and diagonally from the southeast corner (Figure 2.1). Coordinate locations for each corner of the plot were recorded using a global positioning system (GPS) receiver, and coordinate data were differentially corrected. The field data polygons were converted to digital GIS files using the differentially-corrected GPS corner points.

Table 2.1. Number of Canopy Cover Plots Placed in Representative Plant Communities in the Reynolds Creek Experimental Watershed

Plant Community	2006	2007
Greasewood	3	3
Low Sage	6	4
Mixed Big Sage	5	1
Mountain Big Sage	8	8
Mountain sage/Mountain shrub	3	4
Salt Desert Shrub	5	5
Seeding	1	1
Wyoming Big Sage	9	11
	40	37

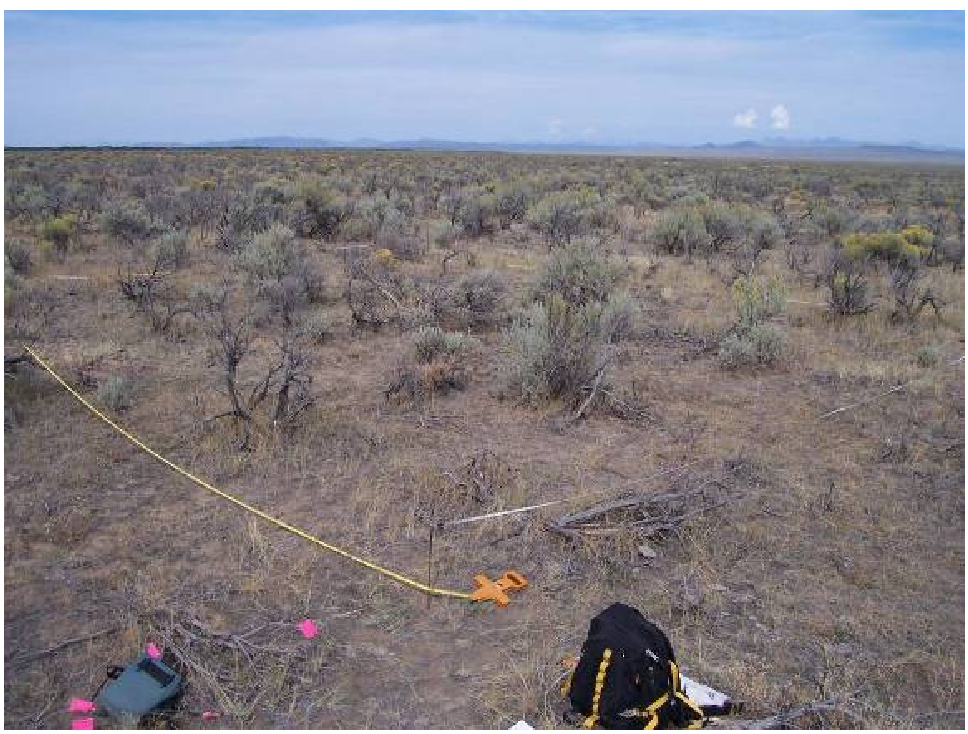

Figure 2.1. Example of a 10-m by 10-m Field Plot in a Wyoming Big Sagebrush Stand

2.1.2 Image Data

The fine-scale image data we used for this study was the 1-m National Agricultural Imagery Program (NAIP) data. The NAIP is designed to acquire 1-m- or 2-m-resolution, natural-color, and/or color infrared images at peak growing season for a region. Imagery is acquired by flights taking place in a grid pattern taking photographs at specific intervals. The imagery is corrected against U.S. Geological Survey (USGS) digital ortho quarter quads (DOQQs) to an absolute accuracy of 5 m for the 1-m product or 10 m for the 2-m product. The image products come in two basic formats. The Compressed County Mosaic product is a mosaic generated by inputting all the individual image tiles for an entire county. This product is stored in MrSID (Multi-Resolution Seamless Image Database technology is patented and developed by LizardTech, Inc. of Seattle) compressed format with a compression ratio of 15:1 for the 2005 and 2006 data or 50:1 for the earlier products. The individual DOQQ areas (3.75 x 3.75 minute plus a 300-meter buffer) are distributed in GeoTIFF format. For this study, we relied on the GeoTIFF product to provide the fine spatial detail to our algorithm because the MrSID compression affects the apparent image texture.

2.1.3 Analysis of Image Texture

Texture, as it applies to image interpretation, is defined as the "visual impression of coarseness or smoothness caused by the variability or uniformity of image tone or color." Figure 2.2 shows an image example with low, medium, and high texture. Our texture methods use the apparent roughness in the visible surface due to drastic changes in brightness between adjacent pixels.

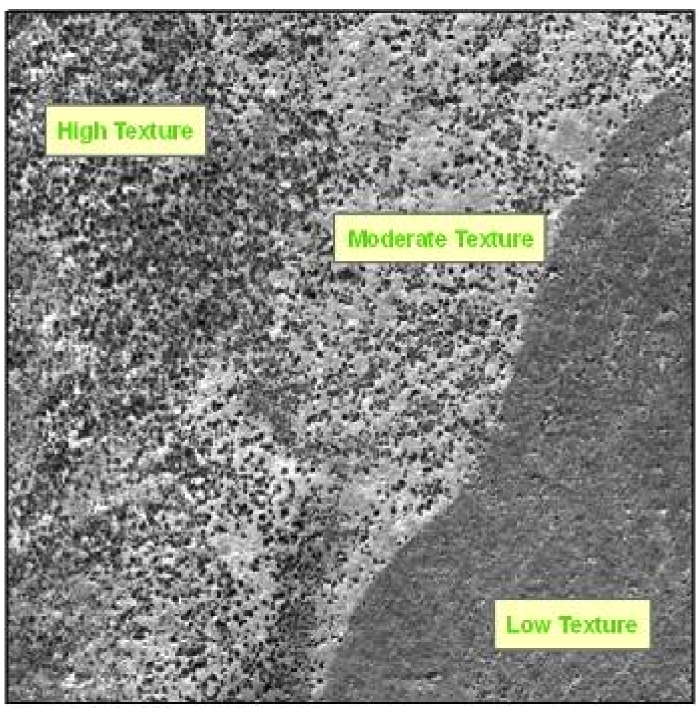

Figure 2.2. Panchromatic Image of an Area of Variable Shrub Cover

Our approach builds on a PNNL-developed texture ratio technique, which has proven useful for road extraction. The analysis technique capitalizes on the mutual information between results of smoothing the image with low-pass filters of two different sizes (for example, 3 x 3 pixels and 5 x 5 pixels). The low-pass filter is often used to smooth an image because the center pixel is replaced with the average value of the pixels around it. The first filter computes the average pixel value for a 3 x 3 window. The second filter computes the average pixel value for a 5 x 5 window.

Although the two low-pass filters act to smooth the image, the information we require is contained in the ratio of the averages for the filters of two different sizes. The texture ratio is calculated as follows:

$$\text{Texture Ratio} = \text{Average of filter 1}/\text{Average of filter 2}$$

The texture model reduces the color signal in the image and maximizes the texture signal. Figure 2.3 shows the result of the texture ratio model. Note the minimization of background color between the northwest and southeast corner of the image when compared to Figure 2.2.

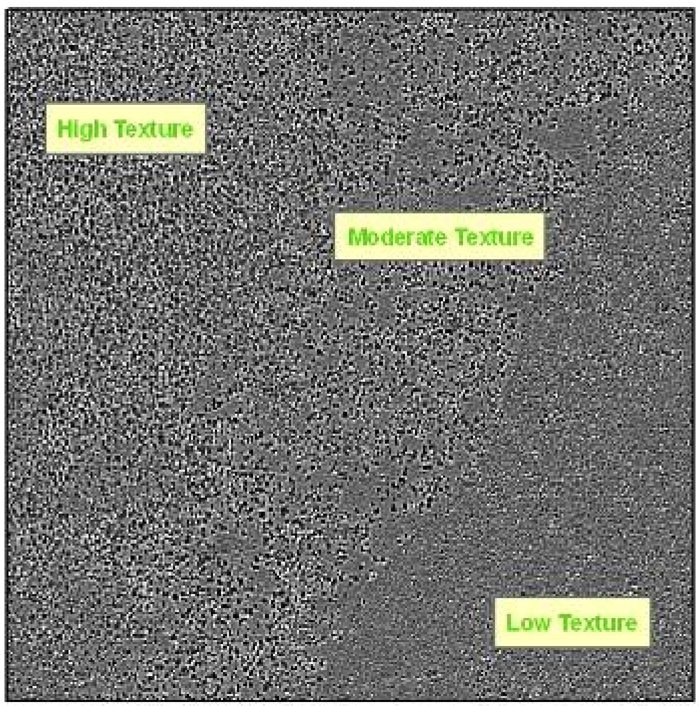

Figure 2.3. Texture Image of an Area of Variable Shrub Cover

2.1.4 Regression Model for Field Plot Data and Texture Data

The field-measured shrub canopy cover in each plot was compared to the corresponding texture ratio values for pixels representing that plot to develop a simple linear regression relationship between shrub canopy cover and image texture (Figure 2.4). Expert judgment was used to remove the outliers from the initial regression model.

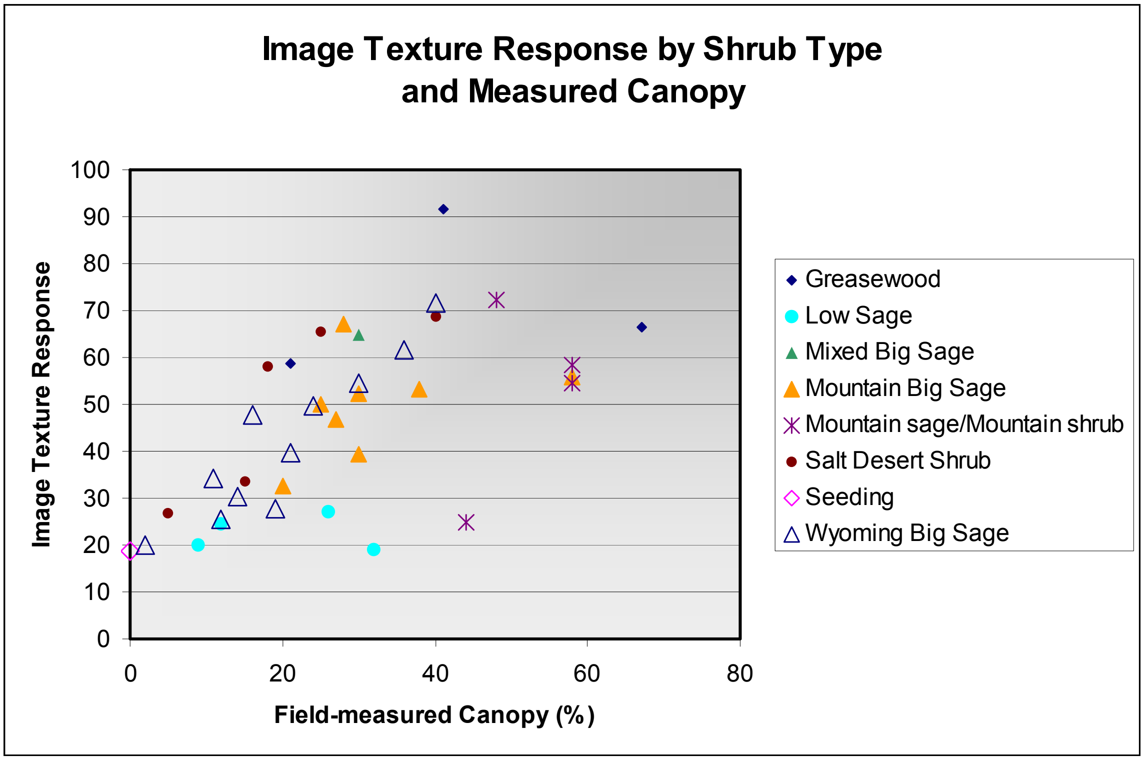

Figure 2.4. Relationship Between Image Texture and Field-Measured Shrub Canopy Cover

We evaluated a number of types of regression models including nonlinear methods and multiple regression using landscape variables and moderate-scale spectral data (Landsat). The best statistical fit model for this data set is composed of two regressions fit to different portions of the data set. This is expressed as a conditional GIS model with two simple linear regression equations: the lowest image texture values (lowest shrub canopy cover) are best fit by an equation with a slightly steeper slope than the best fit equation for moderate and high texture values associated with higher shrub canopy cover values. This conditional regression approach was then applied using the texture image layer across the study area to predict shrub canopy cover and produce a spatial data layer depicting shrub canopy cover.

2.2 Results and Summary

Shrub canopy cover data for 45 field validation plots in the Reynolds Creek watershed were summarized by plot to compare to the modeled shrub cover results for that plot area using four different models: 1) the single-variable (NAIP texture), nonlinear, conditional model; 2) single-variable (NAIP texture), conditional model; 3) multivariable, conditional model; and 4) multivariable, nonconditional model. The multivariable models included NAIP texture, NAIP color, Landsat brightness, Landsat NDVI, digital elevation model (DEM) elevation, and DEM landscape position. The results were compared against the field data summarized to indicate 1) all canopy (live and dead) of all heights, 2) live canopy of all heights, 3) all canopy greater than 0.5 m in height, and 4) live canopy with height greater than 0.5 m.

The best results were achieved for the modeled shrub canopy compared to the shrub canopy for all shrub cover of all heights, which implies that the model maps total canopy and not just live canopy. The approach that provided the best results with the least prediction error was the single-variable, nonlinear model based on the NAIP band-2 image texture. The fit between independent, measured, and modeled data is R^2 = 0.68, with a root mean square error (RMSE) of 7.9% when rocky and extremely dense sites are ignored. If we look only at the canopy from 0–20%, the RMSE drops to 4.3%. This indicates that the mapping in the more sparse canopy is more accurate than in the very dense canopy.

The best multiple-variable model was a simple linear nonconditional model. The relationship between modeled and measured canopy was improved when we removed the data from six extremely rocky plots and two plots with canopy greater than 50%. Scatter plots of the results from these two models, with all the data and data with the eight plots removed, are shown in Figures 2.5 through 2.8.

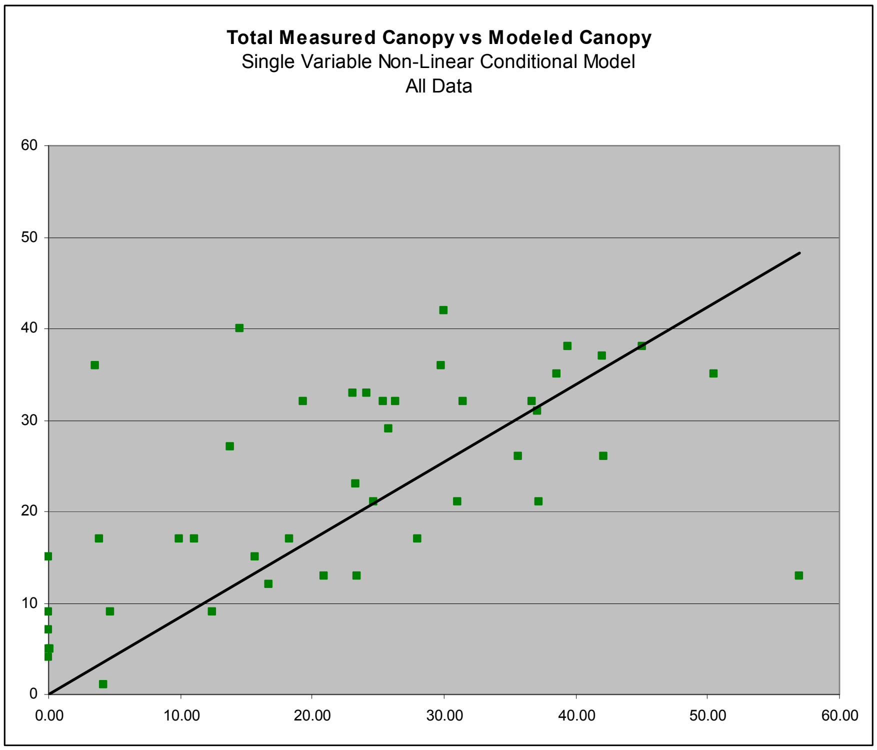

Figure 2.5. Results of Single Variable Nonlinear Model With All Data Shown for Measured vs. Modeled Shrub Canopy Cover

General observations:

- Both single and multi-variable models over-estimate shrub canopy cover in rocky areas. We developed a mask for rocky areas (spatial data layer) to identify these potential problem areas. A separate regression would need to be developed and applied to obtain better estimates of shrub canopy cover in these rock outcrop areas.

- The single variable model seems to over estimate canopy in the very sparse areas. This could likely be solved pretty easily by merging the models or using a smaller dispersion filter.

- Both types of models have significant scatter in the 15-30% cover class, with the multiple variable model showing a wider range than the single variable model.

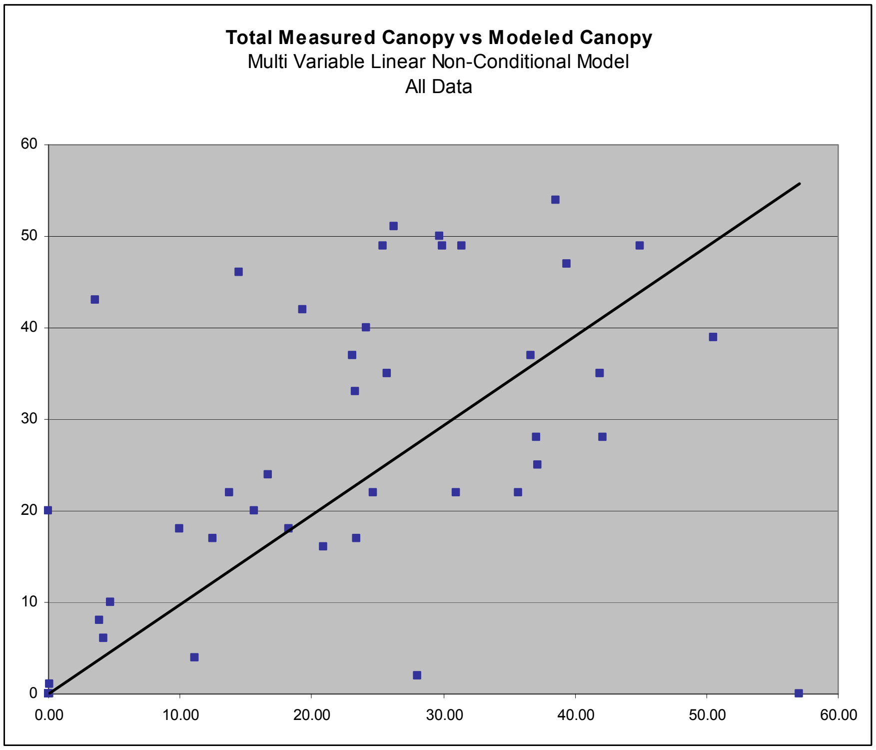

Figure 2.6. Results of Multivariable Linear Non-conditional Model with All Data Shown

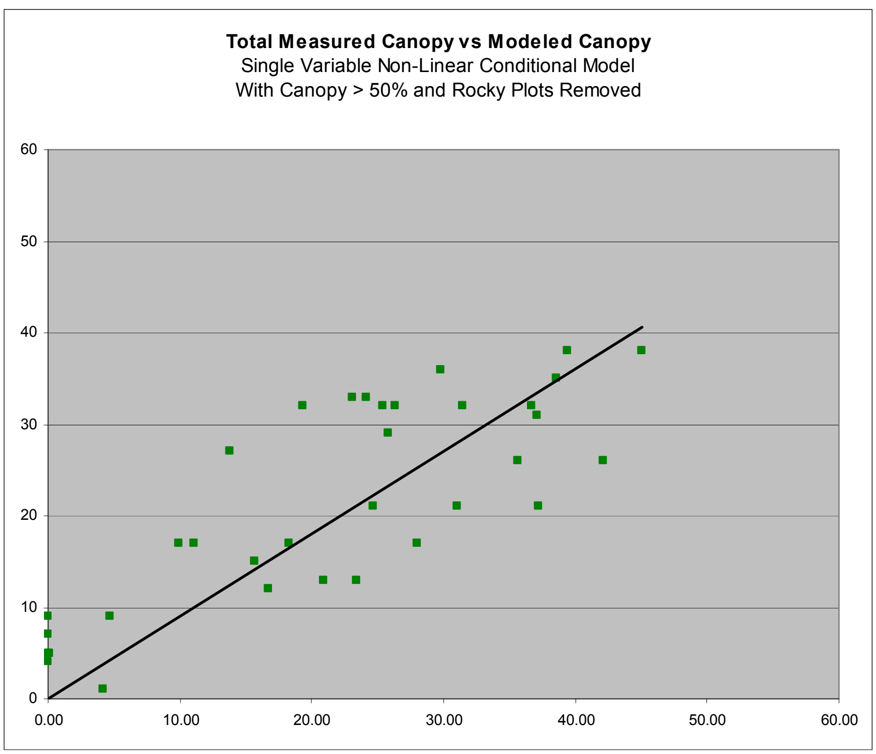

Figure 2.7. Results of Single Variable Nonlinear Model without Values from Rocky Plots or from Plots with Canopy >50%

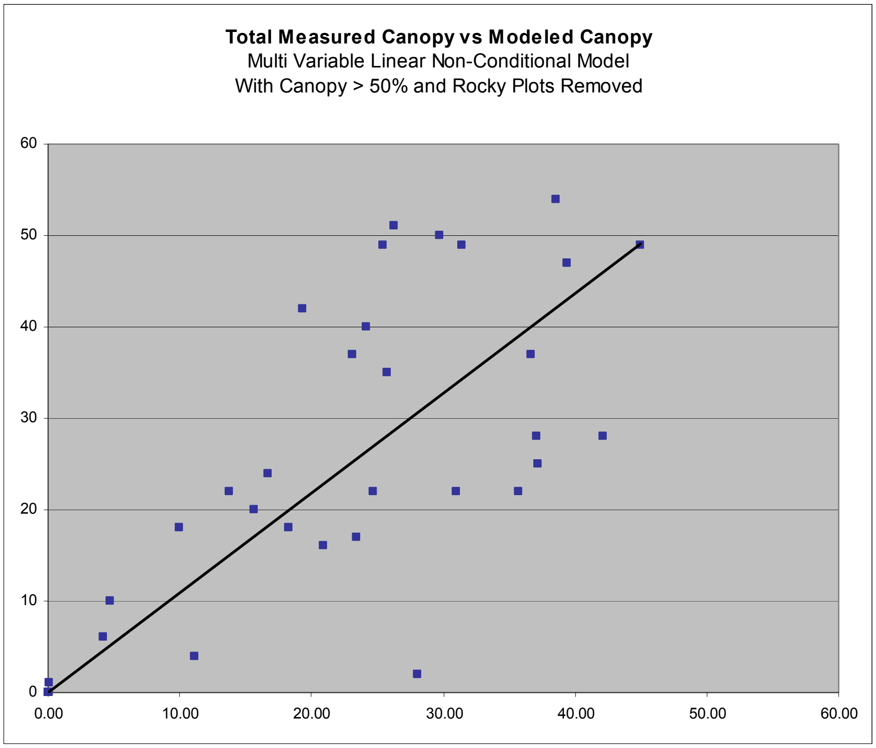

Figure 2.8. Results of Multivariable Linear Non-conditional Model with Data from Rocky Plots and Canopy >50% Removed

- Using the NAIP imagery with 1-m resolution, the texture signature disappears in areas of very dense, closed-canopy shrub and the canopy in these areas is generally underestimated. This effect would likely be reduced with the use of higher resolution imagery.

- Using the NAIP imagery with 1-m resolution, low sagebrush does not provide sufficient texture signal to be included in the model.

- Though the scatter around the best fit line is notable, neither the single nor multiple variable model results in any apparent bias across all canopy classes. Modeled canopy cover from 0-20% appears to be slightly overestimated by both models. Modeled canopy from 20-50% scatters fairly equally about the best fit line.

In general, the results are quite similar between the two model types (single variable and multiple variables). There is a general tendency of the model to overestimate shrub canopy when the image texture is influenced by objects that throw a shadow large enough to affect the pixel response (rocky areas in particular). To address this problem, we developed a mask (spatial data layer) for the rocky area that can provide an indication of potential problem areas—or actually be used to mask out those areas from consideration. Further investigation would be needed to determine the relationship between image texture and actual shrub canopy for these rock outcrop areas.

The multiple regression model uses landscape variables and Landsat spectral data to attempt to account for potentially significant variations which are not visible in the NAIP imagery. The results indicate that the gains of incorporating landscape and spectral data are rather minimal and mostly observed in very sparse canopy areas. The statistical output from the initial model development suggested that same thing. However, our initial model development data set did not include information on rock outcrops, and additional data representing shrub cover in rocky areas could be used to improve and/or develop a separate relationship for estimating shrub cover in such areas. Future efforts should be focused on improving the model for these areas.

It is apparent from this analysis that the application of the current algorithm is not without error. Although we collected a fairly large number of training and validation plots, the amount of data we have may not be sufficient for an area as complex as our study area. The method does provide a quantitative method to develop fine-resolution spatial canopy cover maps over extremely large areas (Figure 2.9). The amount of error in the different types of models might be reduced slightly by constructing individual models for different vegetation types. This approach would be dependent on acquiring a reasonably accurate vegetation classification for the area of interest in addition to developing adequate field data for each vegetation type to construct the model and verify results.

The accuracy of such maps will likely depend on how the data are to be used. If the user attempts to use the map to locate very small areas with shrub canopy cover of a certain range (10-20%), there is some chance that the map will not perfectly guide such an analysis. For instance, if you look at the a canopy values in the 10-20% cover class outside of the rocky areas using the results from the single variable non-linear model, you will see that two out of the eight plots with a measured value of 10-20% mapped as higher than 25% (Figure 2.7). If, however, a range ecologist was to use the map to determine the distribution and amount of canopy in a project area of 100-1000 acres, the map would be an excellent representation of reality.

The current approach requires sparse field data for application. However, we have shown that without modification, we can apply the model to data of similar pixel size, in similar ecotype and obtain reasonable results. The technique is quite effective for mapping shrub canopy up to 50%.

We have developed a simple and effective technique to map shrub canopy in various shrubland ecotypes using high-resolution aerial or satellite imagery and sparse field data. Due to the nature of the texture ratio response, these techniques are applicable without image stratification or segmentation. This technique will allow land management agencies to rapidly assess shrub cover changes in arid lands. These techniques are applicable to many different arid and semi-arid shrubland environments.

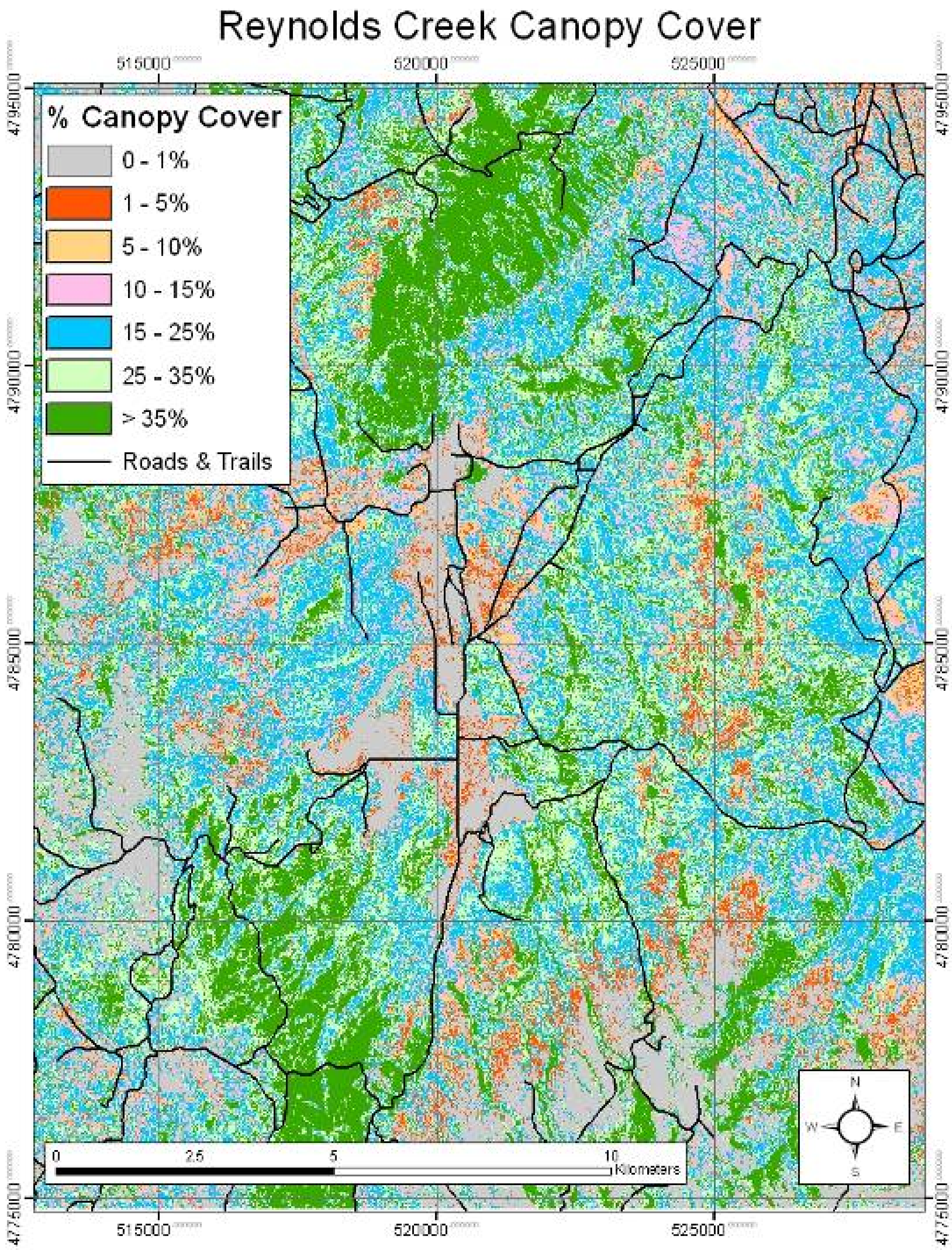

Figure 2.9. Modeled Shrub Canopy Cover for Lower Reynolds Creek Watershed Using NAIP Imagery

3.0 Evaluation of Vegetation Classification Data Products

Many of the components of the Owyhee Uplands project are focused on current status and trend of existing vegetation. Because of this emphasis on existing vegetation, the quality and consistency of the vegetation map layer used as a base layer is critical for acquiring and interpreting rangeland monitoring data. A recent vegetation and fuels cover type mapping effort by PNNL overlaps the Idaho portion of the Owyhee Uplands where the USGS recently completed the SAGEMAP project (http://sagemap.wr.usgs.gov/SAGEMAP_home.htm) (Figure 3.1). In addition to the SAGEMAP vegetation classification, the LANDFIRE project (Landscape Fire and Resource Management Planning Tools; http://www.landfire.gov/index.php) has also recently completed a vegetation and fuels classification for the region. The BLM has requested that PNNL evaluate and analyze available data and map sets to ensure that the best available vegetation information is used for rangeland monitoring on the Owyhee Uplands study area.

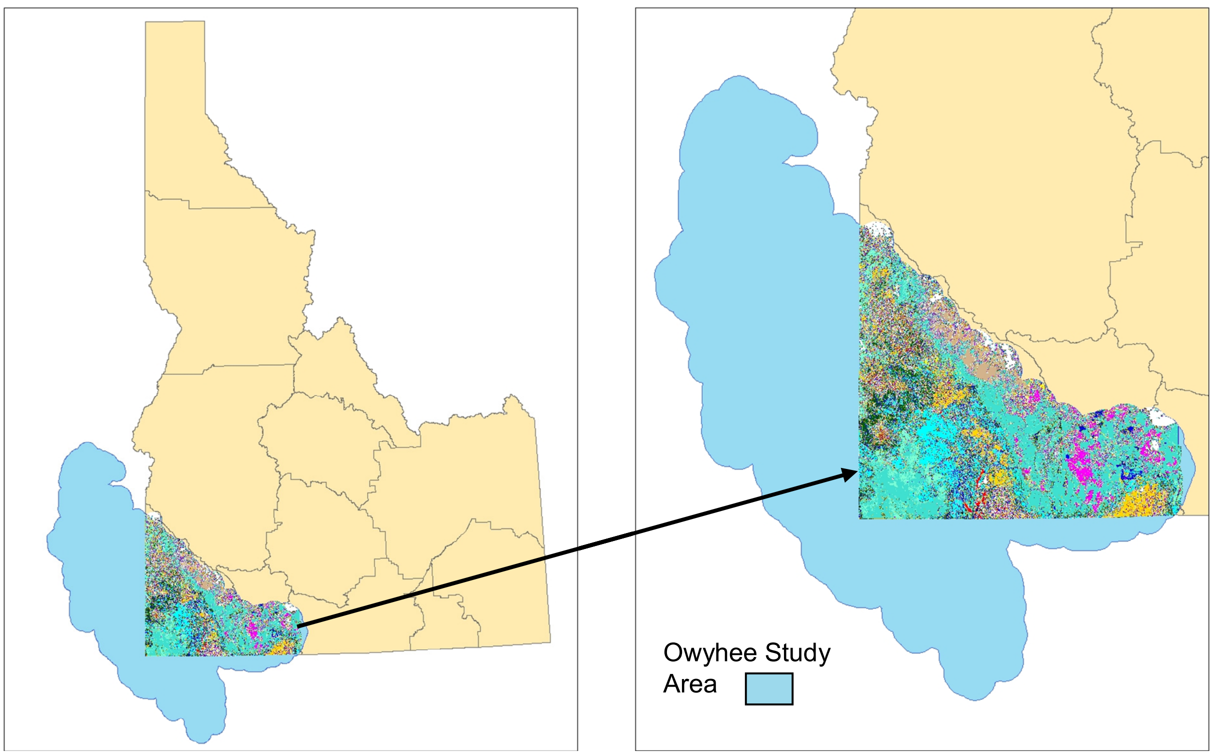

Figure 3.1. Location and Extent of Overlap Between the PNNL Vegetation Classification and the Owyhee Study Area Boundaries

Remote sensing imagery, field reconnaissance data, and GIS map data are being used to evaluate existing GIS layers for vegetation classification of the Owyhee Uplands study area. This section is focused on the area of the Owyhee Uplands where there are congruent data for all three map layers. The PNNL vegetation classification was created for the BLM for the lands within the boundary of the previously designated Lower Snake River District, which is now part of the Boise District. All comparisons and evaluation were completed using the portion of southern Idaho where the three classifications overlap.

3.1 Evaluation Methods

Our approach to evaluating the three separate vegetation classifications involved a series of steps:

- processing the classifications to the same minimum map unit
- assigning map classes and ground-truth data to a common classification legend
- evaluating the level of agreement between the ground-truth data and the three maps
- evaluating the areas of disagreement between the three map layers
- evaluating the spatial agreement/disagreement between the potential vegetation determined by mapped ecological sites (SSURGO data) and the three vegetation classifications.

To render the map layers at the same minimum map unit, the PNNL map was generalized to the minimum mapping unit of 1 acre using Imagine's CLUMP utility (4 connected neighboring pixels) and then Imagine's ELIMINATE utility with a minimum clump of pixels set to approximately 1 acre (5 pixels). These are the same methods used to smooth the SAGEMAP classification.

Assigning the different map classes to a common legend or set of vegetation types for that area where all three classifications are available (see Figure 3.1) required a rule-based approach to assign the PNNL vegetation categories to the comparable National Vegetation Classes (NVC) of Ecological Systems used in SAGEMAP (NatureServe 2005). (Appendix A gives a brief description of the vegetation cover types used in the original PNNL mapping, and lists species and species codes used in this document.) The general assignments of PNNL mapped vegetation types to the ecological systems described in SAGEMAP are listed in Table 3.1. The LANDFIRE vegetation classification is fairly similar to the ecological systems used in SAGEMAP and was relatively straightforward to cross-walk to the NVC classes (Table 3.2).

Once all three maps were cross-walked to represent the same classification, the amount and areas of discrepancy and agreement among the map layers could be assessed. We constructed a GIS layer of known discrepancies between the vegetation classifications represented by the PNNL, SAGEMAP, and LANDFIRE data sets. This was accomplished by spatially representing those areas that did not agree as black or void and calculating the percentage agreement for the classes.

Field data observations available to evaluate the consistency of the map classifications were also cross-walked and initially assigned to the NVC ecological system classification used for SAGEMAP. Two field data sets were used to evaluate the maps: a preliminary assessment with a ground-truth data set containing 331 records, and a final data set incorporating additional BLM assessment points for the Idaho portion of the Owyhee study area totaling 720 data points. The 331 ground-truth points were used to make a preliminary assessment of the ecological system of classification for all three maps. We did not attempt to assign the additional 389 field points to the ecological system classification, but assigned these to a map classification using 21 aggregated classes, which are described in the following paragraphs.

Table 3.1. Assignment of PNNL Vegetation Cover Types to the National Vegetation Classification System Used in the SAGEMAP Classification

SAGEMAP Ecological System Classification	PNNL Vegetation Cover Types[(a)]	Assigned Based on Rule Set
Agriculture	Agriculture	
Columbia Plateau Low Sagebrush Steppe	ARAR/BG	
	ARAR-ARTR/BG	
	ARAR-CHVI/BG	
Columbia Plateau Scabland Shrubland	ARRI/BG	
Columbia Plateau Western Juniper Woodland	JUNIPER	
	JUNIPER-ARTR	
	JUNIPER-MTNSHRUB	
Evergreen Forest	ABLA	
	ABLA-PSME	
	Picea-PSME	
	PICO	
	PIPO	
	PIPO-PSME	
	PSME	
Great Basin Semi-Desert Chaparral	CEVE	
Intermountain Basins Big Sagebrush Shrubland	ARTR/BG	
	ARTR/BG-BRTE	
	ARTR/BRTE	
	ARTR-MIX/BG	
	ARTR-MIX/BG-BRTE	
	ARTR-MIX/BRTE	
	CHVI/BG	
	CHVI/BG-BRTE	
Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe	Silver Sage	
Intermountain Basins Big Sagebrush Steppe	(ARTR)/BG-BRTE	
	ARTR/AGCR	
	CHVI-ARTR/Wheatgrass	
Intermountain Basins Cliff and Canyon	SPARSE VEG	Yes
	SPARSE VEG/ROCK	Yes
Intermountain Basins Greasewood Flat	GREASEWOOD-ARTR	
	SAVE	

Table 3.1. (contd)

SAGEMAP Ecological System Classification	PNNL Vegetation Cover Types*	Assigned Based on Rule Set
Intermountain Basins Mixed Salt Desert Scrub	ARSP-MIX/BG	
	ATCO/BG	
	ATCO/BRTE	
	ATCO-MIX/BG	
	ATCO-MIX/BG-BRTE	
	CELA	
Intermountain Basins Montane Sagebrush Steppe	ARTR-Conifer	
	ARTR-JUNIPER	
	ARTRV/BG	
	ARTRV/BG-BRTE	
	ARTRV-JUNIPER/BG	
	ARTRV-MTNSHRUB	
	ARTRV-PUTR/BG	
	PUTR/BG	
	PUTR/BG-BRTE	
Intermountain Basins Mountain Mahogany Woodland and Shrubland	CELE	
Intermountain Basins Semi-Desert Grassland	BG	Yes
	BG/(shrub)	Yes
Invasive Annual Grassland	BG-BRTE	
	BRTE	
	BRTE-AGCR	
	Exotic Annuals	
Intermountain Basins Mixed Salt Desert Scrub	SPARSE VEG	Yes
	SPARSE VEG/ROCK	Yes
Northern Rocky Mountain Lower Montane-Foothill Deciduous Shrubland	MTNSHRUB	
Northern Rocky Mountain Montane Grassland	BG	Yes
	BG/(shrub)	Yes
Invasive Perennial Grassland	Wheatgrass Seeding	
Riparian	Forbs	
	Riparian	
	WET MEADOW	
Rocky Mountain Aspen Forest and Woodland	ASPEN	
	PSME-ASPEN	
(a) Tables in Appendix A provide definitions and descriptions of the PNNL vegetation cover types used here.		

Table 3.2. Ecological Systems Classification Aggregated to General Vegetation Classes for the SAGEMAP Classification

Aggregate Class	SAGEMAP Ecological System
Agriculture	Agriculture
Cliff Canyon and Barren	Barren Land
	Intermountain Basins Cliff and Canyon
	Intermountain Basins Playa
	Rocky Mountain Cliff and Canyon
Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe	Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe
Developed_Disturbed	Developed
	Non-Specific Disturbed
Evergreen Forest and Meadowland	Evergreen Forest
	Northern Rocky Mountain Montane Grassland
	Northern Rocky Mountain Subalpine-Upper Montane Grassland
	Rocky Mountain Subalpine-Montane Mesic Meadow
Perennial Grassland	Columbia Plateau Steppe and Grassland
	Intermountain Basins Semi-Desert Grassland
Greasewood Salt Desert Shrub	Intermountain Basins Greasewood Flat
	Intermountain Basins Wash
Intermountain Basins Mixed Salt Desert Scrub	Intermountain Basins Mixed Salt Desert Scrub
Intermountain Basins Mountain Mahogany Woodland and Shrub	Intermountain Basins Mountain Mahogany Woodland and Shrubland
Invasive Annual Grassland	Invasive Annual Grassland
Invasive Perennial Forbland	Invasive Perennial Forbland
Introduced Perennial Grassland	Invasive Perennial Grassland
Juniper	Columbia Plateau Western Juniper Woodland
	Intermountain Basins Juniper Savanna
Low Sage/Low SagebrushMix	Columbia Plateau Low Sagebrush Steppe
	Columbia Plateau Scabland Shrubland
	Great Basin Xeric Mixed Sagebrush Shrubland
Montane Sagebrush Steppe	Intermountain Basins Montane Sagebrush Steppe
Montane Shrubland	Great Basin Semi-Desert Chaparral
	Northern Rocky Mountain Lower Montane-Foothill Deciduous Shrubland
Recently Burned	Recently Burned
Riparian	Riparian
Rocky Mountain Aspen Forest and Woodland	Rocky Mountain Aspen Forest and Woodland
Sagebrush/Sagebrush-Mixed Shrub Steppe	Intermountain Basins Big Sagebrush Shrubland
	Intermountain Basins Big Sagebrush Steppe
	Intermountain Basins Semi-Desert Shrub-Steppe
Water	Water

One important issue related to assigning the field and mapped vegetation associations to the ecological systems is that the majority of the field data used to assess the maps was not collected in a manner that allowed us to distinguish the percent cover of the dominant shrubs and grasses at the point. The SAGEMAP classification designates shrub stands with greater than 25% cover of perennial herbs as shrub steppe, and stands with less than 25% cover of perennial herbs as shrubland. The SAGEMAP classification relied on landform and spectral signature to classify steppe versus shrubland. The attributes of the field data used in this comparison were generally not sufficient to distinguish between the classification as "shrub-steppe" versus "shrubland." For example, a field data point might be described as representing Wyoming big sagebrush/bluebunch wheatgrass vegetation. Whether this field point should be assigned to the class "Intermountain Basins Big Sagebrush Steppe" or to "Intermountain Basins Big Sagebrush Shrubland" depends primarily on the amount of perennial forbs and graminoids in the association.

To account for this issue, the shrub steppe and shrubland classes for sagebrush-dominated ecological systems were aggregated into lumped classes (Tables 3.2 and 3.3). These shrub-dominated classes are separate from grassland and steppe. Several other ecological classes were aggregated as well, and the aggregation of 31 classes into 21 classes is shown in Table 3.3. A preliminary assessment was completed on the ecological system classification and the aggregated classes using the 331 ground-truth data points previously described. The ground-truth data set containing 720 field points was used only to assess the 21-class vegetation maps.

The final manner in which we assessed the map layers involves comparisons with the SSURGO 1:24000 soils data using the dominant ecological site designated for each map unit. This involved calculating the percentage of the study area occupied by each ecological site and mapping those ecological sites to potential vegetation classes that reflect the same vegetation classes mapped by PNNL, SAGEMAP, and LANDFIRE.

3.2 Evaluation of Classifications

Results of spatial comparisons of the areas of agreement for the NVCS classification showed little overall agreement (<50% agreement overall) among the three map products. The utility of presenting these discrepancy maps lies in the ability to identify areas or regions that show some level of agreement. For those where two or more map layers agree, it is likely that the classification is correct. Figure 3.2 is an example of these maps, showing the areas of agreement between the PNNL vegetation classification and the SAGEMAP classification.

Comparison of the ground-truth (field-collected) data with the classification provides an indication of the map accuracy for each of the vegetation classes in the three map products. Table 3.4 indicates the overall percentage agreement between the map data and field-collected data for the three vegetation maps at the ecological system level (n = 331) and at the aggregate class level (n = 331 and n = 720). Although the PNNL map has slightly better agreement with the available field data than the SAGEMAP and LandFire classifications, it may also be informative to evaluate the amount of area that is mapped into each class. Figures 3.3, 3.4, and 3.5 provide a graphic comparison of the percentage of the total Owyhee project area that is mapped into the 21 classes for the PNNL, SAGEMAP, and LANDFIRE vegetation classifications, respectively. Both the SAGEMAP and LandFire classifications map significantly more low-elevation big sagebrush vegetation cover types than does the PNNL classification. The PNNL mapping identifies greater percentages of Intermountain Basins Mixed Salt Desert Shrub, Perennial

Table 3.3. LANDFIRE Vegetation Classification Aggregated to General Vegetation Classes

Aggregate Class	LANDFIRE
Agriculture	Agriculture General
	Cultivated Crops
	Pasture/Hay
Cliff Canyon and Barren	Barren
Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe	
Developed_Disturbed	Developed General
	Developed Open Space
Evergreen Forest and Meadowland	*Abies grandis* Forest Alliance
	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
	Northern Rocky Mountain Ponderosa Pine Woodland
	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland
	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland
	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
	Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland
	Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland
	Northern Rocky Mountain Subalpine Woodland and Parkland
	Northern Rocky Mountain Subalpine-Upper Montane Grassland
	Rocky Mountain Subalpine-Montane Mesic Meadow
Perennial Grassland	Columbia Plateau Steppe and Grassland
	Intermountain Basins Semi-Desert Grassland
Greasewood Salt Desert Shrub	Intermountain Basins Greasewood Flat
Intermountain Basins Mixed Salt Desert Scrub	Intermountain Basins Mixed Salt Desert Scrub
	Intermountain Basins Sparsely Vegetated Systems
Intermountain Basins Mountain Mahogany Woodland and Shrub	Intermountain Basins Mountain Mahogany Woodland and Shrubland
Invasive Annual Grassland	Introduced Upland Vegetation - Annual Grassland
Invasive Perennial Forbland	Introduced Upland Vegetation - Annual and Biennial Forbland
Introduced Perennial Grassland	Introduced Upland Vegetation - Perennial Grassland and Forbland
Juniper	Columbia Plateau Western Juniper Woodland and Savanna
	Colorado Plateau Pinyon-Juniper Woodland
	Great Basin Pinyon-Juniper Woodland
	Intermountain Basins Juniper Savanna
	Juniperus occidentalis Woodland Alliance
Low Sage/Low Sagebrush Mix	Columbia Plateau Low Sagebrush Steppe
	Great Basin Xeric Mixed Sagebrush Shrubland
Montane Sagebrush Steppe	Intermountain Basins Montane Sagebrush Steppe
	Artemisia tridentata ssp. vaseyana Shrubland Alliance
Montane Shrubland	Rocky Mountain Lower Montane-Foothill Shrubland
	Northern Rocky Mountain Lower Montane Deciduous Shrubland
	Northern Rocky Mountain Subalpine Deciduous Shrubland
Recently Burned	
Riparian	Intermountain Basins Montane Riparian Systems
	Rocky Mountain Montane Riparian Systems
	Rocky Mountain Subalpine/Upper Montane Riparian Systems
Rocky Mountain Aspen Forest and Woodland	Rocky Mountain Aspen Forest and Woodland
	Intermountain Basins Aspen-Mixed Conifer Forest and Woodland
Sagebrush/Sagebrush-Mixed Shrub Steppe	Intermountain Basins Big Sagebrush Shrubland
	Intermountain Basins Big Sagebrush Steppe
	Intermountain Basins Semi-Desert Shrub-Steppe
Water	Open Water

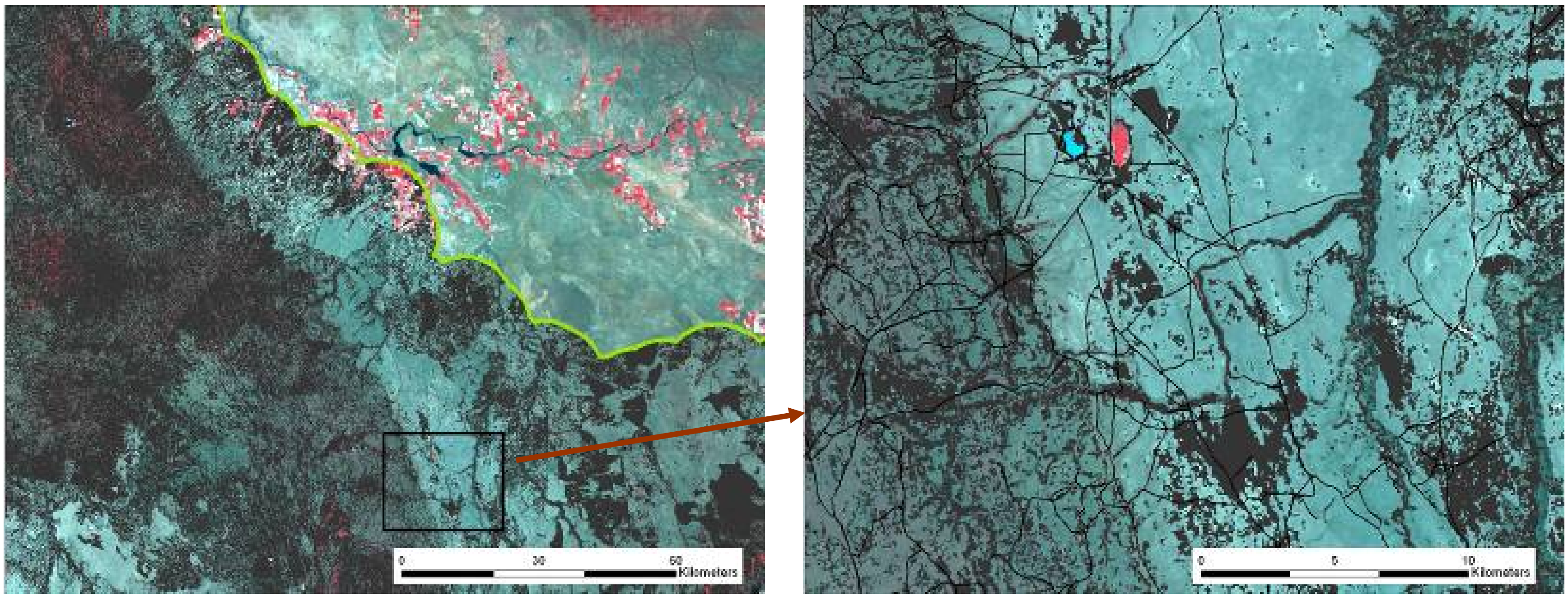

Figure 3.2. Example at Two Scales Showing Areas of Agreement (color) and Disagreement (black) Between the PNNL Vegetation Classification and SAGEMAP for the Owyhee Uplands (green boundary line)

Grassland, Low Sagebrush/Low Sagebrush Mix, Montane Sagebrush, and Introduced Perennial Grassland within the Owyhee Pilot Project area. Some of the discrepancy between the SAGEMAP and PNNL mapping of Introduced Perennial Grassland occurs because PNNL used BLM district mapping of seeded areas to revise those map classes. The SAGEMAP classification may class some of those areas as Recently Burned.

Comparison of the ground-truth (field-collected) data with the classification provides an indication of the map accuracy for each of the vegetation classes in the three map products. Table 3.4 indicates the overall percentage agreement between the map data and field-collected data for the three vegetation maps at the ecological system level (n = 331) and at the aggregate class level (n = 331 and n = 720). Appendix B tables describe the agreement for each vegetation type.

Table 3.4. Overall Agreement Between Ground-Truth Data and Three Vegetation Classifications Based on Remotely Sensed Imagery

Vegetation Classification	Agreement for Ecological System Classification (31 map classes with 331 ground points)	Agreement for Aggregated Classes (21 map classes with 331 ground points)	Agreement for Aggregated Classes (21 map classes with 720 ground points)
SAGEMAP	23%	36%	38%
LANDFIRE	18%	35%	39%
PNNL	44%	49%	45%

Although the PNNL map has slightly better agreement with the available field data than the SAGEMAP and LANDFIRE classifications, it also may be informative to evaluate the amount of area that is mapped into each class. Figures 3.3, 3.4, and 3.5 provide a graphic comparison of the percentage of the total Owyhee project area that is mapped into the 21 classes for the PNNL, SAGEMAP, and LANDFIRE vegetation classifications, respectively. Both the SAGEMAP and LandFire classifications map significantly more low-elevation big sagebrush vegetation cover types than does the PNNL classification. The PNNL mapping identifies greater percentages of Intermountain Basins Mixed Salt Desert Shrub, Perennial Grassland, Low Sagebrush/Low Sagebrush Mix, Montane Sagebrush, and Introduced Perennial Grassland within the Owyhee Pilot Project area. Some of the discrepancy between the SAGEMAP and PNNL mapping of Introduced Perennial Grassland occurs because PNNL used BLM district mapping of seeded areas to revise those map classes. The SAGEMAP classification may class some of those areas as Recently Burned.

The final manner in which we evaluated the data involves comparing the mapped vegetation for the three classifications with the dominant potential vegetation identified using the ecological site descriptions in the SSURGO soils maps for the areas in question. The primary class of potential dominant vegetation predicted by the SSURGO ecological site data is shown as a percentage of the majority of the Idaho portion of the Owyhee pilot project area in Figure 3.6. The soils data used in this analysis did not provide complete coverage for all of the counties in the project area—85% of the study region is accounted for in this comparison. The southeast corner of the study area and the portion of the Duck Valley Indian Reservation were not included in this analysis. However, the results presented here should represent the trends in mapping for the entire Idaho region that was considered.

The potential dominant vegetation identified by the soils ecological sites was used to evaluate the three vegetation classifications at two levels. First, for each potential vegetation type predicted by the soils mapping, we can evaluate how much of that vegetation type was indicated by each of the three different classifications in the study area. This comparison is a qualitative evaluation at best, because a number of factors may operate to cause existing vegetation to differ from potential or expected vegetation. Table 3.5 provides the information describing the percentage of each expected vegetation type predicted by soils coverage of the study area in comparison to the proportions of the actual mapped vegetation types in the three classifications. Table 3.6 lists the soil ecological sites and dominant potential vegetation identified in the SSURGO databases for each ecological site.

Table 3.5. Comparison of Expected Vegetation Types to Actual Mapped Vegetation Types

Vegetation Class	Percentage of Total Mapped Area			Percentage of Expected Vegetation Based on Soils Ecological Sites
	PNNL	SAGEMAP	LANDFIRE	
Cliff Canyon and Barren	0.63	0.22	0.16	
Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe	0.52	0.24		4.02
Greasewood Salt Desert Shrub	0.62	0.27	0.33	1.37
Intermountain Basins Mixed Salt Desert Scrub	6.21	3.97	3.53	9.41
Invasive Annual Grassland	2.19	4.83	2.52	
Introduced Perennial Grassland	4.82	0.04	0.70	
Perennial Grassland	5.91	4.83	2.84	0.01
Sagebrush/Sagebrush-Mixed Shrub Steppe	35.49	51.87	59.76	42.15
Low Sage/Low Sage Mix	19.08	10.04	11.32	13.88
Montane Sagebrush Steppe	12.35	9.40	3.31	26.60
Montane Shrubland	0.37	0.01	0.03	0.41
Riparian	0.63	1.91	2.85	
Juniper	6.07	3.69	7.44	1.08
Intermountain Basins Mountain Mahogany Woodland and Shrub	1.74	0.14	0.42	
Rocky Mountain Aspen Forest and Woodland	0.60	0.13	2.08	
Evergreen Forest and Meadowland	0.84	2.77	0.99	0.68
Agriculture	1.88	1.73	1.27	
Developed_Disturbed	0.01	0.75	0.08	
Water	0.05	0.08	0.07	
Recently Burned		3.09		
Perennial Forbland			0.29	
Semiwet Meadow				0.22

Table 3.6. Potential Dominant Vegetation for Soil Ecological Sites Found in the Owyhee Study Area

Potential Dominant Vegetation	Soil Ecological Site
Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe	Churning Clay 12-16
Evergreen Forest and Meadowland	Douglas Fir Snowberry 22+
Greasewood Salt Desert Shrub	Saline Bottom 8-12
	Semiwet Saline Meadow
Inter-Mountain Basins Mixed Salt Desert Scrub	Calcareous Loam 7-10
	Silty 7-10
Low Sage/Low Sage Mix	Clayey 12-15
	Mountain Ridge 14-18
	Shallow Claypan 11-13
	Shallow Claypan 12-16
	Shallow Stony Loam 8-16
	Stony Clayey 12-16
	Very Shallow Stony 8-12
	Very Shallow Stony Loam 10-14
Meadow	Dry Meadow 8
	Semiwet Meadow Carex-Poa
Montane Sagebrush Steppe	Loamy 12-16
	Loamy 13-16
	Loamy 16+
	North Slope Loamy 16-20
	South Slope Fractured 12-16
	South Slope Gravelly 12-16
Rocky Mountain Aspen Forest and Woodland	Aspen Thicket 16-22
	Aspen Woodland 16+
Sagebrush/Sagebrush-Mixed Shrub Steppe	Loam 12-16
	Loamy 10-12
	Loamy 10-13
	Loamy 11-13
	Loamy 7-10
	Loamy Bottom 12-16
	Loamy Bottom 8-14
	Sand 8-12
	Sandy Loam 8-12
	South Slope Stony 12-16

The second comparison of interest involves a more focused assessment of the cover types mapped by each classification in a specific ecological site. For the Owyhee Uplands Pilot study, we focused on the sagebrush-dominated ecological sites. For each sagebrush-dominated ecological site, we identified the potential vegetation, and then compared the mapped vegetation types in each ecological site for each of the three classifications. We also carried out this analysis step for ecological sites where the potential vegetation is expected to be dominated by salt desert shrubs because these areas are interspersed with and adjacent to lower-elevation sagebrush-dominated ecological sites.

Figure 3.7 shows an example of the mapped vegetation in the low-elevation big sagebrush ecological sites for each of the three classifications. Note that more than 50% of this ecological site is mapped as Sagebrush/Sagebrush-Mixed Shrub Steppe in all three classifications (PNNL = 61%; SAGEMAP = 70%; LANDFIRE = 79%). Within the Sagebrush/Sagebrush-Mixed Shrub Steppe, several other classes may occupy significant percentages of the total land area for those ecological sites. Given the topographic and geographic position on the landscape of these ecological sites and the land use history of the area (grazing, fire, and agricultural development), we would also expect to find Agriculture, Invasive Annual Grassland, Perennial Grassland and Introduced Perennial Grassland within these areas. The PNNL classification maps an additional 20% in these classes (total = 80.7%); SAGEMAP maps an additional 17.9% with the Recently Burned Class is included, but with less than 0.1% Introduced Perennial Grassland (total = 88.2); and LANDFIRE maps an additional 9.5% for these map classes (total = 88.2%). Based on our use of BLM GIS maps for seedings and discussions with other map producers, we believe that the PNNL map provides a more realistic depiction of Introduced Perennial Grassland in these ecological sites.

Evaluation of the ecological sites dominated by low sagebrush vegetation associations (Figure 3.8), indicates that only the PNNL classification maps more than 50% of that ecological site as Low Sage/Low Sage Mix. Both the SAGEMAP and LANDFIRE classifications map large proportions of big sagebrush vegetation associations—the Sagebrush/Sagebrush-Mixed Shrub Steppe class (47% and 59.4%, respectively). Other vegetation types that are likely to exist on these soils include Montane Sagebrush Steppe, Juniper, and Perennial Grassland. Additional area mapped in these three classes is 35% in the PNNL classification; 16.8% in the SAGEMAP classification; 14% in the LANDFIRE classification.

Comparisons of the mapped vegetation on ecological sites expected to be dominated by mountain big sagebrush (Montane Sagebrush Steppe—Figure 3.9) also indicates that the PNNL classification maps the largest percentage of Montane Sagebrush (32.6%) compared to SAGEMAP (27.8%), and LANDFIRE (5.2%). These ecological sites are likely to support a mosaic of low sage interspersed with mountain big sage vegetation as well as juniper and mountain mahogany, which are identified on all three classifications. All 3 classifications identify more than significant proportions of these soils as being dominated by low sagebrush vegetation (PNNL = 18.6%, SAGEMAP = 12.5%, and LANDFIRE = 23.7%. All three classifications also identify juniper on these soils: PNNL, 16%; SAGEMAP, 13.7%; and LANDFIRE, 29%. Both the PNNL and LANDFIRE classifications map some aspen on these soils (1% and 5.2%, respectively), which could occur as inclusions in the soil survey polygons. SAGEMAP and LANDFIRE both identify more big sagebrush (22.5% and 26.5%) than PNNL (7%). It is unlikely that significant proportions of these montane sagebrush ecological sites are dominated by the more xeric associations typified by Wyoming big sagebrush and other shrubs that comprise the Sagebrush/Sagebrush-Mixed Shrub Steppe vegetation types.

Mapping in the ecological sites dominated by mixed salt desert scrub vegetation shows similar trends, where both SAGEMAP and LANDFIRE map significantly more big sagebrush vegetation in these soils than salt desert shrub vegetation. PNNL maps nearly 50% of these soils as salt desert shrubs and also maps 32% big sagebrush dominated vegetation. All three classifications map approximately the same amount of agriculture on these soils, but SAGEMAP and LANDFIRE map more Invasive Annual Grassland in these areas than the PNNL classification.

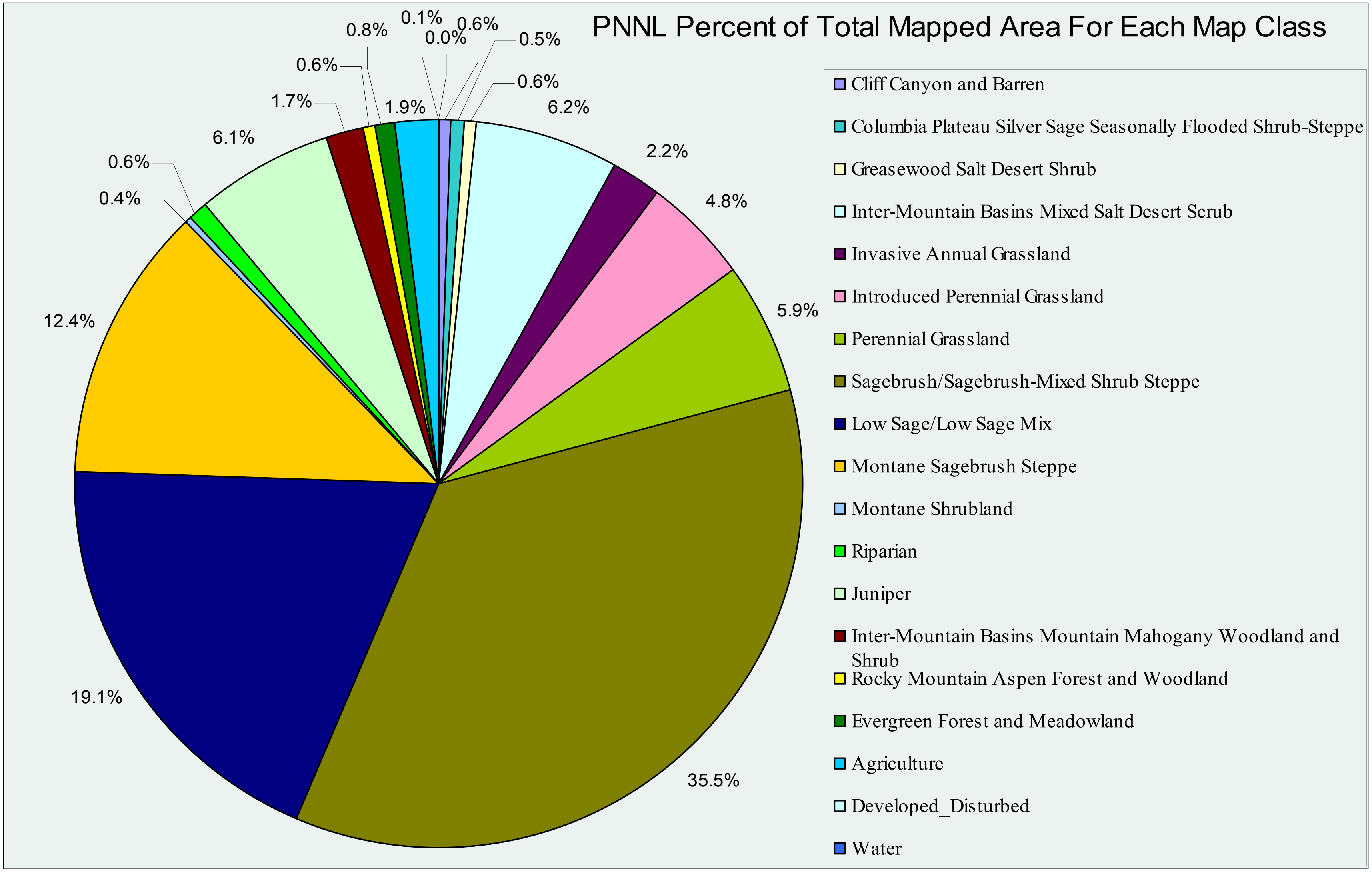

Figure 3.3. Proportion of Mapped Vegetation Classes (21-Class Aggregation) in the PNNL Vegetation Classification

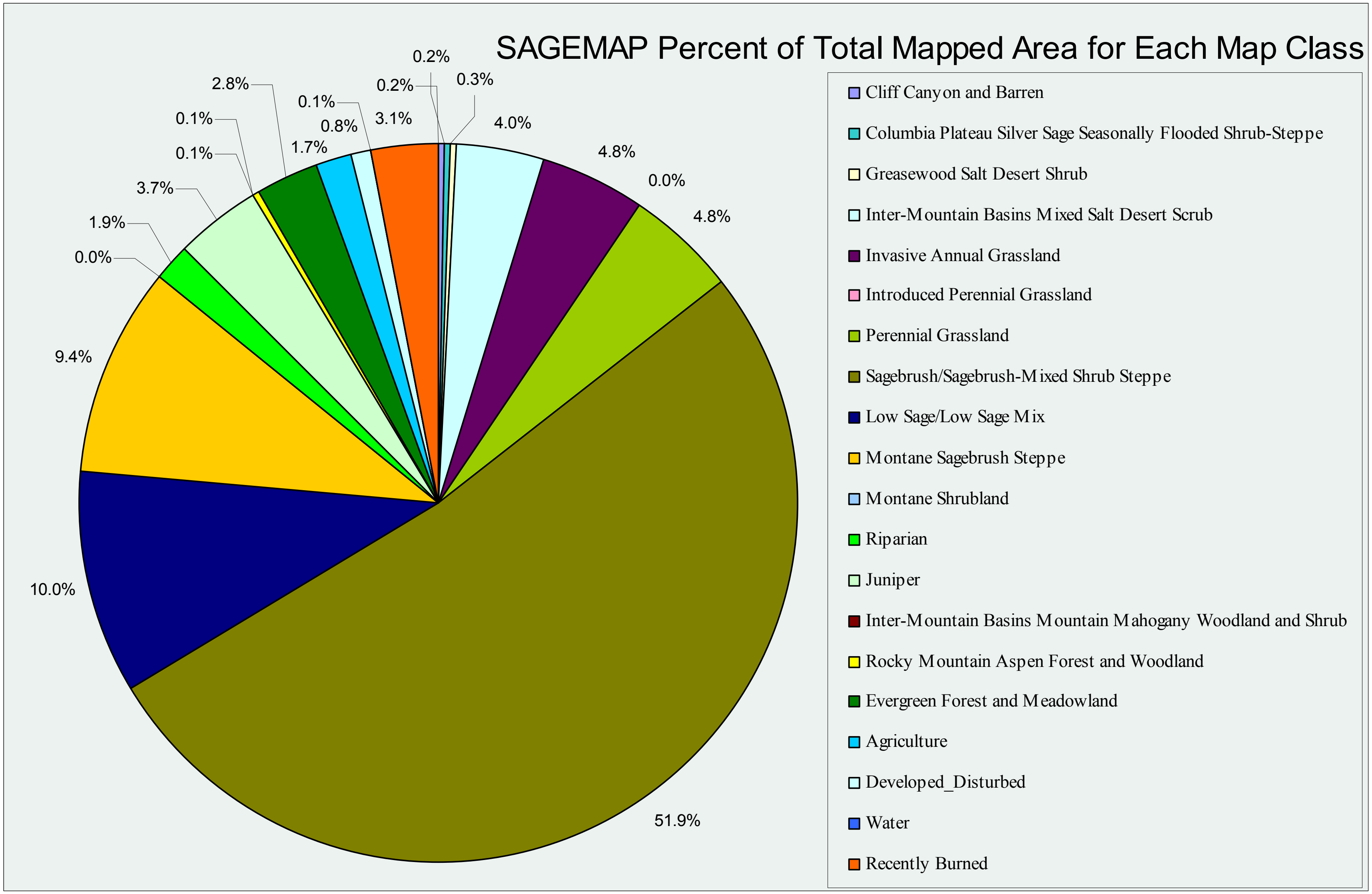

Figure 3.4. Proportion of Mapped Vegetation Classes (21-Class Aggregation) in the SAGEMAP Vegetation Classification

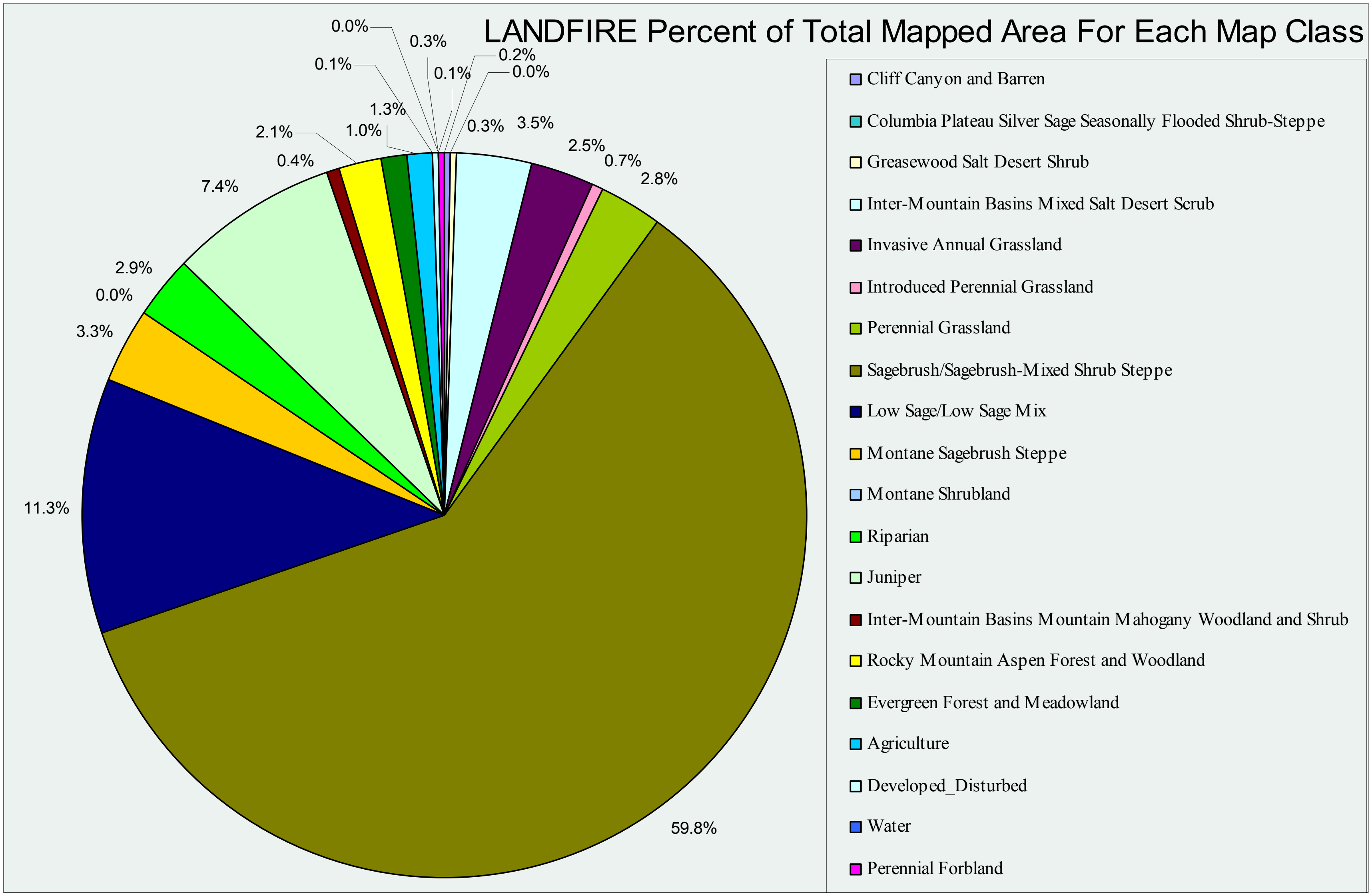

Figure 3.5. Proportion of Mapped Vegetation Classes (21-Class Aggregation) in the LANDFIRE Vegetation Classification

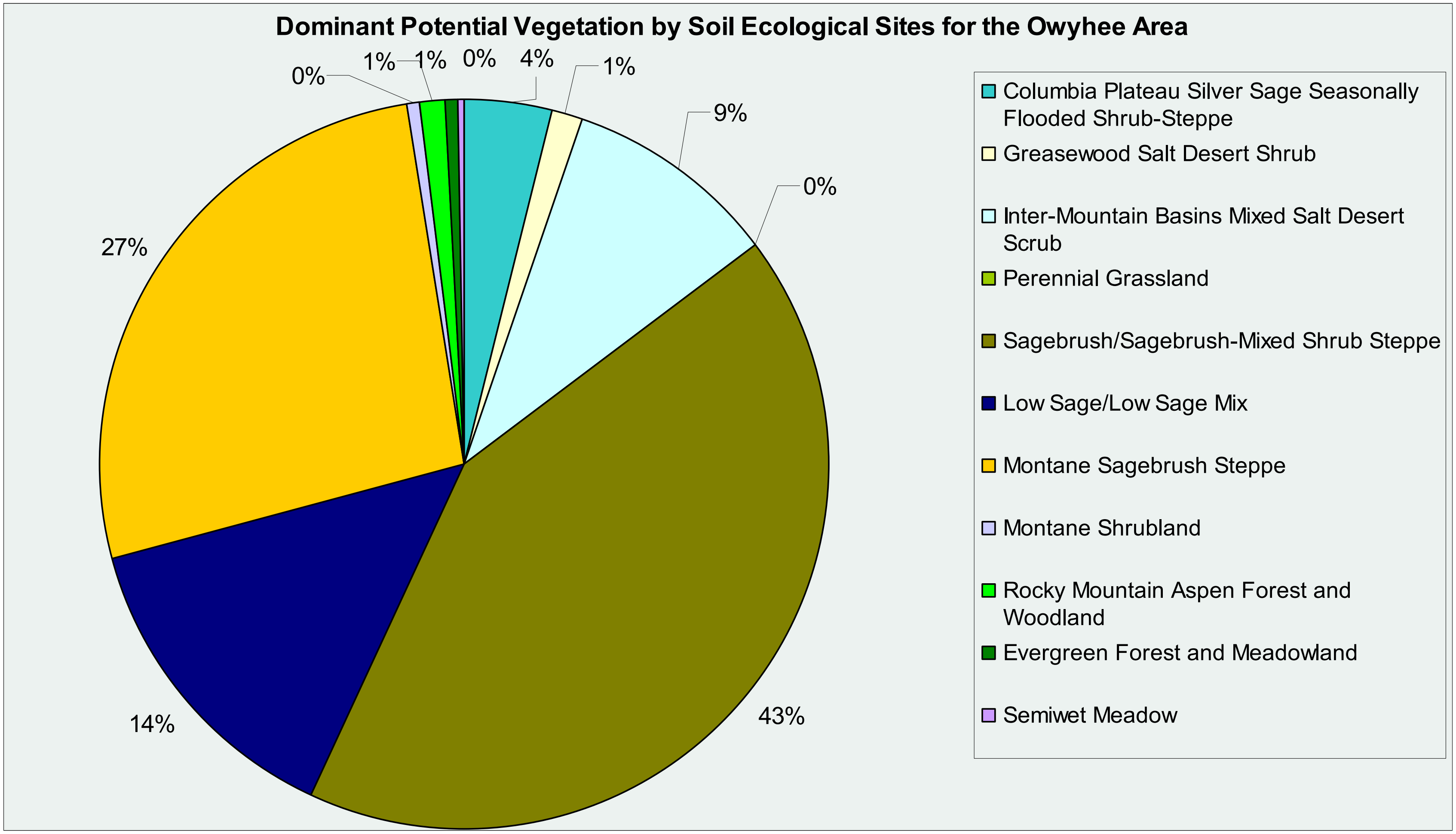

Figure 3.6. Potential Vegetation Types as Indicated by Dominant Ecological Site for Soil Survey Polygons in Majority of the Idaho Study Region

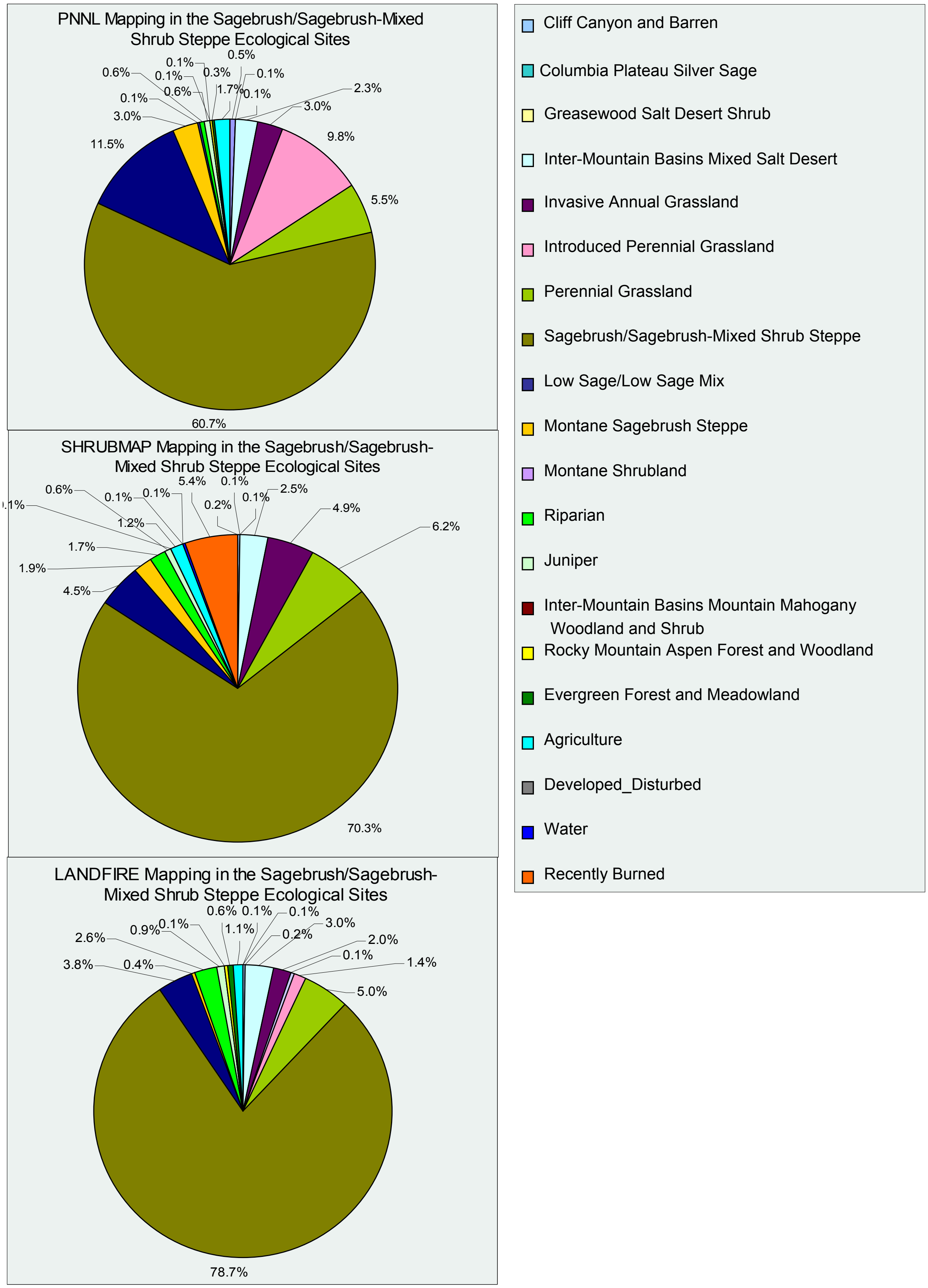

Figure 3.7. Comparison of the Three Vegetation Classification Map Products for the Ecological Sites Dominated by Big Sagebrush Community Types

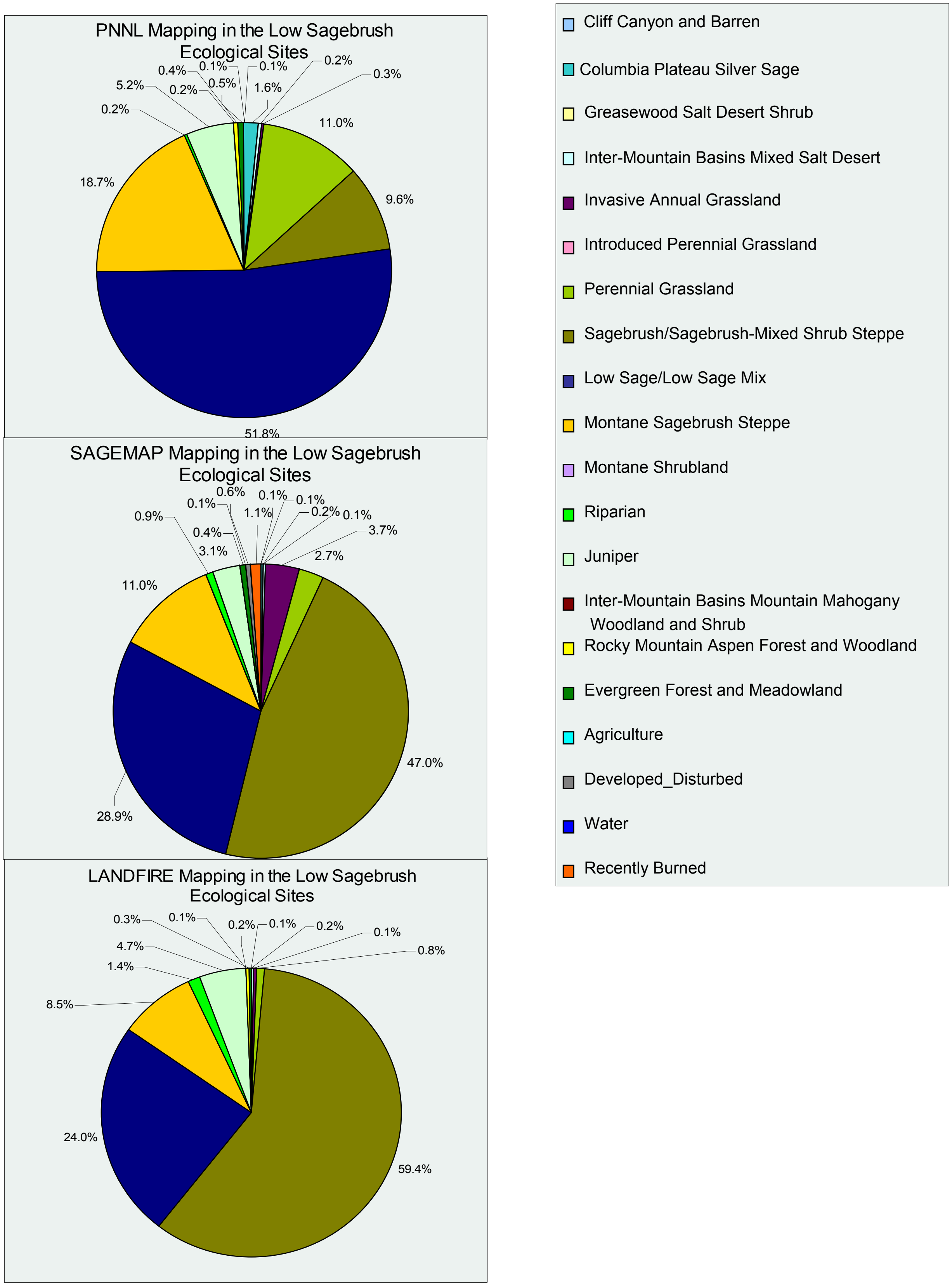

Figure 3.8. Comparison of the Three Vegetation Classification Map Products for the Ecological Sites Dominated by Low Sagebrush Community Types

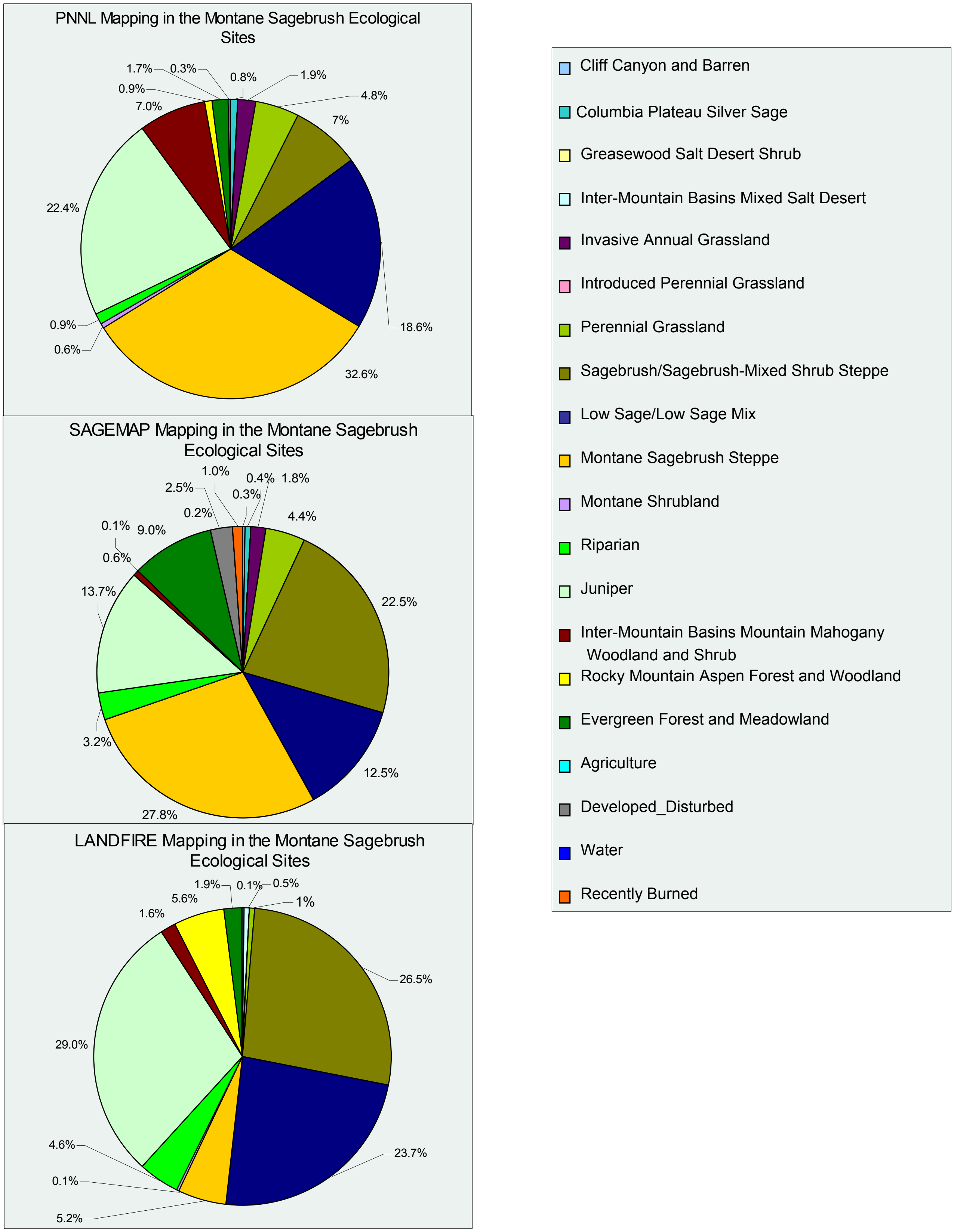

Figure 3.9. Comparison of the Three Vegetation Classification Map Products for the Ecological Sites Dominated by Mountain Sagebrush Community Types

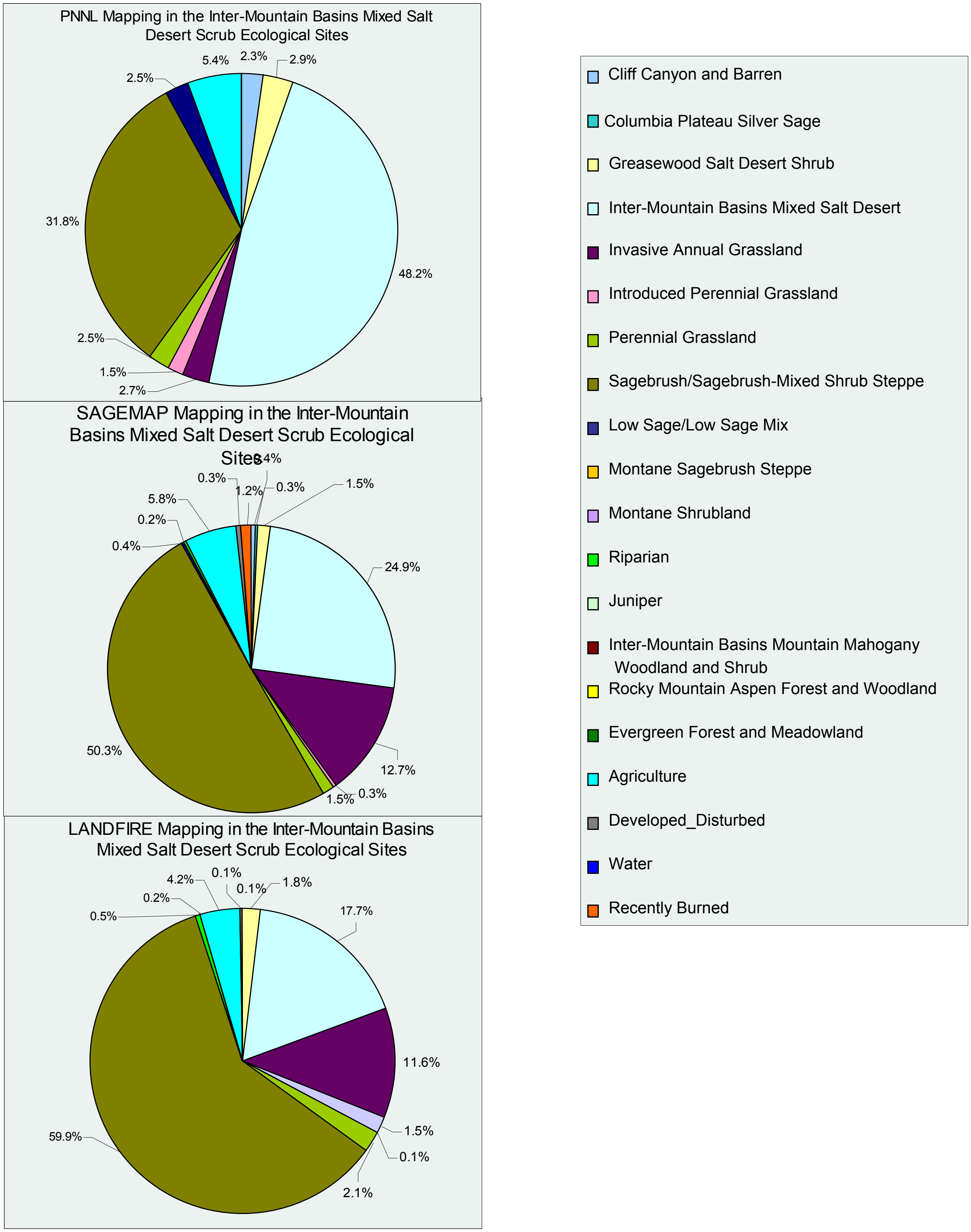

Figure 3.10. Comparison of the Three Vegetation Classification Map Products for the Ecological Sites Dominated by Intermountain Basins Mixed Salt Desert Scrub Community Types

4.0 Anomaly Analysis

PNNL's anomaly mapping method defines anomalous pixels by comparing individual pixel response to the median response within a larger land unit (strata). This was accomplished in the Owyhee region by using the SSURGO soil ecological site descriptions as strata. The ecological site polygons are appropriate for this analysis because they represent land units that are potentially, biologically homogenous because each ecological site has similar soil type, elevation and precipitation. If SSURGO soils are not available, a vegetation map for the region may be used to the same effect. Landsat spectral data were analyzed by these polygons to determine the statistical distribution. Our working hypothesis was that the pixels nearest the median response for an ecological site represent rangeland in good condition and the pixels farthest from the median response for the ecological site were areas of concern. Maps of these areas were produced for field and remote validation of the hypothesis (Figure 4.1).

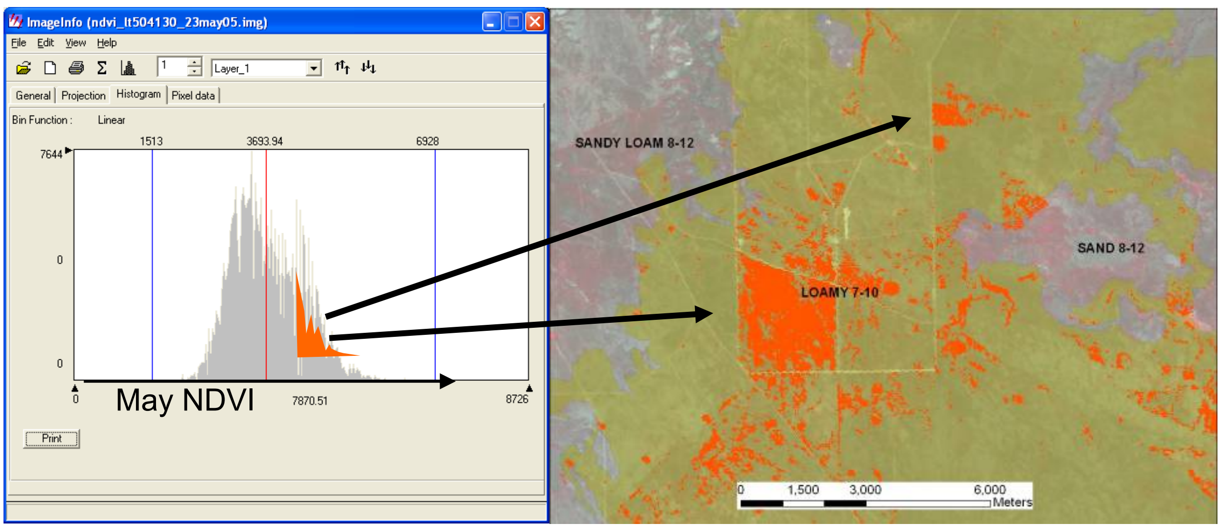

Figure 4.1. Identifying Anomalous Pixels Within a Landscape Unit by Isolating NDVI Values at the Extreme of the Distribution for That Unit

We performed two tests of our anomaly mapping methodology to identify specific areas of management concern. The anomaly mapping approach was similar between the two tests; pixels nearest to and farthest from the median were identified as low and high concern, but the validation analyses differed between the two. In the first test, the management concern being evaluated was juniper encroachments in low sagebrush-dominated ecological sites. The second test involves the identification of areas with excessive amounts of bare soil and/or exotic vegetation. In the case of juniper encroachment anomalies, we used aerial photography interpretation techniques to asses the results. In the case of bare ground and exotic annual anomalies, we collected field measurements.

4.1 Juniper Anomalies

To identify juniper anomalies, we focused on several ecological sites dominated by low sagebrush from the SSURGO soils data in the Owyhee area. We used the Landsat data from October 2003 to identify areas of concern. Areas of concern were defined by calculating and mapping the 90th percentile and 10th percentile values of NDVI for the selected ecological sites (Figure 4.2). The 90th percentile

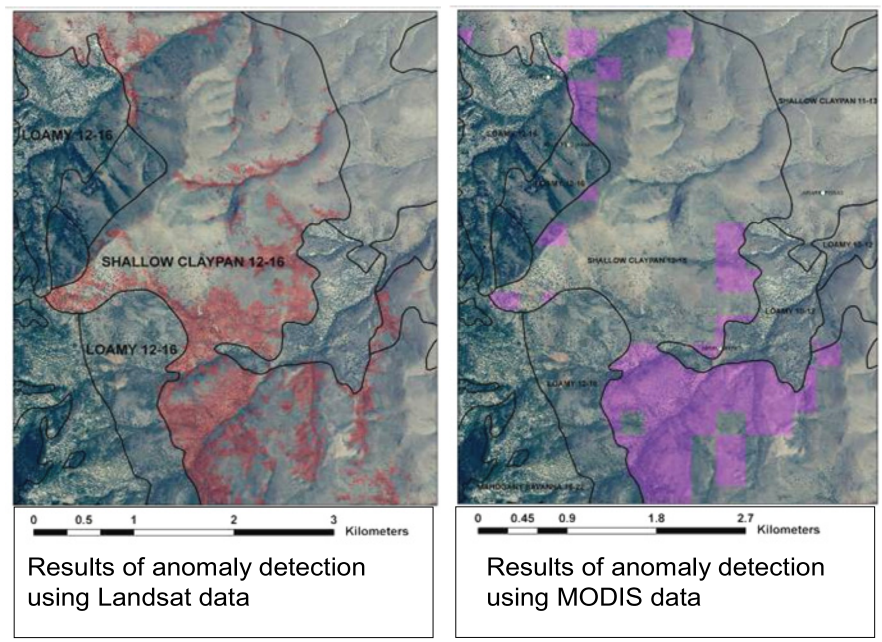

Figure 4.2. Results of High NDVI Anomaly Mapping with Landsat and MODIS Imagery Showing Juniper Encroachment into a Shallow Claypan 12-16 Ecological Site

represents the highest NDVI values in the ecological site of interest; the 10th percentile represents the lowest NDVI response in those ecological sites. We used the October imagery to identify high NDVI areas for juniper because in the fall, much of the herbaceous vegetation has senesced, and only meadows, riparian vegetation, nondeciduous shrubs, and juniper are green. The anomaly algorithm that we employed simply identifies the pixels that are at the extremes of the NDVI distribution for each ecological site type. In addition to identifying the high NDVI anomalous areas in the low sagebrush habitat type, we also calculated and mapped the median NDVI response for that ecological site.

We tested the hypothesis that the high NDVI anomaly areas contain more juniper trees than the areas mapped with a median NDVI response. To accomplish this, we located 30 random points in the high NDVI and 30 in the median NDVI map class and then buffered these points by 30 m. For each of the 30-m-diameter points, we then visually interpreted the NAIP air photo to 1) determine the number of juniper trees in the buffered areas and 2) determine whether the random point fell in or near a riparian area. Our final step was to compare the number of juniper trees visible in the areas identified as high NDVI anomalies to the number of juniper trees in the median NDVI areas (Table 4.1). By evaluating each point as “riparian,” or “not riparian,” we gain insight as to whether riparian areas strongly influenced the high NDVI anomalies and biased the results.

The data clearly show that more juniper trees are identified by the high NDVI response in the low sagebrush habitat type (Figure 4.3) than are visible in the median NDVI. It should be noted that the methodology we used allowed us to detect trees that were large enough to resolve in 1-m-resolution imagery. The small seedling juniper trees were not visible in this imagery. In addition, 11 of the high NDVI random points were in or adjacent to riparian vegetation. There was some concern at the outset that the method would identify only riparian areas. Although riparian areas in shrubland and semi-arid landscapes are of interest, that was not the objective of this analysis. The results show that although some riparian areas were identified, the riparian areas also had juniper trees visible in all 11 cases.

Table 4.1. Summary of Juniper Count Samples in High and Median Normalized Difference Vegetation Index Anomalous Areas

High NDVI (trees/hectare)	High NDVI Riparian (Yes/No)	Median NDVI (trees/hectare)	Median NDVI Riparian
141	No	11	No
7	Yes	18	No
14	Yes	18	No
113	No	4	No
42	Yes	35	No
81	Yes	0	No
85	No	7	No
141	Yes	35	No
60	No	18	No
71	No	0	No
92	No	0	No
53	Yes	0	No
0	No	0	No
124	No	0	No
7	Yes	4	No
18	Yes	0	No
74	No	0	No
64	No	0	No
124	No	0	No
50	No	0	No
42	Yes	21	No
57	Yes	0	No
42	Yes	0	No
67	No	0	No
18	No	0	No
141	No	11	No
85	No	0	No
57	No	0	No
85	No	0	No
106	No	0	No

The method of analyzing spectral data stratified by ecological site polygons has the potential to be developed into a tool for broader application in rangeland monitoring. A recent publication by Maynard et al. (2007) describes a technique similar to what we present here. Applying these types of technique presents some challenges for adaptation to rangeland monitoring, but mounting evidence suggests that such tools can be developed and applied to provide rangeland managers with the ability to monitor large areas for potential trouble spots.

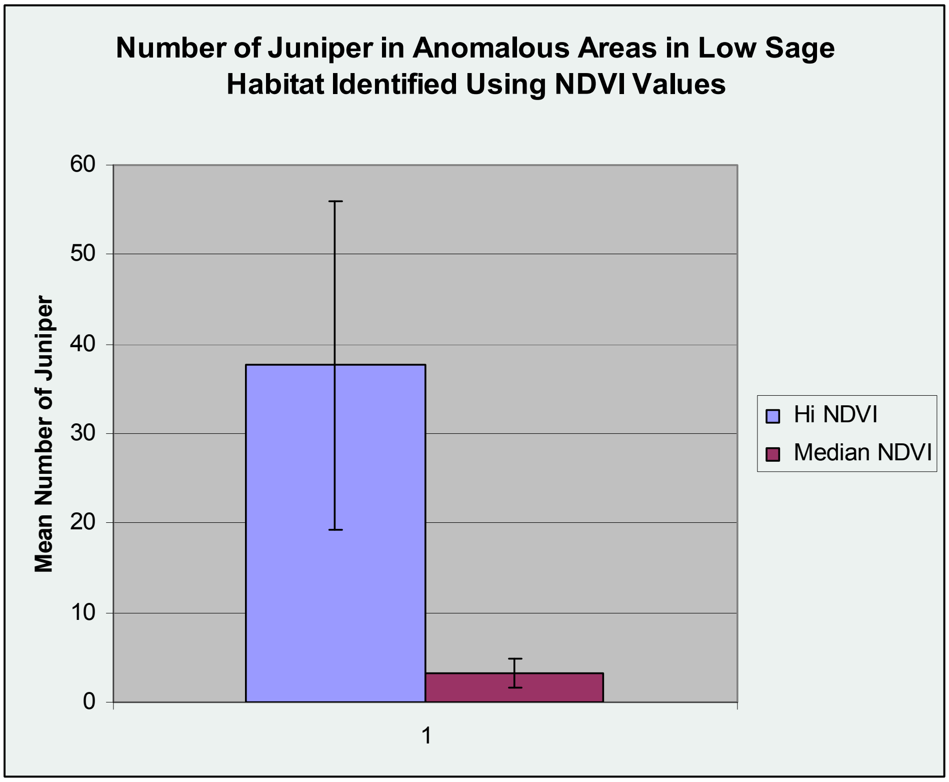

Figure 4.3. Number of Juniper Trees Identified Within in 30-m Radius of Random Points in High and Median NDVI Anomalies

4.2 Bare Soil and Invasive Species Anomalies

To identify areas of excessive bare soil and potential exotic species, we employed primarily Landsat data from May 10 and June 27, 2006. We also evaluated Landsat data from 2005 for approximately the same dates. This range in dates—early May and late June—allowed us to look at two different phenological stages of vegetation. The native and exotic plants in the region exhibited a green response in the May 2006 scene, while many annual plant species had senesced by June 27. The scenes were processed to provide spectral index values for NDVI and brightness, greenness, and wetness (Crist et al. 1986). These Landsat-derived images were then analyzed by the ecological site polygons for the region. The 10th, 50th, and 90th index percentiles (low, median, and high NDVI values) were identified for each unique ecological site and the low, median, and high pixels were mapped across the landscape (Figure 4.4).

During the second week of June 2007, we visited 30 field points representing areas identified as exhibiting high, median, or low responses in ecological sites dominated by big sagebrush or salt desert shrub associations (Table 4.2). Exact locations for validation field points were selected according to the following criteria: size of anomalous area identified was greater than 1 hectare and more than 50 m from existing roadways. A random start point was determined by tossing a pin flag in the direction traveled to access the point or toward the center of the mapped anomalous area. Two parallel 50-m transects were then laid out in a north-south direction at a spacing of 10 m. These transects were sampled at 10-m intervals along the tape using a 0.5-m^2 quadrat, which was subdivided by a grid at 10-cm intervals, to provide guidance in estimating percentage cover. In each quadrat, we recorded the plant canopy cover by

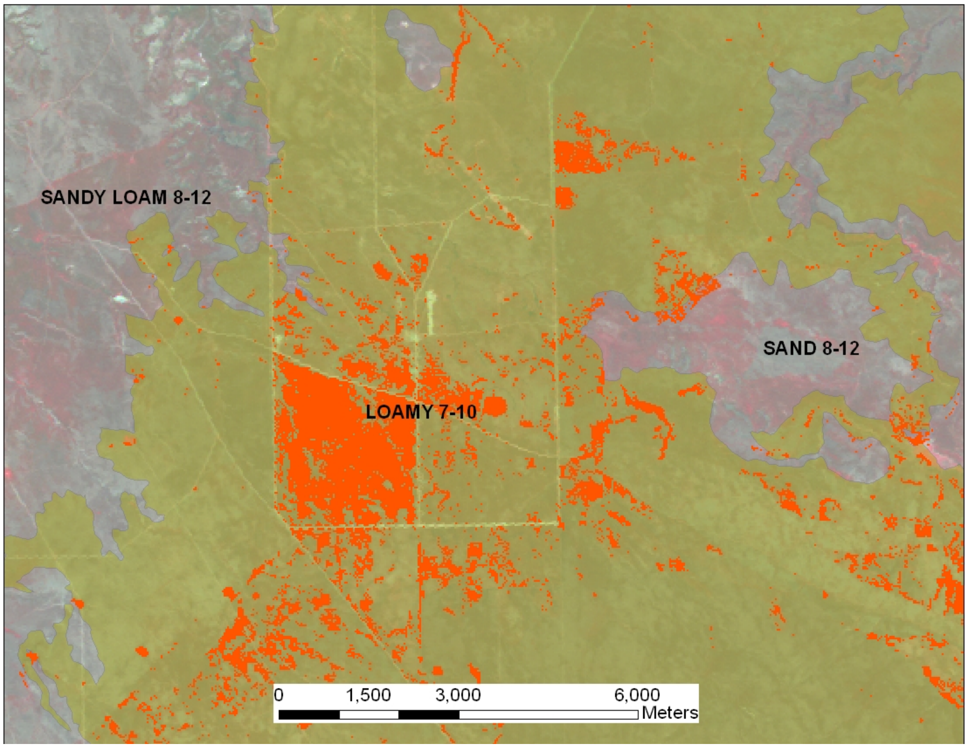

Figure 4.4. High May NDVI Anomalies in Loamy 7-10 Ecological Site, Potentially Indicating Exotic Annual Weed Infestation

Table 4.2. Number of Field Sites in Big Sagebrush-Dominated Ecological Sites

Ecological Site Classification	Number of Field Sites
Calcareous Loam 7-10	2
Loamy 10-13	12
Loamy 13-16	4
Loamy 16+	2
Loamy 7-10	6
Sandy Loam 8-12	4

species, the percentage ground cover of litter, bare soil, or rock, and also recorded an initial point intercept at five grid intersect points down the center of each quadrat. The point intercept data were used to determine frequency of occurrence. Canopy cover data for the two transects were averaged to provide an estimate of canopy cover by species and ground condition for each anomalous point. Frequency was determined as a proportion of the points sampled on the two transects (5 points/quadrat x 10 quadrats= 50 points).

Field data were summarized by the categories of NDVI and brightness from May 2006 to determine if the high, median, and low anomalies indicate significantly different amounts of bare ground, introduced annual grass, and other rangeland attributes of concern. Figure 4.5 shows the results from all transects for the May 2006 Landsat NDVI comparison. Areas identified as high-value anomalies have significantly

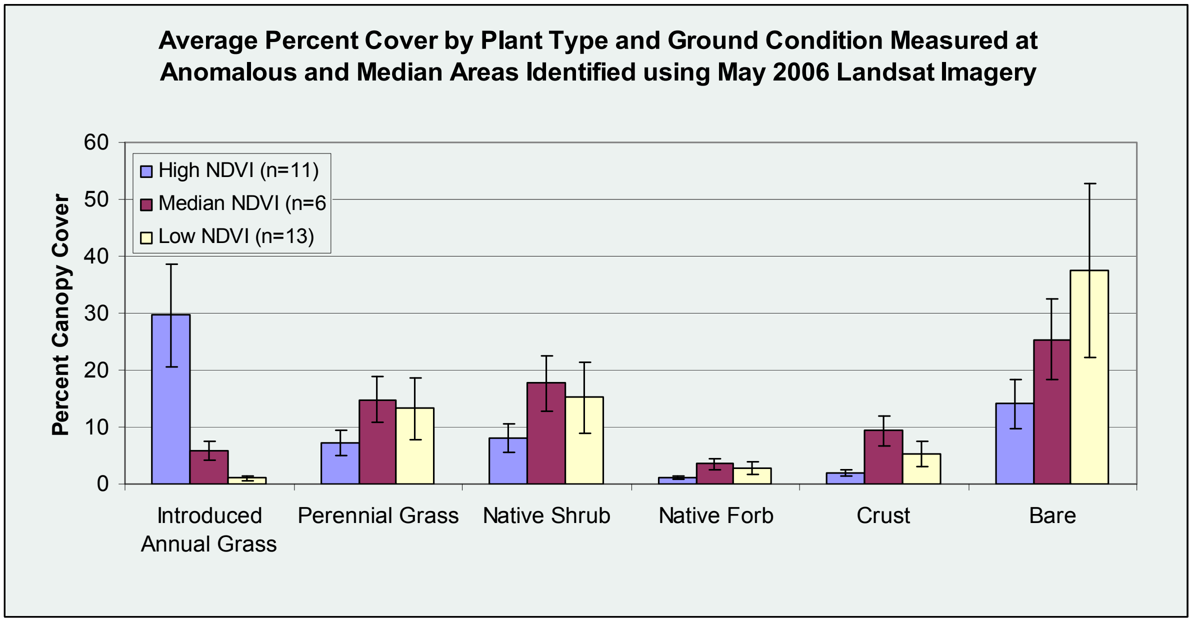

Figure 4.5. Measured Canopy Cover for Vegetation and Ground Condition Within Low, Median, and High Anomalous Areas Based on May 2006 NDVI Values

more introduced annual grass and significantly less bare soil and biological crusts than median and low anomaly areas. Although the small sample size and unequal replication within categories limits the robustness of any statistical analysis, a general analysis of variance for all sites for introduced annual grass and bare soils give some indication of significant differences between the high, median, and low NDVI categories ($P < 0.01$).

The data available to evaluate June brightness anomalies did not provide as clear a relationship between high brightness values and bare soils as seen in the May NDVI anomaly data (Figure 4.6). Measured ground cover of bare soil was higher for areas exhibiting high brightness values than that measured for median or low brightness values, but the variability in measured bare ground cover was much higher for these three categories. Part of this variability could be attributed to the small sample size and unequal replication obtained.

Analysis of anomalous areas does appear to provide methods to identify areas of management concern and information that could be summarized to give insight regarding current condition on allotments, pastures, or other land areas of interest.

Whether this type of strategy for stratifying the spectral response by ecological sites might provide insight in locating and identifying areas in good condition is less obvious. However, the average values for perennial grass cover and biotic crust cover are greater for areas with low or median NDVI values in May. An interesting assumption might be that if a majority of the land in a particular ecological site is in good condition, then the median of the anomaly distribution should represent areas in good condition. Two attributes which might indicate rangeland in “good” condition are perennial grasses and biotic crust. If we look at the May NDVI data, we see that the perennial grass and biotic crust measurements were highest in the median areas.

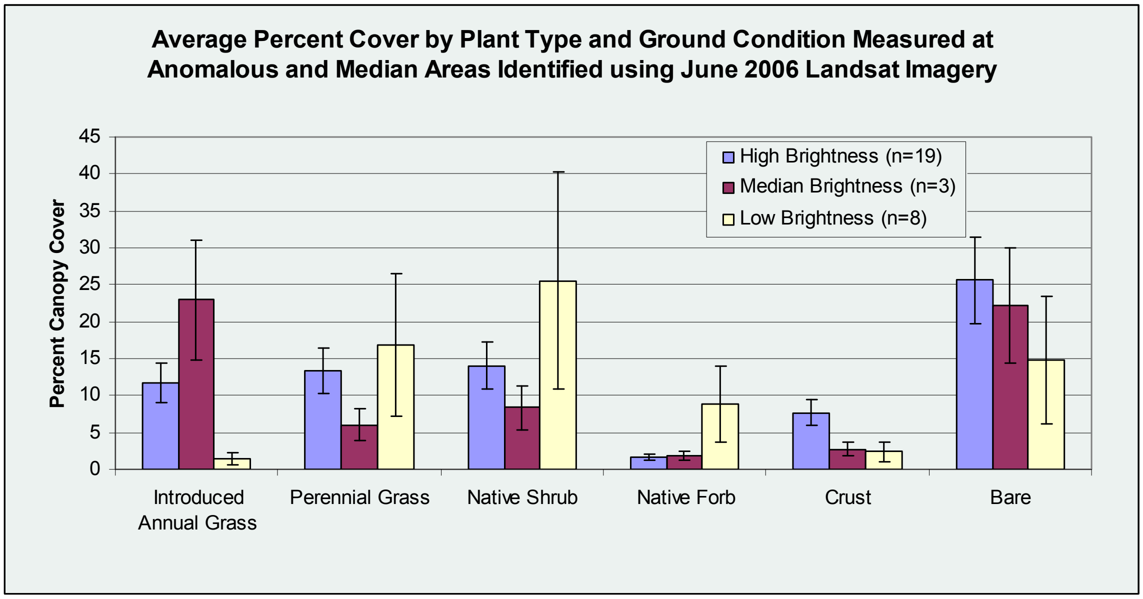

Figure 4.6. Measured Canopy Cover for Vegetation and Ground Condition Within Low, Median, and High Anomalous Areas Based on June 2006 Brightness Values

The timing of the imagery is important to consider when interpreting the low, median, and high spectral values for an ecological site or landscape. Note that the June values for low brightness correspond to higher cover of shrubs, native forbs and perennial grasses and lower cover of bare soils and introduced annual grass. These types of findings need to be interpreted with consideration of the growth stages of the vegetation of interest. In late June, perennial grasses and shrubs are still mostly green—annual grasses have completed growth for the year and are senescent at that time. The areas with green vegetation exhibit a lower brightness value than areas with senesced vegetation.

In general, the anomalous area analysis using several different spectral indexes for image dates that are relevant to the vegetation growth stages of the region can provide a strong starting point for assessing the condition of rangelands. Low NDVI values, depending on the image date, can be interpreted in several ways: high amounts of bare soils or a lack of vegetation cover. It may also be possible to use these types of index values to indicate utilization of forage in particular pastures.

5.0 References

Crist EP, R Laurin, and RC Cicone. 1986. "Vegetation and Soils Information Contained in Transformed Thematic Mapper Data." In *IGARSS '86 – Remote Sensing – Today's Solutions for Tomorrow's Information Needs*, pp. 1465–1470. ESA SP-254, European Space Agency, Paris.

Maynard CL, RL Lawrence, GA Nielsen, and G Decker. 2007. "Ecological Site Descriptions and Remotely Sensed Imagery as a Tool for Rangeland Evaluation." *Canadian Journal of Remote Sensing* 33(2):109–115.

NatureServe. 2005. *International Ecological Classification Standard: Terrestrial Ecological Classifications*. NatureServe Central Databases, Arlington, Virginia. Data current as of September 20, 2005.

Appendix A

Description of Vegetation Cover Types and Plant Codes Used in the PNNL Classification of Vegetation in the Snake River Study Area (Boise District)

Table A.1. Vegetation Cover Types Used in PNNL Classification

General Cover Type	Dominant Plant Species
Agriculture	N/A
Aspen	Aspen
Big Sagebrush/Bunchgrass (ARTR/BG)	Wyoming Big Sage/Sandberg's Bluegrass, Wyoming Big Sage/ Bluebunch Wheatgrass, Wyoming Big Sage/Squirreltail, Wyoming Big Sage/Sand Dropseed, Wyoming Big Sage/Cheatgrass
Bitterbrush (PUTR/BG)	Bitterbrush/Bluebunch Wheatgrass, Bitterbrush-Gray Rabbitbrush/ BG-Cheatgrass
Bunchgrass (BG)	Bluebunch Wheatgrass, Idaho Fescue, Bunchgrass-Cheatgrass
Conifer	Douglas Fir
Cheatgrass-Exotic Annuals (BRTE)	Cheatgrass, Bur Buttercup, Mustard spp. and other exotic annual species
Greasewood (SAVE)	
Juniper	Juniper/Bunchgrass, Juniper-Mountain Sagebrush/Bunchgrass, Juniper-Wyoming Big Sage/bunchgrass
Low Sagebrush (ARAR/BG)	Low Sagebrush/Sandberg's bluegrass, Low sagebrush/Bluebunch wheatgrass, Low Sagebrush/Idaho Fescue, possibly some areas of Alkali Sage or Black Sagebrush with Sandberg's bluegrass
Mountain Sagebrush/ Bunchgrass (ARTRV/BG)	Mountain Big Sagebrush-Rabbitbrush/Bunchgrass, Mountain Big Sagebrush-Bitterbrush/Idaho Fescue-Bluebunch wheatgrass, Mountain Big Sage-Bitterbrush-Rabbitbrush/Bunchgrass
Mountain Shrub (MTNSHRUB)	Mountain Big Sagebrush-Snowberry, Buckbrush, Serviceberry, Ocean spray, Snowberry, or Bitterbrush with scattered Juniper and Aspen
Rabbitbrush (CHVI/BG)	Green Rabbitbrush primarily, but some areas of Gray Rabbitbrush
Riparian	Willow, Cottonwoods, Riparian shrubs
Salt Desert Shrub (ATCO/BG, ARSP/BG, CELA/BG, ATCA/BG)	Budsage-Shadscale/Cheatgrass, Budsage-Shadscale/Sandberg's Bluegrass, Winterfat/Bunchgrass, Shadscale-Horsebrush/ Bunchgrass
Seeding	Siberian Wheatgrass, Crested Wheatgrass, Desert Wheatgrass
Sparse Vegetation	Badlands, Playa, Rock Outcrop
Stiff Sagebrush (ARRI/BG)	Stiff Sage/Sandberg's Bluegrass, Stiff Sage/Bluebunch Wheatgrass
Urban	Residential, Transportation, Urban
Water	Water
Wet Meadow	Wet Meadow

Table A.2. Plant Codes Used in Identification and Classification

Code	Species Name	Comment or Explanation
ARAR	*Artemisia arbuscula*	Low sagebrush
ARRI	*Artemisia rigida*	Stiff sagebrush
ARSP	*Artemisia spinescens (Picrothamnus desertorum)*	Bud sagebrush
ARTR	*Artemisia tridentata*	Big sagebrush
ARTRV	*Artemisia tridentata* subsp *vaseyana*	Mountain big sagebrush
ARTR4	*Artemisia tripartita*	Three-tip sagebrush
AGSP	*Agropyron spicatum (Pseudoroegnaria spicata)*	Bluebunch wheatgrass
AGCR	*Agropyron cristatum*	May include *Agropyron sibericum* or other wheatgrass seeded species
ATCO	*Atriplex confertifolia*	Shadscale saltbush
BG	*Bunchgrasses*	Includes perennial bunchgrass species, primarily native bunchgrasses
BRTE	*Bromus tectorum*	Cheatgrass
CELA	*Ceratoides lanata (Krascheninnikovia lanata)*	Winterfat
CHNA	*Chrysothamnus nauseosus (Ericameria nauseosa)*	Gray rabbitbrush
CHVI	*Chrysothamnus viscidiflorous*	Green rabbitbrush
JUOC	*Juniperus occidentalis*	Western juniper
POSE	*Poa secunda*	Sandberg's bluegrass
PSME	*Pseudotsuga menziesii*	Douglas fir
PUTR	*Purshia tridentata*	Antelope bitterbrush
SAVE	*Sarcobatus vermiculatus*	Greasewood
SIHY	*Sitanion hysterix*	Bottlebrush squirreltail
STCO	*Stipa comata*	Needle-and-thread grass
STTH	*Stipa thurberiana*	Thurber's needle-and-thread grass

Appendix B

Evaluation of Accuracy of Vegetation Classifications Using Ground-Truth Data

Table B.1. Agreement between SAGEMAP Classification and Ground-Truth Data

Ground Truth Data→ SAGEMAP Vegetation Classification Error Matrix – SAGEMAP Class↓	Agriculture	Cliff Canyon and Barren	Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe	Developed_Disturbed	Evergreen Forest and Meadowland	Greasewood Salt Desert Shrub	Inter-Mountain Basins Mixed Salt Desert Scrub	Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland	Introduced Perennial Grassland	Invasive Annual Grassland	Juniper	Low Sage/Low Sagebrush Mix	Montane Sagebrush Steppe	Montane Shrubland	Perennial Grassland	Recently Burned	Riparian	Rocky Mountain Aspen Forest and Woodland	Sagebrush/Sagebrush-Mixed Shrub Steppe	Water	Grand Total
Agriculture						1															1
Cliff Canyon and Barren							1												3		4
Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe											1	1	2								4
Developed_Disturbed				1			1		1			1							3		7
Evergreen Forest and Meadowland					2						2	2	6	2							14
Greasewood Salt Desert Shrub							1			1		1									3
Inter-Mountain Basins Mixed Salt Desert Scrub						10	22		1	2			1						10		46
Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland								1			2	2									5
Introduced Perennial Grassland																					
Invasive Annual Grassland							2		3	5		6	2						16		34
Juniper								1			2	12	6						2		23
Low Sage/Low Sagebrush Mix								2	2	1	3	39	14		1				11		73
Montane Sagebrush Steppe												38	43	1				2	7		91
Montane Shrubland																					
Perennial Grassland												9	5		1			1	10		26
Recently Burned					1				9	2		1	2		1				8		24
Riparian					1						1	2			1		2	2	1		10
Rocky Mountain Aspen Forest and Woodland																					
Sagebrush/Sagebrush-Mixed Shrub Steppe		1				4	28	2	25	5	3	66	57		9		3		151		354
Water																				1	1
Grand Total		1		1	4	15	55	6	41	16	14	180	138	3	13		5	5	222	1	720

Table B.2. Agreement between PNNL Classification and Ground-Truth Data

PNNL Vegetation Error Matrix--PNNL Map Class↓ / Ground Truth Data→	Agriculture	Cliff Canyon and Barren	Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe	Developed_Disturbed	Evergreen Forest and Meadowland	Greasewood Salt Desert Shrub	Inter-Mountain Basins Mixed Salt Desert Scrub	Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland	Introduced Perennial Grassland	Invasive Annual Grassland	Juniper	Low Sage/Low Sagebrush Mix	Montane Sagebrush Steppe	Montane Shrubland	Perennial Grassland	Riparian	Rocky Mountain Aspen Forest and Woodland	Sagebrush/Sagebrush-Mixed Shrub Steppe	Water	Grand Total
Agriculture															1					1
Cliff Canyon and Barren						2	1											1		4
Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe													1					1		2
Developed_Disturbed																				
Evergreen Forest and Meadowland					3							1	1					1		6
Greasewood Salt Desert Shrub						5	2											1		8
Inter-Mountain Basins Mixed Salt Desert Scrub						3	28		2	3								23		59
Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland											3	1	12					1		17
Introduced Perennial Grassland									13	5					1			12		31
Invasive Annual Grassland		1					1		3	2		4	2					7		20
Juniper								2			6	19	21	1	1		1	3		54
Low Sage/Low Sagebrush Mix									3	2		81	13		1	1		28		129
Montane Sagebrush Steppe								4			4	30	59	2	1	1	3	7		111
Montane Shrubland												3								3
Perennial Grassland							1		3			8	3		3			19		37
Riparian					1								2			1				4
Rocky Mountain Aspen Forest and Woodland																	1			1
Sagebrush/Sagebrush-Mixed Shrub Steppe				1		5	22		17	4	1	33	24		5	2		118		232
Water																			1	1
Grand Total		1		1	4	15	55	6	41	16	14	180	138	3	13	5	5	222	1	720

Table B.3. Agreement Between Landfire Classification and Ground-Truth Data

	Ground Truth Data→																				
LandFire Vegetation Classification Error Matrix – Map Class↓	Agriculture	Cliff Canyon and Barren	Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe	Developed_Disturbed	Evergreen Forest and Meadowland	Greasewood Salt Desert Shrub	Inter-Mountain Basins Mixed Salt Desert Scrub	Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland	Introduced Perennial Grassland	Invasive Annual Grassland	Invasive Perennial Forbland	Juniper	Low Sage/Low Sage Sagebrush Mix	Montane Sagebrush Steppe	Montane Shrubland	Perennial Grassland	Riparian	Rocky Mountain Aspen Forest and Woodland	Sagebrush/Sagebrush-Mixed Shrub Steppe	Water	Grand Total
Agriculture																					
Cliff Canyon and Barren						1			1	1											3
Columbia Plateau Silver Sage Seasonally Flooded Shrub-Steppe																					
Developed_Disturbed																					
Evergreen Forest and Meadowland					3							3	3	6	1		3	2	1		22
Greasewood Salt Desert Shrub						1	2												1		4
Inter-Mountain Basins Mixed Salt Desert Scrub		1		1			9			1			1						6		19
Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland													2	3							5
Introduced Perennial Grassland																					
Invasive Annual Grassland						2	4		2					1					7		16
Invasive Perennial Forbland							3														3
Juniper								3				8	14	32	1			1			59
Low Sage/Low Sagebrush Mix					1			2	1			2	72	38	1	1	1		16		135
Montane Sagebrush Steppe													4	2					2		8
Montane Shrubland													8								8
Perennial Grassland									2	6			1			1			8		16
Riparian						1			1	1				1			1	1	2		8
Rocky Mountain Aspen Forest and Woodland																					
Sagebrush/Sagebrush-Mixed Shrub Steppe						10	37	1	34	9		2	75	54		11		1	179		413
Water																				1	1
Grand Total		1		1	4	15	55	6	41	16		14	180	138	3	13	5	5	222	1	720

Distribution

No. of
Copies

OFFSITE

2 Mike Pellant
Great Basin Restoration Initiative
Coordinator
Idaho Bureau of Land Management
1387 S. Vinnell Way
Boise, ID 83709

Don J. Major, PhD.
Fire & Landscape Ecologist - Great Basin
Restoration Initiative The Nature
Conservancy of Idaho & Bureau of Land
Management
1387 S. Vinnell Way
Boise, ID 83709

No. of
Copies

ONSITE

3 **Pacific Northwest National Laboratory**

J. D. Tagestad	K6-85
Hanford Technical Library (2)	P8-55