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Multi-Agency Oregon Pilot: Working Towards a National Inventory and Assessment of Rangelands Using Onsite Data

Paul L. Patterson, James Alegria, Leonard Jolley, Doug Powell, J. Jeffery Goebel, Gregg M. Riegel, Kurt H. Riitters, and Craig Ducey

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Abstract

Rangelands are lands dominated by grasses, forbs, and shrubs and are managed as a natural ecosystem. Although these lands comprise approximately 40 percent of the landmass of the continental United States, there is no coordinated effort designed to inventory, monitor, or assess rangeland conditions at the national scale. A pilot project in central Oregon with the U.S. Forest Service, the Natural Resources Conservation Service, and the Bureau of Land Management showed how consistent information could be collected to produce approximately unbiased estimates across the landscape. Exploratory data analysis was conducted to illustrate some of the uses for the data.

Keywords: rangeland inventory, rangeland monitoring, inter-agency, FIA, NRI, BLM

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1. Introduction

Rangelands are a type of land on which the natural vegetation is dominated by grasses, forbs, and shrubs and are managed as a natural ecosystem. These lands comprise approximately 40 percent of the landmass of the continental United States (Bentley 1985), and are a valuable source for various products and ecosystem services including food, fiber, clean water, wildlife habitat, open space, and carbon sequestration. They are also a setting for outdoor recreation and are used by millions of Americans every year. Various threats can impact the capacity of rangelands to continue producing these goods and services. Increased development and other changes in the use of rangelands can result in increased erosion, domination by invasive species or other changes in the plant community that change the kinds of products and services that can be produced. Climate changes may be causing altered fire cycles or other changes to these plant communities. Although the importance of rangelands is recognized and several agencies have responsibilities for various aspects of rangeland inventory and assessment, there is no coordinated effort specifically designed to inventory, monitor, or assess rangeland conditions at the national scale. There are many different ways to inventory and monitor resources present on the nation's rangelands and each agency has developed their own methods for documenting and reporting on rangeland conditions. As a result, comparable information that could be used to make comprehensive assessments of private and public rangelands managed by various agencies does not currently exist.

The lack of reliable consistent information on the status of rangelands at national and regional scales reduces the ability to understand and address rangeland issues. This lack of standardization has led to uncertainty as to the condition of public lands (Mitchell 2000), and is likely to become even more important as we face significant changes in these ecosystems resulting from expanding human populations, residential development, and climate change. Several of these significant and emerging issues are discussed in more detail in Section 7 (Next Steps). It is important to have reliable information for any assessment of America's rangelands to assist in addressing these issues in a meaningful way.

There is a need for a rangeland inventory and assessment protocol that is consistent, quantitative, relatively inexpensive, repeatable, systematic, statistically sound, and can be accomplished with minimal technical skills (O'Brien and others 2003). The need for a national assessment tool for the Nation's rangelands has been at the forefront of discussion for many years. In the past, many different groups and organizations, including the livestock industry and rangeland professionals, have expressed their desire for more consistent assessments of rangelands. Since the early 1970s, the Society for Range

Management has actively been pursuing more consistent terminology and procedures for range condition and trend assessment, as well as the development of a national rangeland survey. The National Research Council (1994) identified an “urgent need to develop the methods and data collection systems at both the local and national levels to assess federal and nonfederal rangelands”. More recently a report published by the Heinz Center (2002) titled “The State of the Nation’s Ecosystems” identified inadequacies associated with the data that could be used to report on 8 of the 14 indicators they believed would be useful for describing grassland and shrubland use and condition. Additionally Congress has expressed a desire for more consistency in the way that agencies assess and report on rangeland conditions.

With this in mind, the U.S. Forest Service (USFS), the Natural Resources Conservation Service (NRCS), and the Bureau of Land Management (BLM) have worked together to explore how consistent information could be collected for each of these agencies. This pilot project referred to as the “Multi-agency Oregon Pilot” (MAOP) is an effort to demonstrate how the three agencies responsible for the majority of the nation’s rangeland resources can begin to work together to assess and report on rangeland conditions at the regional and national scale. This report documents the accomplishments of this effort.

Objectives

The objective of this project is to test the feasibility of collecting a core set of rangeland indicators in a consistent manner using the existing frameworks of the Forest Inventory and Analysis (FIA) program operated by USFS and the National Resources Inventory (NRI) program operated by NRCS. The initial proposal was to compare the separate metrics that FIA and NRI gather on rangelands. However, due to the significant advantages associated with maintaining consistency with the data collected previously within the two existing systems, the proposal involved making modifications and collecting data using both the FIA and NRI survey programs. This pilot examined the application of consistent definitions and protocols, the adequacy of the FIA and NRI sampling frames, the adaptability of existing survey operations, the extension of scientifically credible surveys to non-forested Federal lands, and quality assurance processes.

2. Background

Two earlier efforts working toward a national inventory occurred in the mid 1990s. In central Oregon a pilot project initiated a data collection and analysis effort using both FIA and NRI plots to test the feasibility of integrating those systems for terrestrial systems (Goebel and others 1998). The BLM launched a pilot project to test the feasibility of applying the NRI design to public rangeland in Colorado. These efforts are discussed in Appendix 1. Although MAOP is not a continuation of these efforts they informed development of this project (Pellant and others 1999; Spaeth and others 1999).

Participants in the Sustainable Rangelands Roundtable (SRR) include rangeland scientists and managers, ecologists, sociologists, economists, policy and legal experts, environmental advocates, industry representatives and agency staff. Representatives of SRR expressed the advantages of incorporating indicators that had been identified by SRR into rangeland assessments that could be applied to all U.S. rangelands across all land ownerships. As a result, managers from the Council on Environmental Quality, the U.S. Forest Service, the Natural Resources Conservation Service, the U.S. Geological Survey, and the Bureau of Land Management met in Washington, DC to discuss how they could collect consistent information using the Criteria and Indicator concept for rangeland sustainability. Existing systems were evaluated to see if they could be used to accomplish the goals of this effort. Two Federal agency programs were identified as having the existing infrastructure, operational capabilities, and national experience in data collection, analysis, and assessment:

- T*he Forest Inventory and Analysis* (FIA) program operated by USFS
- *The National Resources Inventory* (NRI) program operated by NRCS.

These existing large-scale sampling programs were examined to see how they could be enhanced/modified to address rangeland indicators nationally. Both surveys are approximately 70 years old, collect quantitative information from sample points, and supplement ground data with remote sensed data. The surveys vary in terms of sample design, data collected, protocols used, and geographic scope.

FIA Program

The FIA Program of the U.S. Forest Service has a long history of providing information needed to assess America's forests; it reports on status and trends in forest area and location; on the species, size, and health of trees; on total tree growth, mortality, and removals by harvest; on wood production and utilization rates by various products; and on forest land ownership. The FIA program is actually a collection of scientifically based surveys designed to focus on various aspects of the Nation's forested ecosystems. The surveys fall into four broad categories: (1) Forest Monitoring; (2) Ownership Study; (3) Timber Product Output; and (4) Utilization Studies. The forest monitoring component is the best known aspect of FIA and is the survey framework portion of FIA utilized for MAOP (see http://fia.fs.fed.us/ for further details).

NRI Program

The NRI program is conducted by the Natural Resources Conservation Service, in cooperation with Iowa State University's Center for Survey Statistics and Methodology. The NRI is a longitudinal scientifically based survey designed to gauge natural resource status, conditions, and trends of the Nation's non-Federal land. It has an important role in farm policy development, conservation program implementation, and strategic planning and accountability. NRI data were collected at 5-year intervals between 1977 and 1997, and in 1997 the NRI transitioned to a 5-year inter-penetrating panel design with each year measuring one panel of plots and with a subset of plots measured annually. The NRI focuses on land cover and use, soils, soil erosion, wetlands, habitat diversity, selected conservation practices, and related resource attributes with soil characteristics and interpretations playing very important roles in NRI-based analysis and assessment.

Concept

The agency representatives discussed comparing both the FIA and NRI survey programs and focusing on a small suite of SRR indicators. Making changes to NRI or FIA inventory efforts could result in reduced data quality or availability; therefore, maintaining the ability to use the data already collected by the existing surveys was also a primary consideration. The agencies explored whether each system could be modified slightly to maintain the integrity of the data already collected, but make the data collected by each system for the selected set of shared indicators comparable. The representatives of the agencies discussed and agreed upon a small suite of indicators that they believed were valuable for reporting on rangeland resources and for which they could cooperatively develop consistent protocols. The small set of indicators was chosen based on constraints of cost and timing and was never intended to be a complete set of indicators.

These five indicators were eventually selected (Goebel and Reams, 2006):

1. Amount and distribution of rangelands
2. Amount and distribution of bare ground on rangelands
3. Amount and distribution of vegetation cover types on rangelands
4. Amount and distribution of invasive species on rangelands
5. Degree of fragmentation on rangelands

Information on these indicators can be used to help the agencies and other entities address the following points:

1. Amount and distribution of rangelands.
    a. Rationale: To provide information on conversion of rangelands over time, identify farm bill program needs, support initiatives related to rangelands, resource planning, allocation, resource decision making and valuation.

2. Amount and distribution of bare ground on public and private rangelands.
    a. Rationale: A stable and sustainable soil base is needed for rangeland watersheds to yield a variety of multiple-use products, services, and amenities (Ellison and others 1951). The soil base, no matter what the soil classification, needs an adequate ground cover of vegetation, litter, and rock for protection from rain, erosion, and use (O'Brien and others 2003). Bare ground is a predictive indicator; it can precede acceleration of wind and water erosion, which could affect water quality and quantity, and wildlife habitat.

3. Amount and distribution of vegetation cover types on public and private rangelands.
    a. Rationale: Vegetation communities have evolved a characteristic kind (cool season, warm season, grassland, shrub-grass, sedge meadowland) and amount of vegetation. The plant community can be typified by an association of species that differs from that of other communities or ecological sites in the kind and/or proportion of species or in annual production. These vegetation communities evolved with a characteristic kind of herbivory (kinds and numbers of herbivores, seasons of use, intensity of use) and fire regime. Fire frequency and intensity contributed to the characteristic plant community of the site (Habich 2001). This indicator can be utilized to determine when changes are occurring, and assist in better understanding forage and browse production, which could affect carbon sequestration, rangeland products, water quality and quantity, and wildlife habitat.

4. Amount and distribution of invasive species on public and private rangelands.
    a. Rationale: Invasive species are of growing concern and recognition as a threat to land health. It is a predictive indicator; initial early infestations often foreshadow larger scale land health issues. As the extent of these invasions expand across the landscape, changes within functions and/or processes may result in an irreversible decline in the overall productivity of the rangeland system (SRR 2006).

5. Degree of fragmentation on public and private rangelands.
    a. Rationale: Fragmentation is an interruptive process affecting the sustainability of rangeland ecosystems. Fragmentation of community

> types is particularly critical for wildlife and some plant populations; sufficient habitat and niche size is required to sustain breeding, rearing, feeding, and shelter needs. Specific agents of fragmentation, such as intensive land uses, roads, and concentrations of exotic species, may affect the overall impact this process has upon rangeland ecosystem function and watershed values (SRR 2006).

There were two issues that made use of the fragmentation indicator difficult. First there was no clear definition of the fragmentation indicator. Second, because the FIA and NRI systems are plot based, they allow for only limited measures of fragmentation. Rather than delay data collection for the entire project, the agencies decided to proceed with data collection on the other indicators while the work on fragmentation continued. There are various groups including SRR and the Heinz Center that continue to work on concepts related to fragmentation. SRR scheduled a workshop and invited various scientists that had experience with fragmentation to help identify a means for collecting consistent information on that subject. After the inventory study had been completed, a pattern analysis study was conducted on an area that contains the inventory study area. The pattern analysis was used to investigate fragmentation. The pattern analysis study is discussed in Section 5 (Fragmentation: Land-Cover Pattern Analysis).

To test their ability to collect consistent information on these indicators the agencies developed a proposal for a pilot project. Various areas where a pilot could be conducted were considered and central Oregon was identified as most suitable for the pilot because:

1. it contained a variety of rangeland plant communities that occurred on both private land and public land representing both the BLM and the Forest Service,
2. there was good coordination and good working relationships between the various agencies in Oregon, and
3. there was a wealth of other data available that would help in both developing and evaluating the pilot.

Figure 2.1 displays the 13-county area in central Oregon where the pilot was conducted. This area includes 30 million acres of Federal, state, private and tribal lands.

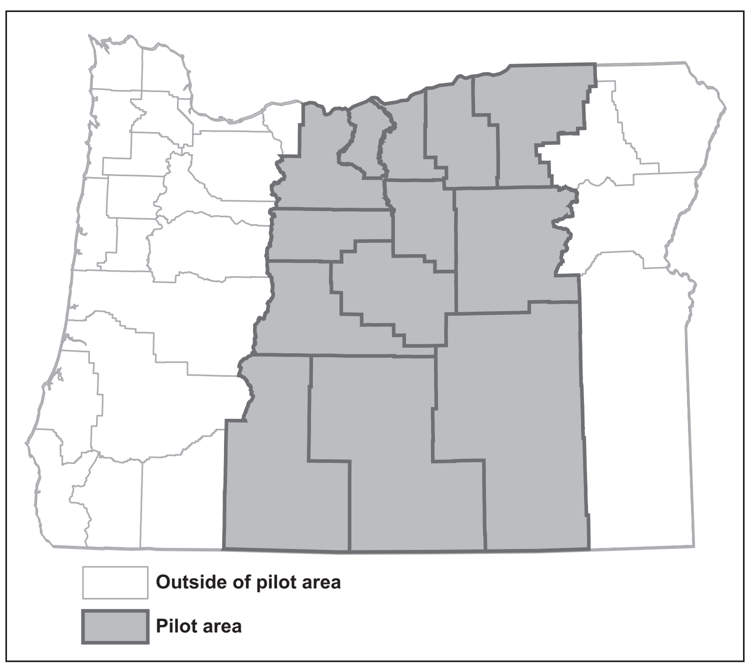

Figure 2.1—Multi-agency Oregon Pilot 13-county area in central Oregon encompassing 30 million acres of Federal, state, private, and tribal lands.

The initial data collection for this pilot project was conducted during 2007 and the report written in 2008. An external review of this project was conducted in January 2009, and the report was revised, based on reviewers' comments.

In response to the pilot project, members of SRR collected information on several of the social and economic indicators for the same area. The Social and Economic indicators for which data was collected included (1) population pyramid and population change; (2) source of income and level of dependence on livestock production; (3) employment, unemployment, underemployment, and discouraged workers by sector; and (4) land tenure, land use and ownership patterns by size classes.

This work has not been published. For overview of the literature see Tanaka and others 2011.

3. Survey Design and Methodology

The long-term objective under development is a science-based sample survey approach that addresses short-term and long-term needs for nationally consistent information, including the capability to derive scientifically credible estimates of trends in the Nation's rangeland resources. For this initial step, the survey approach being tested featured a blending of survey methodology utilized by the FIA and the NRI programs.

The survey approach developed for this pilot included a sample design that accommodates the different geographical scopes of the FIA and NRI programs, a set of common agreed-to protocols for on-site data collection in addition to collection of each program's standard set of protocols, and the acquisition of high-resolution large-scale aerial photography for each sample plot. This approach allows investigation of how utilization of large-scale photography can increase the precision of estimates based on field plot data, and whether some indicators and assessments can be based solely on data collected from photography.

Data Collection Methodology: Protocols, Plot Design

The data collection protocols and methodology were to be based on existing NRI and FIA methodologies to the extent possible. The intent was to initiate data collection in May 2007 concurrently with data collection already planned as part of FIA's and NRI's regular on-site data collection programs. This meant procedures developed for MAOP needed to fit within the methodology already employed by the two inventory programs. NRI and FIA employ different protocols and plot designs, so the methodology implemented for the pilot represents a selection and modification of several existing protocols. It was agreed that both NRI and FIA would utilize a limited number of agreed-to protocols, but that each would also implement their usual full suite of protocols at their respective sample sites. The focus of this report is only the indicators agreed to by the three agencies; the full suite of data is not included in this report. Additional analysis will be conducted by the agencies to determine if data collected using the full suite of NRI and FIA protocols can be used to address additional indicators.

This section includes a brief overview of the FIA and the NRI plot design as implemented in their respective inventories followed by the modification to their design for the MAOP study.

FIA Ground Plots**—**The FIA plots consist of a cluster of four circular subplots spaced out in a fixed pattern. The plot is designed to provide a sampling location for all measurements. There are three 24-foot radius subplots arranged in a triangular pattern around a central subplot (see figure 3.1). Subplot centers are located 120 ft apart with subplots 2, 3, and 4 oriented at 120^{o} angles around the plot center. Each subplot contains a 6.8-foot radius micro-plot; and each subplot is surrounded by a 58.9-ft radius macro plot as an

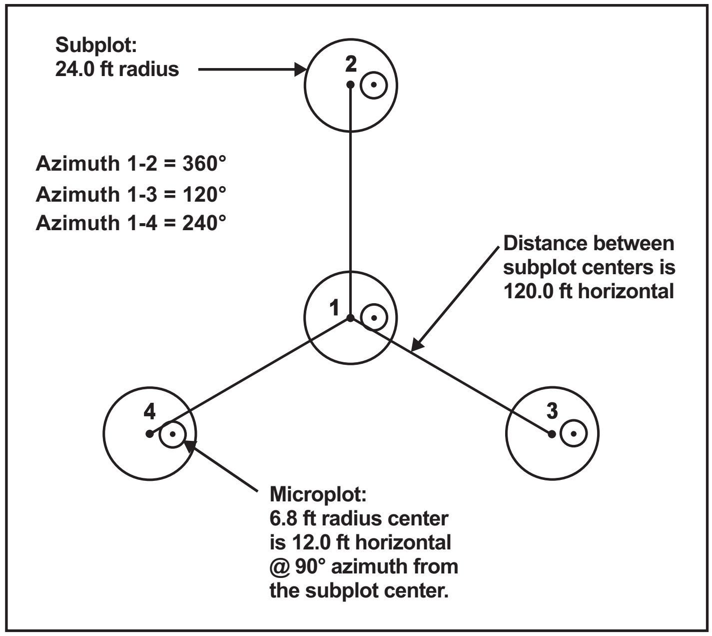

Figure 3.1—Layout of FIA ground plot.

optional feature to supplement the 24.0-foot subplot for less common measurements. The four subplots total approximately 1/6th of an acre, and the four micro-plots total about 1/75th of an acre.

NRI Ground Plots—The NRI ground plots consist of two 150-foot transects that are perpendicular and cross at the NRI sample point (see figure 3.2). These transects support three types of line transect observations of which only line point intercepts for cover and composition were examined for MAOP (see the NRI field handbook (USDA NRCS 2007) for details). Observations and interpretations are also made for the 150-foot diameter circular plot formed by the ends of the transects, and for the quadrants within this large 0.41-acre plot.

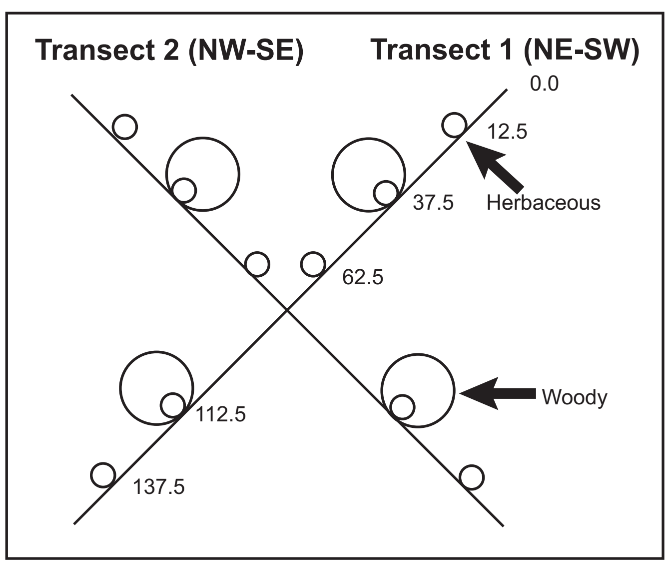

Figure 3.2—Layout of NRI ground plot.

MAOP Line Point Intercept**—**Data on cover was collected for MAOP using *line point intercept* methodology on permanent transects. Cover is one of the most common measures of community composition because it equalizes the contribution of very small, abundant species, and species that are very large, but few (Elzinga and others 2001). Measuring cover by points is considered the least biased and most objective of the three basic cover measures (Bonham 1989). Line-point intercept is a rapid and accurate method for quantifying soil cover, including vegetation, litter, rocks, and biotic crusts (Heady and others 1959). These measurements are related to wind and water erosion, water infiltration, and the ability of the site to resist and recover from degradation (Herrick and others 2005). This method was chosen to gather data regarding bare ground and vegetation composition.

The NRI protocols were followed by both inventories, where the basal layer, the aerial layer (foliar cover) and up to six species and litter (herbaceous, woody, or artificial) were recorded for the canopy cover, while the basal layer includes bare ground, rock fragments, lichen crust, moss, and basal cover of species. The implementation of the line point intercept methods were as follows:

- FIA: On subplots 1, 2, and 3 of the FIA plot design, two 48-ft transects were formed, one running north-south and the other east-west, with data recorded every 3 ft. (see figure 3.3).
- NRI: Data were recorded every 3 ft along the two 150-ft transects running north-south and the other east-west according to their standard protocol.

While the line point intercept method produces unbiased estimates of cover, it does not detect well uncommon species that may be present in the area.

MAOP Species Enumeration**—**Valuable data can be collected through species enumeration. Many protocols were considered for testing in MAOP; each with their strengths and weaknesses. Considerations included skills needed by data collection teams/crews, the time it takes to complete data collection, repeatability, and usefulness of the data. The protocol selected should be beneficial in addressing species diversity and supplementing line point intercept data when assessing the presence of invasive species. This method was chosen to gather data regarding invasive species.

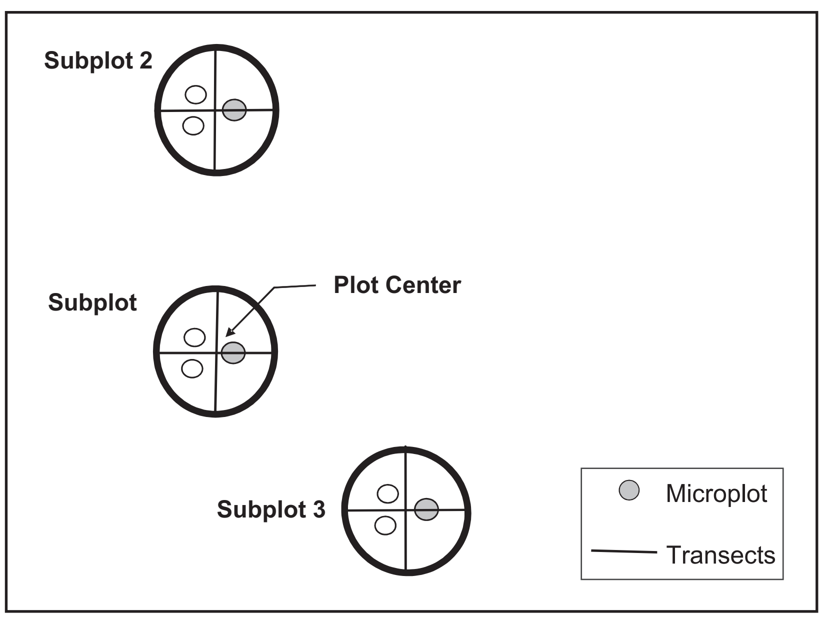

Figure 3.3—Modified FIA plot design, for Oregon Pilot.

All species identified within each micro-plot were recorded; no emphasis was given to recording invasive species, as lists of species of interest change regionally and over time. The specifications of the installation of these permanently marked micro-plots follow:

- FIA: Three micro-plots (6.8-ft radius) were examined for MAOP within the FIA subplots 1, 2, and 3, with one micro-plot being the existing micro-plot and the other two spatially separated on other areas of the subplot (see figure 3.3);
- NRI: Three micro-plots of the same radius and spatial distribution as the FIA ground plots were established (see figure 3.4).

A summary comparison of the plot design and variable definitions between the two inventories is found in table 3.1. Note that all variables collected for the pilot are identically defined and that the plot designs are identical for the categorical variables. Although the continuous variables were collected on different plot designs, the design was consistent within an estimation unit consequently yielding approximately unbiased estimates within a stratified design. The photo plot illustrates how both definitions of rangelands can be accommodated with the use of high resolution photography.

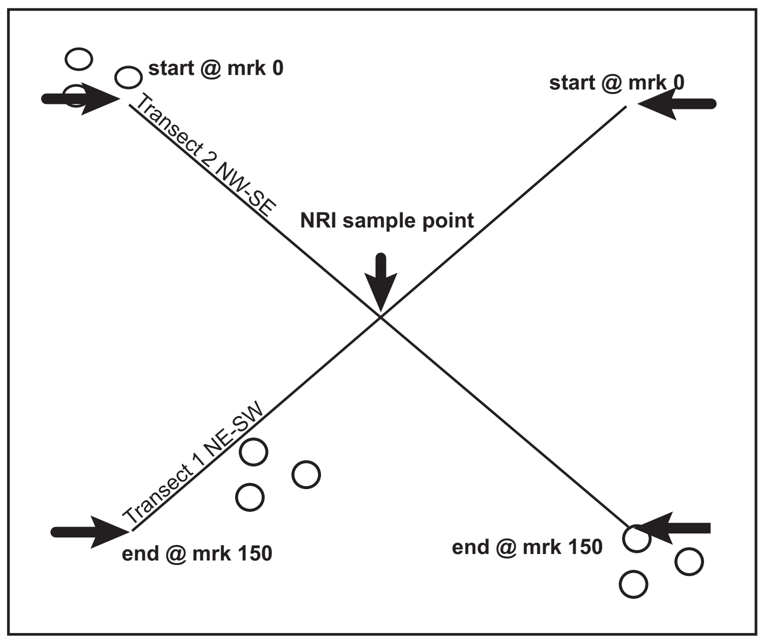

Figure 3.4—Modified NRI plot design, for multi-agency Oregon Pilot.

Table 3.1—Plot design comparison between FIA and NRI inventories.

Design	Variable type	Identical plot design within estimation units?	Variable definition	Remarks
Point line intercept	Continuous	Yes	Identical	The plot design varied between the inventories.
Micro-plots	Categorical	Yes	Identical	
Photo Plot	Categorical	Yes	No	Each plot was classified according the each inventory's protocols

Sample Design

The sample design developed for MAOP represents one particular strategy for sampling private and public lands, taking advantage of the existing survey frameworks of the FIA and NRI national survey programs. To be cost effective, data collection needed to occur in unison with regular operations to take advantage of scheduled travel for crews but not disrupt these operations.

There were numerous possible strategies for determining which NRI and FIA samples would be observed across the 13-county MAOP area. It was decided to use a panel or combination of panels as the basis for the sample. All lands that were assigned to FIA to survey were collected on plots assigned to the FIA panel for 2007. Similarly, all lands that were assigned to NRI were collected on plots assigned to the panel for 2007 on non-Federal lands. Due to the light sample densities on Federal lands, several NRI panels were combined and were the basis for the NRI sample for these lands. Both FIA and NRI have all lands as part of their sample frame but the field visits are restricted to their area of interest and all panels for both inventories are a probabilistic sample of the population; hence, combining panels in certain defined areas results in a probabilistic sample. For this pilot, both FIA and NRI collected field samples according to the rule sets below.

The determination and selection of which subset of sample units to include took into account both statistical and operational factors.

- Approximately unbiased estimates of acreages and indices could be derived for the entire 13-county area, as well as for several domains/subdivisions of the entire area (this means that the sample needed to provide complete and non-overlapping coverage—or if there were overlaps, there needed to be a legitimate statistical procedure to handle the over-lap).
- Estimates of statistical uncertainty due to sampling (e.g., standard errors of statistical estimates) could be provided to those interpreting and analyzing the results.
- FIA and NRI crews would mostly collect data for ecosystems and/or ownership units where they were used to working, based on these rules. These plot assignments were made according to the rules set forth here and the crews did not make plot assignments in the field.
- Data collection for BLM-managed lands would be split between FIA and NRI crews, both to test feasibility and because of budgetary issues.
- Counties were used to help with the distribution of plots, because counties or clusters of counties are basic reporting units for both inventories.

The selection method partitioned the entire 31-million acre area by both predicted land cover and ownership category.

> *Predicted Land Cover:* The 2001 National Land Cover Database (NLCD) produced by the Multi-Resolution Land Characteristics Consortium (MRLC) was used to predict two categories of land cover: (1) forested and (2) non-forested (see http://www.mrlc.gov/about.php for particulars of this land classification program). Each FIA and NRI sample plot/point was classified as either predicted forested or predicted non-forested based upon this 30-meter resolution GIS coverage, using an estimated tree coverage threshold of 25 percent (see figure 3.5). Six MRLC categories were used to designate predicted forested: 41 – deciduous forest; 42 – evergreen forest; 43 – mixed forest; 90 – woody wetland; 91 – Palustrine forested wetland; and 93 – Estuarine forested wetland. It should be noted that many partitioning schemes can be used but the higher

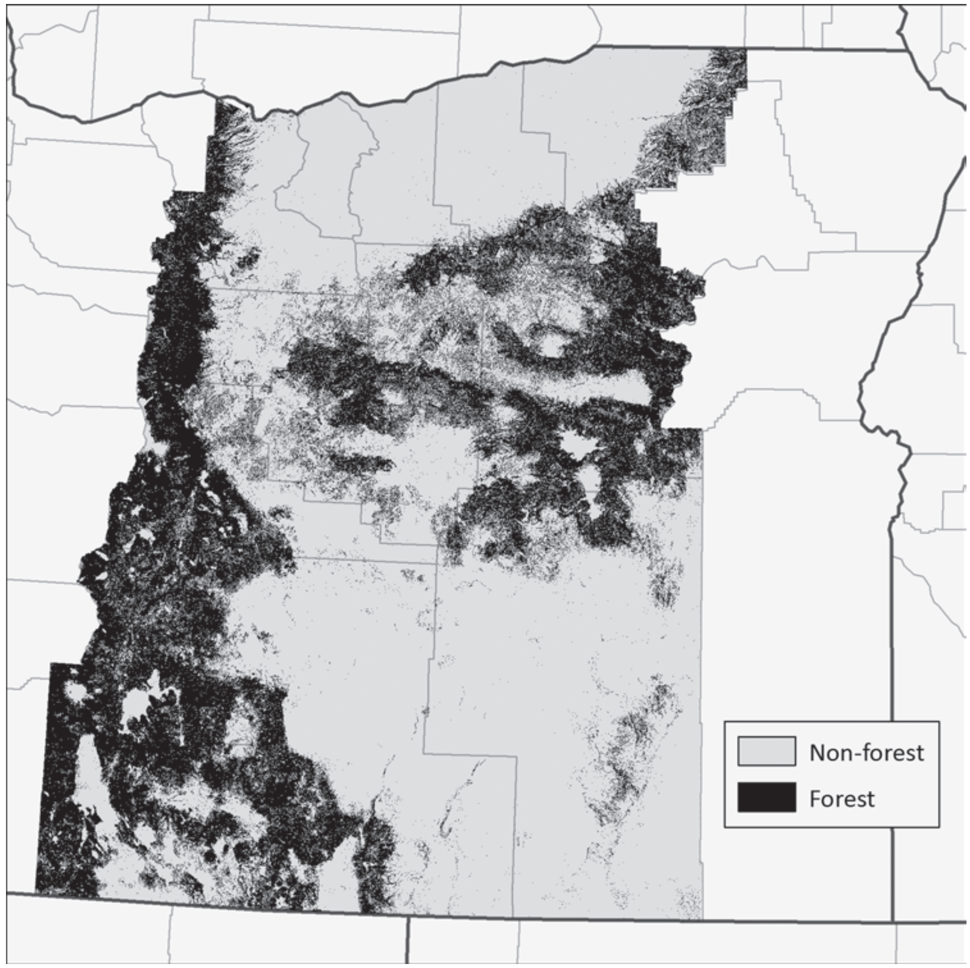

Figure 3.5—Predicted land cover map.

the agreement between the predicted land cover and reality on the ground, the more efficient will be the allocation of human resources to the field, for example, FIA crews are more likely to visit forest land and NRI crews are more likely to visit rangeland. Hence, the field plots were not used to 'correct' the NLCD classification or to assess the accuracy of the NLCD classification

Ownership Category: GIS coverage was compiled for this selection process by the Pacific Northwest FIA GIS unit. Five ownership categories were identified: BLM; USFS; Other Federal; Private (including tribal lands); and Other Gov (including state and local governmental units).

Allocation Rules

- FIA would sample all lands predicted to be forested, regardless of ownership.
- FIA would sample all lands managed by USFS, whether predicted forested or not.
- NRI would sample all non-Federal lands predicted to be non-forested—this included private, tribal, and non-Federal governmental units.
- BLM-managed lands predicted to be non-forested were assigned to one or both inventory units, on a county-by-county basis.

- FIA would sample all lands classified as Other Federal (in other words, not managed by either USFS or BLM), whether predicted forest or not.

The assignment of non-forested BLM lands was based on a desire to balance workload and took into account whether FIA or NRI had nearby sample sites. For example, there are few forested or USFS-managed lands along the Columbia River, so those counties were assigned to NRI since there are significant numbers of NRI sample sites on the non-Federal non-forested lands. Similarly, Crook County has a number of FIA forested plots so it was assigned to the FIA. Other counties, such as the Deschutes and Lake counties, have significant amounts of both NRI and FIA plots so they were assigned to both inventories.

The FIA and NRI concepts of forested land are different, which meant it was not possible to use the respective inventory's classification to partition the landscape; it was decided that the NLCD land cover map provided a good compromise. The map (GIS classification) partitioned the landscape and obligated each inventory to cover all areas assigned to them for the pilot, but the crews were free to visit other locations for the purpose of collecting data for their respective inventories independent of the pilot's requirements.

The GIS-derived base acres for the 13-county MAOP area are presented in table 3.2. As mentioned above, the 8,156,000-acre area predicted to be BLM non-forested was sub-divided into three sets of counties. The set of four counties assigned to NRI for the pilot contained 4,060,000 acres of BLM land predicted to be non-forested; the three counties assigned to FIA contained 740,000 acres; and the six counties assigned jointly to both NRI and FIA contained 3,357,000 acres.

Table 3.2—Predicted land cover and ownership for 13-county multi-agency Oregon Pilot area, in acres.

Land ownership category	MRLC predicted forest cover	MRLC predicted non-forest	Total area
BLM	314,237	8,156,455	8,470,692
USFS	5,547,178	1,934,188	7,481,366
Other Federal	163,908	709,928	873,836
Non-Federal	2,329,677	11,893,499	14,223,176
All ownerships	8,355,000	22,694,070	31,049,070

Statistical Estimation Procedures

Statistical estimation procedures for MAOP were developed taking into account the partitioning of the landscape by predicted land cover, ownership, and selection procedures used for this pilot and the sampling schemes of the FIA and NRI annual survey programs for Oregon.

The estimation procedures used to construct the estimates presented in Section 4 (Survey Results) are fairly standard statistical procedures and took into account several factors:

- Sample sites (FIA plots and NRI points) were spread across four "estimation units," due to the partitioning/allocation process (see Appendix 2 for details).
- Data collection teams were not able to collect data for all assigned sample sites due to landowner refusals and other inaccessibility issues. It was assumed that missing whole plots were randomly distributed across the landscape and the weights were

adjusted to estimate population parameters without those missing plots. Transects or portions of transects were imputed from a pool of similar transects when data were missing with no explanation.

- FIA and NRI utilize different sampling schemes and different estimation procedures but the estimation procedures were consistent within an estimation unit. The FIA and NRI estimates for the jointly sampled area were combined using weights proportional to the number of plots each inventory measured. Since the other areas are independent of each other, the estimates can be simply added together.
- GIS-derived acreages were used as controls for the four estimation units.

Aerial Photography

The aerial photography interpretation was performed by the Remote Sensing Application Center of the USFS in Salt Lake City with experienced interpreters after field visits to locations spanning a variety of vegetation types. The interpreters used FIA and NRI rules sets described below.

Aerial photography acquisition occurred during July 2007 over 454 NRI and FIA field locations in MAOP. A 6-inch lens was used to acquire 1:8000 scale imagery, with 60 percent endlap (triplicates) over each FIA and NRI plot center using traditional film photography. The negatives were scanned at 14 microns for a nominal ground sample distance of 4.5 inches. The scanned images were ortho-rectified using 2005 NAIP compressed county mosaics and a 10-meter digital elevation model.

Aerial photo interpretation determined land classes according to both the NRI and the FIA land classification rule sets; both the FIA and the NRI rule sets were applied to all FIA plot centers and all NRI sample points by interpreting the support region around the plot centers to classify the plot into one and only one class. The NRI and FIA dichotomous rule sets were designed from each program's field manuals for defining land classes. A land class is defined as an area with uniform cover, as interpreted from above. Several differences exist between the FIA and the NRI rule sets (see table 3.3 for a summary of differences and similarities).

- The FIA operational definition for designating an area as forest is 10 percent or more crown cover in trees, whereas NRI typically uses 25 percent or more. The Agencies originally agreed to a definition of forest land as at least a 10 percent stocking in trees, but it is difficult to measure stocking rates in the field, and an operational definition based on crown cover was developed.
- There are differences in which land classes are considered forest or grass lands and in the species that are considered trees. The FIA classifies "oak woodland" and "juniper woodland" as forest land, whereas the NRI classifies them as rangeland. The FIA considers junipers as trees, whereas the NRI often does not.

Data acquired through interpretation of aerial photography can play an integral part in a natural resource inventory; improved efficiency is one benefit (MacLean 1972; Moessner 1963). Methods of applying aerial photo interpreted data to forest estimations are the result of work by early forest photogrammetrists such as Moessner (1949, 1960, 1961), Rogers (1946, 1947), and Spurr (1945, 1948), as noted by Aldrich (1979). The Nevada Photo Inventory Project was a recent pilot effort conducted by Interior West FIA to explore potential gains in efficiency combining photo-based data with FIA field sampled data (Frescino and others 2009). The NRI program has relied on aerial photography to monitor a number of land use and natural resource issues since the mid-1990s (see http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/).

Table 3.3—A comparison of the NRI and the FIA land classification rule sets.

Topic definition	NRI rule set definitions	FIA rule set definitions
Basic minimum area	≥1 acre	≥1 acre
Basic minimum width	≥ 100 feet wide	≥ 120 feet wide
Water feature width	≥ 5 feet wide	Must be ≥ 30 feet: ≥ Census linear water < Noncensus linear water
Water feature area	≥ 0.25 acre	Must be ≥ 1 acre: ≥ 4.5 acre (census water feature) < 4.5 acre (noncensus water feature)
Forest land cover (%)	≥ 25% crown cover of living tree species, or ≥ 25% crown cover of historical tree cover (due to fire, beetle kill, etc.)	≥ 10% crown cover of living tree 'tally' tree species, or ≥ 10% crown cover of recent historical tree cover (due to fire, beetle kill, etc.), or >200 seedlings.
Juniper tree cover	Adjust the crown cover estimate of total tree cover by subtracting "new" Juniper cover, then applying forest land cover of ≥ 25%.	
	If adjusted crown cover (excluding Juniper) is ≥ 25%, then forested, otherwise the land class is rangeland Juniper.	No adjustment for Juniper encroachment into historical rangelands.
Human influenced-developed	Industrial areas, residential, recreation areas, transportation routes, etc.	Cultural, right of ways, recreation areas, etc.
Agriculture lands	Cropland, pastureland, hayland, agro-forestry, feedlots, etc.	Crops, pasture, land uses towards heavy grazing, agro-forestry, improved land through cultural practice, etc.
Rangeland – shrub lands	≥ 5% shrub cover	≥ 5% shrub cover
Rangeland – Other	≥ 5% vegetation cover	Vegetated
Non-vegetated	Salt flats, bare rock, sand dunes, river wash, permanent snow, etc.	Rock, sand, permanent snow, lava flow, etc.

Other Considerations

On-Site Photography—Field crews used digital cameras while on-site at each NRI sample point or FIA ground plot to photograph various perspectives of the site. The photos were taken from the subplot center shooting north, east, south, and west. A photo placard was placed within the photo view with the state, county, location, and the photo direction. In addition to the four photos, another photograph was taken from the southern perimeter of the subplot to provide a view of the entire plot area. These photographs are of particular value for Quality Assurance purposes, for training, and for monitoring purposes over time. These photos were also of value in defining the *ecological groupings* discussed in Section 4 (Survey Results).

***Quality Assurance and Repeatability of Measurements*—**Quality assurance is an important and standard part of both FIA and NRI field data collection activities and begins with trained data collectors. Data collected on NRI plots were by contract employees that were qualified to collect data for NRI and were experienced with rangeland ecosystems. Each FIA crew had a professional botanist experienced in collecting species level information on the Forest Health Monitoring microplots, which were the basis for the species enumeration plots. In addition, each inventory used the same quality assurance approach and protocols for MAOP as they used for their own inventory.

The decision not to superimpose each plot design at a location was not taken lightly. There are several potential issues that were considered: differences in how each agency's crews implement the protocols and potential estimation differences due to the plot designs.

It is acknowledged that differences in background training of the crews carry forward in how field measurements are collected and could possibly produce differing results. To test for possible differences in how the two agency's crews implement the protocols, have crews from each agency independently measure the four field indicators on the two plot designs in a classic two-factor design with sufficient replications to ensure adequate power to test the hypothesis that there are no differences between the two agency's crews. The interaction between plot design and crews could also be tested. It should be noted that these tests do not need to be completed on co-located sites. The authors recommend that this test be included in a future pilot study.

Testing potential estimation differences due to plot designs should be separated into estimating continuous and categorical parameters. In this study, we treat percent cover as a continuous variable. It has long been established that differing plot designs will produce unbiased parameter estimates if it is within a stratified design and that each stratum contains one and only one plot design but may vary across strata (Cochran 1977). The same cannot be said for categorical variables. The presence and absence of a species is a prime example for this type of variable and is dependent on plot size, shape, and spatial pattern of the micro-plot. For this reason, the exact size, distance and angle of the micro-plots within a cluster and the distance and angle of the clusters themselves are identical between the two national inventories. The requirement for the exact plot design for categorical variables also precludes the comparison of presence/absence data between the micro-plot and the line intercept and presence/absence data on the line intersect between inventories.

***Fragmentation*—**BLM, NRCS, and USFS, in collaboration with the Sustainable Rangeland Roundtable, decided that this indicator would be tested outside the survey efforts of MAOP. During 2009 a pattern analysis study was conducted, and the methods and results are reported in Section 5 (Fragmentation: Land-Cover Pattern Analysis).

4. Survey Results

This section contains information on land classification from aerial interpretation and estimates of invasive, noxious species and vegetation composition based on field surveys. The results of aerial interpretation were based on 591 plots (points in NRI parlance) , which exceeds the number of aerial field location reported in Section 3 (Survey Design and Methodology); this was due to having up to three NRI plots (points) per segment and the aerial photographs covering the entire segment.

The analysis of invasive species, noxious weed species and ecological groupings are based on data collected in the field and restricted by stated vegetation and ecological conditions. This lead to a reduction in the number of plots that were used in the estimates; a more in-depth discussion on the estimation units and sample sizes for the tables presented in this section can be found in Appendix 2.

Land Classification

Table 4.1 contains an overview of the 13-county MAOP study area, which is based on broad land classes. The classification of these plots into broad land class categories was identical with either agency's rule set, which illustrates that the two inventories have very similar, although not identical, rules at this broad level. The classification of other plots may not result in the same outcome. There are larger differences in the rule sets at the next finer level and this is the subject of subsequent tables. Acreage estimates were derived using MAOP sample data, supplemented with selected survey results from the 2003 Annual NRI and data collection for the 2007 Annual FIA plots (for details see Appendix 2).

Present estimates of rangeland acreage using both the FIA and the NRI definition of rangeland are shown across ownership (table 4.2) and by ownership (table 4.3). These results are based on interpretation of aerial photography performed by the Remote Sensing Applications Center, a USFS unit located in Salt Lake City, Utah.

Both tables 4.2 and 4.3 show that the two survey programs differ on how to classify 1,320,000 acres; these are acres that NRI classifies as rangeland but the FIA classifies as forest land. The differences are mainly due to two factors: (1) FIA classifies land as forest if crown cover in trees is at least 10 percent, whereas NRI typically uses a 25 percent threshold; (2) certain Juniper woodlands are classified as forest land by FIA but as rangeland by NRI. These tables show the breakdown of the rangeland and forest

Table 4.1—Land classification for the 13-county multi-agency Oregon Pilot area.

Category	Estimated acres (with standard errors)
Agricultural land	3,187,600 (± 203,700)
Developed land	266,300 (± 58,100)
Rangeland and forest land	26,711,300 (± 424,900)
Other	883,900 (± 141,300)
Total	31,049,100

Table 4.2—Land classification using FIA and NRI definitions.

	Forest Land, NRI	Rangeland, NRI	Total
	- - - - Estimated acres (with standard errors) - - - -		
Forest Land, FIA	11,436,900 (± 500,200)	1,320,000 (± 305,500)	12,756,900 (± 549,700)
Rangeland, FIA	0 (---)	13,954,400 (± 609,200)	13,954,400 (± 609,200)
Total	11,436,900 (± 500,200)	15,274,400 (± 567,000)	26,711,300 (± 424,933)

Table 4.3—Rangeland classification using FIA and NRI protocols.

Land ownership category	NRI protocol	FIA protocol	Difference
	- - - *Estimated Acres (with standard errors)* - - -		
BLM	7,239,900 (± 303,800)	6,807,300 (± 309,000)	432,600 (± 119,800)
USFS	759,000 (± 193,000)	542,100 (± 165,700)	216,900 (± 107,200)
Non-Federal	6,731,800 (± 400,000)	6,117,138 (± 470,800)	614,700 (± 249,300)
All ownerships[a]	15,274,400 (± 567,000)	13,954,400 (± 609,200)	1,320,000 (± 305,500)

[a]Includes Federal acres not included in other land ownership categories.

land cell of table 4.1 into the various categories based on the FIA and NRI rule sets. Note that any land defined as forest by NRI will also be defined as forest by FIA and that any land defined as rangeland by FIA will also be defined as rangeland by NRI. While this is usually the case for most lands it is not always the case in other regions of the United States. One implication is that there cannot be any lands that are classified as FIA-range and NRI-forest.

Cells within table 4.3 estimate the rangeland for three ownership categories. These are domains within the pilot area and this can cause a reduction in the sample size within the estimation units.

Invasive Species

Table 4.4 presents results from plant species enumeration on the micro-plots established at the FIA and NRI sample sites. Each plot has three clusters of micro-plots with each cluster having three 1-meter square micro-plots. The table is an average of a 100 Monte Carlo runs where one micro-plot is selected per cluster from each of the three clusters on every plot. For the two micro-plots results, one of the three possible combinations (C_2^3) of micro-plots within each and every cluster for every plot was selected. No simulation was necessary for the three micro-plot result since all of the data were available for every plot. Each plot was weighted according to the survey design for MAOP. These data can be analyzed to help detect new invasions or expansion of state-listed invasive species.

Table 4.4—Number of total species and invasive species measured in the micro plots.

	Average number of species (with standard errors)	Average number of invasive species (with standard errors)
One micro plot	10.5 (± 0.3)	0.15 (± 0.3)
Two micro plots	13.2 (± 0.4)	0.18 (± 0.4)
Three micro plots	14.7 (± 0.5)	0.21 (± 0.5)

For the purpose of table 4.4, invasive species are those listed on the Oregon State list as displayed in the USDA Plants database. It does not reflect expansion of juniper from its historic ranges or cheat grass, which is a troublesome non-native species, but is often considered naturalized on the landscape.

In table 4.4, the average number of species increased significantly with a second microplot but there was a much smaller increase with the addition of a third microplot. This indicates that having three microplots may be adequate in this ecosystem. In contrast, the average number of invasive species recorded shows no indication of leveling off with the addition of another microplot. This indicates that a larger plot is necessary to have a reasonable probability of recording the number of invasive species that are found in the area.

Noxious Weed Species

Table 4.5 is a list of the noxious weeds species recorded in the field and the number of micro plots. Note that these frequencies have not been weighted to take into account the sample design. The table does not distinguish if a species was recorded on one microplot on each of nine plots or that all nine occurrences were found on every micro-plot on one plot. However the number of invasive species captured in the micro plots may be deceiving, but could be utilized as an early indicator of expansion or detection of new state-listed invasive species.

Multivariate Analysis

The MAOP data collection effort yielded a large database derived from all the plots and variables measured. Many vegetative data and associated soil surface measurements were taken without corresponding detailed soil survey or ecological site descriptions. Ecological site descriptions are defined as “A distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation.”

Table 4.5—Noxious weed species recorded for multi-agency Oregon Pilot, where frequency is the number of micro-plots where the species was recorded.

Species	Common name	Scientific name	Frequency
CADR	whitetop	*Cardaria draba*	10
CANU4	nodding plumeless thistle	*Carduus nutans*	4
CEDI3	white knapweed	*Centaurea diffusa*	40
CESO3	yellow star-thistle	*Centaurea solstitialis*	10
CHJU	hogbite	*Chondrilla juncea*	1
CIAR4	Canada thistle	*Cirsium arvense*	6
CIVU	bull thistle	*Cirsium vulgare*	24
COAR4	field bindweed	*Convolvulus arvensis*	5
COMA2	poison hemlock	*Conium maculatum*	1
CRVU2	common crupina	*Crupina vulgaris*	1
CYOF	gypsyflower	*Cynoglossum officinale*	5
HAGL	saltlover	*Halogeton glomeratus*	1
KOSC	Mexican-fireweed	*Kochia scoparia*	1
LIDA	Dalmatrun Toad Flax	*Linaria dalmatica*	5
ONAC	Scotch cottonthistle	*Onopordum acanthium*	1
POCU6	Knotweed	*Polygonum cuspidatum*	7
TACA8	medusahead	*Taeniatherum caput-medusae*	114

The BLM, NRCS, and USFS have agreed that ecological potential on rangeland is best described by Ecological Site Descriptions (ESDs) (USDA and USDI 2013). ESDs characterize alternative stable vegetative states, and the biotic or abiotic drivers that cause shifts in these vegetative communities (Moseley and others 2010). Soils with 'like' properties that produce and support characteristic plant communities are grouped into the same ecological site (Duniway and others 2010). As the USDA Agricultural Research Service lab in Las Cruces has described in their research, interpretation of assessment and monitoring data requires land classification systems that represent spatial variation in ecological potential (Bestelmeyer 2009).

Unfortunately, detailed soils maps do not exist for many Federal lands. Therefore, it was not possible to characterize MAOP sample plots by ecological site, which greatly limits the capability to fully analyze the field data.

Since soil survey and ecological site information was not available for interpretation of the data collected for this pilot, a temporary surrogate process was needed to help highlight how the data could be presented and used. Identification of dominant species for each plot by tree, shrub, grass, grass-like, forbs, and other categories is the first step leading to meaningful interpretation of community response and resilience to disturbance. The distribution and abundance of vegetation in central Oregon is affected by a multitude of biotic and abiotic factors that affect the presence of the vegetative community; hence, using multivariate analysis was deemed appropriate to group plots into vegetative groups.

The analysis performed is but one of a multitude of analysis that could have been chosen for illustrative purposes and classifies the vegetation data into interpretable groups. The multivariate techniques act as exploratory and descriptive tools, yielding groups worthy of further analysis and interpretation, but are not proposed as a long-term alternative to detailed soil survey and ecological site descriptions. Since it is an example of possible uses of the data and not meant to be a rigorous implementation of the technique, the analysis does not include sample weights.

PC-ORD, Version 4.35 (McCune and Grace 2002), was used to group the plots. A hierarchical cluster analysis, using Sorenson group average, was performed using the species cover data. Cluster analysis is agglomerative, that is, groups are created between plots that are similar. TWINSPAN, a divisive method, was then used to compare the groups created by the cluster analysis. Divisive clustering methods begin by lumping all the plots together and then dividing the plots into two groups, four groups, and so on. The two methods created groups that were very similar, but in the cases where the two methods did not agree, ecologists carefully considered the plot's species and relevant environmental data before grouping the plots. While TWINSPAN is used less frequently today than in past years, it proved very effective in suggesting representative vegetative groupings for this project.

After viewing both aerial and horizontal on-the-ground photos, of all of plots with juniper, plots were determined to be "historic Juniper woodland" or "invasive Juniper" in one of the sagebrush types. The plots with more than one large juniper that appeared to be more than 150 years old were grouped together and removed from the rangeland analysis. Miller and others (2005, 2007) and Waichler and others (2001) were referred to when making the judgment call on whether a plot photo looked like historic or invasive juniper were in or around the plot. These same publications were used by the field crews in making the on-the-ground judgment calls.

The ecological groupings developed above were then 'collapsed' using logical genus-based decisions to increase the sample size for statistical analysis, as shown in table 4.6. The collapsed groups are described below; Group 2 is the synthesis of four groups that are dominated by ponderosa pine.

Table 4.6—Summary of the core environmental variables by ecological group, within land classified as NRI rangeland.

All plots: Plot summary								
Groups	**Description**	**Count of plots**	**Avg Elev ft**	**Min Elev ft**	**Max elev ft**	**Avg ppt in**	**Min ppt in**	**Max ppt in**
1	ARTR2/POSE-PSSP6	110	2,711	487	5,582	14.4	8.9	63.3
2	PIPO-PSME/CARU-CAGE PIPO-JUOC/FEID PIPO/PUTR2/Gram PIPO-PICO/PUTR2	84	4,788	2,731	7,396	20.9	9.5	39.8
3	SAVE4	17	4,213	4,047	4,441	11.3	8.2	20.3
4	AGCR	13	4,304	3,303	4,548	10.7	9.6	14.5
5	ARTRW8/ELEL5 ARTRW8/PSSP6	78	4,737	1,656	6,058	11.6	8.0	21.5
7	ARAR8/POSE	29	4,981	1,328	6,245	14.1	9.2	20.3
8	JUOC/ARTRV/FEID(w/ARAR8) ARTRV/FEID	64	4,216	631	6,191	13.4	8.5	21.7
14	Upland tree	71	5,367	1,681	7,455	29.6	13.7	59.5
15	JUOC Historic	19	4,077	2,921	5,755	13.8	9.5	29.1

Group 1

ARTR2/POSE-PSSP6: Plots=110

This is a grassy type with few shrubs. Sandberg bluegrass occurs in 34 percent of the plots and bluebunch wheatgrass is in 29 percent, while basin big sagebrush occurs in 15 percent of the plots, and rubber rabbitbrush in 14 percent of the plots. A clear identity of this group is less strongly supported by cluster analysis than the others.

Group 2

- PIPO-PSME/CARU-CAGE: Plots=18

This is a Ponderosa pine type, with some Douglas fir. Geyer's sedge, pinegrass and Idaho fescue are often found in the understory.

- PIPO-JUOC/FEID: Plots=21

This is the driest ponderosa pine type. Ponderosa occurs on 76 percent of the plots, and western juniper can be found on most of the sites. Idaho fescue is also common. This group seems similar in some respects to the JUOC/FEID-AGSP plant association described by Johnson and Clausnitzer (1992). The JUOC/FEID-AGSP has 100 percent constancy for juniper and bluebunch wheatgrass, 85 percent constancy for Idaho fescue and Sandberg's bluegrass, and 57 percent constancy for ponderosa pine.

- PIPO/PUTR2/Graminoid: Plots=17

Ponderosa pine occurs on 82 percent of the plots, and antelope bitterbrush and Idaho fescue occur on most of the plots.

- PIPO-PICO/PUTR2: Plots=28

Lodgepole pine, antelope bitterbrush and ponderosa pine are found on most of the plots in this group.

Group 3

SAVE4: Plots=17

Greasewood occurs in 76 percent of the plots, along with yellow rabbitbrush and inland saltgrass.

Group 4

AGCR: Plots=13

Crested wheatgrass and rubber rabbitbrush are found on most of these plots. Crested wheatgrass is an exotic that was planted on previously cultivated lands and revegetated rangeland for forage and erosion control. Where it occurs, there has probably been some disturbance.

Group 5

- ARTRW8/ELEL5: Plots=43

  Wyoming big sagebrush is found on most of the plots, with Sandberg bluegrass, squirreltail, yellow rabbitbrush and basin big sagebrush also occurring on some of the plots.

- ARTRW8/PSSP6: Plots=35

  Sandberg bluegrass and Wyoming big sagebrush are often found on these plots, with some bluebunch wheatgrass, squirreltail, and Thurber's needlegrass.

Group 7

ARAR8/POSE: Plots=29

Little sagebrush and Sandberg bluegrass is found on most of the plots, with squirreltail often occurring with them.

Group 8

- JUOC/ARTRV/FEID(w/ARAR8): Plots=36

  Idaho fescue, Sandberg bluegrass and western juniper occur in most of the plots, along with some basin big sagebrush and bluebunch wheatgrass. This group seems similar in some respects to the JUOC/PUTR/FEID-AGSP plant association described first by Volland (1988) and then by Johnson and Clausnitzer (1992). Johnson and Clausnitzer only had 4 plots in their description of this type, but there was 100 percent constancy for juniper, bitterbrush, Idaho fescue, bluebunch wheatgrass, Sandberg's bluegrass, and yarrow, and 50 percent constancy for little sagebrush and mountain big sagebrush.

- ARTRV/FEID: Plots=28

  Mountain big sagebrush and Idaho fescue occur on most of the plots, along with some Sandberg bluegrass, squirreltail, and yellow rabbitbrush. This group seems similar to the ARTERV/FEID-AGSP plant association described by Johnson and Clausnitzer (1992). Johnson and Clausnitzer's description of this type has 100 percent constancy for mountain big sagebrush, 93 percent constancy for Idaho fescue and creamy buckwheat (ERHE), and 86 percent constancy for Bluebunch wheatgrass and Sandberg's bluegrass.

Group 14

Upland Tree Non-Rangeland: Plots=71

After conducting the first cluster analysis it became obvious we needed to define a break in types at the ponderosa pine type, as it: (1) was the upper end of the gradient where the majority of western juniper could be found and (2) wetter pine sites, where the true firs quickly succeed into the reproduction layer when periodic low intensity fires are not allowed to burn, and other forested types in higher elevations are not important as forested grazing lands. We defined upland forest types as those plots that had grand, white, silver, noble, or Shasta red firs, western larch, blue spruce, incense cedar, western red cedar, Alaska yellow cedar, sugar pine, western white pine, mt. hemlock, and white bark pine.

Group 15

JUOC Historic: Plots=19

These plots were removed from the analysis and lumped together because the plot photos showed more than one large juniper that appeared to be more than 150 years old. Most of the plots had western juniper, Idaho fescue, and Sandberg bluegrass (Miller and others 2005, 2007; Waichler and others 2001).

Percent Cover

Using the transect data collected in the field, percent plant canopy cover and basal level cover were estimated for land classified as rangeland within the MAOP study area. Since all FIA rangeland is also NRI rangeland, we used the NRI definition of rangeland as the basis for further analysis. This reduces the number of plots available to make estimates. An in-depth discussion of sample sizes for the tables that follow can be found in Appendix 2

The first row of table 4.7 contains the estimates of the mean and standard deviations of percent plant canopy and basal level cover for rangelands as classified by the NRI. Rangeland was further sub-divided by ecological groups. There are intriguing biological explanations of how these variables differ by plant communities. For example, bare soil and mineral soil exposed in the SAVE4/greasewood vegetation group is apparently higher than for most sagebrush communities, possibly by virtue of the saline soils typically associated with that plant type.

Table 4.8 displays the dominant species by life form for three of the ecological groupings with sufficient sample size (see Appendix 2 for a detailed discussion of sample sizes). The data displays the estimated cover on the acres that those species occupy within the ecological group. A couple of key points of interest are the encroaching juniper. Although of limited cover, it could represent the early stages of conversion to a woodland community. Another point of interest is the dominance of cheatgrass in all of these ecological groupings. Also of interest is the frequency that encroaching juniper and invasive cheatgrass are documented in these groups.

The plant assemblages in table 4.9 were created to display information for the Pilot area that is of particular interest as it relates to specific species or assemblage of species. The data displays the estimated cover within the area that those species or assemblages of species are found. There are several interesting points in this table.

Cheatgrass is found on a significant number of acres and at a significant percent cover across the landscape. This has implications regarding several aspects of rangelands health from fuels and fire, erosion, wildlife and domestic forage quality and availability, etc. Rubber rabbit brush is also an interesting indicator related to disturbance.

Table 4.7—Estimated mean and standard deviation of percent cover and acres within rangelands classified according to the NRI protocols by vegetative groups and select variables.

	Estimates												
Vegetative groups	**Exposed mineral soil**	**Bare soil**	**Herb. litter**	**Lichen crust**	**Moss**	**Rock fragment**	**Woody litter**	**Und. mineral soil**	**Forb**	**Graminoid**	**Shrub**	**Tree**	**Acres**
Total rangeland	19.3 ±1.4	72.8 ±2.0	44.7 ±1.7	0.4 ±0.1	4.0 ±0.4	14.3 ±1.7	5.0 ±0.5	10.4 ±1.0	6.2 ±0.8	36.0 ±1.3	14.4 ±0.9	1.7 ±0.3	15,274,400 ±567,000
ARTR/POSE-PSSP6	12.8 ±2.5	70.9 ±3.4	51.6 ±3.4	0.3 ±0.1	4.2 ±0.9	16 ±2.7	1.5 ±.3	10.5 ±1.5	14 ±2.4	61.8 ±3.5	9.4 ±2	1.3 ±.4	4,517,208 ±740,725
PIPO [a]	13.4	84.3	63.2	0	4	7.5	6.4	8	5	39.6	14.6	15.3	237184
SAVE4 [a]	33.3	89.1	39.4	1.9	1.4	1.3	7.2	13.1	2.8	26.7	24.4	0	827,571
AGCR	21.2 ±4.6	81.0 ±7.4	52.8 ±5.2	0	0.9 ±1.0	12.0 ±3.9	2.9 ±0.9	9.0 ±3.7	5.3 ±3.0	36.8 ±7.0	4.4 ±1.9	0.3 ±0.4	672,414 ±363,089
ARTRW	22.6 ±2.8	70.6 ±3.3	38.6 ±2.2	0.4 ±0.3	4.0 ±0.6	14.7 ±2.6	6.6 ±0.8	9.8 ±0.8	3.9 ±0.9	39.0 ±3.7	20.7 ±1.8	0.1 ±0.0	4,707,152 ±686,696
ARAR8 [a]	16.1	58.5	34.7	0.6	4	29.2	4.7	11.4	4	39.4	19.7	0.2	1,346,673
ARTRV [a]	22.5	79.4	45.3	0.3	4.4	9.2	7.7	10.9	5.2	38.5	17.8	3.3	2,426,575
Upland tree non-rangeland	17.2 ±6.0	75.8 ±14.1	50.5 ±9.1	0	4.0 ±4.0	17.7 ±9.6	6.0 ±5.1	5.6 ±2.5	3.5 ±2.5	14.6 ±5.6	20.2 ±11.0	25.3 ±3.0	110,269 ±76,816
JUOC [a]	25.8	73.8	46.6	0.9	11.0	12.3	9.3	5.6	1.7	24.2	5.4	17.8	269,462
Unclassified													270,161

[a] Variance cannot be calculated or estimated for the attributes of the indicated vegetative grouping because of small sample size.

Table 4.8—Dominant species by life form listed by ecological grouping with estimated percent cover and occupied acres for the ecological group; within lands classified as NRI rangeland.

Ecological group	Growth form	Dominant species	Estimated percent cover on occupied acres	Estimated acres occupied
ARTR/POSE-PSSP6	forb	EPBR3	10.3 +3.4	872,253[a]
	forb	ERCI6	4.8 +2.1	879,025[a]
	graminoid	BRTE	31.6a	1,596,170[a]
	graminoid	POSE	20.6[a]	424,681[a]
	shrub	ARTRT	19.0 ±4.7	919,076[a]
	shrub	ERNA10	4.9 ±2.0	675987 ±206,415
	Tree	JUOC	5.5 ±1.6	993,966[a]
	Tree	PIPO	1.0[a]	55,134 ±55,134
ARTRW	Forb	CRAC2	2.2 ±0.5	755,924 ±260,116
	Forb	COPA3	3.5[a]	259,896[a]
	graminoid	BRTE	23.6[a]	936,634[a]
	graminoid	POSE	24.3[a]	1,075,883[a]
	Shrub	ARTRW8	18.5[a]	2,333,947[a]
	Shrub	ARTRT	18.3[a]	706,688[a]
	Tree	JUOC	2.6[a]	85,880[a]
ARTRV	Forb	COPA3	2.3[a]	114,715 ±69,121
	Forb	PHHO	3.4[a]	177,133 ±119,088
	graminoid	BRTE	24.4 ±7.5	715,460 ±297,537
	graminoid	FEID	29.3 ±3.3	600,632 ±241,481
	Shrub	ARTRV	13.9[a]	695,665[a]
	Shrub	ARTRT	13.1[a]	278,133[a]
	Tree	JUOC	8.3 ±3.2	951,811 ±338,419
	Tree	PIPO	2.0[a]	110,269 ±76,816

[a]Variance cannot be calculated or estimated for attribute because of small sample size.

Table 4.9—Plant assemblage description, the number of estimated acres the plant assemblage occupies within lands classified as NRI rangeland, and the estimated percent cover of the plant assemblage on the occupied acres.

Plant assemblage	Estimated percent cover on occupied acres	Estimated acres occupied
Cheatgrass	15.4 ±1.7	10,467,226 ±659,471
Rubber rabbit brush	5.1 ±0.8	4,742,794 ±755,994
Non old growth juniper[a]	8.0	2,469,271
Sage-grouse herbs regardless of the presence of Sagebrush presence/absence[b]	3.0 +0.4	5,504,888 ±718,631
Sagebrush (all life forms of *Artemesia*)[b]	13.4 +0.9	11,078,186 ±747,552
Sage-grouse herbs in association with sagebrush[b]	3.2 +0.5	3,849,598 ±623,989

[a]Indicates that variance cannot be calculated or estimated for the attributes of the indicated assemblage.
[b]These assemblages are all related to the potential for sage-grouse habitat.

The juniper assemblage consists of an estimate of the acres and percent cover of those acres where no "old growth" juniper was identified on the plots. Although of limited cover the encroaching juniper could represent the early stages of conversion to a woodland community on those acres.

The next several assemblages are related to potential sage-grouse habitat. A list of herbs that may indicate better sage-grouse habitat was developed based on information from Mike Gregg (personal communication) (*Phlox gracilis*, *Crepis* sp., *Agoseris* sp., *Salsify* sp., *Astragalus* sp., *Lomatium* sp. and *Trifolium* sp.). This list was not meant to be exhaustive, but representative of forb species important to sage-grouse diets, particularly during brood rearing. The first line in this grouping represents the estimated acres and cover that at least one of these species occurs regardless of sagebrush presence or absence. The next list is the estimated acreage and cover of sagebrush across the pilot area. The third list in this category is the estimated acreage and cover of the combination of one or more of the key herbs in association with sagebrush. This was identified to provide a quick example of the type of data that could be utilized to display acres of potential sage grouse habitat in the pilot area. The list of herbs was used to help identify better quality brood rearing habitat. This does not imply that the areas with sagebrush that do not contain these herbs are not providing valuable habitat or that they would be considered degraded.

5. Fragmentation: Land-Cover Pattern Analysis

There is no consensus on ways to measure fragmentation, and many of the popular approaches are motivated by a desire to measure the causes or effects of fragmentation rather than fragmentation itself. The approach taken here was to look at pattern *per se.* There are many types of individuals and groups that are interested in patterns—spatial ecologists, resource managers, land use planners, assessment scientists, and society as a whole. Each brings a unique perspective as to why patterns are important in the landscape. Our problem is to identify data and methods that are useful for addressing all of the questions that could be asked about patterns. There is a body of work that has investigated metrics of pattern *per se* and the uses of those metrics to quantify aspects of fragmentation. For this study, three metrics were investigated: area density metrics, landscape mosaic metrics, and morphological spatial pattern metrics. This choice was made because the same metrics are currently employed in national resource assessments prepared by the U.S. Forest Service (Riitters 2011).

Study Area and Input Data

The study area for the fragmentation study was larger than the study area for the rangeland resources study (figure 5.1). The fragmentation study was based on the rangeland resources study area and the ecosystem provinces from Bailey's ecoregion classification of the United States (Bailey 1995). The rangeland resource study area contains five ecosystem provinces. Two of which, the Sierran Steppe-Mixed Forest-Coniferous Forest-Alpine Meadow province and the Great Plains- Palouse Dry Steppe province are just slivers and were discarded. The three remaining ecosystem provinces are (1) Cascade Mixed Forest, Coniferous Forest, Alpine Meadow; (2) Intermountain Semi-Desert; and (3) Middle Rocky Mountain Steppe, Coniferous Forest, Alpine Meadow. The study area was expanded by extending the area within the Intermountain Semi-Desert and Middle Rocky Mountain Steppe eastward to contain the agricultural and human influenced Snake River valley.

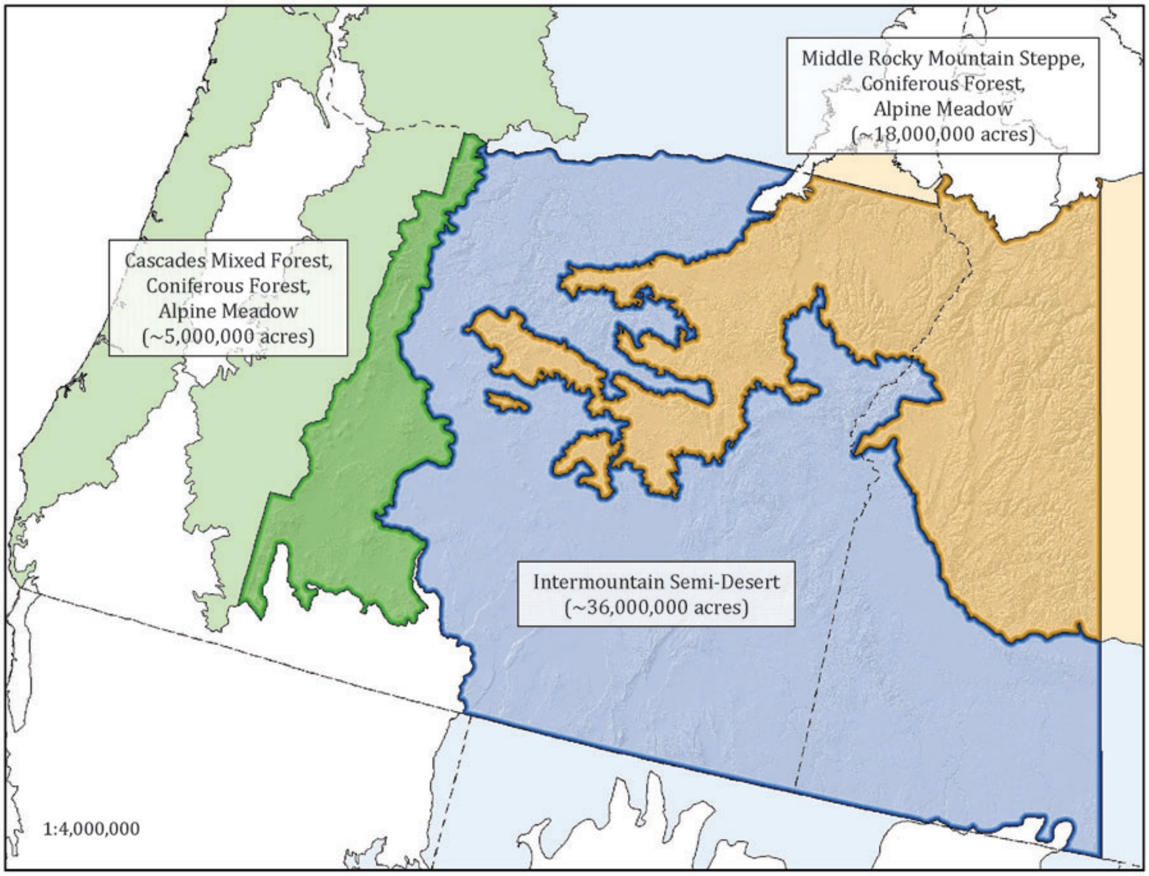

Figure 5.1—The study area for the fragmentation analysis of the Oregon Pilot.

The three landscape pattern metrics were implemented with the 2001 National Land-Cover Database (NLCD) (see http://www.mrlc.gov/about.php for particulars of this land classification program): a land-cover map of the conterminous United States with a spatial resolution of 0.09 ha/pixel (30 x 30 meters) and a thematic resolution of 16 land-cover types.

Area Density Metrics

The area density metric was constructed separately for each of two land-cover types—shrub and grassland. In the following, the construction of the shrub area density metric will be described but the same procedures were used for grassland. First, the NLCD map legend was condensed to show a dichotomous (presence/absence) map of shrubland (NLCD land-cover code 52). For each shrub pixel on the dichotomous map, the density of shrub pixels within a series of square windows (or neighborhoods) centered on that pixel was calculated. For example, for a 3x3 pixel window centered on a given pixel, the shrub area density is calculated as the number of shrub pixels in the window divided by 9. This process was repeated for a series of windows up to a 729x729 pixels. The calculation of the shrub density over the set of neighborhoods was completed for every pixel in the study area. Hereafter, the neighborhood sizes will be cited by their area rather than by the number of pixels they contain. Summarizing up to this point, every pixel has a set of values: its NCLD classification and the density of shrubs for a set of neighborhoods ranging from 38 acres to 118,000 acres.

There are many ways to use area density values to explore fragmentation. For example the question: “How much shrub is surrounded by different “threshold” levels of other shrub at different neighborhood sizes?” yields information on the extent of fragmentation. To answer this question we used the set of pixels with NCLD value of shrub and examined the percentage of shrub pixels at different density thresholds over the range of neighborhoods. Figure 5.2 shows the percentage of shrub pixels with density over the thresholds of 60, 90 and 100 percent for a range of neighborhood sizes. Note the horizontal axis is scaled logarithmically although the numbers are the actual acres. The key to interpreting figure 5.2 is to notice that if there was no fragmentation, then all three lines would be at the 100 percent level at the top of the graph; any departure from that condition therefore indicates fragmentation. This presentation makes it clear that fragmentation depends on both scale (window size) and assessment criterion (threshold value).

For the 100 percentage threshold at the 38 acre neighborhood size, 77 percent of the shrub pixels occur in neighborhoods that are 100 percent shrub. The implication is that 23 percent of shrub pixels have less than 100 percent shrub density, which means that they are within 90 meters of a shrub edge; an indication of fragmentation. Meanwhile, the 60 percent threshold indicates that 88 percent of shrub land-cover occurs in a landscape that contains greater than 60 percentage shrub within 118,000 acres, which indicates that shrub land-cover tends to be dominant where it occurs.

Figure 5.3 contains the analysis of the percentage 60, 90 and 100 thresholds for each of the eco-provinces. It is clear from figure 5.3 that in the Middle Rocky Mountain Steppe and Cascade Mixed Forest provinces the shrub lands are much more fragmented than in the Intermountain Semi-Desert province. Note that from the 60 percent threshold that only 40 percent of shrubs occur in a landscape that contains more the 60 percent shrubs within 38 acres. Shrubs lands are approximately 20 percent of Middle Rocky Mountain Steppe and Cascade Mixed Forest provinces and it is intermixed with the other land cover types within the provinces. Most of the characteristics shown for all shrubland (in figure 5.2) mirror those in figure 5.3 for the Intermountain Semi-Desert province, because most of the total shrubland area occurs in that province.

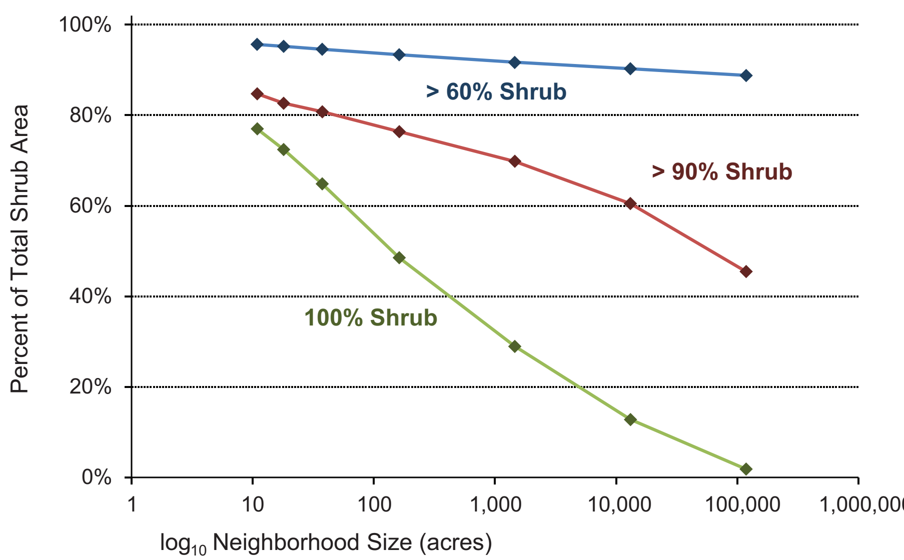

Figure 5.2—Percentage of shrub pixels in the study area with the density of shrub pixels in a neighborhood greater than or equal to the thresholds 60, 90 and 100 percent. Note the horizontal axis is scaled logarithmically. Each curve represents a different threshold value.

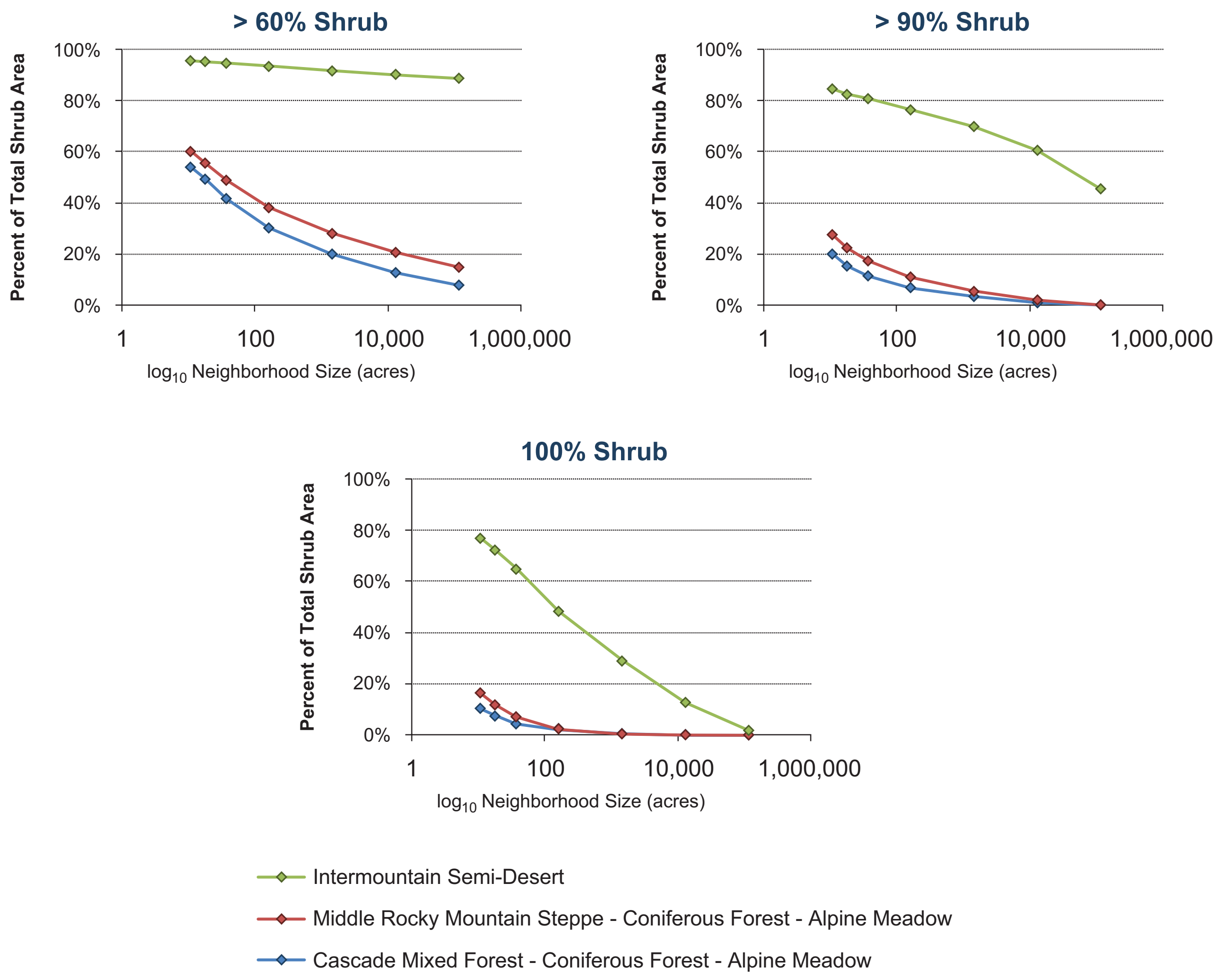

Figure 5.3—For each of the three provinces within the study area, the percentage of shrub pixels in the province with the density of shrub pixels in a neighborhood greater than or equal to the thresholds 60, 90 and 100 percent. Note the horizontal axis is scaled logarithmically. There are three graphs; one for each threshold; and each graph contains three curves, one for each province.

Similarly, dichotomous maps were created for grassland (NLCD land-cover code 71). The neighborhood analysis was then repeated for each grassland pixel following the same approach that was used for shrubland. The results of the analysis are presented in figure 5.4. The graphs show that grassland is a highly fragmented land cover type for all three of the provinces, with the Intermountain Semi-Desert slightly less fragmented. The 100 percentage threshold shows that a majority of grasslands are in neighborhoods that contain other land cover types. For the Intermountain Semi-Desert and the Middle Rocky Mountain Steppe provinces, the 60 percentage threshold indicates a large percentage of grassland is contained in small neighborhoods where grasslands are the dominant cover type. See Riitters (2011) and Riitters and others (2002) for further information on the Area Density metrics.

Landscape Mosaic Metrics

The landscape mosaic classifies the landscape surrounding each pixel based on the proportion of three generalized land-cover types contained in the analysis window, as opposed to only one for the area density metric. For the landscape mosaic, a three-class

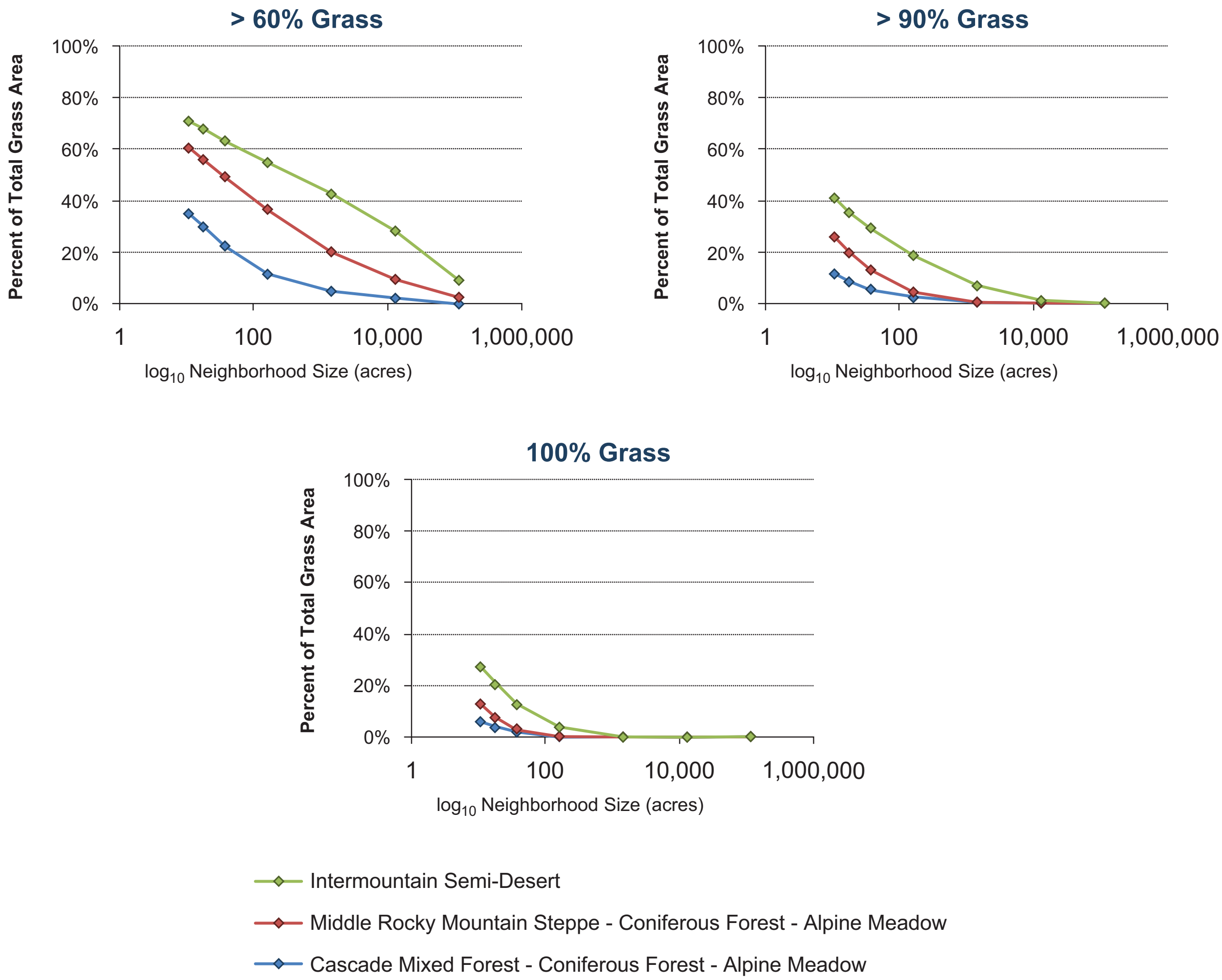

Figure 5.4—For each of the three provinces within the study area, the percentage of grass pixels in the province with the density of grass pixels in a neighborhood greater than or equal to the thresholds 60, 90 and 100 percent. Note the horizontal axis is scaled logarithmically. There are three graphs; one for each threshold; and each graph contains three curves, one for each province.

land-cover map was created by collapsing the NLCD land-cover types into three generalized land-cover types. Then each pixel was classified into one of 19 mosaic classes based on the proportions of the three generalized land-cover types in a neighborhood of the pixel. The three generalized land-cover types were Natural (forest, shrub, grass), Human Influenced (agriculture and developed), and Other Natural (water, bare ground, ice/snow, herbaceous wetland). The 19 mosaic classes were defined using the threshold values of 0, 10, 60 and 100 percent along each of the three axes in a tri-polar classification model (figure 5.5). For example, if the neighborhood is 9 percent Human Influenced, 66 percent Natural and 35 percent Other Natural, then the pixel would be placed in the Nd category. For visual presentation, the RGB color selected to shade each pixel was selected based on the proportions of Natural (more green), Human Influenced (more red), and Other Natural (more blue). This calculation is done for each pixel and over a variety of neighborhood sizes. While the original 19 mosaic categories are often used in national reporting, they were reduced to four classes for this analysis by declaring the three tips of the triangle to be "dominated" by the generalized land-cover type; in other words, when a land-cover type is greater than 60 percent of an neighborhood, then it dominates the neighborhood (figure 5.6).

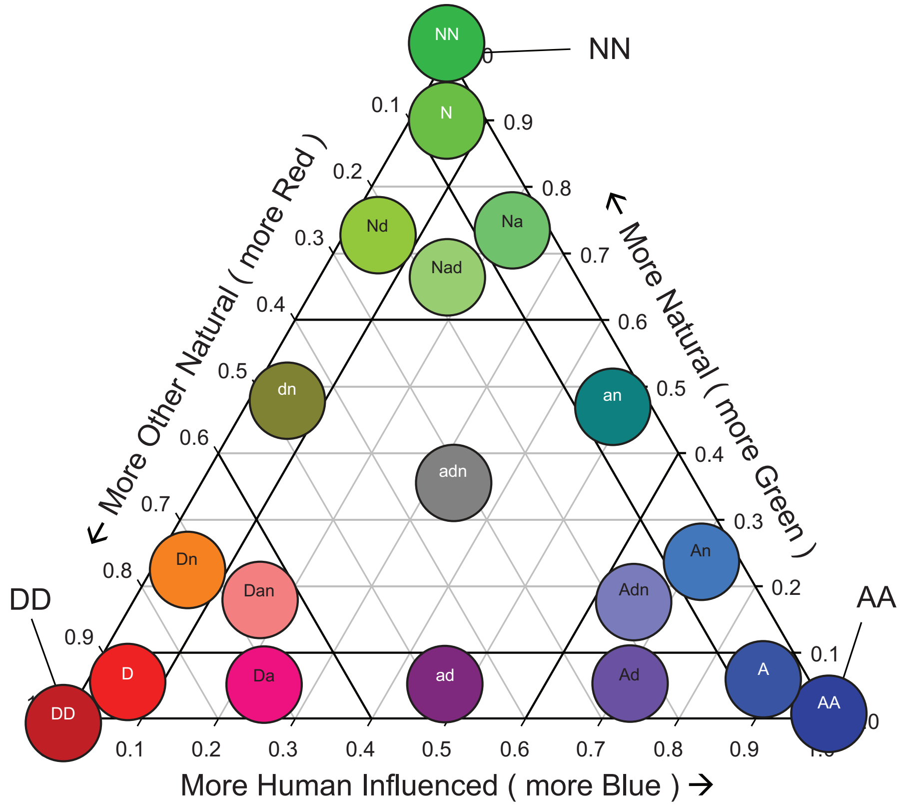

Figure 5.5—The tri-polar landscape mosaic classification model identifies 19 mosaic classes from the proportions of Natural, other Natural and Human Influences land-cover types in a fixed neighborhood of the pixel. The 19 mosaic classes are defined by using the thresholds of zero, 10, 60 and 100 percent for each of the three axes.

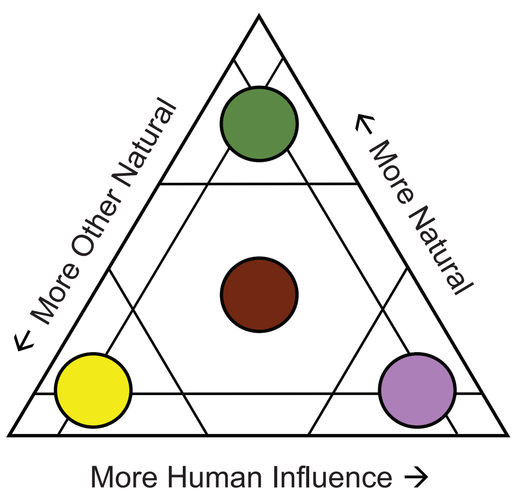

Figure 5.6—The 19 mosaic classes in figure 5.5 are condensed into four classes in the first level model. Three classes are dominated by either Natural, or Other Natural or Human Influenced (that is, greater than 60 percent of the respective class), with the fourth class being mixed (that is, all the classes Natural, or Other Natural or Human Influenced have less than 60 percent).

For example, a region surrounding Boise, Idaho, was chosen for pattern analysis using this metric. Figure 5.7 shows the original NLCD land-cover map for this region and figure 5.8 shows the three generalized land-cover types at the pixel level, while figure 5.9 shows the region with the four mosaic classes using the 38 acre neighborhood. For comparisons, note that figure 5.7 shows land cover at the pixel level, while figure 5.9 shows the mixtures of land cover in a neighborhood surrounding each pixel. Of particular interest is the mixed mosaic category, which indicates the interface zones that may not be visually apparent by looking at the original land-cover map. The location of interface zones depends on the spatial scale (neighborhood size) at which they are measured. The interface zones in figure 5.9 are fine-scale (or small-scale) attributes, such as a boundary between the city and the river. For comparison, figure 5.10 shows the four mosaic classes for a series of neighborhood sizes from 1,500 acres to 118,000 acres. As the neighborhood size increases, the mixed mosaic identifies coarser-scale (or larger-scale features) such as the boundary between the city and the region around the city. Landscape mosaic is scale dependent; for example, the northern region of the metropolitan area is an interface zones at 118,000-acre scale, but human influenced at smaller measurement scales.

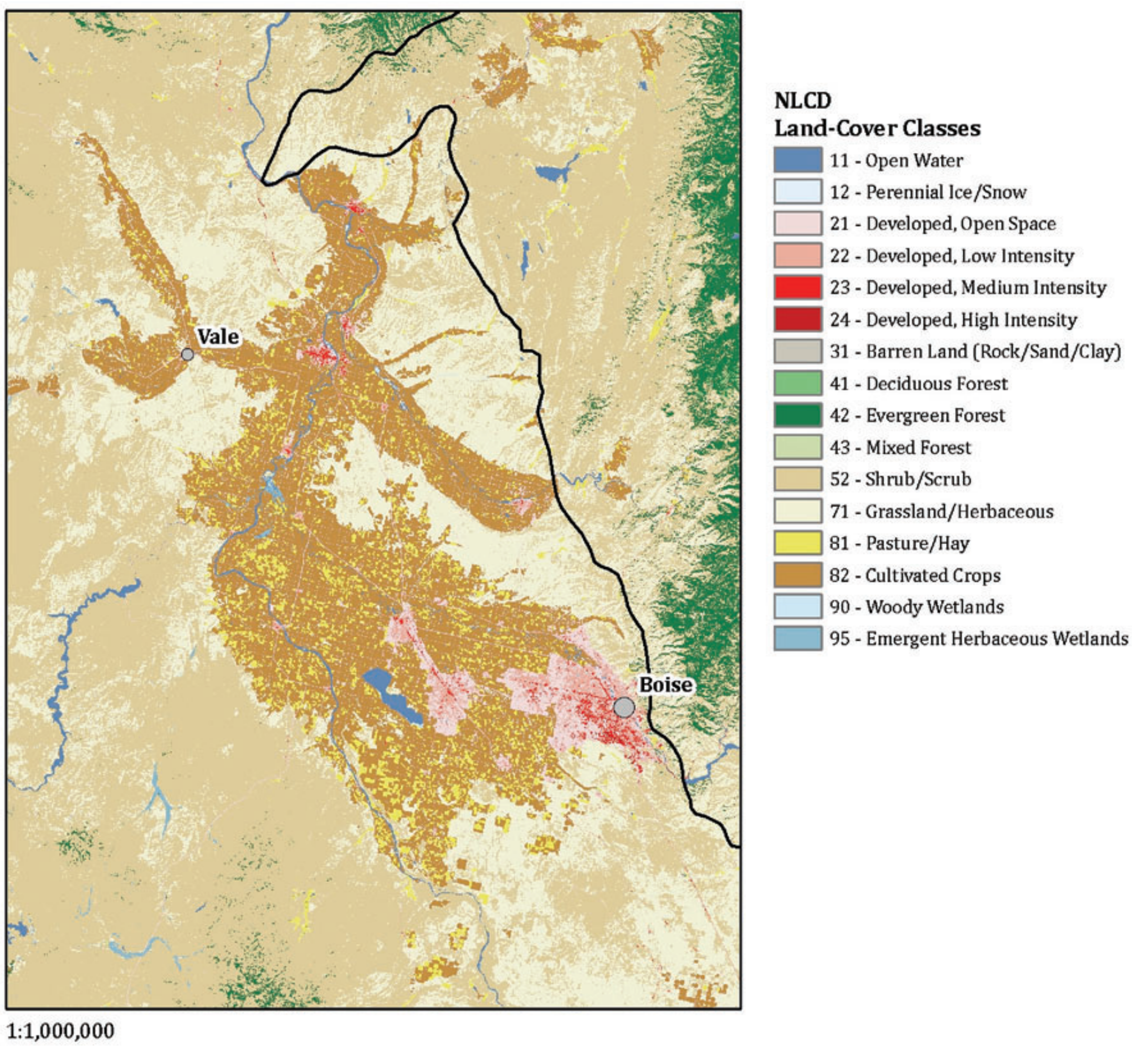

Figure 5.7—The NLCD land cover map for the study area around Boise, Idaho.

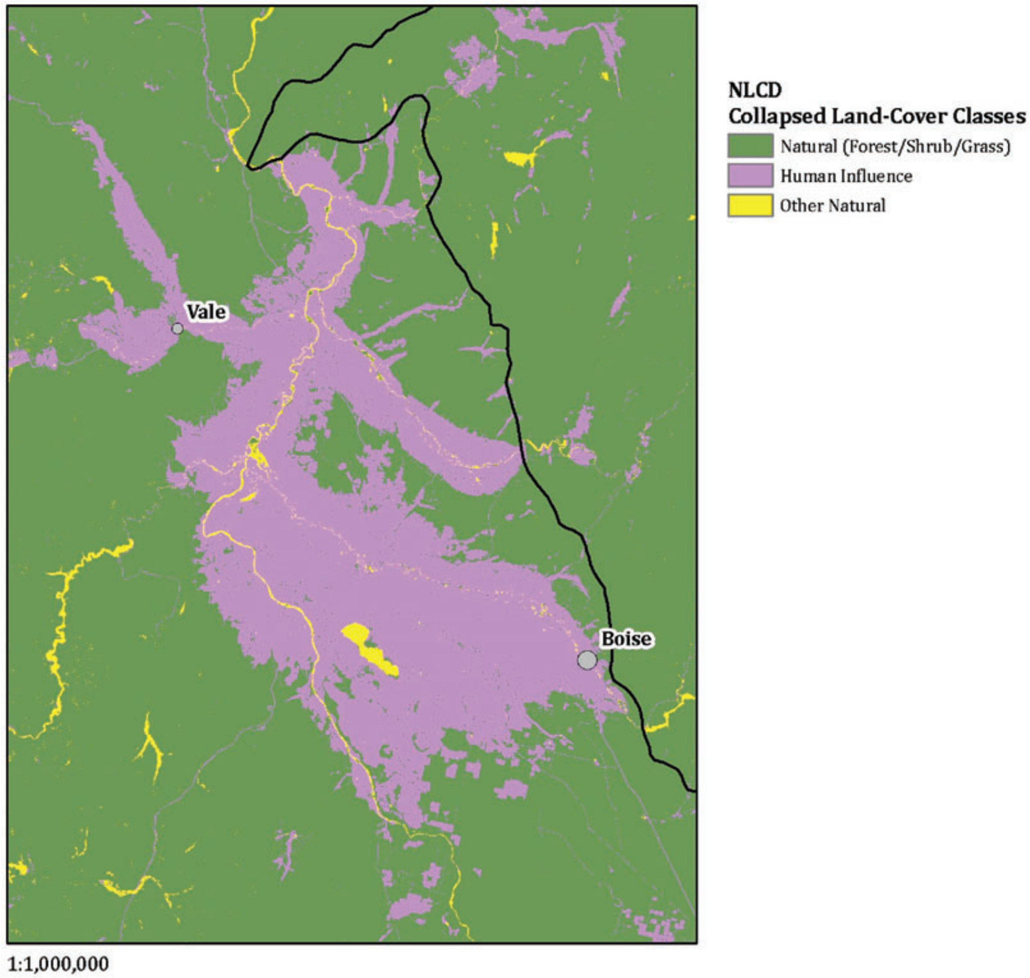

Figure 5.8—The map of the generalized NLCD land cover classes for the area around Boise, Idaho; see table 5.1 for which NLCD land cover classes were combined to form the collapsed land cover classes.

While any classification model is arbitrary, this approach is flexible and allows the analyst to make three assumptions that may be considered to be "tuning parameters" to tune the analysis in different ways: (1) the choice of the generalized land-cover types; (2) the size of the neighborhood; and (3) the partition of the tri-polar space (that is, the thresholds used to define the mosaic categories).

A second set of analysis extended the above concept to only those pixels that occurred in a Natural mosaic. The second version of the landscape mosaic map was produced by re-defining the tri-polar classification in terms of forest, grass, and shrub, and ignoring all other land cover types. The second level metric was analyzed only for those pixels for which the first level mosaic metric was denoted as being dominated by Natural for a given neighborhood size. For example, suppose we are using a 7x7 window as our neighborhood and there are six Other Natural pixels (6/49 = 12 percent), nine Human Influenced pixels (9/49 = 18 percent) and 34 Natural pixels (34/49 = 70 percent) in the neighborhood. In that case the center pixel is classified as Natural dominated using the first level mosaic metric.

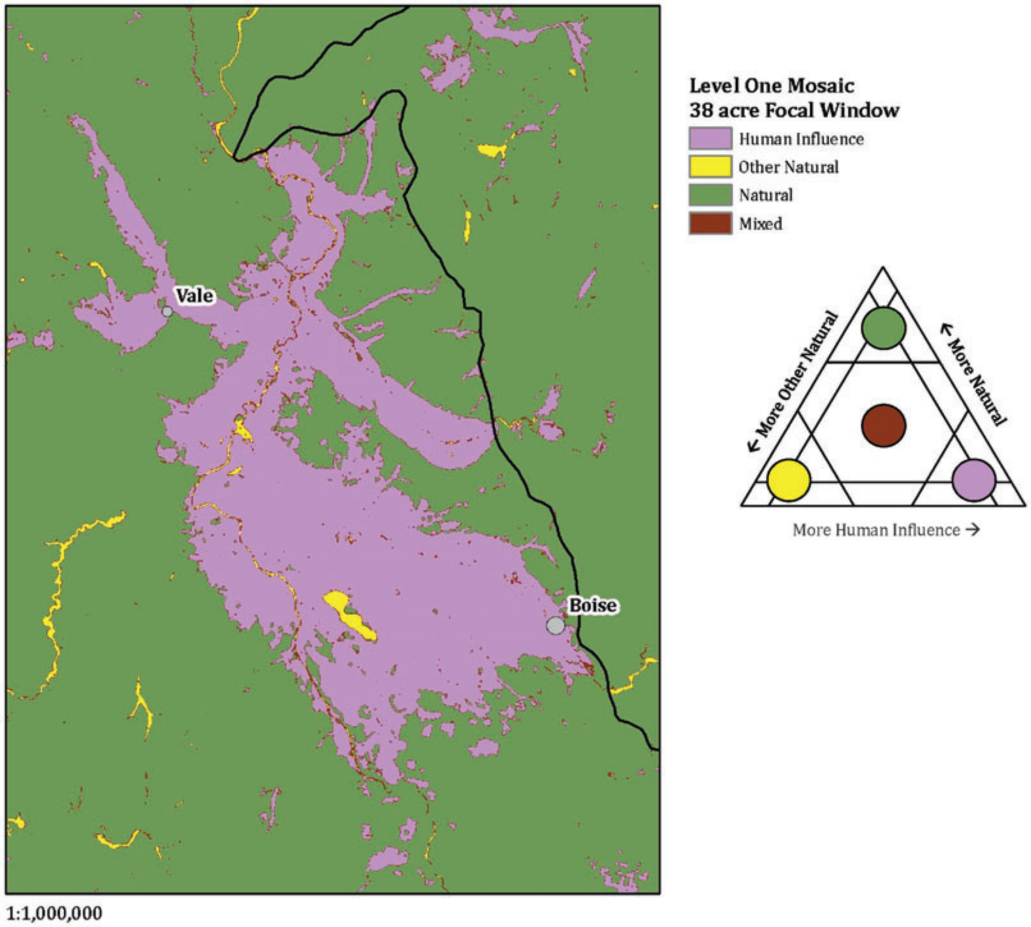

Figure 5.9—The fine scale landscape patterns for the area around Boise, Idaho. The level one mosaic is based on the Natural, Other Natural, and Human Influenced generalized NLCD classes and a 38-acre neighborhood.

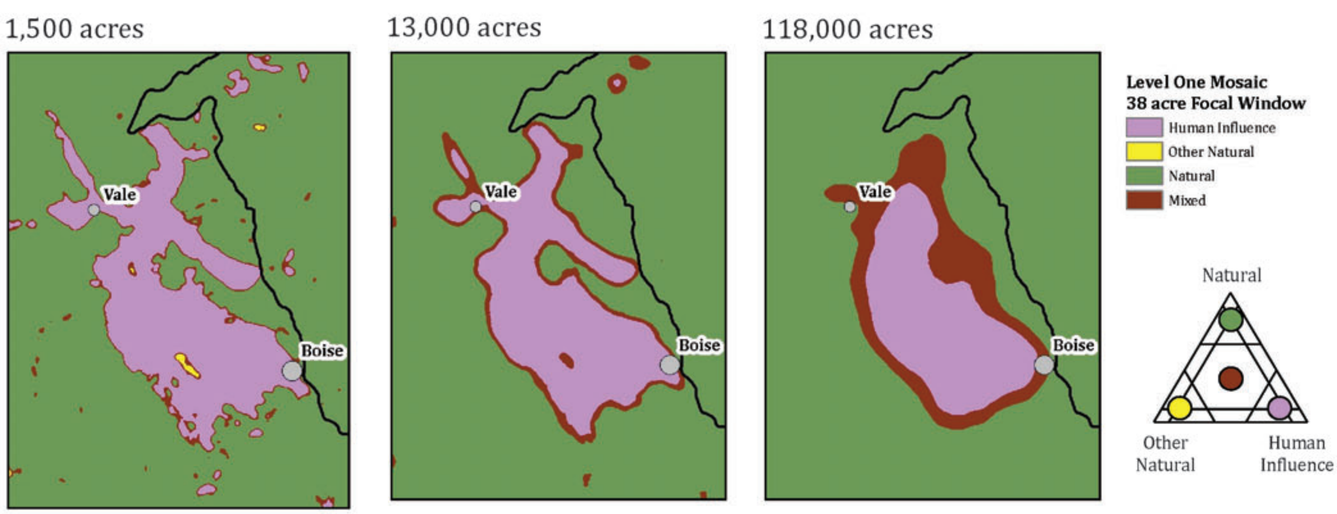

Figure 5.10—Mid-scale to coarse-scale landscape patterns for the area around Boise, Idaho, using the level one mosaic metric based on Natural, Other Natural, and Human Influenced generalized NLCD classes. The neighborhoods sizes are 1,500, 13,000 and 118,000 acres.

The second level mosaic metric is calculated using only the 34 Natural pixels. Suppose in this example that these comprise seven Grass pixels (7/34 = 21 percent), 14 Shrub pixels (14/34 = 41 percent) and 13 Forest pixels (13/34 = 38 percent); the second level metric would classify the pixel as a Mixed pixel (that is, no natural land-cover type is dominant). Figure 5.11 shows the second level mosaic value for the area around Boise for the same set of neighborhoods that were used for the first level mosaic. In this figure, the pixels with first level values of Mixed or dominated

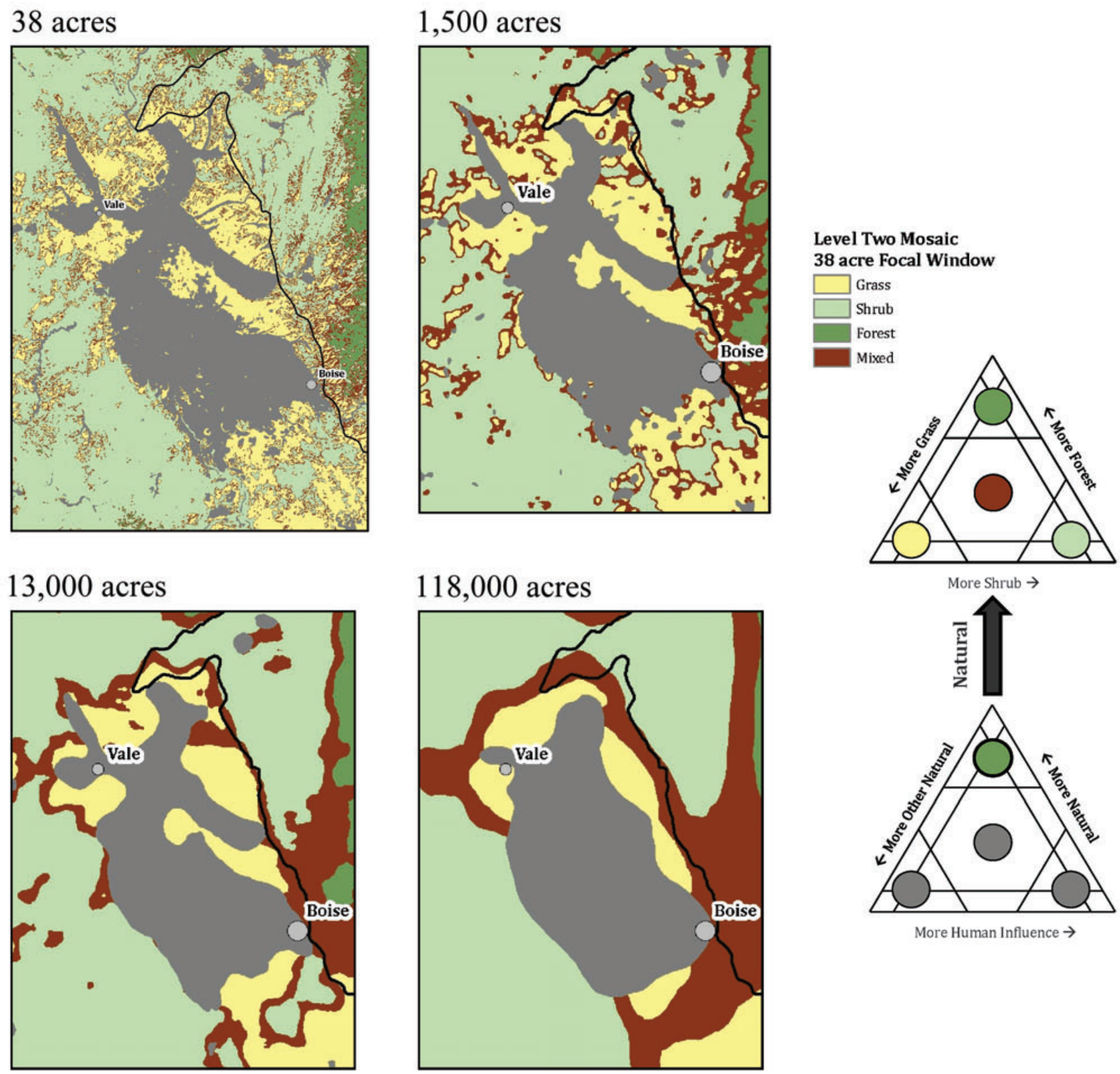

Figure 5.11—Fine-scale to coarse-scale landscape patterns for the area around Boise, Idaho, using the level two mosaic metric. The level two mosaic metric is based on the Grass, Shrub, and Tree NLCD classes with neighborhood sizes of 38, 1,500, 13,000 and 118,000 acres; the level two mosaic is only applied to regions classified as Natural by the level one mosaic using Natural, Other Natural and Human Influenced generalized NLCD classes and the corresponding neighborhood size.

by Other Natural or Human Influenced are shown in gray. The figure suggests that the area immediately surrounding the Human Influenced region (in gray) is dominated by Grass, which transitions into Shrub dominated lands. The 38-acre neighborhood shows Grass dominated areas are intermixed with areas dominated by either Shrub or Non-Natural cover.

Figure 5.12 is the first level mosaic for the study area using a 118,000-acre neighborhood. The study area is dominated by Natural land cover with a few pockets of Human Influenced areas mainly in the Snake River Valley and along the Columbia River. This example also illustrates that the neighborhood size used to measure the mosaic metric needs to be appropriate to (or "tuned" to) the task. It may not make sense to use the fine-scale 38-acre window for an area this size. Yet if the task was to examine the interplay between Human Influenced and Natural areas in Central Oregon around Bend, then a neighborhood smaller than 118,000 acres would be needed.

Riitters (2011) provides additional descriptions of the methods, including a national application of another version of the first level Landscape Mosaic metric that classified pixels based on the proportions of Agriculture, Developed, and Semi-natural land-cover types in a neighborhood. Those same basic methods were applied in this study, with the only difference being the definitions of the three axes in the tri-polar classification model.

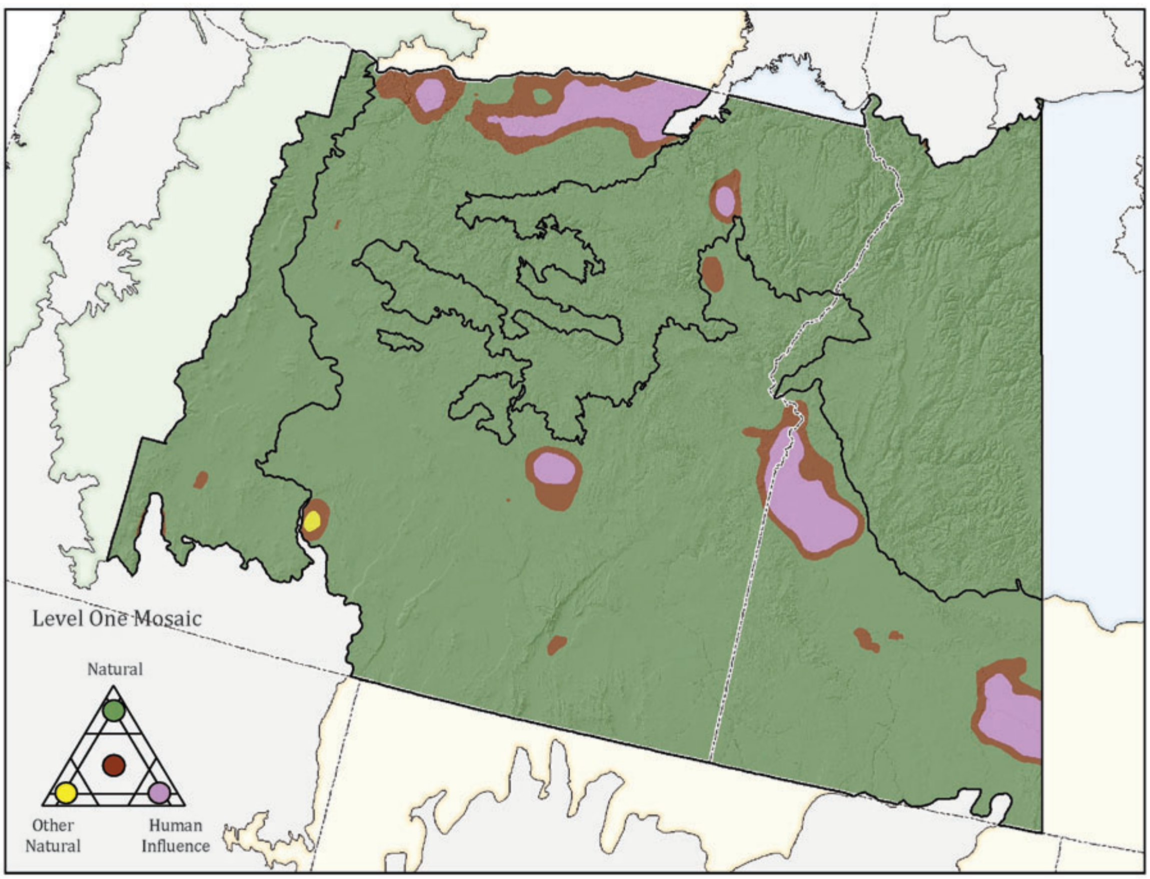

Figure 5.12—Coarse-scale landscape patterns for the study area, using the level one mosaic metric based on Natural, Other Natural, and Human Influenced NLCD classes and a 118,000-acre neighborhood.

Morphological Spatial Pattern Metrics

Morphological Spatial Pattern Analysis (MSPA) uses mathematical morphology, and has been used for classifying the structural patterns of natural land-cover types (Riitters 2011; Soille and Vogt 2009). In this study, the shrubland, forest, and grassland pixels were analyzed separately using a shrub/non-shrub map, forest/non-forest map, and grass/non-grass map, respectively, derived from the NLCD land cover map. Using shrubland as an example, the output of the MSPA analysis is a map of shrub pixels only, each labeled by one of six possible MSPA classes (the non-shrubland pixels are classified as background). The six MSPA classes are defined as follows: Core, shrubland pixels surrounded by other shrubland pixels; Edge, exterior perimeter pixels surrounding core shrubland pixels; Perforation, interior perimeter pixels enclosing holes in clusters of core shrubland; Connector, shrubland clusters that are connected to an edge at both ends or to perforation at both ends (connectors are sometimes called "bridges" or "corridors"); Branch, shrubland clusters that are connected to edge, perforation, or connector at only one end; and Islet, isolated shrubland clusters that are too small to contain core (islets are sometimes called "patches"). For example, figure 5.13 displays the morphological analysis for shrubland in north-central Oregon containing Pendleton.

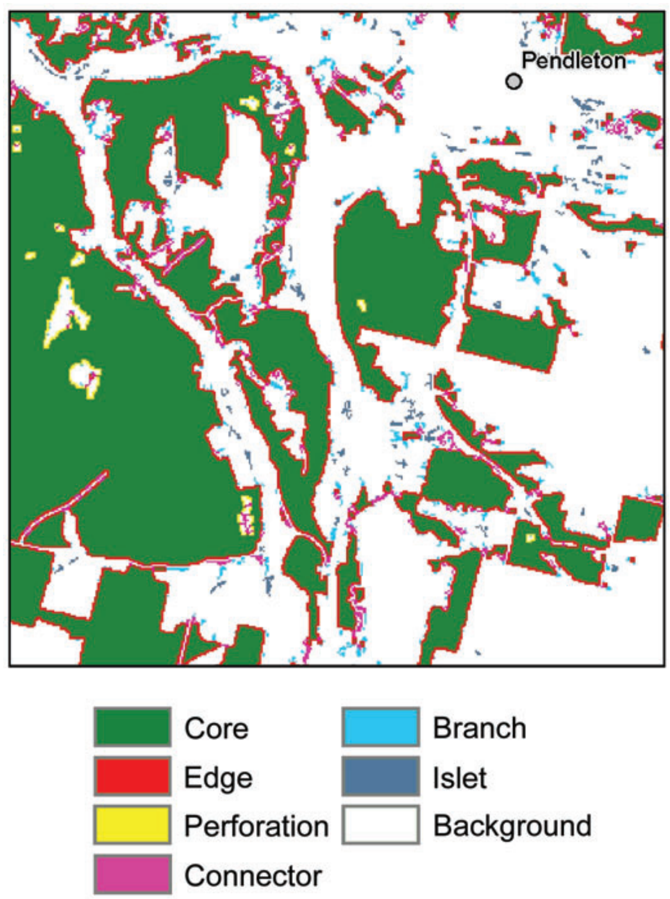

Figure 5.13—Morphological Pattern Analysis of the shrub/non-shrub map for an area in north-central Oregon containing Pendleton. White is background, which is all non-shrub pixels. The assumed edge width is 30 meters.

MSPA results are also scale-dependent but in the case of this metric, the scale or "tuning" parameter is the assumed edge width (Soille and Vogt 2009). The map in figure 5.13 was produced using a relatively narrow edge width of 30 meters; figure 5.14 shows the MSPA classification of shrubland in the same area over a range of edge widths, from 60 meters to 240 meters. As the assumed edge width increases, there is less 'core' and consequently the labeling of individual pixels can change as their structural relationships to the remaining 'core' changes. For example, in figure 5.14 there is an increase in the Connector class as the edge width increases.

The relative proportions of shrub pixels with core and non-core morphologies are of interest because the class core indicates land that is relatively far from a non-shrub land cover type. For this discussion the term "edge" will refer to non-core MSPA classes; in other words, it includes all of the original Edge, Perforation, Connector, Branch and Islet MSPA classes. The bottom two rows of charts in figure 5.15 show the percentages of core and edge (non-core) shrubland in the three provinces for a range of edge widths. The percentage of the total land area covered by Shrub land cover is indicated at the top of bar graphs. As expected, the percentage of edge increases as the edge width increases. The impact of different edge widths on the amount of available core habitat for interior species may be addressed with this type of analysis.

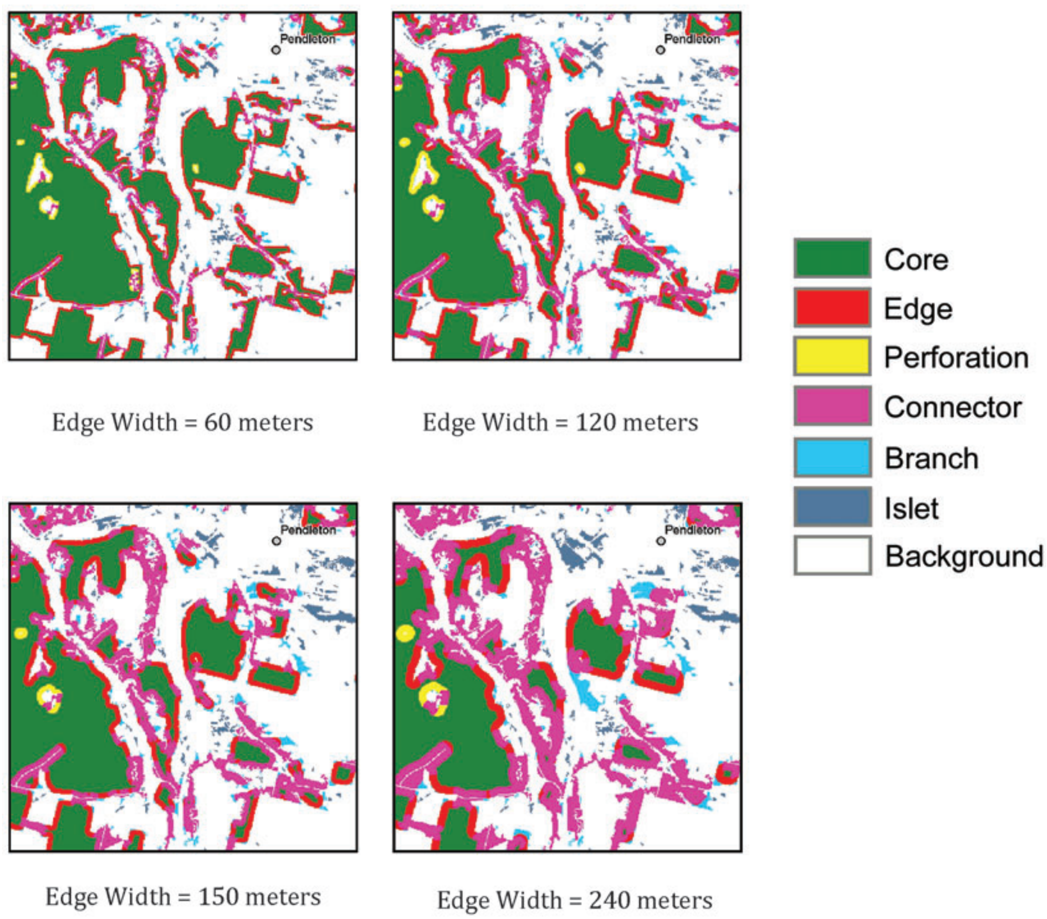

Figure 5.14—Morphological Pattern Analysis of the shrub/non-shrub map for an area in north-central Oregon containing Pendleton. The assumed edge widths range from 60 meters to 240 meters. White is background, which is all non-shrub pixels.

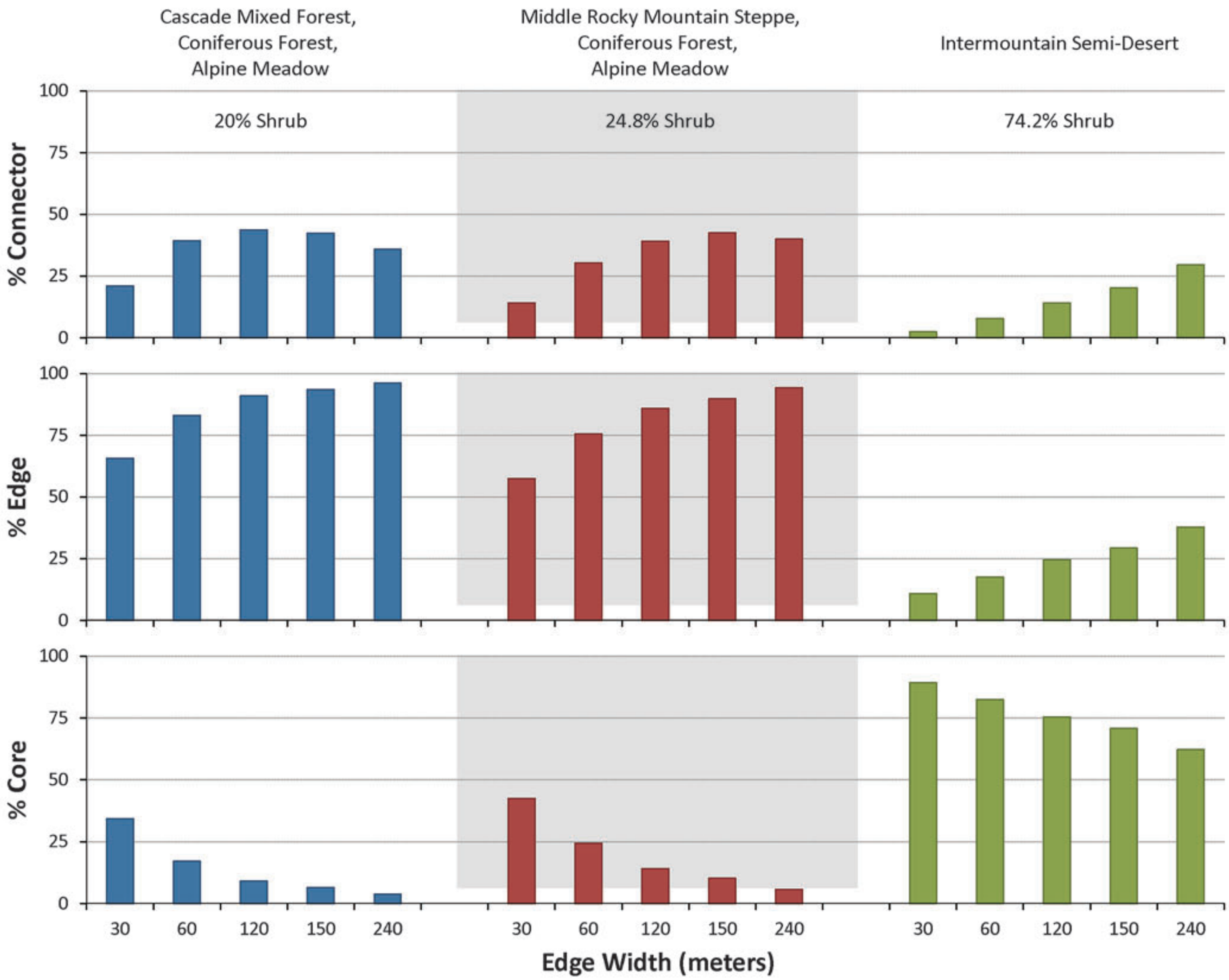

Figure 5.15—Core, Edge and Connector classes as a percentage of the shrub area for the Cascade Mixed Forest, Middle Rocky Mountain Steppe, and Intermountain Semi-Desert provinces; over a range of edge widths. Here, the Edge class is the combination of all non-core morphological classes, and the Connector class is a subset of that combined Edge class. The percentage of shrub area in each province is indicated at the top of the figure.

Depending on the topic of interest, additional information may be gained by analysis of specific edge classes. For example, looking at the percent of the Connector class as a subset of the total Edge (that is on the same scale as the combined Edge class) emphasizes the amount of the cover type acting as corridors between Core areas (see top row of charts figure 5.15). Note that the sum of the percentage Core and percentage combined Edge is equal to 100 percent. Since the Connector class is a subset of Edge, the percentage Connector is compared relative to the percentage Edge; for example, a 30 meter edge width for the Cascade Mixed Forest province means that the Edge is approximately 60 percent of all shrubland, while the Connector class is approximately 20 percent of all shrubland, or one-third of Edges are Connectors. In addition, the analysis can be extended to the Grass and Forest cover types (figures 5.16 and 5.17). For some

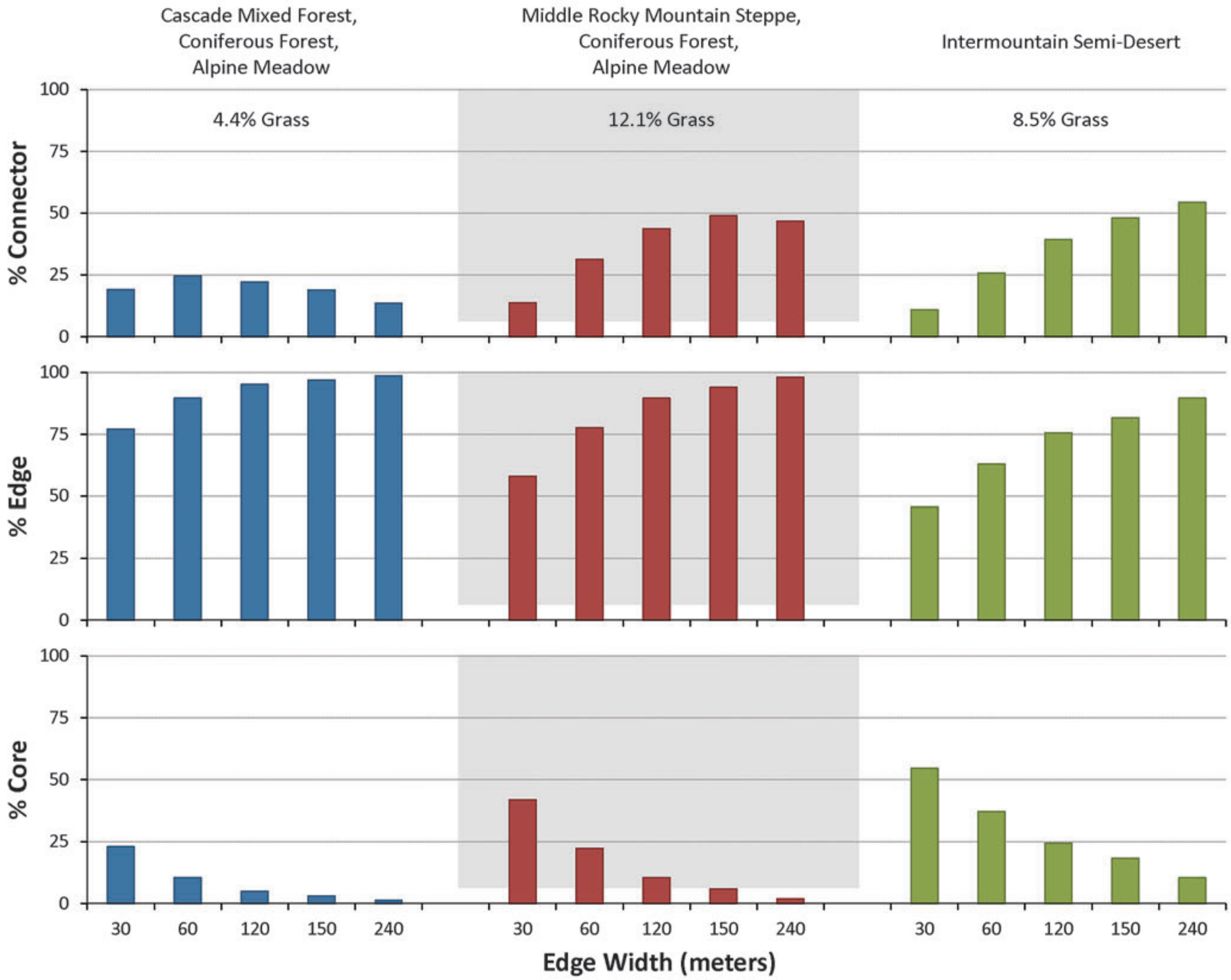

Figure 5.16—Core, Edge and Connector classes as a percentage of the grass area for the three ecosystem provinces contained in the study area; over a range of edge widths. The Edge class is the combination of all non-core morphological classes; so the Connector class is a subset of the combined Edge class. The percentage of grassland in each province is indicated at the top of the figure.

provinces and cover types, as the edge width increases the proportion of Connector class increases (for example, Shrub in the Intermountain Semi-Desert or Forest in the Cascade Mixed Forest). This increase in the ratio of Connector to the Edge does not appear to be a function amount of the cover; for example, the Grass cover type is a low percentage in all the provinces, yet for a 240-meter edge width the Connector to Edge ratio is quite small for the Cascade Mixed Forest and much larger for the Intermountain Semi-Desert. This may be of interest to wildlife specialists. (See Riitters (2011) and Soille and Vogt (2009) for further information on Morphological Spatial Pattern metrics.)

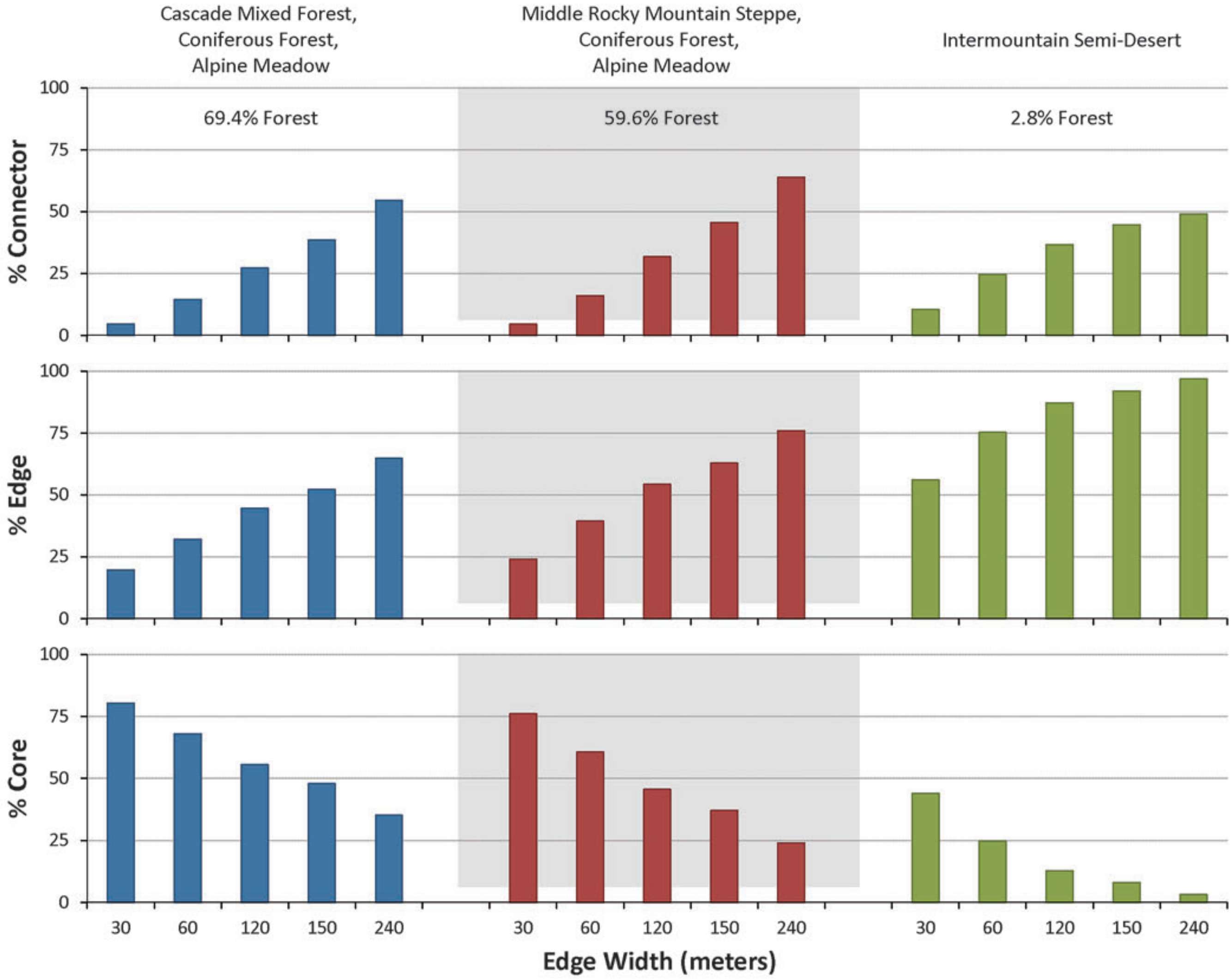

Figure 5.17—Core, Edge and Connector classes as a percentage of the forest area for the three ecosystem provinces contained in the study area; over a range of edge widths. The Edge class is the combination of all non-core morphological classes; so the Connector class is a subset of the combined Edge class. The percentage of forest land in each province is indicated at the top of the figure.

Summary

The three landscape pattern metrics provide a feasible and consistent way to use readily available national land-cover maps to analyze landscape patterns over large areas at multiple scales. While the definition and interpretation of fragmentation is naturally discipline dependent, the metrics are versatile and can be adapted to a variety of definitions of fragmentation. Several possible uses of the three metrics were given above; Reeves and Mitchell (2012) used similar metrics to analyze fragmentation on U.S. Rangelands.

Although these metrics can provide useful information on fragmentation, there are several factors that make collecting or analyzing information on fragmentation above the local scale difficult. As mentioned earlier, the interpretation of fragmentation is very issue specific. For example, changes in land cover that would fragment useful habitat for one species of wildlife, would have very little impact or may even improve habitat for many other species of wildlife. In addition, site specific information is needed to provide the context to interpret fragmentation. This is particularly true for rangeland systems because rangelands are often heterogeneous by nature. Rangelands commonly contain mosaic patterns of both shrub and grass dominated plant communities. Conversions from grass dominated plant communities to plant communities that contain or are dominated by shrubs is often part of the natural succession of those systems. Without the site specific information, plant community changes resulting from proper management could easily be identified as fragmentation because they result in mosaic patterns of different stages of plant succession. Conversely, large expanses of degraded rangelands dominated by invasive species such as cheatgrass could appear to be unfragmented grassland. Without the site specific information, the potential for misinterpretation of information on fragmentation is great, and needs to be taken into consideration when regional or national scale data are interpreted at site specific scales.

6. Lessons Learned

The coordination necessary for the implementation of assessment protocols across national inventories is no small feat. There are policy issues that must be clear prior to data collection and technical challenges to overcome where ancillary protocols are similar but not identical. A quality control and quality assurance plan should be agreed to and be in place prior to any national implementation. Working across agencies, while beneficial in the long run, requires special attention to the differences in agency culture and management commitment for a successful outcome. These challenges are not confined to this pilot and have been encountered in previous inter-agency efforts. Ringold and others (1999) describe technical and institutional considerations in establishing a regional strategy for the Pacific Northwest Forest Plan. Below are some of the specific lessons learned and recommendations for the expansion of the rangeland assessment effort.

One of the basic principles of survey planning and design is that the survey's primary data analysis goals must be specifically outlined and described before the survey is designed and implemented. This principle needs to be addressed for future efforts, to ensure that all needed data items will be available and that resources are not wasted collecting unnecessary data elements.

Coordination across agencies is a task that requires a time commitment often more than can be accommodated as an 'additional task' to existing work load. It is suggested that a full-time employee(s) be tasked with coordinating the inventories, and a person in each inventory be tasked to act as a liaison.

This coordination role should also include discussions on related attributes and protocols. Great care was taken to define and implement the core set of protocols in this pilot but there are other protocols and definitions that relate to the classification of lands that are similar but not identical across inventories. These other land classification categories have an effect on the extent of range lands especially when the boundaries are vague. Examples include the boundaries between range land and forest, rural development, barren ground, and rights-of-ways. These protocols should include an aerial and a field assessment from both inventories perspective when common protocols cannot be adopted. This will require both inventories implementing the other inventory's definitions and reconciling the differences in the process that each inventory uses to classify the sample point. This means that each inventory needs to be satisfied not only with the definition but also with the process that is used by the other inventory when applying their definitions and procedures.

This pilot did not attempt to sub-divide a plot into general land classes or apply the concepts of ecological site (an NRI procedure) or condition class (an FIA procedure). In other words, the entire plot was classified as belonging to one and only one general land class. A review of whether a plot should be sub-divided into general land classes or even a further refinement into ecological sites or condition class should be explored. Further refinement would require identical protocols across inventories.

A quality assessment and quality control plan should be jointly agreed to by all parties involved in the data acquisition and processing. This includes integrating common components in data recorders and identical processing routines once the data are uploaded to the respective agency computers. A standard set of tolerances and inspection protocols for field data should also be in place with provisions for reporting the results along with published tables.

Careful thought should be given to the sample size necessary to make meaningful estimates over typical domain of interest, for example, the ecological groups in Section 4 (Survey Results). This essentially means having a full discussion on the scale that the information will be typically used and reported. Although it is not possible to predict upcoming issues and the data needs, a general discussion on the relationship between sample size, domain of interest, and costs before a national roll-out should reduce potential frustrations on what an inventory of this type can realistically provide.

At the de-briefing of field personnel at the close of the 2007 field season, a desire was expressed that further training in the identification of sagebrush species and sub-species be provided, since there are subtleties to their identification.

7. Next Steps

The vegetation protocols employed by agencies involved in MAOP provided adequate characterization of the more than 800 plant species found within the 13-county area of central Oregon that was inventoried. We attempted to develop plant groupings or associations from these associated plants to reflect the landscape and spatial heterogeneity across the different land ownerships.

Principles of community and ecosystem ecology reveal the importance of accurate depiction of plant associations for the purpose of predicting plant community dynamics and responses to disturbance, climate change, and human land management. The current MAOP was hindered by lack of a modern and detailed soil survey across all ownerships, which would have helped to differentiate and interpret plant communities. Chapin and others (2002) found that soil properties are the major control over ecosystem processes within a given climate. Future efforts must make use of soils information and ecological site descriptions (ESDs).

This project evaluated the capability of using the existing FIA and NRI programs to collect consistent information on a small suite of indicators. Based on preliminary results, we were able to integrate components of the two existing systems (NRI and FIA) to collect consistent information on public and private rangelands through a cooperative effort between BLM, Forest Service, and NRCS. The indicators that were chosen for this pilot, although robust, were never intended to be inclusive. However, there is a need to expand the suite of indicators in order to adequately assess rangeland resources within the United States. The expanded suite of indicators needs to be robust and concise in order to allow for economical effective assessment. Several key actions that should be pursued included:

- Identify where Gaps in coverage of rangelands occur between FIA and NRI across the United States in order to coordinate a more efficient coverage of the landscape with a minimum overlap of services. [After the completion of this project, agreements were put in place to expand the NRI survey onto BLM managed public rangelands, and data collection began in 2011.]
- Compare complete NRI and FIA datasets to determine what other data can be utilized/compared for rangelands.
- Evaluate the potential for expanded use of remote sensing and other technology in conjunction with field observations to reduce costs of data collection.

- Determine where, how, and when to move forward with survey of all lands for a comprehensive national assessment.

Significant and Emerging Issues

There are several significant and emerging rangeland issues land managers are and will be facing. It is important for any assessment of America's rangelands to assist in addressing these issues in a meaningful way. It is an increasing challenge to utilize an ecosystem services perspective that involves measuring the flow of ecosystem services across a landscape and connecting these services to the people who benefit from them (Collins and Larry 2007; Havstad and others 2007). Rangeland health is the degree to which the integrity of the soil, vegetation, water and air, as well as the ecological processes of the rangeland ecosystem, are balanced and sustained (SRM 1999). By maintaining or improving rangeland health, land managers can more effectively deal with the major issues affecting America's rangelands. This pilot project was never designed to identify or collect information for a complete list of indicators that would address all rangeland issues. Although the indicators used for the pilot by themselves will not provide all of the information needed to resolve rangeland issues that land managers are currently facing, these indicators can help address some of the issues. In this section we briefly discuss some of the more significant issues facing rangeland managers.

Climate change: Climate change affects ecological interactions, and ecosystem processes. Because changes in the climate system will continue into the future regardless of emissions mitigation, strategies for protecting climate-sensitive ecosystems through management will be increasingly important. While there will always be uncertainties associated with the future path of climate change, the response of ecosystems to climate impacts, and the effects of management, it is both possible and essential for adaptation to proceed using the best available science (Julius and others 2008). With repeated measures and reference to ecological sites plant composition, bare ground, and invasive species can be indicators of effects of climate change.

Wildlife Habitat: Wildlife often responds to broad landscape patterns as well as individual patches of resources. How humans occupy landscapes, use resources, and cause disturbance has drastic effects on wildlife habitat (Morrison and others 2006). There is a need for better information on community structure and distribution across the landscape to understand habitat quality and condition. Complete species census, species composition, invasive species, rangeland extent and bare ground are all indicators that are important in understanding impacts to wildlife including threatened and endangered species. Extent of rangelands is an indicator of land conversion and habitat quality. There is a need for data on fragmentation, community structure and distribution to inform trend and impacts on wildlife, including threatened and endangered species.

Fire Cycle: Species composition, invasive species, ground cover (litter), fuel loads, and grazing effects are important indicators of fire cycle and potential departure from the historic range of variability (HRV). Invasive nonnative plants are responsible for serious, long-term ecological impacts, including altering fire behavior and fire regimes, which further impacts ecosystem function and structure (Erickson and White 2007; Zouhar and others 2008). Information on fragmentation/landscape patterning and data on ecological sites are needed to fully understand changes in fire cycles.

Biodiversity: Rangelands span a variety of ecosystems including grasslands, savannas, sagebrush steppe, shrublands, tundra, mountain meadows, and deserts. The variety of life and its processes (biodiversity) is important for moral, aesthetic, and economic reasons, as well as for the services biodiversity provides to society. Rangeland biodiversity is constantly changing by reduction in habitat, land use changes, loss of species, global environmental change, and invasion by non-native species. Biological diversity (biodiversity) includes all living organisms (plants, animals, microbes, etc.) and the genetic differences among them. Essential ecosystem benefits provided by rangelands include maintaining the composition of the atmosphere; mitigating climate and moderating weather; creating, fertilizing, and stabilizing soils; disposing of wastes; cycling nutrients; storing and purifying water; and providing natural control of diseases and pests, to name only a few. Loss of biodiversity can negatively influence the quality and quantity of these benefits (SRM 2003). Species composition, invasive species, and the extent of rangelands are all indicators that would provide useful information on biodiversity.

Invasive Species: Invasive species have been characterized as a "catastrophic wildfire in slow motion." Thousands of invasive plants, insects, fish, mollusks, crustaceans, pathogens, mammals, birds, reptiles, and amphibians have infested hundreds of millions of acres of land and water across the Nation, causing massive disruptions in ecosystem function, reducing biodiversity, and degrading ecosystem health in our Nation's forests, rangelands, mountains, wetlands, rivers, and oceans. Invasive organisms affect the health of not only the Nation's forests and rangelands but also the health of wildlife, livestock, and fish (USDA FS 2004). Invasive species know no boundaries; they span landscapes, land ownerships, and jurisdictions. Their consequences cost the American public an estimated $138 billion each year (Pimentel and others 2000). Direct measures of invasive species composition as well as bare ground are indicators that help identify areas of concern. Repeated measures are important to understand trend and potential for new invasion.

Carbon Sequestration: In addition to looking at the potential to sequester carbon in soils, we must consider the effect that global climate change, particularly elevated carbon dioxide, will have on soil properties and plant life. Soil organic carbon positively affects soil structure, soil erodibility, crusting, compaction, infiltration rates, runoff, salinity, and cycling of plant nutrients and thus helps prevent or reverse degradative processes. Therefore, anything that can increase or maintain soil organic carbon will have a positive effect on soil quality (Follett and others. 2001). Species composition, invasive species, and bare ground are good indicators of carbon cycles. Ecological site correlation and repeated monitoring are important to understanding potential and trend.

Water Quantity and Quality: The provision of high quality water is one of the most common ecosystem services associated with rangelands. Because rangelands are a dominant land type in the western United States, this will become even more important due to rapidly expanding human populations throughout the West. Management changes on rangelands can have significant and often unexpected impacts on water quality and quantity. The properties most sensitive to management include soil structure and vegetation cover, spatial pattern, and composition (Thurow 1991). Water as a supporting service from rangelands needs to be evaluated from multiple spatial scales, including watershed and basin perspectives, before we can better predict what may result under different management scenarios (Havstadand others 2007). Species composition, invasive species, and bare ground are key indicators related to effects on water quality and quantity. This information will help rangeland managers deal with disturbances and identify conservation practices so rangelands can continue to provide high quality water for future generations.

Open Space: Open space describes land that is valued for natural processes and wildlife, agricultural and forest production, aesthetic beauty, active and passive recreation, and other public benefits. Such lands include working and natural forests, rangelands and grasslands, farms, ranches, parks, stream and river corridors, and other natural lands within rural, suburban, and urban areas. Open space may be protected or unprotected, public or private. Development of open space affects the ability to manage rangelands and forests, as well as private landowners and communities' ability to sustainably manage their land to maintain private and public benefits and ecosystem services. At stake is the ability of private and public forests and rangelands to provide clean water, scenic beauty, biodiversity, outdoor recreation, natural-resource-based jobs, forest products, and carbon sequestration. Development in many parts of the country surrounding public and private open spaces increases the risk of wildfire for people and property, raises the cost and risk of fighting fires, contributes to the spread of invasive species, increases conflicts among recreational users, reduces access to recreation lands, and fragments fish and wildlife habitat (Plantinga and others 2007). Plant composition, the extent of rangelands and invasive species can be indicators of impacts from loss of open space. Fragmentation can be a direct measure of the impacts from loss of open space.

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Appendix 1: Earlier Efforts

Two earlier efforts working toward a national inventory occurred in 1997. In central Oregon a pilot project initiated a data collection and analysis effort using both FIA and NRI plots to test the feasibility of integrating those systems for terrestrial systems (Goebel and others 1998). Concurrently the BLM launched a pilot project to test the feasibility of applying the NRI design to public rangeland in Colorado (Pellant and others 1999; Spaeth and others 1999).

Oregon Demonstration Project (1997)

Introduction

The demonstration project in Oregon examined the feasibility of integrating Federal surveys of terrestrial natural resources. Combined data collection teams from the U.S. Department of Agriculture (USDA) Forest Service (FS) and USDA Natural Resources Conservation Service (NRCS) made photo interpretation measurements and field plot observations on points that were selected from the Forest Inventory and Analysis (FIA), National Forest System (NFS) Region 6, and National Resources Inventory (NRI) surveys in a six-county area in North Central Oregon. They collected a subset of existing FIA, NRI, NFS Region 6, and Forest Health Monitoring (FHM) variables, supplemented with measures of soil quality and vegetation profile. A team from the U.S. Department of the U.S. Interior (DOI), US Geological Survey (USGS) Biological Research Division (BRD) supplemented this information with bird, amphibian, ground insect, and flying insect observations on a subset of points that were on Federal lands. The USDA National Agricultural Statistics Service (NASS) assisted the project by producing a combined data base and analyzed the data. Representatives of the Environmental Protection Agency (EPA) and DOI Bureau of Land Management (BLM) actively participated in the planning and report writing in support of this project.

Objectives

This project did not address all of the issues and concerns, many of which have policy and political implications. In particular, they could not identify agency information priorities and develop a comprehensive set of data needs. Rather, it focused on the technical feasibility of integrating surveys and set seven specific objectives:

- Ascertain whether the sampling frames used by the existing national monitoring surveys give complete and representative coverage of the populations of interest.
- Determine if any one of these frames, a combination of the frames, or a new frame is preferable. Investigate the statistical and operational aspects of constructing a joint database combining historical and future information from the surveys.
- Investigate the utility of collecting a subset of common information on a common set of ground plots from the existing surveys using joint FIA/NRI data-collection teams. Each variable in the subset must have the same plot design across the common sample points but may be subsampled differently on the plot.
- Explain and illustrate why FIA and NRI can yield very different estimates of area of forest and range land.
- Explore data-collection methods for vegetation and soil attributes in an integrated survey context.
- Determine whether sampling for animal abundance can be included in the survey design.
- Analyze measurement errors associated with the collection of different variables. This is especially important relative to the development of new variables.

Field Effort

Oregon Demonstration Project was split into Phase I and Phase II

Phase I: Measurements focused on earth cover, land class, wildlife habitat diversity, and land class diversity. Data were collected in the office from aerial photos, GIS data layers, and hard copy ancillary materials.

Phase II: Measurements focused on vegetation, soils, and animal relative abundance. On-site measurements of vegetation, soils samples, and animal relative abundance were made on Phase II sample plots.

Sample Design: Phase I consisted of the set of points from the NRI, FIA, and NSF sample frames. The Phase II field plots were a random selection of the Phase I points.

Conclusions and Recommendations

Recommendations that came out of the 1997 Oregon Study:

- Measure all variables on each plot, regardless of whether located in forest, range, cropland, etc. If a feature does not exist, record a zero or a not-present code. The decision on how to classify a plot or subplot is best done by the data analysts using all available information. It is almost a certainty that people with different backgrounds and interests will classify vegetative types differently. Recording the underlying measurements instead of classifications ensures that the data base will be compatible. With this approach, the needs of different agencies and programs can be satisfied using the same data base.
- It is highly desirable to collect a subset of common information on all plots using interagency crews, because the information currently collected by NRI and FIA complement each other well (in other words, information on soil quality, erosion, and species of trees, herbs, forbs, and grasses). Interagency crews combine expertise and experiences with the different measurements and interpretations.
- Selection of variables to describe the vegetation is also critical. Much work is still required on the appropriate detail and protocols.
- Measurement of key soil variables is critical in surveys involving permanent plots but less destructive methodologies need to be developed (e.g., soil pits are unacceptable but limited soil coring is tolerable).
- Measurement repeatability needs to be addressed. It can often be enhanced by reducing subjectivity, clarifying instructions, and improving training.

Oregon Demonstration Project 1997 recommendations for the operation of inter-agency surveys and use of field crews; these recommendations are based on experience of and suggestions from the field crews:

1. There must be an appropriate mix of skills amongst the crew members to match the requirements of data collection. Highly trained crews are essential because specialized skills are required for identifying plant species, making soil measurements, and comprehending the suite of variables requiring measurement.
2. Additional training should be given to crews when they encounter new ecosystems, especially for identifying soils, plants, wildlife, insects, and plant diseases.
3. The crews need access to experts for identifying plant species and applying protocols in unusual situations.
4. A reconnaissance person would be useful in obtaining permission for access from landowners and determining the best access routes prior to the arrival of the field crew.

5. The crews must be thoroughly conversant with the objectives and rationales for the field procedures to increase their ability to interpret the instructions and maximize their commitment to quality work.
6. The size of crews should be so determined that the collection of data is cost effective and impacts on the land owners and the land are minimized.

The complexity of the field work requires that weekly review meetings for crews be scheduled during the first month of work; subsequent meetings should be organized as the need arises.

Advantages and Concerns

The 1997 Oregon Demonstration Project noted that there are several advantages and concerns for developing an integrated inventory, monitoring, and assessment framework for the Nations ecosystems

Advantages:

- Uniform information would be available for all rangelands, whether private or public.
- A common public database of environmental information would facilitate interdisciplinary and interagency studies that could address the Nation's major environmental issues.
- Ecosystem and watershed health assessments have to cover all lands to be meaningful.
- Uniformity of definitions, sample design, and measurements throughout the United States would permit data collected by different agencies to be meaningfully combined, leveraging their investments and allowing agencies to address broader issues.
- Reduction of actual and apparent conflicts in estimates would result from the use of common definitions and estimates.
- Improved efficiency in data collection would be possible through the pooling of resources and the elimination of duplicate efforts.
- Accommodating multiple conditions and objectives is possible from a broad-based interagency survey, compared to highly focused, agency-specific surveys.
- Reduced bureaucratic competition and enhanced budget stability would result from the cooperation and mutual support of participating agencies.
- Increased national commitment to a reliable and complete environmental inventory, monitoring, and assessment program would be possible from a high profile interagency effort.
- Standardization of information gathering and dissemination would reduce the possibility for apparent conflicts and confusion between the inventory tools.
- Maximized opportunity to reexamine the objectives of these surveys and bring them in line with current needs and knowledge (variables to be measured, acceptable quality standards, need for highly trained crews that are completely committed to the data collection effort, organizational structures, etc.).

Concerns:

- Current surveys each have a legislative mandate with a requirement for the data collected. If an integrated survey is proposed, will a new, or modified, legislative mandate be required?
- Although a new survey design may be advantageous, it is necessary to preserve the historical data series associated with permanent plot locations for existing surveys, such as the NRI and FIA surveys.
- There is concern that a broader focus to the monitoring effort may lead to a loss of agency, state, industry, and political support that has been present for individual

programs that are more narrowly focused. How will state and industry participation be developed; hence incorporating their objectives and concerns into the planning process?

Colorado 1997 Resource Inventory

Objectives

There were two primary reasons for this test: (1) Current BLM procedures of reporting National rangeland conditions have had little public credibility and do not reflect current concepts regarding “rangeland health.” Inventory methodologies and the data produced on public rangelands vary between BLM districts and states. This results in potentially contrasting reports, conclusions that are not statistically valid, and information that is vulnerable to challenge; and (2) Section 201(a) of the Federal Land Policy and Management Act and Section 4(a) of the Public Rangelands Improvement Act require BLM to inventory public lands and, in particular, develop, maintain, and regularly update an inventory of rangeland resource conditions and trends. The NRI process appears to have the capability to address these concerns.

The 1997 Colorado Resource Inventory was designed to: (1) help identify rangeland resource strengths and weaknesses; (2) test the NRI approach on public lands administered by BLM; and (3) determine if NRI, or some variation, is appropriate to meet BLM’s and other Federal public lands continuing inventory requirements under Section 201 of the Federal Land Policy and Management Act (FLPMA).

Field Effort

A cooperative agreement was established between BLM and NRCS to test the new NRI methodology—which included the Rangeland Health Model—on 7.6 million acres of Public Land in Colorado. The NRCS provided the initial statistical design for the project, which was consistent with the National NRI assessment platform. Field data was collected by four interagency crews of three people each (one soil scientist and two vegetation specialists) at 448 sites throughout the state from June 1 until mid-October 1997 (Pellant and others 1999). The field data represents six Major Land Resource Areas (table A1.1).

The field effort represents the most comprehensive survey on this scale to date. Field data verified soils and ecological sites and included soil profile descriptions, some soil chemistry, information about soil surface morphology, recorded information about landscape characteristics, samples of plant species composition by weight, Rangeland Health assessments, plant canopy and ground cover transects, woody cover line transects, assessment and abundance of noxious and invasive plants, species counts of trees by height classes and quantification of tree damage.

Table A1.1—Major land resource areas with number of NRI points samples.

MLRA	Points	MLRA description
34	152	Central desert basins, mountains, and plateaus
39	20	Arizona and New Mexico mountains
47	15	Wasatch and Uinta Mountains
48A	131	Southern Rocky Mountains
48B	13	Southern Rocky Mountain Parks
51	1	High Intermountain Valleys

Conclusions and Recommendations

The pilot study showed that rangeland health can be assessed efficiently and accurately. The NRI assessments can provide land managers with timely information on site stability and biotic integrity. Early warnings of resource problems can be detected, which will allow application of conservation treatments and management actions (Spaeth and others 1999)

Appendix 2: Estimation Units

Estimation units served several purposes: the construction of plot/point weights constrained to sum certain acres for additive reasons; a means of constructing estimates consisting of similar sample and plot design; and the distribution of plots across agencies for the equitable work-load distribution. These estimation units are not identical to the table cells reported in this document. Each table cell may be composed of one or more full or partial estimation unit(s). Derivation of statistical estimation weights and variances differs across estimation units and follows the published statistical procedures for the FIA and the NRI. The four estimation units, defined in terms of the partitioning and allocation process discussed in Section 3 (Survey Design and Methodology), are in table A2.1. There are two items worth noting in table A2.1. First, estimation units 3a and 3b cover the same area with both inventories using their respective sample and plot designs. Separate estimates are made for estimation units 3a and 3b and the two estimates are combined into a single estimate for estimation 3 using the weighted variance procedures. Second, the sample and plot designs for estimation units 4a, 4b and 4c are the same, so they are treated as a single estimation unit 4.

Furthermore, the information sources for the construction of acres in table 4.1 varied by estimation unit. A summary of these sources is given in table A2.2. The aerial photograph interpretation was performed by experienced interpreters with the Remote Sensing Application Center of USFS (see Aerial Photography in Section 3).

The weights for estimation units 2, 3a, 3b, and 4 were area controlled so that the sum of the weights equaled the area as computed by the NLCD map intersected by ownership and county boundaries in GIS. The weights for estimation unit 1 were controlled by the estimate of rangeland acres based on the 2003 annual NRI dataset, with adjustments made using the GIS data base.

The sample sizes per estimation unit vary among the tables and within the rows and columns of the tables. Table A2.3 has the sample size for tables 4.1 through 4.5, and table 4.7.

Table A2.1—Estimation units, defined in terms of predicted land cover, ownership and geographical location.

Estimation Estimation unit	Predicted land cover	Ownership	Counties	Program responsibility
1	Non-forested	Non-Federal	All	NRI
2	Non-forested	BLM	Gilliam, Harney, Morrow, Umatilla	NRI
3a[a]	Non-forested	BLM	Deschutes, Jefferson, Klamath, Lake, Sherman, Wasco	NRI
3b[a]	Non-forested	BLM	Deschutes, Jefferson, Klamath, Lake, Sherman, Wasco	FIA
4a[b]	Forested	All	All	FIA
4b[b]	Non-forested	Non-BLM Federal	All	FIA
4c[b]	Non-forested	BLM	Crook, Grant, Wheeler	FIA

[a] Note that estimation units 3a and 3b cover the same area.
[b] The statistical procedures treat 4a, 4b, and 4c as one unit [Unit 4].

Table A2.2—Information source used to obtain a plot's land use class.

Estimation unit	Information source
1	2003 annual NRI dataset
2, 3a, 3b, 4	Aerial photography interpretation of pilot plots

Table A2.3—Number of sample sites in tables 4.1 through 4.4.

	Estimation Unit 1	Estimation Unit 2	Estimation Unit 3a	Estimation Unit 3b	Estimation Unit 4
Table 4.1, each row	Annual NRI, 2003	48	54	63	219
Table 4.2, Rangeland NRI column	207	48	54	63	219
Table 4.2, Forest Land NRI column	Annual NRI, 2003	48	54	63	219
Table 4.3, BLM row	N/Aa	48	54	63	27
Table 4.3, USFS row	N/Aa	N/A[a]	N/A[a]	N/A[a]	138
Table 4.3, Non-Federal row	207	N/A[a]	N/A[a]	N/A[a]	39
Table 4.3, All ownership row	207	48	54	63	219
Tables 4.4 and 4.5	139	48	49	59	201
Table 4.7, ALL Row	136	45	44	49	35

[a]N/A (Not Applicable) indicates where the domain does not intersect the estimation unit.

As noted in Section 4 (Survey Results), selective use was made of the 2003 Annual NRI. This occurred in estimation unit 1. The reductions in sample size for estimation unit 4 in table 4.3 were caused by the restriction in ownership in one of estimation units 4a, 4b, or 4c. The analysis presented in tables 4.4 and 4.5 are based on field measurements for vegetated plots. Tables 4.4 and 4.5 are based on a subset of plots used in table 4.3 and the excluded plots were access denied, non-vegetative, and human influenced.

The construction of the ecological groups using the multivariate analysis was based on all vegetative plots during the construction process. Some groups were excluded because they were significantly different from other groups to be combined and had too few plots to be analyzed separately. This reduced the number of plots from 496 for tables 4.4 and 4.5 to 485 in table 4.6. The number of plots included in table 4.7 is based on only those plots in tables 4.4 and 4.5 that are also classified as rangeland using the NRI protocols.

The ecological groups are a subdivision of estimation units; table A2.4 contains the number of plots per estimation unit for each of the ecological groups. Note three of plots that are classified as NRI rangeland did not fit into the ecological group classification scheme. For several of the estimation units, the number of plots was insufficient to calculate a variance. For these ecological groups, the mean was calculated in table 4.7.

In table 4.8 the estimates are made over sub-divisions of the ecological groups, which further reduces the sample size. Estimates were only completed for a few ecological groups that had larger sample sizes. Due to the limited sample size, there are a number of cells with no estimate of the standard deviation. It was impractical to list the sample size for all the sub-domains, consequently they have been omitted.

Table A2.4—Number of sample sites with transect data, by ecological group.

Ecological group	Estimation unit 1	Estimation unit 2	Estimation unit 3a	Estimation unit 3b	Estimation unit 4
ARTR/POSE-PSSP6	85	3	2	2	9
PIPO	1	0	0	2	3
SAVE4	9	3	0	3	1
AGCR	6	5	0	1	0
ARTRW	5	31	21	13	7
ARAR8	8	2	5	13	1
ARTRV	18	1	13	12	11
Upland tree	0	0	0	0	2
JUOC	1	0	3	3	1
Not classified	3	0	0	0	0
All	**136**	**45**	**44**	**49**	**35**

Glossary

bare ground: All land surface not covered by vegetation, rock, or litter

basal area/cover: The cross sectional area of the stem or stems of a plant or of all plants in a stand. Herbaceous and small woody plants are measured at or near the ground level; larger woody plants are measured at breast or other designated height. Syn. basal cover.

canopy cover: The percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants. Small openings within the canopy are included. Syn. crown cover.

dominant Plant species or species groups that, by means of their number, coverage, or size, have considerable influence or control upon the conditions of existence of associated species.

foliar cover: The percentage of ground covered by the vertical projection of the aerial portion of plants. Small openings in the canopy and intraspecific overlap are excluded. Foliar cover is always less than canopy cover; either may exceed 100 percent. Syn. cover.

ground cover. The percentage of material, other than bare ground, covering the land surface. It may include live and standing dead vegetation, litter, cobble, gravel, stones, and bedrock. Ground cover plus bare ground would total 100 percent. Syn. cover, see foliar cover.

species composition The proportions of various plant species in relation to the total on a given area. It may be expressed in terms of cover, density, weight, etc.

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