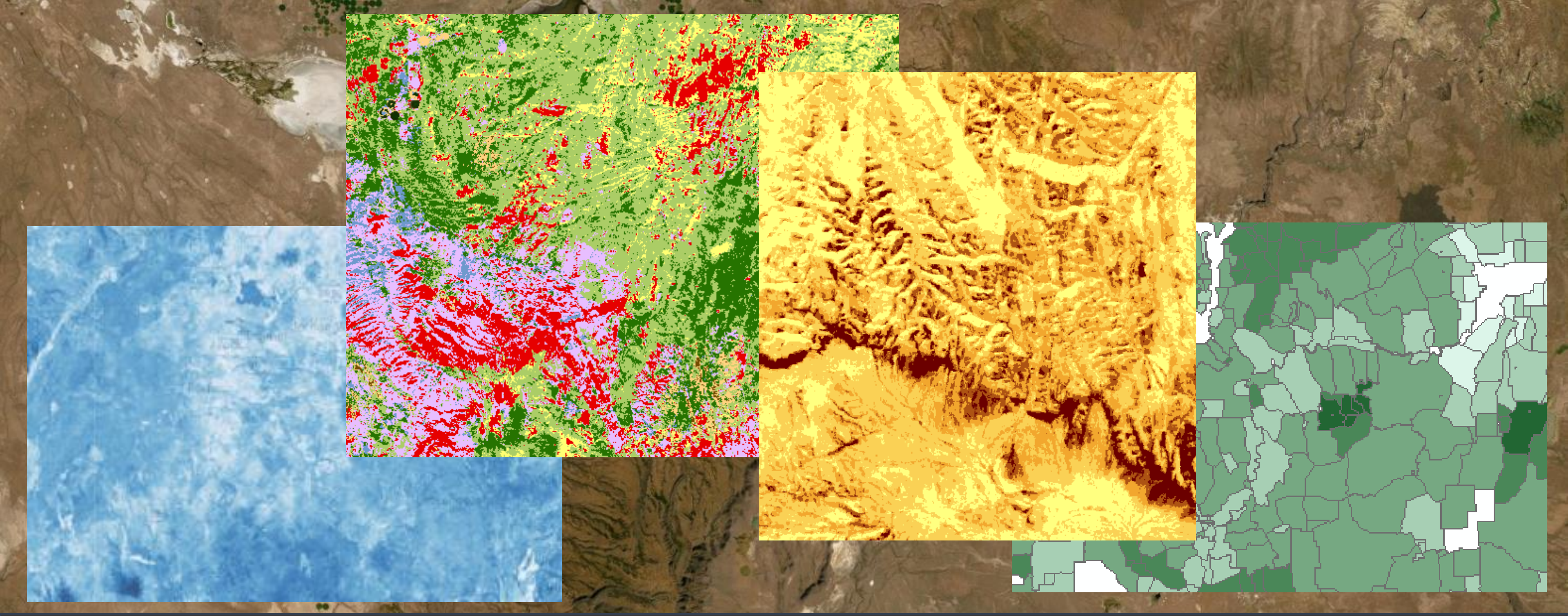


Guidance for Evaluating and Summarizing Rangeland Vegetation Maps

Megan Creutzburg, Institute for Natural Resources
Megan.Creutzburg@oregonstate.edu
April 2021

Introduction

The field of remote sensing has advanced dramatically in the last decade, resulting in a proliferation of vegetation maps for rangelands in the western U.S. There is wide acceptance that remotely sensed map products could be extremely useful and improve the efficiency and effectiveness of management decision-making at multiple scales. However, there are various challenges to understanding and adopting products, lack of accessible information about their uses at local scales, lack of examples of uses in real management contexts, and other challenges to adoption.

This guidance intends to help practitioners in the sagebrush rangelands of the Great Basin use maps by providing guidance on **how to approach the use of maps, steps for evaluating or choosing a product, and options for summarizing maps for an area of interest**. Although vegetation maps can be used at a wide range of scales, this guidance is primarily intended for managers working at **landscape scales** across Counties, Districts or Field Offices. At these scales, the need for vegetation maps is high but adoption of map products in management planning is often low due to various practical and technical barriers.

This guidance applies primarily to **rangeland vegetation cover maps**, although it may be transferrable to other types of remotely sensed products. For more information about currently available vegetation maps and other technical guidance on decision support tools for sagebrush rangelands, see the Rangeland Assessment and Management Tools resource page developed for the Oregon SageCon Partnership.

Purpose of this guidance

This guidance consists of several steps, starting with broad principles and a framework for decision-making, evaluating and summarizing maps to support that decision, and bringing those results back into the decision-making framework. This document can be referenced at various stages (planning, implementation, monitoring, etc) as needed. This workflow provides a suggested starting point, but not all steps will be relevant to all users, and this should not be considered a prescriptive list. More detail on each step in the upcoming slides.

Step 1: **Review** common uses for vegetation maps and guiding principles for using maps to make management decisions.

Step 2: **Define** your decision-making framework, management question and scale. Consider where maps may be most useful.

Step 3: **Compile** information for your area of interest and find the map products that are most relevant for your application and geography.

Step 4: **Evaluate** different available map products, if needed. This document provides some best practices for evaluating maps for a local geography.

Step 5: **Summarize** maps based on area of interest and objective, as needed. This document provides some tips on map summarization.

Step 6: **Integrate** results back into the decision-making framework.

Step 1: Review common uses for maps

Remotely sensed maps can efficiently provide a continuous estimate of vegetation composition across broad scales, including areas that are difficult to access. Primary applications of rangeland vegetation maps include:

- **Assessment** of vegetation condition across multiple scales in space and time. Vegetation can be characterized in different ways for mapping (e.g., land cover types, functional groups, individual species distribution or cover).
  - Maps may be helpful for pre-assessment planning – see an example Rangeland pre-assessment workflow for ideas about how to streamline a condition assessment.
  - Vegetation maps can be used qualitatively (e.g., illustrate spatial patterns) and quantitatively (e.g., estimate the proportion of an area meeting certain criteria).
- **Monitoring** change over time. Remotely sensed maps can monitor changes in vegetation condition, including long-term trends and change due to disturbance or restoration activities. An increasing number of rangeland vegetation maps cover multi-decade time frames, providing opportunities to monitor change over time at multiple scales.
- **Management** planning needs, such as prioritizing areas for management actions. Maps can help identify spatial patterns and landscape context; for example, the SageCon invasives geographic strategy uses maps to help strategically and proactively address invasive annual grasses at a landscape scale.

Maps may fit into your decision-making framework for one of these purposes - but maps are not always appropriate for every management application, geography and scale. *See slides 6-7*.

Step 1: Review guiding principles for using maps

- When considering the use of maps in rangeland management, keep the following **guiding principles** in mind (Allred et al. in revision, *Rangelands*).
  - **Use maps within a decision-making framework**. Maps provide valuable information to support decision-making, but it is important to apply them within a pre-defined decision-making framework where they are most useful and appropriate. Maps may not be useful in all stages but incorporating maps early in a planning process, as appropriate, will often increase the value provided by maps. *See slides 6-7*.
  - **Use maps to better understand and embrace landscape variability**. Due to their continuous coverage, maps can capture important aspects of heterogeneity across the landscape that are generally not possible with more traditional sampling. *See slides 21-24*.
  - **Keep error in perspective**. Accuracy and error concepts can be difficult to understand, and map error can limit the utility of maps. However, it is important to keep this error in perspective relative to error from other data sources and think critically about the level of local accuracy required for your management application. *See slide 10 for context, and slides 9-19 for guidance about how to evaluate maps for an area of interest*.
  - **Think critically about contradictions**. Maps can contradict each other, expert opinion or other data sources, making it difficult to choose the most reliable data source or interpret multiple types of information. When this happens, some key questions can help clarify the path forward. *See slide 19*.
- Maps should not be used in isolation to answer management questions; other evidence and on-the-ground knowledge are essential for making robust decisions. Additional **best practices** for using maps can be found in this short guidance document.

Step 2: Define decision-making framework

Remotely sensed maps are not appropriate for all management applications or decisions. It is important to have a clear understanding of the utility of maps and how they fit into your decision-making framework to answer a management question. Some guidance on the utility and types of information that may be contributed by maps at various stages of management planning is provided in the table below.

Key Questions	Planning Step	Potential Utility and Role of Maps
Where are we now?	Inventory and assessment	**High utility**. Maps efficiently provide data on vegetation through time. Value of maps generally goes up with broader spatial scales.
Where do we want to be?	Goals	**Moderate utility**. Goal setting is inherently a qualitative process, but maps may help managers set realistic goals by providing critical landscape context.
How do we get there?	Strategy and prioritization	**High utility**. Maps can provide crucial spatial data needed to inform a strategy for accomplishing goals and prioritizing where to act.
What needs to change and when?	Objectives	**Moderate utility**. Maps can aid in establishing quantifiable targets for management. Maps may also inform how quickly change needs to happen. Value of maps goes up at larger scales (e.g., allotment, watershed).
What are we going to do?	Implementation	**Low to moderate utility**. The role and utility of maps is more limited during project-level implementation where local knowledge and data are most important. However, maps may be helpful for anticipating the degree of management intervention that may be required (e.g., restoration seeding, weed control).
How will we know when we get there?	Monitoring	**High utility**. Maps efficiently provide data on vegetation through time, allowing managers to track and quantify progress towards goals and objectives and adaptively manage. Value of maps goes up with scale of monitoring required.

Adapted from Allred et al. in revision

Step 2: Define decision-making framework

An example of a **condition assessment** workflow is shown below, with the management objective of determining if an area meets criteria set for ecological function. In this example, four steps in the decision-making framework are shown, with potential contributions of remote sensing.

1. Prioritize assessment areas
(e.g., pre-assessment)

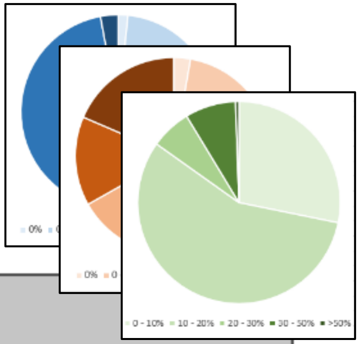
Maps may help **prioritize** field time and maximize efficiency
- What are the dominant conditions and primary threats?
- How complex or variable is the landscape?
- Can the landscape be simplified into assessment units?

2. Gather information for assessment

Maps are **one line of evidence** to complement others
- Provide continuous information to assess condition across entire landscape, including places that are difficult to reach.
- Provide broader context for site-specific plot data.

3. Assess and evaluate information

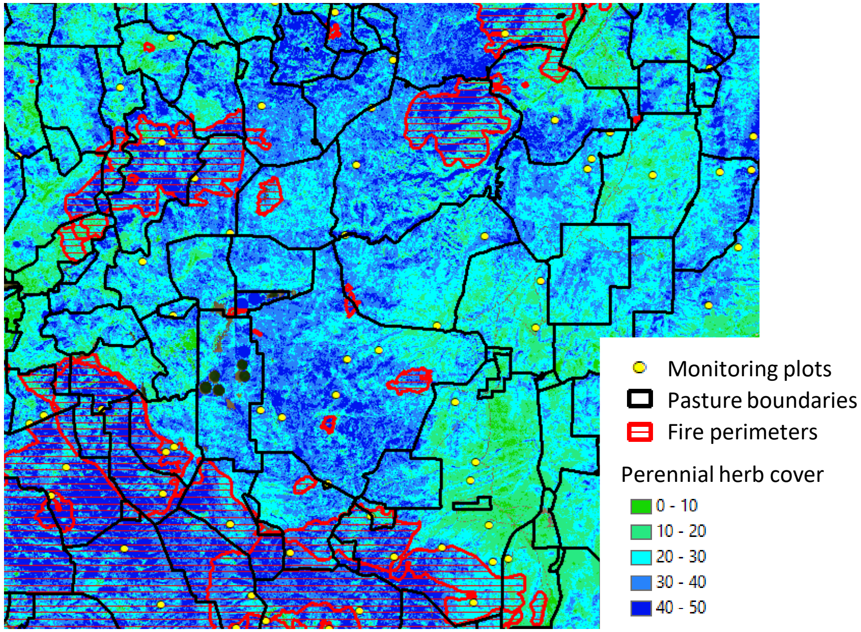
4. Document results



Map figures and/or summaries can help **communicate** complex issues for a broad audience

Step 3: Compile information

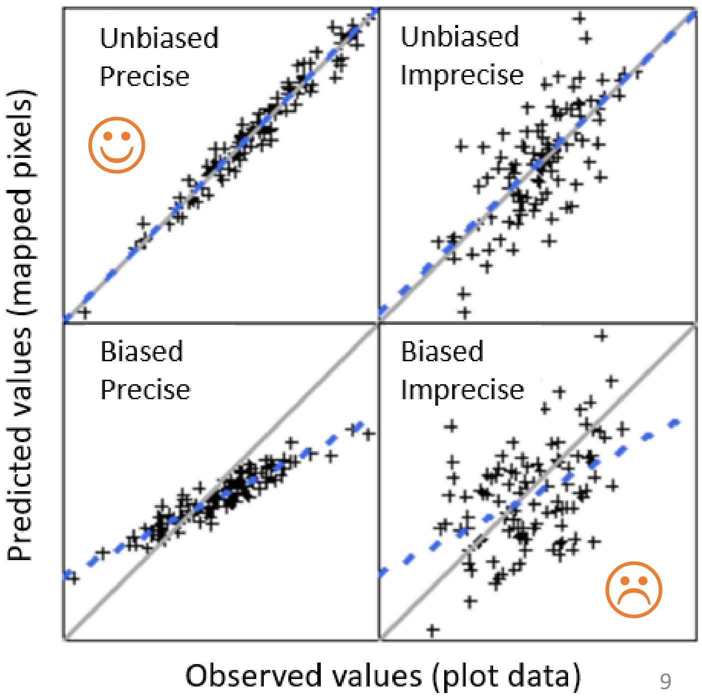
- If possible, gather the information you have about your area in one place and create a map project with the relevant geospatial data layers. Having all this information in a single place can aid in evaluating map products, identifying specific issues, and explaining patterns. It can also help with efficiency in later project steps – see the rangeland pre-assessment workflow for ideas on how pre-assessment may help streamline collection of field data.
- See the list of rangeland vegetation map products available in Oregon and across the western U.S. Each map product has different strengths and weaknesses; evaluate each independently and use the appropriate product or combinations of products as needed. The following pages provide guidance for evaluating multiple products, if needed.
- Other spatial information to compile alongside vegetation maps may include:
  - Imagery basemap.
  - Field plot data – standardized monitoring plots (e.g., BLM AIM), range trend plots, etc and associated photos.
  - Site potential – soil types, ecological sites, disturbance response groups.
  - Management units – allotments or pastures, ownership boundaries, management designations.
  - Management information – grazing infrastructure, permittee and utilization information, etc.
  - Disturbances or treatments –fire perimeters, treatment perimeters, proposed treatment areas, etc.
  - Infrastructure – roads, fences, etc as needed.



Step 4: Evaluate map products

This section provides guidance on choosing a map where multiple products are available.

- All maps should include some form of accuracy assessment, and published maps will likely have a reasonable level of error. However, these statistics may be difficult to interpret, and users may want to evaluate multiple map products for an area of interest based on local expertise and data. The following slides provide guidance for this type of informal evaluation.
- When evaluating maps, choose the broadest spatial scale possible for your application and avoid evaluating small groups of pixels, where fine-scale patterns may not be representative of broader map accuracy.
- Broad accuracy concepts include:
    - **Precision** – measures how well the spatial patterns in the maps match the known patterns on the landscape. Higher precision is shown on the left panels of the schematic where there is less scatter of points in the graph.
    - **Bias** – measures how well mapped values match plot data values. Lower bias is shown on the top panels of the schematic, where the regression line (blue) follows the 1:1 line (gray). Note that many accuracy statistics don't capture bias.
- Some products perform better in either improving precision or reducing bias, but often not both.



Step 4: Evaluate map products

The utility of vegetation maps will vary depending on the application, scale and other considerations. Given that all map products will contain error but many also provide a high level of value, think critically about the question: **for my management application, what level of accuracy is needed?**

Broad-scale and general questions (top): maps generally add **high value** and local accuracy may be less critical.

- What is the **distribution and severity of threats** across a large landscape?
- Which allotments or pastures are likely to have widespread problems that may affect **land health standards**?
- What is the **trend in condition** of an allotment or pasture over time?
- Where is **field sampling** needed across an assessment area?
- What was the **pre-fire condition** of an area that recently burned?
- Where should **treatments be prioritized** in an assessment area or previously burned area?
- Were treatments **effective** in changing vegetation composition?

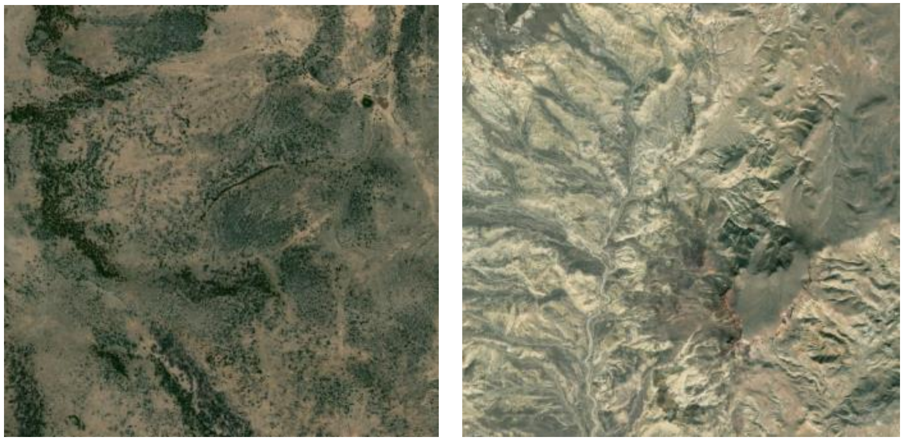
Finer-scale and specific questions (bottom): local accuracy of maps is important. Maps may be useful on a **case-by-case basis**.

Step 4: Evaluate map products

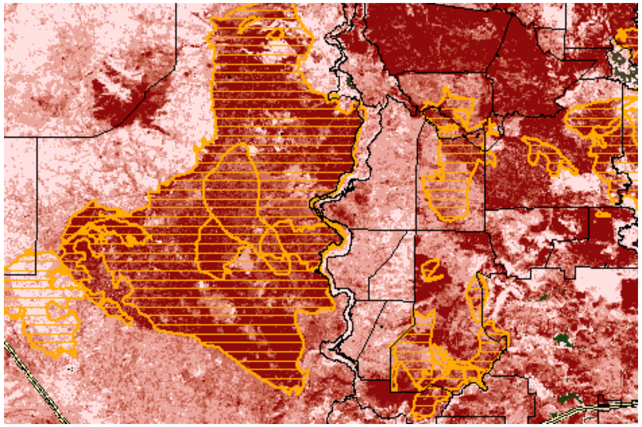
The following slides provide tips on using different types of information to help in a map evaluation for a local area of interest. These steps may help narrow down map product(s) for a particular location, management application, and scale, but should not be considered a rigorous or independent accuracy assessment.

1. Use **expert knowledge**

2. Use **aerial imagery**



3. Overlay **boundaries** - management designations, disturbances, treatments, etc



4. Use **plot data**

Step 4: Evaluate map products

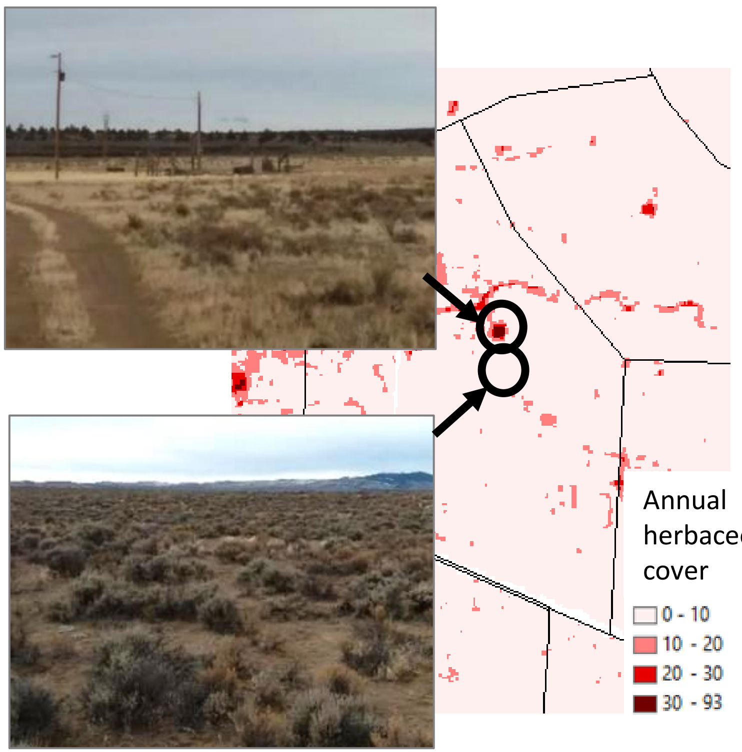
1. **Use expert knowledge** – do broad patterns hold up in known areas?

- Get a group of experts together. Sometimes the collective knowledge of experts can rule out products that are not sufficiently accurate or find clear consensus on a product that is best for the management question.
- Approach maps with an open mind. Even for the most experienced expert or manager, maps can challenge assumptions and bring new information to light. Maps also have an unparalleled ability to cover large areas (including remote and inaccessible areas) and long time frames (some maps cover multiple decades). Few experts will have this breadth of knowledge.
- Evaluate maps at the broadest scale applicable to your management question and avoid scrutinizing individual pixels or groups of pixels.
- Visual evaluation of maps may be informative - or may be overwhelming. Use a visual evaluation with experts as a first cut to rule out products that are not appropriate for your scale or management question, or document tradeoffs between different products.
- It is okay to eliminate some products and use others; evaluate each map independently and only use the one(s) that you find useful.

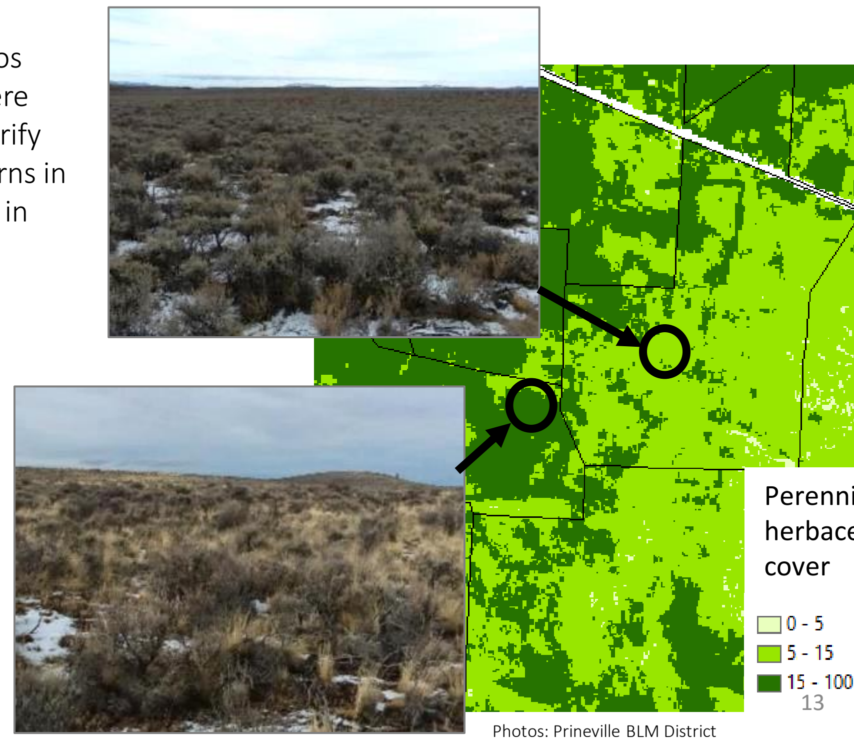
Step 4: Evaluate map products

A. Use expert knowledge – spot check map

- Spot checking of maps can be a useful method of field validation. Comparing georeferenced photos against patterns in the map can help determine the general level of accuracy in a specific area and identify major weaknesses. Maps may vary in accuracy across the landscape.
- Remember that all maps contain error and a map that does not reproduce every pattern on the landscape may still be very useful, especially at broad scales. Also note that disturbed landscapes (e.g., post-fire) will often be more variable and accuracy may be more difficult to assess.



The photos shown here largely verify the patterns in the maps in multiple locations.



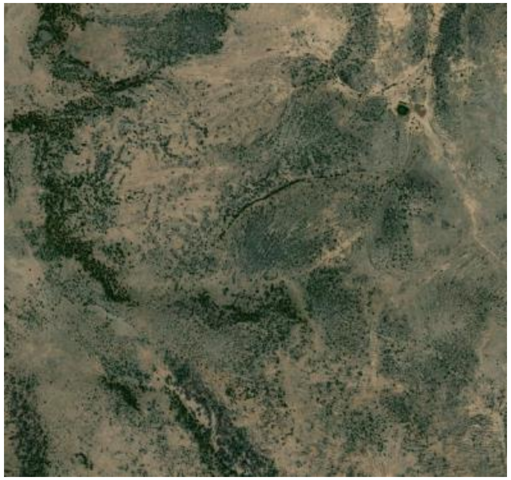
Photos: Prineville BLM District

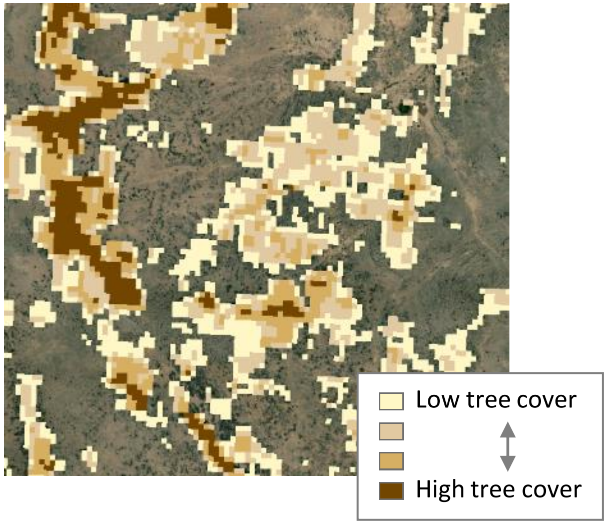
Step 4: Evaluate map products

B. Use aerial imagery

- Aerial imagery can be extremely useful for visualizing patterns at multiple spatial scales. Imagery can often identify prominent soil characteristics, trees, shrubs, and sometimes invasive species.
- Imagery is often most helpful at very fine scales; if you use imagery to evaluate a map product, make sure you look in multiple places across your area of interest for a landscape-scale view.
- When using imagery to evaluate a map, be aware of differences in the time frame of the imagery compared to the maps – e.g., pre- and post-fire.

Aerial imagery can provide a high-resolution view of tree and shrub cover at fine scales. At broader scales, imagery can identify prominent soil characteristics, juniper, and shrubs. Sometimes shadows can be interpreted by the model as vegetation components.

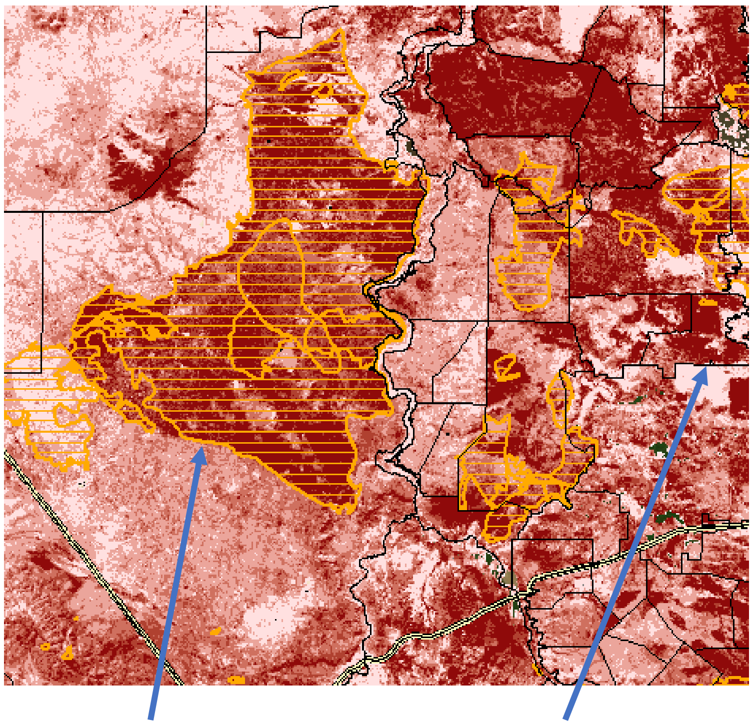




Some areas have soils or geologic features that dominate the image. Maps may perform less consistently in areas with prominent soil characteristics (mineral deposits or lava beds) or rare soil types.

Step 4: Evaluate map products

C. Overlay boundaries - management designations, disturbances, treatments, etc

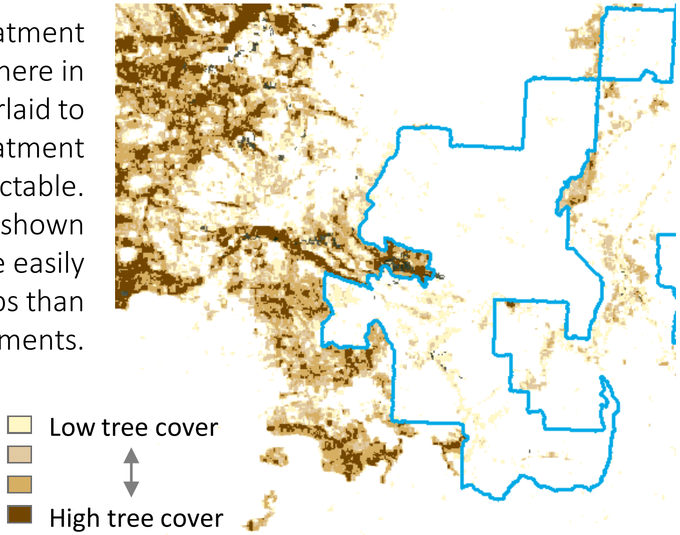


Fire perimeters (orange hash marks) or other disturbance boundaries may identify the cause of some landscape-level patterns

Distinct patterns along fence lines (black lines) or management designations can identify potential historic or current management issues.

- Management, disturbance and/or treatment boundaries provide context to explain patterns in the map and can be used to evaluate the sensitivity of maps in detecting differences in management or changes over time.
- Be aware of the time frame(s) of the map relative to treatments or disturbance.

Known treatment perimeters (shown here in blue) can be overlaid to determine if treatment effects are detectable. Juniper removal as shown here is often more easily visualized in maps than other types of treatments.

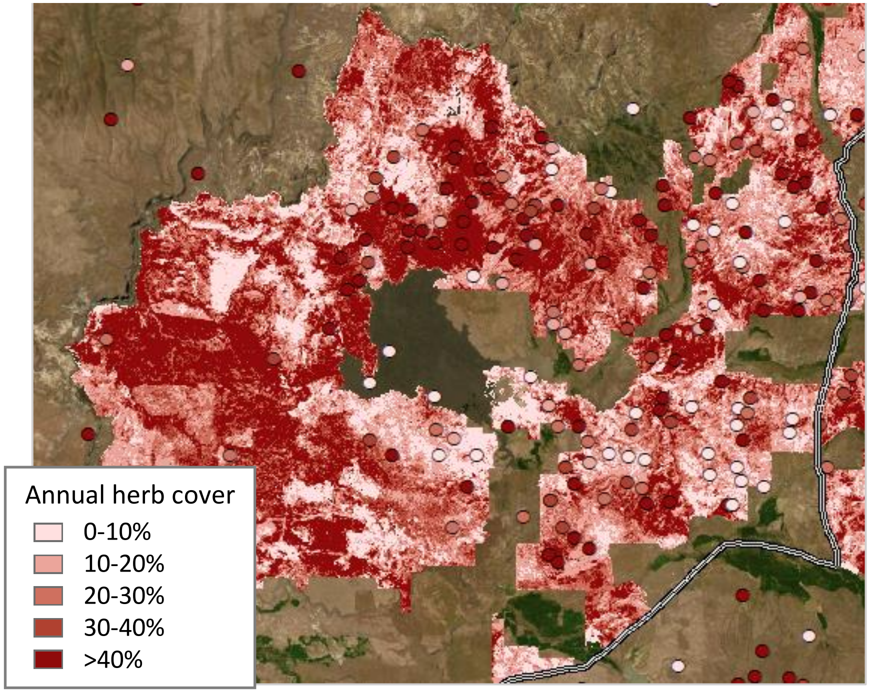


Step 4: Evaluate map products

D. Use plot data

- You may be able to use plot data to evaluate how a map is performing in your area of interest. However, use caution and consider the guidelines on the following slides. These steps are not an accuracy assessment; this guidance is geared toward an informal and non-statistical evaluation by a user.
- Overlay plot data with your map, summarizing the same vegetation indicator consistently. Evaluate patterns in the map and plots at the broadest scale applicable for your management question.
- Plots are often unevenly distributed across an area of interest, as shown in this example. Some plot data (e.g., BLM AIM plots) may have been used to build the map, and therefore the plots are not independent from the map creation. They can still be useful for a general map evaluation but should be interpreted with caution.
- Be aware of sample size – if there are only a few plots available in an area, the conclusions will be very limited. Try evaluating a broader area if the sample size is low.
- Also keep in mind the time frame of the map relative to the plot data. Some vegetation components vary substantially from year to year.

Plots (circles) are overlayed on a map and symbolized consistently. In this example, plot density is high in the east but very sparse in the west. Evaluate the eastern part of the map to choose a product for use where plot density is low.



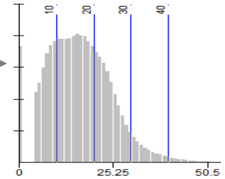
Step 4: Evaluate map products

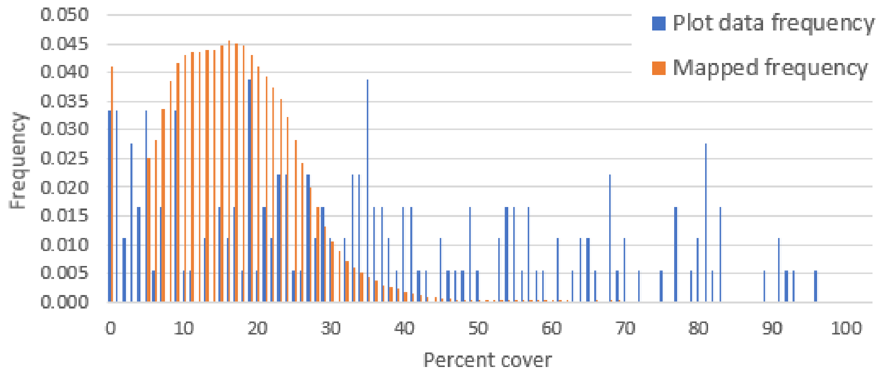
D. Use plot data

- Basic statistics and visualization such as histograms can be used to understand the distribution of cover values and variability across an area. For an area with adequate plot coverage, loosely compare the distribution of values in plots and maps to identify major discrepancies or biases.
  - Mapped and plot-derived distributions are not directly comparable and should not be expected to match, but may identify bias in the map predictions, as shown below.
  - Clip maps to the area of interest, or a larger area if the plot sample is low (e.g., <50 plots).
  - Calculate basic statistics such as mean, median, minimum and maximum across the pixels in the map, and compare to plot data or field knowledge. Evaluate the distribution of mapped values relative to plot values using a histogram if your sample size is adequate, as in the example below. Histograms do not need to be stacked on the same graph; side by side comparison is adequate.
  - Most maps under-predict the highest and lowest values, as in the example. It is important to adjust for major biases if you are summarizing maps into cover classes *(slide 22).*

Histograms of plot and map cover frequencies are not directly comparable but can help identify severe bias, such as this case where mapped cover rarely exceeds 40% but more than one-third of the measured plot values exceed 40% cover.

Basic histograms can be easily viewed in ArcMap when symbolizing raster data based on classified values.



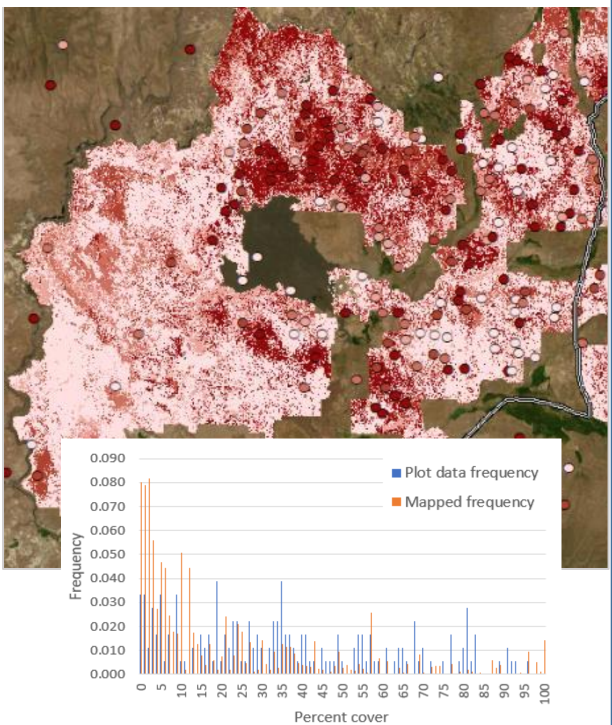


Step 4: Evaluate map products

D. Use plot data

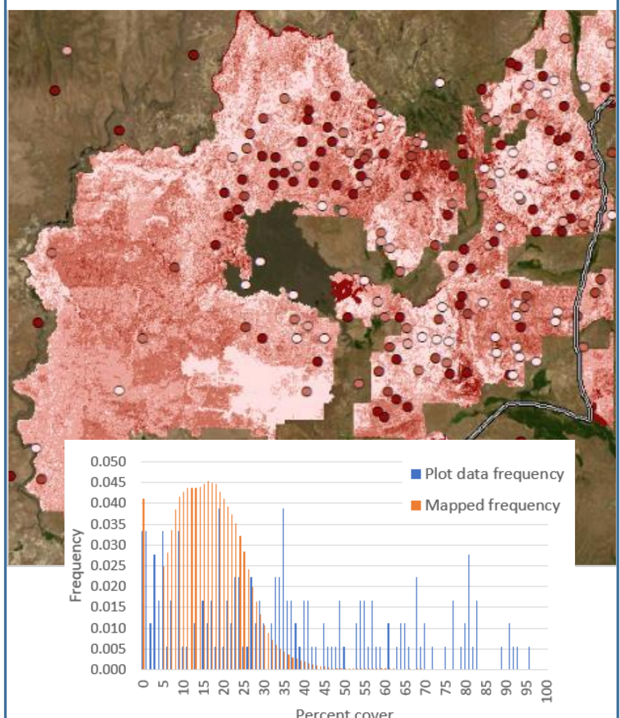
Three different maps of annual herbaceous cover from different sources are shown below, with plot data overlaid and symbolized consistently (cover classes follow slide 16). The distribution of mapped values compared to plot data is shown in a histogram below each map.

This map has low bias (full range of low and high values), but spatial patterns are scattered (high pixelization), indicating lower spatial precision and limitations for uses at fine spatial scales.



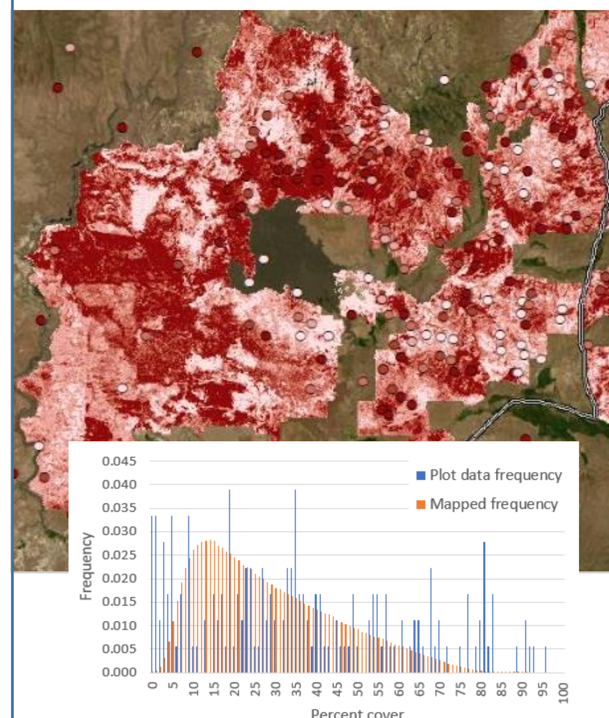
This map contains the full range of values roughly proportional to the plot data, but slightly over-predicts low values.

This map does not capture high cover values (dark red) shown in the plot data, showing substantial bias. Spatial patterns are similar to the map on the right, but less pronounced.



This map predicts most values between 5-30% cover. Binning this map into classes could vastly underestimate the high cover class.

This map has a range of predicted values that approximates the plot data (moderate bias). It appears to have high spatial precision to detect patterns along boundaries like fence lines.



This map somewhat under-predicts very low and very high values but captures most of the range of variation.

Step 4: Evaluate map products

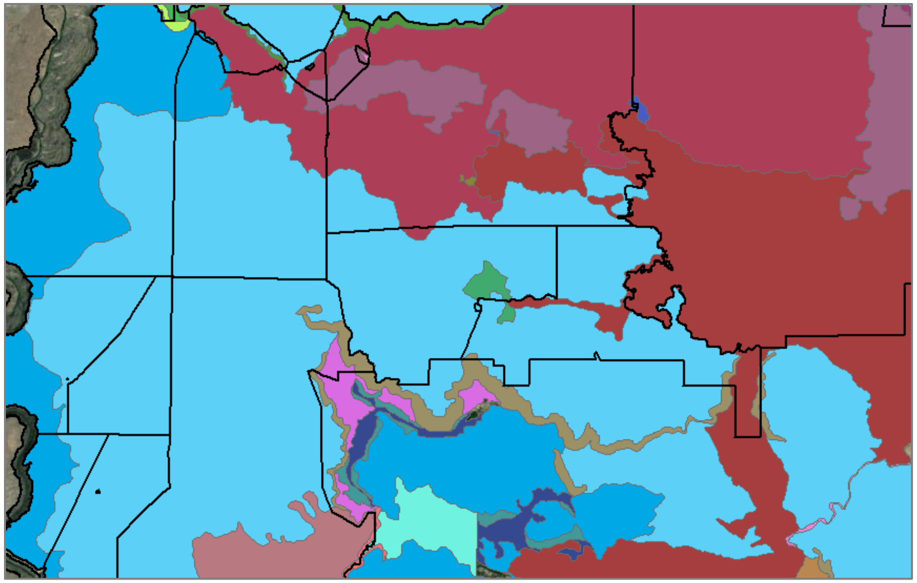
Choosing a product: putting it all together

- The steps on the previous slides may identify a clear product that is most applicable to your geographic area, question, and scale. Multiple map products may also be used together, as in the annual herbaceous cover map for the Great Basin, derived from three different map sources.
- Maps can provide valuable information across large landscapes but may make decision-making more complex, particularly if there are discrepancies between multiple maps, conflicts between maps and other data sources (e.g., plot data), or when maps do not match expert opinion. If discrepancies or contradictions arise, think through the following questions:
  - What other information do I have in this area? Do I have plot data I can compare to the maps? How many plots relative to the size of the area? Is plot data representative of the whole area or are sites biased (e.g., placed in more productive areas)?
  - How reliable is my existing information? What proportion of the area have I seen in person? How spatially or temporally representative are the data? Does the spatial scale of my question match the available information?
  - Has anything significantly changed that would affect the reliability of some data sources? (e.g., has some of the data been collected pre- or post-disturbance?)
  - If there are discrepancies or contradictions between data sources, how large is the contradiction? Is it a matter of degrees or is it vastly different? Would I come to a different conclusion if I used a different source of data?
  - What do others think? Do others have more information or data to contribute? Can I get a group together for a discussion?

Step 5: Summarize maps

Delineate analysis areas or summarization units

- Maps can be used to depict spatial patterns across the landscape. However, spatial patterns can also be complex and overwhelming, and map summaries for an area of interest can provide a useful snapshot of vegetation condition.
- Stratify the landscape into **analysis areas** for map summaries based on meaningful boundaries such as:
  - Management units – Ownerships, allotments, pastures, planning units
  - Biophysical units – Soil types, potential vegetation types, disturbance response groups
  - Disturbance or treatment units – Wildfire perimeters, treatment boundaries, project areas
  - Combinations of the above
- Maps can be summarized across these analysis areas in multiple ways, including average values, cover classes, synthesis maps, and trend analysis (*slides 21-24*).

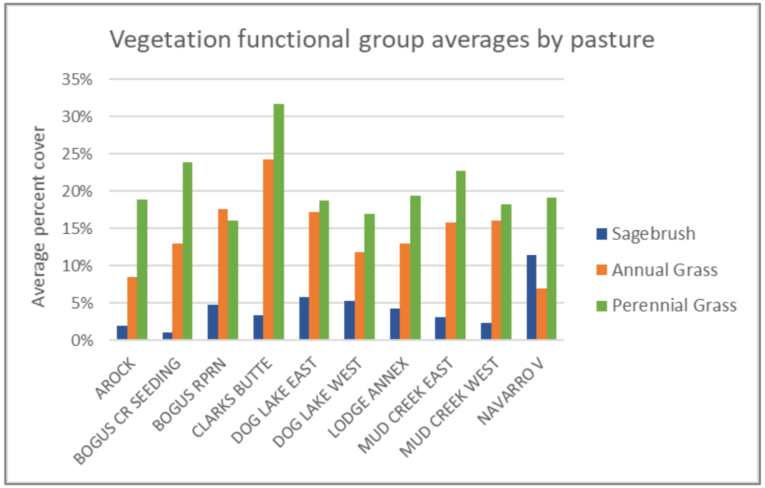


Here pasture boundaries (black) are overlaid over grouped ecological sites (unique colors). Vegetation maps could be summarized for each of these combinations of pasture and ecological site units, to make summaries relevant in the context of both management units and ecological site potential.

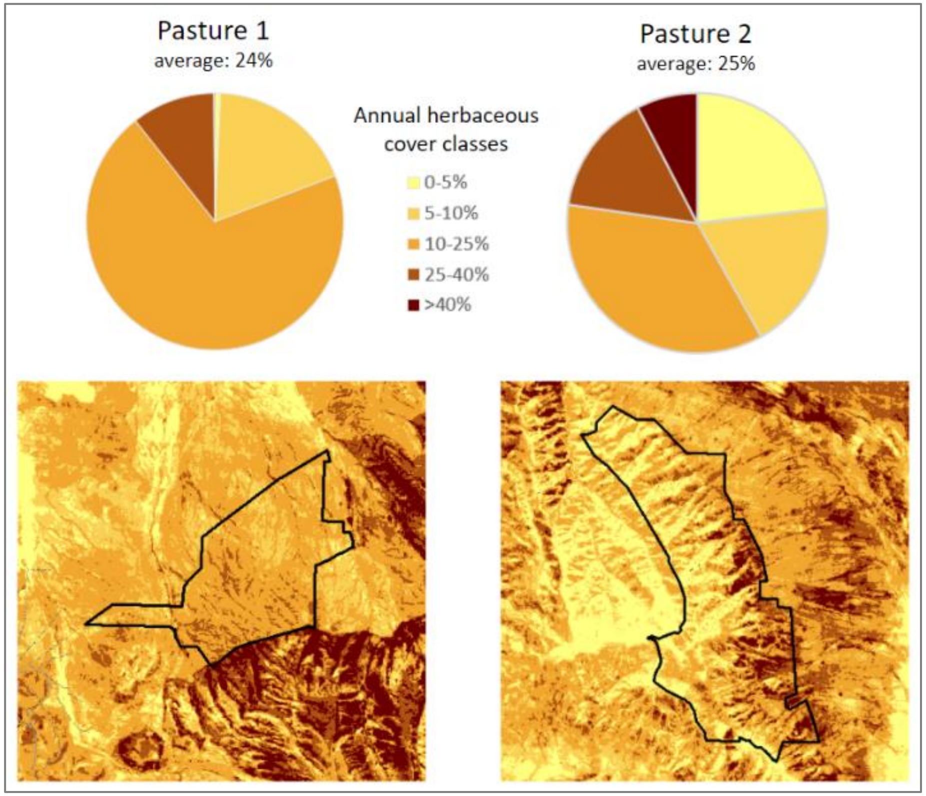
Step 5: Summarize maps

A. Summarize average values

Averaging vegetation cover across an area gives a broad snapshot of the **overall condition** and provides a single number for simple comparison. However, averages remove variation that may be meaningful.



Average values can be easily calculated and compared across units such as pastures or treatment areas, as in the example to the left.



In the example to the right, two pastures have a nearly identical average cover value, but the spatial patterns and distribution of cover classes are vastly different. An average value may be useful in pasture 1, but an average across pasture 2 provides very little information due to the high variability within the pasture. The distribution of cover classes shown in a table or chart can provide much more meaningful information in these situations (see next page).

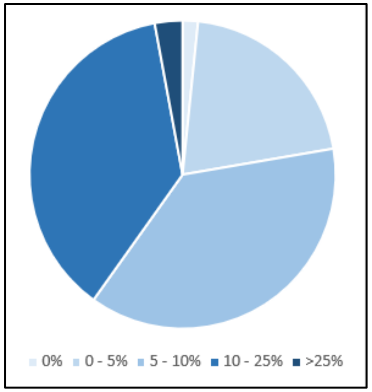
Step 5: Summarize maps

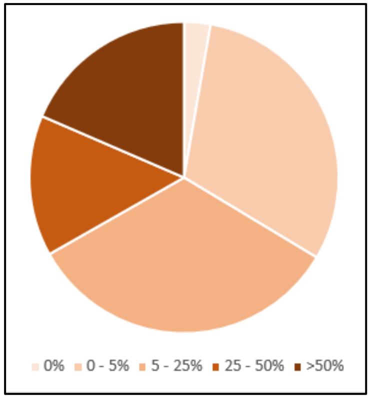
B. Summarize cover classes

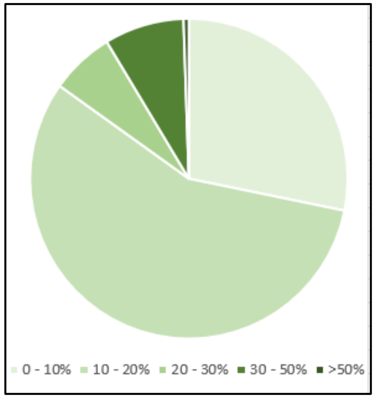
Cover classes provide information about the **prevalence of condition classes** across the landscape.

- Classes can be defined by the user using pre-defined thresholds (e.g., thresholds set in a planning document) or based on the distribution of values (e.g., quantiles). The Tabulate Area tool in ArcMap will generate summaries for rasters that have been classified into cover classes.
- Some products contain biased predictions (*see slides 17-18*) and high and/or low cover classes may be under-represented. In these cases, you may need to adjust your analysis accordingly. For instance, you may also adjust your condition classes – e.g., instead of using set cover thresholds (e.g., 5%, 10%, 15%), use quantiles based on the distribution of values (low, moderate high).

	Sagebrush Cover Classes					Invasive Annual Grass Cover Classes					Perennial Grass Cover Classes				
	0%	0 - 5%	5 - 10%	10 - 25%	>25%	0%	0 - 5%	5 - 25%	25 - 50%	>50%	0 - 10%	10 - 20%	20 - 30%	30 - 50%	>50%
Acres	50	634	**1152**	**1140**	90	85	**944**	**1018**	448	568	**864**	**1736**	199	249	16
Percent	2%	21%	**38%**	**37%**	3%	3%	**31%**	**33%**	15%	19%	**28%**	**57%**	6%	8%	1%







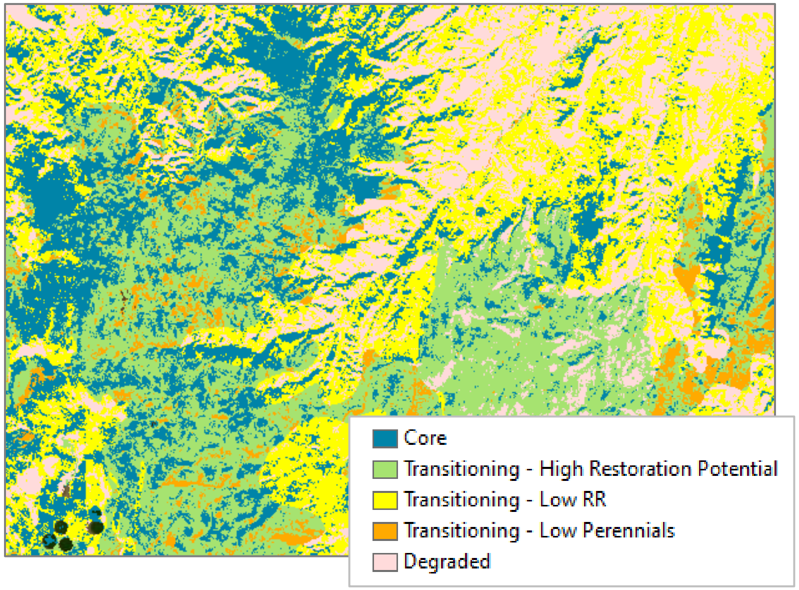
The tables and pie charts show a snapshot of condition across multiple functional groups for a pasture, distilling complex spatial patterns into simplified information. In this case, more than three-quarters of the pasture contains low to moderate (5-25%) sagebrush cover. Invasive annual grasses are present in most of the pasture and roughly one-fifth of the pasture contains heavy infestation. Perennial grasses are sparse, with three-quarters of the pasture containing less than 20% perennial cover.

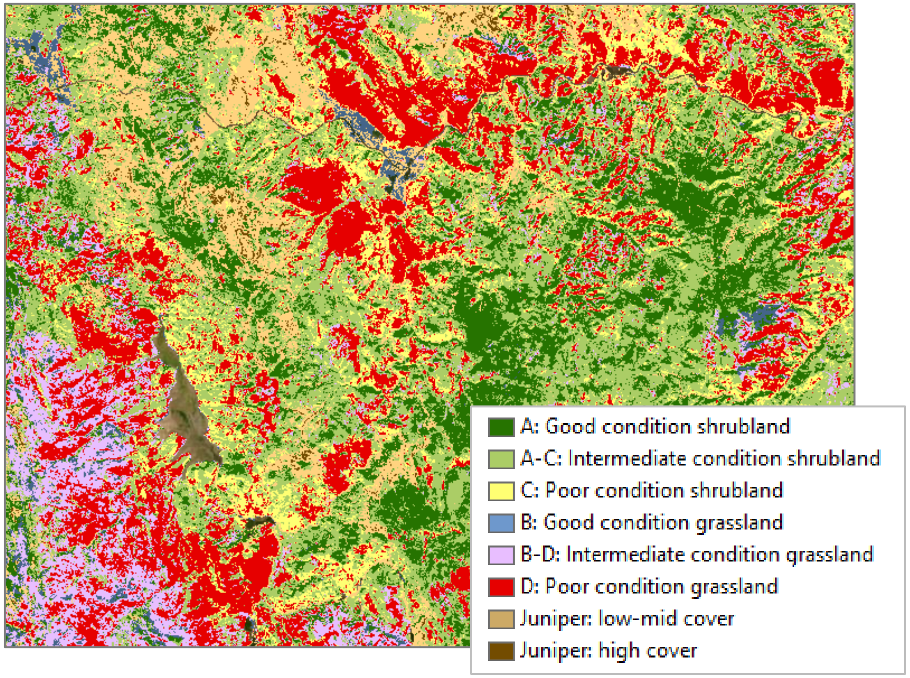
Step 5: Summarize maps

C. Summarize synthesis maps

Multiple maps can be combined into categories tailored to a management application, such as a **synthesis of condition** or **management-relevant categories**.

The SageCon Invasives Initiative geographic strategy map combines annual and perennial herbaceous cover with site potential (resistance & resilience) to provide **landscape context** and **facilitate cross-boundary coordination** for managing invasive annual grasses in Oregon.





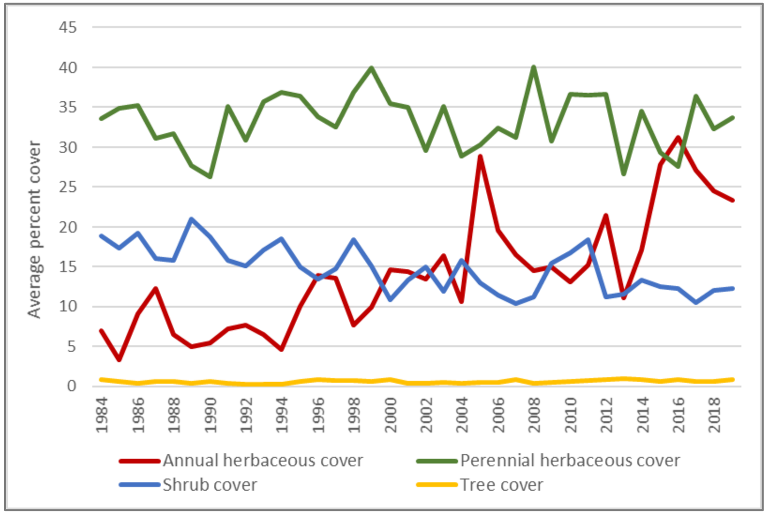
Threat-based ecostate maps combine four functional groups to give a simplified **snapshot of vegetation condition**, focusing on the **extent and distribution of threats** from wildfire, annual grass invasion, and juniper encroachment.

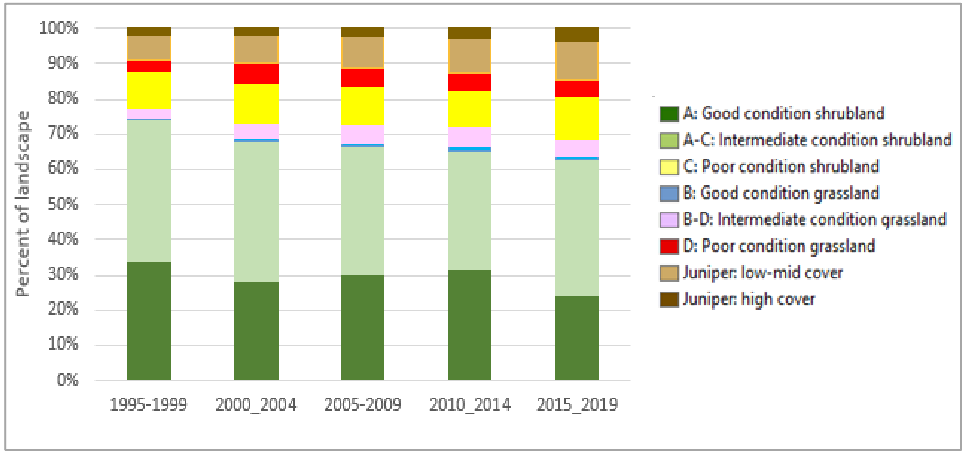
Step 5: Summarize maps

D. Summarize trend over time

Many newer vegetation maps provide yearly estimates of rangeland vegetation cover through time, allowing users to **evaluate change over time** across large landscapes.

Average cover across an area of interest (below) can be displayed over time to detect broad trends. However, averages may miss meaningful changes in vegetation over the area, particularly for changes that occur in limited areas (e.g., tree encroachment or invasion in ecological sites that cover part of the area). Some web applications provide users with a time series graph for an area of interest without the need for desktop GIS analysis.





The SageCon Ecostate Time Series map (summarized above) shows change over time in the proportion of condition classes depicting the level of impact from wildfire, annual grass invasion and juniper encroachment. These maps were **simplified for interpretation by broad audiences** in multiple ways: 1) multiple functional groups were combined into relatively few condition classes focusing on on primary threats, and 2) maps were averaged across 5-year time slices to reduce interannual variability and portray long-term trend.

Step 6: Return to decision-making framework

The steps identified above may help users make intentional choices about when to use a vegetation map, how to select a map for an area of interest, and how to summarize a map for your purpose. Maps should be used at the discretion of the manager or practitioner to suit their specific needs and location, and there is often not a clear "correct" way to choose or use products. After completing these steps, return to your decision-making framework to ensure that maps are providing meaningful information to support your management decision.

Contact map developers with questions; dialogue and feedback between map producers and users is essential for data delivery and effective use of vegetation maps in rangeland management. Please contact Megan Creutzburg with any feedback or questions about this guidance at megan.creutzburg@oregonstate.edu.

A shorter summary of some **best practices** for using maps can be found in this guidance document.