CHAPTER IV

Indicators for Maintenance of Productive Capacity on Rangelands

INTRODUCTION

Productive capacity is a trait of ecological systems that science has identified, and the general public accepted, as an important rangeland sustainability indicator. As such, standardized assessment and monitoring protocols for productive capacity need development. This chapter outlines current thoughts toward developing standardized indicators for monitoring rangeland ecosystem productivity, based on today's information and today's research. As research and knowledge continue to evolve, the indicators will reflect new input and information.

Productive capacity can have different meanings, such as the maximum possible on a site or the production possible given current conditions. Long-term sustainability requires that the uses of the land, regardless of what they are, do not change the resource or resource base to the point that the land is no longer capable of producing plant communities that once were possible on the site. One may argue that short-term sustainability requires that the current uses of the land are (1) maintained if they are capable of maintaining the resource productivity without degradation over the long timeframe (decades to centuries) and suit the social, cultural, and economic management goals or (2) changed if they are not. There is further argument that understanding whether or not maintenance of current conditions is sustainable. Part of the solution to this argument would be to establish the monitoring system to determine if current conditions are sustainable. This chapter lays out the response that there is a significant lack of data to provide decision makers with adequate information to respond positively or negatively to that question of sustainability. The indicators as currently framed measure "what is." It is expected that over time, the data will show what is sustainable, given current conditions. Decision makers must then determine the policies and criteria for keeping the sustainable conditions, if they do exist, or altering current management to shift toward sustainable conditions. It is not the intent to develop data that will determine the "value" of current conditions, but rather, to develop data that may be provided to policy makers, both public and private, that enable decisions about what change, if any, in management strategies must occur.

These indicators reflect expert opinions from rangeland scientists, private consultants and affiliated Federal agency rangeland management personnel, non-governmental organization representatives, practitioners, and other stakeholders. Concepts and ideas have evolved from SRR meetings, as well as from a Delphi process between meetings. This is an assessment of all U.S. rangelands, both public and private.

Sustainability is broadly defined as providing goods and services for the current generation without compromising options for future generations to meet their own needs. Rangelands have capacity to provide highly diverse goods and services, depending, at any particular time, on cultural, economic and societal values. We currently define productive capacity as plant and animal biomass yield in response to climate, soils, plant composition and current uses. It is the combination of annual primary and secondary productivity that defines rangeland's sustainability, a process ultimately tied to photosynthesis. Other measures of productive capacity are manifested in indicators contained in other criteria; e.g. capacity to provide water, open space, etc. Droughts, tied to periodic El Nino phenomena, represent changes in production that can be tracked over the long term (Diaz & Markgraf, 1992). Drought will be considered in each of the indicators presented below.

Maintaining rangeland productive capacity implies that future generations, also, will obtain a mix of desired market and non-market goods and services. Thus, estimates of this criterion must consider temporal and spatial scale across a wide variety of goods and services. It is important to understand that productive capacity includes more than forage and livestock. It also includes non-consumptive goods and services; for example, wildlife habitat, landscape values, medicinal plants, and wood products.

Some components of productive capacity are mutually exclusive (competitive) while others are compatible (co-existing). This, however, is a fundamental principle of ecology. Seldom are different uses mutually exchangeable. For example, tradeoffs exist between the amount of forage available for use by livestock and wildlife in critical areas such as elk winter range, and tradeoffs between forage grazed versus forage harvested through haying. Identifying and monitoring key goods and services over long timeframes requires multi-scale measurement capabilities at the ecological site, as well as the national level. Data must be compatible over these long time series. This latter issue has been defined, but the set of solutions have not. As the indicators reflect, some data do not exist or exist in such disparate form that they provide little information about trends or changes. These indicators will require long time-series data to provide the necessary information policy makers require for future decision processes.

In order to understand productive capacity indicators at the national scale, one must describe their dynamics at a regional level. As is described in Chapter I, the mechanism of a system's function is manifested at the next finer scale of measurement. Consequently, data supporting the following indicators must be adequate to monitor and explain how they change regionally. We have selected the Bailey Ecoregion classification system to portray regional variations in productive capacity (Bailey 1998).

INDICATORS

We have identified, developed and adopted six indicators (Table 1). The indicators represent key aspects of rangeland productive capacity and vary from ecoregion to detailed management unit assessments that provide primary production for various demands.

Table 4-1. The six productive capacity indicators.

Indicators	What the indicator describes
Rangeland aboveground biomass	A direct measure of total standing (aboveground) biomass.
Rangeland annual productivity	A direct measure of rangeland annual primary production.
Percent of available rangeland grazed by livestock	Provides information on use patterns, of rangeland that could be grazed by livestock, that may shift production from one commodity to another.
Number of domestic livestock on range	A direct, secondary production, measure of rangeland.
Presence and density of wildlife functional groups on rangeland	The presence & density of wildlife functional groups give an additional direct secondary production measure.
Annual removal of native hay and non-forage plant materials, landscaping materials, edible and medicinal plants, wood products	The removal of native hay and non-forage products are additional measures of rangeland productive capacity, as well as, sustainability and biodiversity.

Aboveground Biomass

This is a direct measure of biomass production available to potential grazers and users of rangelands. It is a state variable measured in terms of mass/unit area. This is not to be confused with the next indicator, “productivity” which describes rates of biomass productivity.

Importance: What does the indicator measure and why is it important to sustainability?
The measurement of aboveground biomass provides the best estimate for net (above and below ground) primary productivity (NPP). In some systems (for example, temperate grasslands) aboveground biomass is considered equivalent to NPP (Sala 2001). In others, the estimate provides the foundation for an evolution towards true measures of NPP. Most of the data available (see Appendix 4-1) have been collected in terms of annual production estimates of herbaceous and shrub vegetation. These data are considered traditional, and are defined within the context of rangelands uses (for example, grazing, game management, etc.). These data provide a valuable tie to past management actions, giving trends in biomass production through space and time.

Geographic Variation: Is the indicator meaningful in different regions?
Rangeland vegetation types are highly variable in annual biomass production because of variation in precipitation, temperature, soil fertility, soil texture and depth, and other soil and climatic factors.

Data
Data collecting, analyzing, and reporting occurs at local, regional, and national scales. Data collection methods are not standardized among or within scales. In addition, organizations can have intrinsic problems with data at a given scale (for example, an organization may have protocols that are not followed or interpreted the same way).

Aboveground biomass data are collected both directly and indirectly. Direct methods require destructive sampling of aboveground biomass through clipping and weighing plant material. Indirect methods involve weight-estimate procedures, where mass per unit area is estimated visually or in some other manner. Double sampling techniques utilize both approaches in combination with regression techniques for developing correction factors.

Clarity: Do stakeholders understand the indicator and indicator unit?
This indicator can be understood by stakeholders and is critically important for understanding rangeland sustainability and maintenance of productive capacity on rangelands.

Rangeland Annual Productivity

Rangeland Annual Productivity is measured as net primary productivity (or NPP) and is the rate (on an annual basis) at which energy is converted to biomass (all plant life-forms) within an ecosystem. It is a flow or ecosystem process measured in terms of mass/unit area/time. NPP includes both above- and belowground biomass (i.e. plant shoots and roots). However, the reality is that, other than for a few local studies, very few data exist on belowground productivity, even though the proportion and turnover of belowground biomass varies among ecosystems (Pérez and Frangi 2000, Roy et al. 2001). Annual aboveground net primary productivity (ANPP) is the ecosystem measure of the rate at which aboveground biomass produced annually, and include litter fall. Although ANPP and aboveground biomass (Indicator 1) are two separate measures, represented by two different units, they are often used interchangeably to describe rangeland production (Sala 2001, Rambal 2001).

Importance

Primary productivity is the foundation for measuring the productive capacity of terrestrial ecosystems, and is key to understanding ecosystem sustainability. Sunlight is the engine that drives all productivity through the process of converting light energy and CO_2 to energy in the form of sugars. These plant carbon compounds provide the food base for all secondary production in ecosystems and fuel the many, complex food webs over the earth. Thus, changes in terrestrial primary productivity affect the kind, amount, and distribution of life on the planet (Roy et al. 2001).

Our focus is on rangeland ecosystems. All life in rangeland ecosystems is sustained through primary productivity, i.e. the rate at which new plant biomass is produced. This plant material is then available for consumption by herbivores, and feeds the entire food web as described above. Increasing or decreasing values of productivity are therefore an indication of what is happening on rangeland systems, where Joyce et al. (1994) estimated that U.S. rangelands feed approximately 7 million cattle, 8 million sheep, 45,000 wild horses and burros, 20 million deer, 400,000 elk, 600,000 pronghorn, and smaller numbers of goats, bison, wild sheep, and moose, plus unknown numbers of rodents, rabbits, insects, and other creatures.

Monitoring sustainability requires long term data sets that may provide information about the stability or degradation of the land base. Terrestrial ecologists generally define physical rangeland degradation in terms of parameters related to vegetation and soil. Land degradation includes (Behnke and Scoones 1993, NRC 1994):

- A change in plant species or life-form composition that is contrary to management goals related to sustainability of rangeland health;
- A decrease in plant productivity, cover, density, or some other plant parameter or measurement of attributes that adversely affect rangeland health;
- A reduction in soil quality; for example, nutrient loss;
- Accelerated soil erosion; and
- Changes in landscapes that adversely affect ecosystem function at the landscape/watershed level.

Geographic Variation

Rangeland net primary productivity has high spatial variability. This variability occurs for a variety of reasons in which one variable can seemingly “drive” the system or a combination of variables collectively control the environment. Below are some sample explanations.

The principal change drivers that affect primary productivity on rangelands include: land use change (including changes that affect soil), climate change (precipitation and temperature), change in composition of the atmosphere (CO_2), and changes in biodiversity. In most cases NPP declines with changes in land use (Burke et al. 1991, Alcamo 1994). In some cases NPP may be increased with land use changes that include high energy inputs such as irrigation and fertilizer. Similarly, as precipitation decreases and temperature increases, NPP generally declines (Sala 2001). This may or may not be the case with global warming, since climate change models indicate that changes may include increasing precipitation as well as declining precipitation, in different global regions (Evans, personal communication). With increasing CO_2 in the atmosphere, NPP often increases (Field et al. 1995, Owensby et al. 1999). In some regions like the tallgrass prairie, researchers have found a positive correlation between biodiversity and NPP (Mooney et al. 1995, Tilman et al. 1996). Sufficient monitoring does not exist to determine if this will be true across all rangelands.

In U.S. Mediterranean shrublands and woodlands (California), timing and amount of precipitation and soil nutrients are the major environmental variables controlling plant productivity (Rambal 2001). A drying climate is a primary global climate change driver in the Mediterranean system, which, when coupled with fire and intermittent heavy rain events, fosters flushes of annual grass biomass – thus fueling more fire.

The main controls on primary productivity in desert ecosystems are precipitation and soil fertility (Ehleringer 2001) and to some extent soil texture. The ability of desert plants to convert precipitation to NPP varies by season, growth form (shrub/herb), and ability to utilize deep soil moisture (mainly shrubs) versus shallow soil moisture. Crytobiotic crusts play a critical role in maintaining productivity in desert ecosystems through the regulation of input and loss of nitrogen (Dregne 1983), by limiting soil erosion, and by affecting soil water infiltration.

Scale: Is the indicator meaningful at different spatial and temporal scales?

Rangeland productivity is highly variable spatially and temporally. The indicators are meaningful when sample sizes are large enough to provide the necessary statistical power to detect change. Further interpretation can be enhanced through an understanding of climate and land use changes.

Data

Although NPP and annual aboveground biomass production are two different concepts, the most common way to estimate NPP is to equate peak aboveground biomass with annual productivity (Sala and Austin 2000). Data are available for all rangelands although quality and quantity vary. In addition, belowground biomass is rarely estimated thus few data are available for estimating true NPP.

NPP is measured in three ways. The first method is by the direct, destructive sampling of above and belowground biomass. For example, in temperate grasslands, the annual turnover of biomass approximates 1. Therefore the most common way to estimate NPP in grasslands is by estimating aboveground biomass only, often by directly clipping and weighing the biomass, or using weight estimate procedures (Bonham 1989). It should be noted that several methods are available for directly measuring or estimating productivity. The most effective methods to meet long term monitoring goals have yet to be agreed upon. The second approach involves a network of sensors to measure the CO_2 flux at the atmosphere/vegetation interface. This is a micrometeorological approach using eddy correlation and has not yet seen widespread application (Angell et al. 2001). The third method is modeling. Two modeling approaches have been developed to estimate NPP: remote sensing-based and physiological-based models. Remote sensing-based models interpret the light spectrum reflected by the land surface, converting known relationships developed from direct measurements, while physiological-based models simulate NPP from environmental variables. Some (Rambal 2001) suggest that remote sensing measurements of NDVI (normalized difference vegetation index) should be used to determine ANPP in Mediterranean shrublands and woodlands as well as deserts. In general, the use of remote sensing-based models is becoming more widespread. As indicated at the start of this section, critical review and comparison of various data methods are essential. This is critical for correlating remotely sensed data with ground validation. Extensive analysis is needed for the most effective available measurements to meet monitoring needs.

Clarity

This indicator can be understood by stakeholders and is critically important for understanding rangeland sustainability and maintenance of productive capacity on rangelands.

Percent of Available Rangeland Grazed by Livestock

The percent of available rangeland grazed by livestock is a measure of the proportion of total rangeland that is grazed annually by domestic livestock. As such, this indicator does not reflect a biological capacity. Rather, it is an administrative and economic capacity, limited by laws, regulations, planning documents and market forces.

Importance

This indicator provides information on rangeland use patterns, tracking shifts in commodity demand, including wildlife and other non-livestock uses, as social and economic values change over time. The indicator may be used separately or with other indicators reporting livestock numbers to quantify primary production consumed by livestock. It describes the net land area used to produce livestock forage in proportion to total rangeland, by ecoregion (Bailey, 1998) and for the nation as a whole.

Geographic Variation

This indicator provides consistent information across geographic regions.

Scale

This indicator is meaningful at different scales and provides a measure that is aggregated from public and private land management records to the ecoregion (Bailey 1998).

Data

Conceptually feasible or initially promising, but techniques to quickly quantify all possible grazer species and the proportion of the ANPP consumed by any individual species do not currently exist. Conceptually, remote sensing techniques hold promise to produce data valid at temporal and spatial scales for practical decision applications by the landowner / manager. This indicator requires two kinds of data not readily available: (1) area of rangeland by ecoregion (Bailey, 1998) and (2) available rangelands actually grazed. The area actually grazed is a sensitive issue with many landowners/ managers and will require proprietary protections for data to be collected.

Clarity

The indicator is understandable. However, it requires a clear definition of the term “available rangeland.”

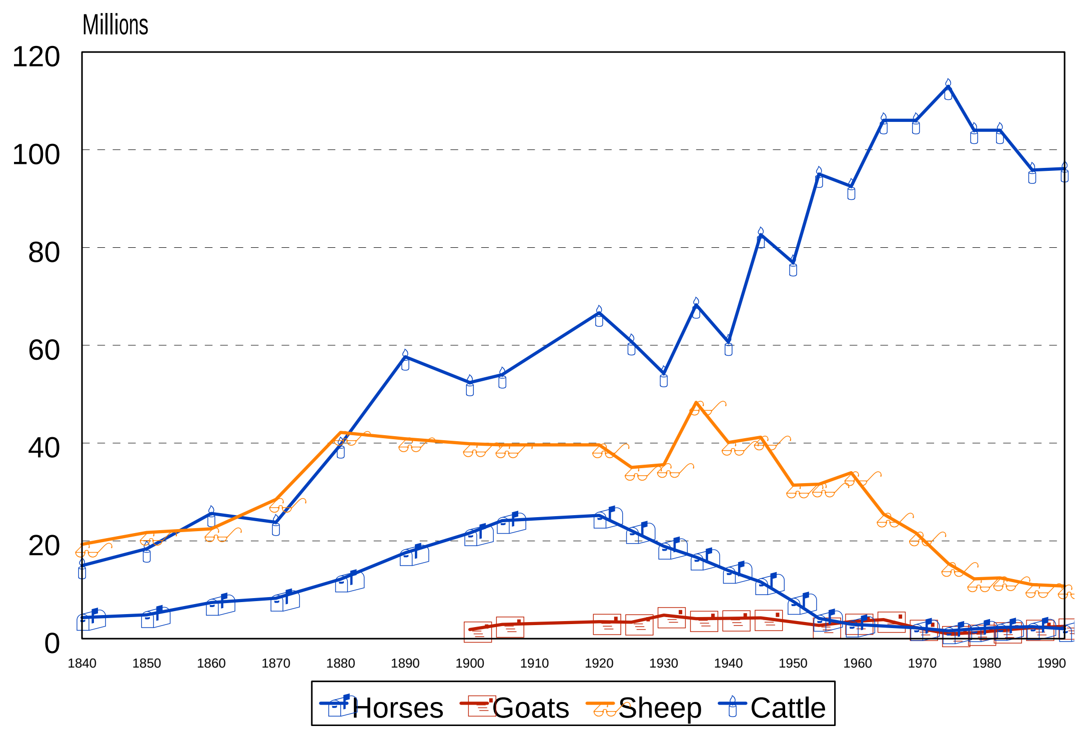
Number of Livestock on Rangeland

The number of livestock on rangeland is the quantity of livestock that spend part of the year on rangeland. It is a gauge of secondary productive capacity by a major category of primary consumer. Livestock do not spend their entire life on rangeland, so an inventory at any one time will underestimate their extent of rangeland use.

This indicator, linked with other indicators, represents rangeland domestic livestock use. It accounts for short-term management strategies, as well as long-term strategies. Furthermore, this indicator focuses upon the numbers of cattle and sheep that spend at least part of the year upon rangeland. Animal Units (AU) and numbers of livestock will be used to represent this indicator, if adequate data are available. The Animal Unit Month (AUM) measure, which adds a time dimension) will enable the Social and Economic Criterion Group to provide economic valuation of rangeland products. It also integrates the amount of rangeland use by cattle and sheep that spend part of the year on feed or grazing cropland.

Importance

Domestic livestock found upon rangelands include cattle, sheep, goats, horses, burros, and mules, along with a number of minor grazing animals like llamas and alpacas. The long-term trends in numbers of cattle, sheep, goats, and horses in the United States are shown below (Mitchell 2000):



U.S. cattle (all cattle and calves) numbers rose steadily since records were kept in the mid-19th Century until 1975, when they peaked at 132 million head. Over the next decade the number of cattle declined to about 100 million head, where it has maintained a somewhat dynamic equilibrium. U.S. cattle numbers have undergone cycles lasting roughly 10 years since the 1880s. The latest national cycle topped in 1996 at 103.5 million head.

The number of sheep has slowly declined from nearly 50 million head to less than 8 million head over the past half-century (Mitchell 2000). Monitoring U.S. sheep numbers on rangeland is certainly feasible, and it may be more important to society from a sustainability context than mere numbers imply; i.e., as an acceptable management tool for prescription grazing of invasive weeds.

Equine are now primarily used for various forms of recreation. Their numbers appear to be insensitive to agricultural and other land use economic forces, resulting in a fairly constant national herd size over the last 50 years.

Livestock numbers (as well as changes) annually grazing rangeland is an appropriate indicator of the extent that natural vegetation supplies a portion of the Nation's requirement for grazed forage. Cattle cycles, to some extent, are based upon the relationship between livestock markets (price of cattle), trade policies, and forage availability. Droughts, land use changes, and reservation of public lands for biodiversity, wilderness and watershed stabilization constitute mechanisms that reduce our Nation's forage supply, and thus livestock numbers. Above-normal precipitation, investments in rangeland improvement practices (restoration/rehabilitation), public policies that promote grazing, and others can increase the supply of forage.

The Heinz Center report (The H. John Heinz III Center 2002) included cattle numbers on "grassland and shrubland" as one of 17 ecological indictors that characterize U.S. rangelands. This report recognizes that cattle production is one of the most important economic uses of rangelands, and remains a vital element of the economic and social fabric of many parts of the United States, particularly west of the 100th Meridian.

Geographic Variation

The number of livestock grazing upon rangelands is equally meaningful in all geographic regions.

Scale

Cattle and sheep numbers are meaningful at all scales. They can be aggregated across scales.

Data

The number of cattle may be determined at a scale necessary for regional and national assessments. We recommend that appropriate questions be incorporated into surveys used by USDA National Agricultural Statistics Service for developing these estimates. Presently, a direct estimate of the number of cattle (or sheep) that spend a part of the year on rangelands is not determined. Indirect estimates (total number of cattle less cattle on feed) require unacceptable assumptions concerning inadequate and incompatible data sets. Data on cattle numbers can be reviewed at http://www.nass.usda.gov:81/ipedb/cattle.htm

This indicator will be most useful with both cattle and sheep numbers on rangeland. It will be necessary to work closely with USDA National Agricultural Statistics Service to acquire the requisite data for both.

Clarity

Cattle and sheep numbers are clearly understood by nearly all people. Expressing these two classes of livestock in terms of Animal units, particularly when describing the joint significance of cattle and sheep, will require some explanation.

Presence and Density of Wildlife Species

This indicator measures both presence and density of representative species within functional groups of wildlife and within ecoregions (Bailey 1998). Examples of functional groups for purposes of measuring this indicator are: large herbivores, small herbivores, large predators, small predators, avian foragers, avian predators, burrowing reptiles, surface reptiles, insect grazers, amphibians, fish, and pollinators.

Importance

Rangeland ecosystems provide all or a critical portion of many wildlife species annual habitat requirements. Habitat components include: food, shelter, water and space. These components provide the critical factors to sustain population dynamics and species diversity. It is demonstrated for some wildlife species that their density is affected by changes in rangeland habitat components (changes in the state of the ecological site and/or landscape), and/or changes in land uses (Winter and Faaborg 1999).

The State of the Nation's Ecosystems (The H. John Heinz III Center 2002) utilizes a similar indicator called At-Risk Native Grassland and Shrubland Species. This indicator uses a combination of factors including numbers and conditions of individuals and populations, area occupied by species, population trends and known threats in an attempt to determine the status of a given wildlife species. The report suggests that, when population trend data become widely available, the indicator be revised. The revision should consider incorporating trend or substituting trend for status.[1] Our indicator does just that; i.e., it quantifies wildlife species trends that can be compared over time. Therefore, rangeland wildlife presence and density, combined with other indicators, is a crucial contributor to the assessment of productive capacity.

Geographic Variation

Some indicator wildlife species transcend ecoregion boundaries, while the home range of other species do not; for example, barren ground caribou and ptarmigan only occur in the grass and brush tundra[2] (Bailey, 1998). It may be beneficial to include both kinds of wildlife species to represent dynamics of this indicator. These representative species can be identified through a cooperative selection process involving the various governmental agencies, in particular state wildlife management agencies, and groups that collect wildlife population data within each ecoregion.

Scale

The indicator is meaningful at different spatial and temporal scales. However, as described above, representative species must be selected at the ecoregion level to be useful at the national level. This does not preclude data collected at local levels from being aggregated upward as long as there is consistent data collection protocol for the representative species that

[1] pgs 168 and 214.
[2] pgs 54, 55.

recognizes the effect of vegetation in sampling population size and extent. It is recognized that all species will never be adequately monitored at a national level.

Temporal scale trends are important when combined with other indicators to evaluate rangeland sustainability. This indicator should show both short-term and long-term trends in presence and density, particularly since many wildlife species densities can be influenced by normal climatic changes and fluctuate up and down, in some cases, year to year; therefore, longer-term trends will typically be representative of productive capacity changes. The evaluation of these changes becomes the role of the policy makers.

Data

Wildlife species numbers (spatially and temporally) could provide both species presence and species density at various scales. However, most wildlife species data are collected by state wildlife agencies and collection methodologies are not always consistent. Little coordination exists across jurisdictions to define survey areas that contain distinct year-round populations, nor are the same species being surveyed consistently across political boundaries such as state lines. There are a variety of survey techniques employed by different agencies; therefore, population estimates are again not consistent across state lines. The U.S. Fish and Wildlife Service, because of national responsibilities, may provide some regional data consistency for certain species. Their data and data collection protocols warrant further investigation. NGOs with scientific ties to particular wildlife species may also provide data for this indicator.

Clarity

The stakeholders and, for the most part, the general public, with little explanation, usually understand the indicator and indicator units. However, rangelands provide habitat for such a variety of wildlife species that representative species must be selected by functional groups within each ecoregion. Representative species for each functional group have yet to be cooperatively selected by the multitude of local, state, and federal jurisdictions. Until specific species are identified, comprehension of the indicator by the general public will be inadequate.

Annual Removal of Commercially Harvested Biomass

Annual removal of commercially harvested biomass measures the reduction or disappearance from rangelands of: (1) landscaping and decorative plant materials; (2) edible and medicinal plants; (3) wood products; and (4) native hay.

Importance

Traditional non-forage biomass products have relatively high local value and may have exceedingly high international value (Lazaroff 2003). The net effect of their removal may or may not be important regionally or nationally; however, they may be significant to ecosystem biodiversity, thus rangeland sustainability. During droughts, the value of native hay can increase significantly, even in adjoining regions not suffering from drought. While productive capacity may or may not be altered due to these commodity removals, excessive removal may severely deplete biodiversity and alter habitats in some U.S. ecoregions.

Desert rangelands comprise some of the highest valued commodities in the form of cacti and yucca (Lazaroff 2003) along with medicinal and ceremonial plants valued by American indigenous cultures.

Grasslands have historically been noted for the presence of native hay meadows. Since the late 19th Century, these meadows have assured livestock forage availability throughout seasonal and climatic variations. During settlement times prior to 1890, the lack of harvested hay could lead to overgrazing (Mitchell and Hart 1987). The recent development of "grass banks" by some grazing associations in cooperation with federal agencies represents a non-harvested form of forage available during droughts and other times when rangeland forage is not available for livestock grazing. However, rangeland set aside for grass banks is not considered in this indicator.

Southern savannas and pinyon-juniper communities contain species that are highly valued for essential oils distilled from root masses, as well as aboveground trunks for fence posts. Pinyon pine communities provide a highly valued pine nut used for cooking and consumption and retail sales by American indigenous cultures.

Geographic Variation

This indicator is important and meaningful to completely characterize the productive capacity of rangelands. Ecoregion sampling designs will reflect unique cultural and biological differences and temporal product demand shifts.

Data

Conceptually feasible or initially promising, but no regional-national methods, procedures, or data sets currently exist. Most of the data are associated with site-specific biodiversity issues, such as: removal and depletion of landscaping cacti (Lazaroff 2003), high value cedar removal (e.g., Edwards Plateau), Ashe juniper - golden cheeked warbler habitat; and uncontrolled harvests of medicinal herbs. Public lands seed collection permits are one source of data to be developed.

Clarity

This is understandable to broad audiences at ecoregion scales.

SUMMARY

Indicator development for the productive capacity criterion focuses upon the quantification of primary and secondary production levels of the ecosystem. The first focus is on primary productivity, both total biomass as well as rates of production. The secondary focus is for indicators of sustainability through long term trends in utilization by grazers and the associated communities, both human and wildlife, that are dependent upon these ecosystems. The tertiary area of focus examines other biodiversity effects from utilization of non-forage rangeland products.

Each set of indicators focuses on descriptions of the energy flow through the ecosystem from photosynthesis through grazers. Rangelands comprise a wide spectrum of ecologic communities, from deserts and prairies to coastal grasslands and savannas. The need to assess total productive capacity, therefore, must include both satellite imagery and remotely-sensed, hyperspectral scanning inventory technologies, aggregated to the macro scale, as well as assessment at the ecoregion and local scales capable of utilizing the previously described inventory technologies. On-site managers will utilize those inventories that produce data sets at a scale (2 inches/mile, for example) capable of characterizing the plant community and its associated physical characteristics.

Much of the data required to assess this criterion is available in disparate forms, which reside within different public, state and local entities and non-government organizations. This SRR forum identifies an initial pathway toward the acquisition and coordination of this disparate data in a usable form for society. If populated with data in their entirety, these indicators generate societal comprehension and appreciation for the productive capacity of the Nation's rangelands.

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APPENDIX 4-1. Data matrix for Maintenance of Productive Capacity on Rangelands indicators.

Maintenance of Productive Capacity on Rangelands **Indicator 1. Annual Aboveground Biomass**			
	Data set # 1	**Data set # 2**	**Data set # 3**
Response from #5 of 6-point evaluation framework (A-D)	B, C	B,C	C
Brief Title for Data Set:	**VegBank**	**NatureServe Explorer**	**Ecological Site Description System**
Contact Person/Agency/Group (email, phone, address):	Ecological Society of America Panel on Vegetation Classification Robert K. Peet Principal Investigator Department of Biology CB#3280 University of North Carolina Chapel Hill, NC 27599-3280 919-962-6942 peet@unc.edu	Nature Serve Larry Sugarbaker Vice President and Chief Information Officer NatureServe 1101 Wilson Boulevard 15th Floor Arlington, VA 22209 TEL 703-908-1800 FAX 703-908-1917	Natural Resources Conservation Service George Peacock Rangeland Management Specialist Grazing Lands Technology Institute Staff (GLTI) Fort Worth, Texas Phone: 817-509-3211 Fax: 817-509-3210 gpeacock@ftw.nrcs.usda.gov gltiforum@ftw.nrcs.usda.gov
Citation (if published):		Grossman et al 1998[3]	
Website (if available):	www.vegbank.org	www.natureserve.org/explorer/	plants.usda.gov/esis/
Additional information on data set:			
For what years are data available and how often are data collected?			
In what format is the data set available? (map only, data point, …)	Plot data (treated as data points) in a relational database	Data for plants, animals, and ecological communities, including exotic species	
Are data nominal, ordinal, or interval?			
What will be the approximate cost of collecting data?			
What barrier(s) prohibit access or use of data? (Restricted use, exorbitant cost, technical or legal barriers, confidential barriers, etc.?) Or are data easily accessible?	Some data are proprietary, much are easily accessible.	Some data are proprietary, some has restricted use, and some may have a cost associated with it.	Data on private lands may be proprietary.
What is the spatial grain of the data?			
What is the spatial extent of the data?			
At what spatial scales can these data be aggregated and reported?			

[3] Grossman DH, Faber-Langendoen D, Weakley AS, Anderson M, Bourgeron P, Crawford R, Goodin K, Landaal S, Metzler K, Patterson KD, Pyne M, Reid M, and Sneddon L. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume I, The National Vegetation Classification System: development, status, and applications. The Nature Conservancy: Arlington, VA.

Maintenance of Productive Capacity on Rangelands **Indicator 1. Annual Aboveground Biomass**			
What is the temporal grain of the data?			
What is the temporal extent of the data?			
At what temporal scales can these data be aggregated and reported?			
Quality: can data be adequately reported over time in a consistent form? (Consistent methodology.)			
Quality: how repeatable are existing data? (Include p value of differences in estimates of independent observers if available)			
Quality: how biased are the sampling methods?			
Quality: how precise are existing data? (Give standard error, if available)			
Quality: how valid are existing data?			
Quality: how responsive are existing data?			
Quality: how much statistical power to detect change does this data set have?			
Quality: how well does this data set meet the data needs for this indicator?			
Other comments: (Include any other relevant aspects of the data set that should be included.)	Plot databases contain site information and taxon co-occurrence data collected at the plot. Plots in the plot databases can be interpreted as representing communities that exist in community classification. Plot observations include observations of one or more plant taxa and associated attributes.	Natural communities thus far defined in the *International Classification of Ecological Communities System*, with emphasis on the continental US and Hawaii. Classification includes physiognomic and floristic levels. Ecological communities records at association level. Over 3000 records which could be potentially described as rangeland vegetation communities. All currently accepted native and exotic vascular species, subspecies, varieties, hybrids, selected bryophytes and lichens.	Data in four categories: (1) site characteristics (physiographic, climate, soil and water features) (2) plant communities (ecological dynamics and common plant communities comprising various possible vegetation states) (3) site interpretations (information pertinent to use and management of site and resources) (4) supporting information (to assess the quality of the site description and relationship to other ecological sites)

Maintenance of Productive Capacity on Rangelands **Indicator 1. Annual Aboveground Biomass**			
	Data set # 4	**Data set # 5**	**Data set # 6**
Response from #5 of 6-point evaluation framework (A-D)	C	B	B, C
Brief Title for Data Set:	**Ecological Site Inventory System for Rangeland**	**USGS/NPS Mapping**	**Gap Analysis Program**
Contact Person/Agency/Group (email, phone, address):	Natural Resource Conservation Service George Peacock Rangeland Management Specialist Grazing Lands Technology Institute Staff (GLTI) Fort Worth, Texas Phone: 817-509-3211 Fax: 817-509-3210 gpeacock@ftw.nrcs.usda.gov gltiforum@ftw.nrcs.usda.gov	US Geological Survey and National Park Service Mike Story NPS Program Coordinator National Park Service, NRID 12795 West Alameda Pkwy Lakewood, CO 80228 (303) 969-2746 FAX: (303) 987-6704 mike_story@nps.gov Karl Brown USGS Program Coordinator USGS Center for Biological Informatics P.O. Box 25046 Denver, CO 80225 (303) 202-4240 FAX: (303) 202-4219 karl_brown@usgs.gov	U.S. Geological Survey Biological Resources Division Kevin Gergely Gap Analysis Program 530 S. Asbury St. Suite 1 Moscow, ID 83843 208/885-3565 gergely@uidaho.edu
Citation (if published):			
Website (if available):	plants.usda.gov/esis/	biology.usgs.gov/npsveg/	www.gap.uidaho.edu
Additional information on data set:		Cooperative effort by USGS NPS to classify, describe, and map vegetation communities in more than 250 national park units across the U.S.	
For what years are data available and how often are data collected?	Inventory data collected over the past 40 years		
In what format is the data set available? (map only, data point, …)	Plot data	Maps and relational databases	Maps and relational databases
Are data nominal, ordinal, or interval?			
What will be the approximate cost of collecting data?			
What barrier(s) prohibit access or use of data? (Restricted use, exorbitant cost, technical or legal barriers, confidential barriers, etc.?) Or are data easily accessible?	Data on private lands may be proprietary.		
What is the spatial grain of the data?		The minimum mapping unit is 0.5 hectares.	

Maintenance of Productive Capacity on Rangelands **Indicator 1. Annual Aboveground Biomass**			
What is the spatial extent of the data?			
At what spatial scales can these data be aggregated and reported?			
What is the temporal grain of the data?			
What is the temporal extent of the data?			
At what temporal scales can these data be aggregated and reported?			
Quality: can data be adequately reported over time in a consistent form? (Consistent methodology.)			
Quality: how repeatable are existing data? (Include p value of differences in estimates of independent observers if available)			
Quality: how biased are the sampling methods?			
Quality: how precise are existing data? (Give standard error, if available)			
Quality: how valid are existing data?			
Quality: how responsive are existing data?			
Quality: how much statistical power to detect change does this data set have?			
Quality: how well does this data set meet the data needs for this indicator?			

Maintenance of Productive Capacity on Rangelands Indicator 1. Annual Aboveground Biomass			
Other comments: (Include any other relevant aspects of the data set that should be included.)	Inventory data includes total annual production of all plant species of a plant community, production (by weight measurement) and composition of individual plant species comprising that plant community. Inventories also include data relative to physiographic features of site (soil, slope, aspect, landform, etc.) Data collected using Soil-Woodland Correlation Field Data Sheet (ECS-005), Windbreak-Soil-Species Evaluation Data Sheet (ECS-004) and the Production and Composition Record for Native Grazing Lands (ECS-417)	Vegetation classification based on FGDC Vegetation Classification Standard for physiognomic units and TNC's Terrestrial Vegetation Classification of the United States for floristic units when used (now spun off as NatureServe). Project results include dataset and information for each park project: Spatial Data (aerial photography, map classification, map classification description and key, spatial database of vegetation communities, hardcopy maps of vegetation communities, metadata for spatial databases, complete accuracy assessment of spatial data) and Vegetation Information (vegetation classification, dichotomous field key of vegetation classes, formal description for each vegetation class, ground photos of vegetation classes, field data in database format) Spatial databases will have a horizontal positional accuracy that meets National Map Accuracy Standards at the 1:24,000 scale. Each well defined object in the spatial database will be within 1/50 of an inch of its actual location or 40 feet (12.2 meters). Each vegetation map class will meet or exceed 80% accuracy at the 90% confidence level. The classification accuracy will be established by the program accuracy assessment protocols (link to AA protocol document).	Vegetation is mapped to the alliance level. Landcover is mapped using Landsat Thematic Mapper raw and hypercluster imagery from the Eros Data Center MRLC program. Other information sources include: existing maps and other records, air photos; air video; and ground points. State and Regional levels.

Maintenance of Productive Capacity on Rangelands **Indicator 1. Annual Aboveground Biomass**			
	Data set # 7	**Data set # 8**	**Data set # 9**
Response from #5 of 6-point evaluation framework (A-D)	C		
Brief Title for Data Set:	**Potential Natural Vegetation Groups, version 2000**	**USFS – NRIS (FSVEG Module)**	**BLM – SVIM (Soil Vegetation Inventory Monitoring)**
Contact Person/Agency/Group (email, phone, address):	Forest Service Fire Sciences Laboratory, Rocky Mountain Research Station Fire Effects Project 5775 Hyw 10 West Missoula, MT 59802 406-329-4800 cjohnston@fs.fed.us		
Citation (if published):			
Website (if available):	www.fs.fed.us/fire/fuelman/pnv2000/pnvgroups_v2k.html		
Additional information on data set:	Arc/Info version 7.2.1		
For what years are data available and how often are data collected?	2000		
In what format is the data set available? (map only, data point, …)	Map[4]		
Are data nominal, ordinal, or interval?			
What will be the approximate cost of collecting data?			
What barrier(s) prohibit access or use of data? (Restricted use, exorbitant cost, technical or legal barriers, confidential barriers, etc.?) Or are data easily accessible?			
What is the spatial grain of the data?	Coarse-scale developed for national-level planning		
What is the spatial extent of the data?			
At what spatial scales can these data be aggregated and reported?	National-level only		
What is the temporal grain of the data?			

[4] Kuchler's PNV map was refined to match terrain using a 500 meter Digital Elevation Model, 4th Code Hydrological Units, and Ecological Subregions (Bailey's Sections). Biophysical layers were integrated with current vegetation layers to develop generalized successional pathway diagrams. Expert regional panels refined the PNV map based on the successional pathways.

Maintenance of Productive Capacity on Rangelands **Indicator 1. Annual Aboveground Biomass**			
What is the temporal extent of the data?			
At what temporal scales can these data be aggregated and reported?			
Quality: can data be adequately reported over time in a consistent form? (Consistent methodology.)			
Quality: how repeatable are existing data? (Include p value of differences in estimates of independent observers if available)			
Quality: how biased are the sampling methods?			
Quality: how precise are existing data? (Give standard error, if available)			
Quality: how valid are existing data?			
Quality: how responsive are existing data?			
Quality: how much statistical power to detect change does this data set have?			
Quality: how well does this data set meet the data needs for this indicator?			
Other comments: (Include any other relevant aspects of the data set that should be included.)			

Maintenance of Productive Capacity on Rangelands **Indicator 1. Annual Aboveground Biomass**			
	Data set # 10	**Data set # 11**	**Data set # 12**
Response from #5 of 6-point evaluation framework (A-D)			
Brief Title for Data Set:	**NRCS - NRI**	**IDS (Inventory Data System) – Ecological status inventory**	NASA Earth Observing System
Contact Person/Agency/Group (email, phone, address):	NRCS	Sherm, Bureau of Land Management	
Citation (if published):			
Website (if available):			http://redhook.gsfc.nasa.gov/~imswww/pub/imswelcome/plain.html
Additional information on data set:			
For what years are data available and how often are data collected?			

Maintenance of Productive Capacity on Rangelands **Indicator 1. Annual Aboveground Biomass**			
In what format is the data set available? (map only, data point, …)			Imagery/
Are data nominal, ordinal, or interval?			
What will be the approximate cost of collecting data?			
What barrier(s) prohibit access or use of data? (Restricted use, exorbitant cost, technical or legal barriers, confidential barriers, etc.?) Or are data easily accessible?			
What is the spatial grain of the data?			
What is the spatial extent of the data?			
At what spatial scales can these data be aggregated and reported?			
What is the temporal grain of the data?			
What is the temporal extent of the data?			
At what temporal scales can these data be aggregated and reported?			
Quality: can data be adequately reported over time in a consistent form? (Consistent methodology.)			
Quality: how repeatable are existing data? (Include p value of differences in estimates of independent observers if available)			
Quality: how biased are the sampling methods?			
Quality: how precise are existing data? (Give standard error, if available)			
Quality: how valid are existing data?			
Quality: how responsive are existing data?			
Quality: how much statistical power to detect change does this data set have?			
Quality: how well does this data set meet the data needs for this indicator?			
Other comments: (Include any other relevant aspects of the data set that should be included.)			

Maintenance of Productive Capacity on Rangelands **Indicator 2. Rangeland Annual Productivity (ANPP)**			
	Data set # 1	**Data set # 2**	**Data set # 3**
Response from #5 of 6-point evaluation framework (A-D)			
Brief Title for Data Set:	**EPA**	**NASA Earth Observing System (e.g., MODIS)**	**DAAC – Distributive Active Archive Center**
Contact Person/Agency/Group (email, phone, address):			
Citation (if published):			
Website (if available):			
Additional information on data set:			
For what years are data available and how often are data collected?			
In what format is the data set available? (map only, data point, …)			
Are data nominal, ordinal, or interval?			
What will be the approximate cost of collecting data?			
What barrier(s) prohibit access or use of data? (Restricted use, exorbitant cost, technical or legal barriers, confidential barriers, etc.?) Or are data easily accessible?			
What is the spatial grain of the data?			
What is the spatial extent of the data?			
At what spatial scales can these data be aggregated and reported?			
What is the temporal grain of the data?			
What is the temporal extent of the data?			
At what temporal scales can these data be aggregated and reported?			
Quality: can data be adequately reported over time in a consistent form? (Consistent methodology.)			
Quality: how repeatable are existing data? (Include p value of differences in estimates of independent observers if available)			
Quality: how biased are the sampling methods?			
Quality: how precise are existing data? (Give standard error, if available)			
Quality: how valid are existing data?			
Quality: how responsive are existing data?			

Maintenance of Productive Capacity on Rangelands **Indicator 2. Rangeland Annual Productivity (ANPP)**			
Quality: how much statistical power to detect change does this data set have?			
Quality: how well does this data set meet the data needs for this indicator?			
Other comments: (Include any other relevant aspects of the data set that should be included.)	Data are collected operationally	Data are collected for research purposes	Data are collected for research purposes

Maintenance of Productive Capacity on Rangelands **Indicator 2. Rangeland Annual Productivity (ANPP)**			
	Data set # 4	**Data set # 5**	**Data set # 6**
Response from #5 of 6-point evaluation framework (A-D)		B	
Brief Title for Data Set:	**Ameriflux (part of DAAC)**	**USGS/NPS Mapping**	
Contact Person/Agency/Group (email, phone, address):		US Geological Survey and National Park Service Mike Story NPS Program Coordinator National Park Service, NRID 12795 West Alameda Pkwy Lakewood, CO 80228 (303) 969-2746 FAX: (303) 987-6704 mike_story@nps.gov Karl Brown USGS Program Coordinator USGS Center for Biological Informatics P.O. Box 25046 Denver, CO 80225 (303) 202-4240 FAX: (303) 202-4219 karl_brown@usgs.gov	
Citation (if published):			
Website (if available):		biology.usgs.gov/npsveg/	
Additional information on data set:		Cooperative effort by USGS NPS to classify, describe, and map vegetation communities in more than 250 national park units across the U.S.	

Maintenance of Productive Capacity on Rangelands **Indicator 2. Rangeland Annual Productivity (ANPP)**			
For what years are data available and how often are data collected?			
In what format is the data set available? (map only, data point, …)		Maps and relational databases	
Are data nominal, ordinal, or interval?			
What will be the approximate cost of collecting data?			
What barrier(s) prohibit access or use of data? (Restricted use, exorbitant cost, technical or legal barriers, confidential barriers, etc.?) Or are data easily accessible?			
What is the spatial grain of the data?		The minimum mapping unit is 0.5 hectares.	
What is the spatial extent of the data?			
At what spatial scales can these data be aggregated and reported?			
What is the temporal grain of the data?			
What is the temporal extent of the data?			
At what temporal scales can these data be aggregated and reported?			
Quality: can data be adequately reported over time in a consistent form? (Consistent methodology.)			
Quality: how repeatable are existing data? (Include p value of differences in estimates of independent observers if available)			
Quality: how biased are the sampling methods?			
Quality: how precise are existing data? (Give standard error, if available)			
Quality: how valid are existing data?			
Quality: how responsive are existing data?			
Quality: how much statistical power to detect change does this data set have?			
Quality: how well does this data set meet the data needs for this indicator?			

Maintenance of Productive Capacity on Rangelands Indicator 2. Rangeland Annual Productivity (ANPP)			
Other comments: (Include any other relevant aspects of the data set that should be included.)		Vegetation classification based on FGDC Vegetation Classification Standard for physiognomic units and TNC's Terrestrial Vegetation Classification of the U.S. for floristic units when used (now spun off as NatureServe). Project results include dataset and information for each park project: Spatial Data (aerial photography, map classification, map classification description and key, spatial database of vegetation communities, hardcopy maps of vegetation communities, metadata for spatial databases, complete accuracy assessment of spatial data) and Vegetation Information (vegetation classification, dichotomous field key of vegetation classes, formal description for each vegetation class, ground photos of vegetation classes, field data in database format) Spatial databases will have a horizontal positional accuracy that meets National Map Accuracy Standards at the 1:24,000 scale. Each well defined object in the spatial database will be within 1/50 of an inch of its actual location or 40 feet (12.2 meters). Each vegetation map class will meet or exceed 80% accuracy at the 90% confidence level. The classification accuracy will be established by the program accuracy assessment protocols (link to AA protocol document).	

Maintenance of Productive Capacity on Rangelands **Indicator 2. Rangeland Annual Productivity (ANPP)**			
	Data set # 7	**Data set # 8**	**Data set # 9**
Response from #5 of 6-point evaluation framework (A-D)	C		
Brief Title for Data Set:	**Potential Natural Vegetation Groups, version 2000**		
Contact Person/Agency/Group (email, phone, address):	Forest Service Fire Sciences Laboratory, Rocky Mountain Research Station Fire Effects Project 5775 Hyw 10 West Missoula, MT 59802 406-329-4800 cjohnston@fs.fed.us		
Citation (if published):			
Website (if available):	www.fs.fed.us/fire/fuelman/pnv2000/pnvgroups_v2k.html		
Additional information on data set:	Arc/Info version 7.2.1		
For what years are data available and how often are data collected?	2000		
In what format is the data set available? (map only, data point, …)	Map[5]		
Are data nominal, ordinal, or interval?			
What will be the approximate cost of collecting data?			
What barrier(s) prohibit access or use of data? (Restricted use, exorbitant cost, technical or legal barriers, confidential barriers, etc.?) Or are data easily accessible?			
What is the spatial grain of the data?	Coarse-scale developed for national-level planning		
What is the spatial extent of the data?			
At what spatial scales can these data be aggregated and reported?	National-level only		
What is the temporal grain of the data?			
What is the temporal extent of the data?			
At what temporal scales can these data be aggregated and reported?			

[5] Kuchler's PNV map was refined to match terrain using a 500 meter Digital Elevation Model, 4th Code Hydrological Units, and Ecological Subregions (Bailey's Sections). Biophysical layers were integrated with current vegetation layers to develop generalized successional pathway diagrams. Expert regional panels refined the PNV map based on the successional pathways.

Maintenance of Productive Capacity on Rangelands **Indicator 2. Rangeland Annual Productivity (ANPP)**			
Quality: can data be adequately reported over time in a consistent form? (Consistent methodology.)			
Quality: how repeatable are existing data? (Include p value of differences in estimates of independent observers if available)			
Quality: how biased are the sampling methods?			
Quality: how precise are existing data? (Give standard error, if available)			
Quality: how valid are existing data?			
Quality: how responsive are existing data?			
Quality: how much statistical power to detect change does this data set have?			
Quality: how well does this data set meet the data needs for this indicator?			
Other comments: (Include any other relevant aspects of the data set that should be included.)			

APPENDIX 4-2. Other data sources.

Numerous possible data sets exist (capacity@cnr.colostate.edu is our internal website list serve). Below captures additional sites worthy of exploration that have not yet been researched for applicability.

- USDA-NRCS: Soil Veg Survey, Range site, Ecological Site Info System, ESIS within Plants Data Base
- USDA-NRCS: NRI (random pts, update every 5 yrs) national
- USDA-NRCS: SERGO (new soil survey information data system)
- USDA National Ag Statistics Service: Agriculture Census
- USDA-FS: range inventory, allotment plans, FIA, NRIS (7 data base modules, including plants collected at management unit level, FSVEG, TERRA(soil), AIR, WATER, FAUNA, and HUMAN DIMENSIONS, RPA (decadal) national
- USDI-BLM: soil survey or ecological status inventory, IDS, SVIM,SIM western US (see Sherm for BLM)
- *Existing Vegetation Classification may be close to standardized across FS, BLM, NRCS
- USDI-NPS I&M strategy (locally developed standards), NRSpecies, Comprehensive resource report
- USDI-BIA
- USDI-FWS
- DOD
- The Nature Conservancy
- Native Plant Groups
- Sierra Nevada Ecosystem Project
- NW Forest Plan, Interior Columbia Basin Plan
- State Fish and Wildlife Inventory Data Sets
- State Lands Departments
- Remote Sensing Data sets, USGS, EROS Data Center,
- Land Use, Land Cover, GAP DATA (USGS)
- NASA Earth Observing System MODIS
- LTER's
- EPA, EMAP (regional data for rangeland health)
- Minimum set of data standards for each indicator…i.e. what *has* to be collected to fulfill the info for a specific indicator.