CHAPTER 3
Criterion II: Indicators for Conservation and Maintenance of Plant and Animal Resources on Rangelands

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Abstract: Five criteria were established by the Sustainable Rangelands Roundtable to be used to assess rangeland sustainability on a national scale. One of those criteria is the conservation and maintenance of plant and animal resources. Within this criterion, 10 indicators were developed through the expert opinions of rangeland scientists, rangeland management agency personnel, non-governmental organization representatives, practitioners, and other interested stakeholders. These indicators are not inclusive but provide a suite of variables that, when complemented with indicators from the other four criteria, produce a viable system to monitor the biophysical, social, and economic characteristics of rangeland sustainability at the national level.

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Introduction

Within the Sustainable Rangelands Roundtable (SRR), a group identified, developed, and adopted standardized indicators that would characterize the conservation and maintenance of plant and animal resources, one of the five criteria for assessing sustainable rangelands. Within this criterion, 10 indicators were developed. The development of these indicators is a reflection of the expert opinions of rangeland scientists, rangeland management agency personnel, non-governmental organization representatives, practitioners, and other interested stakeholders. Associated concepts and ideas evolved from lively discussions at the SRR workshops, as well as electronic correspondence between meetings. These indicators are not inclusive but provide a suite of variables that, when complemented with indicators from the four other criteria, produce a viable system to monitor the biophysical, social, and economic characteristics of rangeland sustainability at the national level.

The 10 indicators identified here reflect multiple factors relevant to the conservation and maintenance of plant and animal resources, from location and area of rangeland to detailed information on population dynamics of species of concern (Table 3.1). The development of these indicators built upon previous work in the refereed literature and work such as the Criteria and Indicators of the Montreal Process (Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests 1995) and The State of the Nation's Ecosystems (Heinz 2002, 2008).

Table 3.1. Indicators for conservation and maintenance of plant and animal resources on rangelands, Criterion II.

Indicator	What the indicator describes	Status of data availability[1]
1. Extent of land area in rangeland	Over several measurements, changes in the total amount of land that fits the definition of rangeland.	B
2. Rangeland area by plant community	Changes in the area of plant communities on rangeland.	B, C
3. Number and extent of wetlands	Changes in wetland abundance.	A
4. Fragmentation of rangeland and rangeland plant communities	Changes in spatial patterns on rangeland and on plant community types.	C
5. Intensity of human uses	Changes in the densities of roads and human structures over time.	A
6. Integrity in natural fire regimes on rangeland	Changes in characteristics associated with the natural disturbance of fire, such as fire frequency, intensity, and extent.	C, D
7. Extent and condition of riparian systems	Condition of riparian vegetation and watershed health.	C
8. Area of infestation and presence/absence of invasive and non-native plant species of concern	Displacement of native plants and habitat.	C
9. Number and distribution of species and communities of concern	Changes in species and communities that are threatened, endangered, or of concern for some identified reason.	A
10. Population status and geographic range of rangeland-dependent species	Finer scale information, such as population levels and current geographic range, on select plant and animal species.	A, C

See Appendix 1-E.

Criterion 1 from the Montreal Process is "Conservation of Forest Biological Diversity." It includes indicators of forest type area, fragmentation, status of species at risk, and population dynamics of representative species. Similarly, national-level indicators proposed for grasslands and shrublands by The Heinz Center included extent of land area in rangelands, integrity of natural fire regimes, extent and condition of riparian systems, fragmentation, the area of infestation, and presence/absence of invasive and non-native species of concern (Heinz 2002, 2008). These indicators are identified here as important factors related to plants and animals on rangelands. West (1993) identified components of biodiversity such as landscape, community, population, and genetics. These components are reflected in our indicators associated with fragmentation, plant communities, presence of species and communities of concern, and population levels of representative species. With the exception of a few shrubs and grasses, few studies have been performed on the genetic diversity of rangeland plants. Therefore, no indicator was identified in this area.

Additional concepts related to rangeland health and biodiversity have been identified under the two other biophysical criteria identified by the SRR: "Maintenance of Soil and Water Resources on Rangelands" and "Productive Capacity and Conservation." Taken together, these three criteria of the SRR and their associated indicators will be a valuable tool in assessing the biophysical sustainability of rangelands on a national scale.

Extent of Land Area in Rangeland

Description and Importance of the Indicator

This indicator quantifies the amount of land area defined as rangeland at any given time. The amount of rangeland at any instant and the associated changes over time are important metrics because they provide information on one of the important global land types as well as inform the spatial and temporal framework from which all other indicators will be considered.

Analysis of this indicator requires a nationally accepted definition of rangeland that encompasses a definition of land cover. We define "land cover" as the ecological state and physical appearance of the land surface, e.g., grassland, savanna, or shrubland (Dale et al. 2000). Change in land cover converts land of one type of cover to another (Dale et al. 2000). Nearly 300 definitions of "rangeland" have been proposed (Lund 2007), including agglomerative (Society for Range Management 1994; IPCC 2007, glossary; Lund 2007; Heinz 2008) and biophysical (UNEP 1992; UNEP 1997; Reynolds 2001; Lepers et al. 2005; MEA 2005; Lund 2007). The common thread for the agglomerative approach is that "rangeland" is a "natural" vegetation complex dominated by grasses, grass-like plants, forbs, and/or shrubs. Thus, by definition, rangelands include indigenous grassland, savanna, shrubland, desert, tundra, alpine, marsh, and meadow ecosystems as well as introduced pasture systems, such as crested wheatgrass, that are managed as "natural" ecosystems. A biophysical definition of "dryland" was developed and accepted internationally by the 192 signatories' of the United Nations Convention to Combat Desertification (UNCCD). The recent Millennium Ecosystem Assessment (MEA 2005) adopted the term "drylands" as a reporting category. "Dryland" is defined as those lands where the ratio of mean annual precipitation to mean annual potential evapotranspiration ranges between 0.05 and 0.65 (UNEP 1992; UNEP 1997; Reynolds 2001; MEA 2005). Within the MEA (2005), rangeland, which encompasses much but not all of the dryland category, is a land-use category. The 10 reporting categories used in the MEA (2005) are not mutually exclusive: their areas can and do overlap (MEA 2005). Recent interest in assessing the amount of carbon stored in ecosystems has led to a set of proposed guidelines of carbon inventories (IPCC 2006). Within these guidelines, the land-area categories are defined on the basis of land use: forest, cropland, grassland, wetlands, settlements, and other land uses. The guidelines suggest that shrublands may be included within the grassland reporting category. Consistency in terminology is critical to assess the sustainability of rangelands. The SRR recommends the Society for Range Management agglomerative definition: rangelands are areas dominated by self-propagating vegetation comprised predominantly of grasses, grass-likes, forbs, shrubs, and dispersed trees (Society for Range Management 1994).

Information has been compiled about the area of rangeland, but little can be concluded about total rangeland area or change in rangeland area over time as estimation methods have varied or are non-existent. Lepers et al. (2005) conducted a global assessment of land cover change from 1981 to 2000 using multiple data sources including national statistics, expert opinion, local field studies, and remote sensing. They conclude that land cover change data were insufficient for the United States. The Heinz Center (Heinz 2008) used the National Land Cover Dataset (NLCD) 2001 to estimate grassland and shrubland area at 332 million ha (830 million acres) for the lower 48 states including pasture, and 82 million ha (205 million acres) for Alaska using the 1992 NLCD. The 1992 and 2001 NLCD thematic maps are derived from LANDSAT satellite data at 30-m spatial resolution for a pixel. An acceptable standardization between the 1992 and 2001 data sets has not yet occurred but will be available in the future (Fry et al. 2008). Despite this ongoing work, The Heinz Center concluded that data were insufficient to estimate changes in shrubland-grassland cover in the U.S. The most consistent and commonly used assessment of non-federal rangeland area and change has been the USDA Natural Resources Conservation Service (NRCS) National Resources Inventory (NRI), collected since the 1970s (Nusser and Goebel 1997). Of interest here are the reported changes in rangeland area between the five-year periodic inventories (USDA Soil Conservation Service 1987; USDA NRCS 1995; Mitchell 2000, table 26). However, no periodic inventory of federally owned rangelands is available (Lepers et al. 2005; Heinz 2008). Further, the extent of federal rangeland has not been consistently determined across agencies and over time (Mitchell 2000). A consistent methodology assessing the area of rangeland over time should be implemented across all U.S. lands, offering a repeatable method to track rangeland area. Current technologies, discussed below, are available to accurately assess rangeland area extent and change in a spatial context.

The area of rangeland at any point in time and the changes over time have major consequences for the availability of ecosystem services from rangelands such as purification of air and water, generation and preservation of soils and renewal of their fertility, detoxification and decomposition of wastes and pollutants, pollination of crops and natural vegetation, dispersal of seeds, cycling and movement of nutrients, control of the vast majority of potential agricultural pests, maintenance of biodiversity, and provision of aesthetic beauty and intellectual stimulation that lift the human spirit (Daily et al. 1997; MEA 2005). The area of rangeland provides an estimate of the availability of forage for livestock in the production of meat, milk, and fiber and to a lesser extent forage for draft animals, as well as the potential gene stock for monocot crops such as wheat, barley, rye, and oats (Sala and Paruelo 1997). Given that 84 percent of mammals and 74 percent of the bird species within the United States (inhabitants or common migrants) use rangeland habitats (Flather et al. 1999), changes in rangeland area have implications to the sustainability of these species and populations. Assessing the capacity of ecosystems to stored carbon as a mitigation practice for climate change has generated the need to quantify the area of rangeland (Joyce 2000; IPCC 2006).Therefore, it is important that we know the extent of land area in rangeland and how that is changing over time. This indicator will allow us to track the amount and location of this important resource.

Geographic Variation

This indicator is meaningful for different geographic regions (e.g., Great Plains, Southwest). All major assessments and environmental reports use land area as an indicator across different geographic regions. For example, Mitchell (2000) reported that privately owned rangeland accounted for 160 million ha (399 million acres) of the total U.S. land base in 1992. And given the common definition of rangeland in the U.S. Department of Agriculture (USDA) NRCS (1995) inventory, Mitchell (2000) could then contrast the amount of rangeland within 4 different regions in the United States. MEA (2005) used the reporting category of drylands with a biophysical definition to compare and contrast the land area of drylands with other reporting categories such as forest/woodlands and mountains globally, in addition to summarizing the relative share of dryland in developing countries and industrial countries. Land area of major ecosystems (i.e., grasslands, deserts) established the basis for comparison of potential climate change impacts in Intergovernmental Panel on Climate Change (IPCC 2007). It should be noted, however, that estimates of area of rangeland vary across these assessments as a result of the way they are defined and subsequently sampled. And thus, the capacity to compare across these studies is limited. A consistent definition of rangelands would address this issue.

Scale in Time and Space

This indicator is meaningful at different spatial (i.e., counties, states, regions, and nationally) and temporal scales. The NRI (USDA NRCS 2010a) reports on the area of rangeland at the national level and, because the definition and sampling techniques are consistent, compares rangeland area across the 50 states. The NRI is a longitudinal sample survey, thus changes in major categories can be compared over time and the shifts between different reporting categories can be summarized (USDA NRCS 2000). For example, the largest loss of rangeland area was to cropland (Table 3.2) as nearly 7 million acres of rangeland were converted to cropland between 1982 and 1997.

Table 3.2. Changes in land cover/use between 1982 and 1997 (USDA NRCS 2000).

	Land cover/use in 1997 per 1,000 acres								
Private land cover/use in 1982	**Cropland**	**CRP land**	**Pasture land**	**Rangeland**	**Forest land**	**Other rural land**	**Developed land**	**Water areas & federal land**	**1982 total**
Cropland	350,265.3	30,412.1	19,269.4	3,659.2	5,606.5	3,158.9	7,097.5	1,485.1	420,954.0
Pasture land	15,347.0	1,329.6	92,088.3	2,567.9	14,091.4	1,619.0	4,230.0	732.8	132,006.0
Rangeland	6,967.5	728.5	3,037.2	394,617.4	3,021.6	1,702.7	3,281.3	3,383.2	416,739.4
Forest land	2,037.1	128.8	4,168.2	2,098.8	380,343.3	1,754.8	10,279.2	2,528.0	403,338.2
Other rural land	1,386.8	93.1	1,013.6	719.1	2,767.7	42,713.3	726.9	227.8	49,648.3
Developed land	196.7	1.2	78.6	110.8	227.0	12.0	72,618.7	0.8	73,245.8
Water areas & federal land	797.5	2.7	336.6	2,204.0	897.7	180.8	18.1	443,760.6	448,198.0
1997 total	376,997.9	32,696.0	119,991.9	405,977.2	406,955.2	51,141.5	98,251.7	452,118.3	1,944,129.7

Notes: 1982 land cover/use totals are listed in the right hand vertical column, titled "1982 total." 1997 land cover/use totals are listed in the bottom horizontal row, titled "1997 total." The number at the intersection of rows and columns with the same land cover/use designation represents acres that did not change from 1982 to 1997. Reading to the right or left of this number are the acres that were lost to another cover/use by 1997. Reading up or down from this number are the acres that were gained from another cover/use by 1997. This table is Table 5 from http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/table5.html

As stated earlier, estimates of rangeland area vary as a result of the definition and estimation techniques. For example, ground-based inventories estimate the amount of land area (in any classification) using a point-based sampling system – an extensive number of sample points where each point represents a certain amount of land area. To capture the heterogeneity of rangeland vegetation, field-based inventories require comprehensive environmental and vegetation attribute data, stratification, and appropriate sample sizes per attribute and the associated person hours to produce statistically acceptable results. The number of samples needed in field-based inventories is typically determined by the desired variation in the estimate. For example, in the 1992 NRI, 800,000 sample points were needed in order to obtain the objective of a coefficient of variation of less than 10 percent for any estimate of surface area within a particular resource (Nusser and Goebel 1997).

Major Land Resource Areas (MLRAs) are geographic areas, usually several thousand acres in extent, which are characterized by a particular pattern of soils, climate, water resources, and type of land use. They are nested within Land Resource Areas (Soil Survey Staff 1981). This classification system is based on the concept that landscapes are hierarchically structured discrete entities that can be mapped at different spatial scales. A number of other federal agencies also use or have developed ecophysical or ecoregional maps that use this hierarchical concept (Bailey 1995; Omernick 1987; Hargrove and Hoffman 2004). These ecoregion maps have been delineated using both expert opinion and/or quantitative procedures, such as Hargrove and Hoffman (2004).

When using remote sensing methods, scale issues arise in association with the pixel size of the remotely sensed imagery. As pixel size increases, the estimates of rangeland area have the potential for increasing bias due to boundary and inclusion effects (Konarska et al. 2002). Still, the argument is often made for qualitative rapid field assessments, even though results are less reliable than desired (e.g., Rasmussen et al. 1999). West (2003) discussed the limitations of field-based data sets and recommended expanded research on the use of Geographic Information System (GIS) and remote sensing technologies within rangeland. It is likely that the future land inventories will use a combination of remotely sensed information in a GIS- and ground-based information (Washington-Allen et al. 2006).

Data Collection and Availability

The available data for this indicator are best described by B (Table 3.1, Appendix 1-E). Some data set(s) exist at the regional-national level, but methods and procedures are not standardized at the regional-national level. The data sets that currently exist for this indicator, though not descriptive of the entire United States, are based on inventory or monitoring systems that were designed at the national level.

At least three sources of extant data at the national level could be evaluated for this indicator: 1) the Landsat derived 1992, 2001, and 2006 National Land Cover Data (NLCD) Sets (Vogelmann et al. 2001; Homer et al. 2007) the remotely sensed Moderate Resolution Imaging Spectroradiometer (MODIS) Global Land Cover Product (Friedl et al. 2002; USGS 2010a), and 3) the ground survey NRCS NRI data for non-federal lands, which is currently the most commonly used assessment data for U.S. rangelands (Nusser and Goebel 1997;USDA NRCS 2010a). The current NRI sampling and analysis procedures have evolved over time (USDA NRCS 2010a) and now incorporate the use of aerial photography and GIS along with ground-based inventories. The USDA Forest Service also conducts inventories of public and private lands, primarily focusing on forestland attributes through the Forest Inventory and Analysis (FIA) program (Smith et al. 2009).

A partnership of six federal agencies called the Multi-Resolution Land Characteristics Consortium (MRLC; http://www.mrlc.gov/. Accessed 20 April 2011) was formed in 1992 to reduce the cost to any one agency of the purchase of Landsat satellite data (Vogelmann_et al.

2001). Two national land cover maps have been produced from the MRLC program, including the 1992 NLCD (USGS Land Cover Institute 1992; Loveland et al. 2000) and the 2001 NLCD (Homer et al. 2007). While the MRLC Consortium supported the 1992 and 2001 NLCD products, substantial differences in imagery, legends, and methods between these two products inhibit a direct comparison (Fry et al. 2008). The NLCD 1992-2001 Land Cover Change Retrofit product allows for the analysis of land cover change over time and documents an estimated 3 percent change in land cover between 1992 and 2001 with an increase of 30,417 km^2 of grass/shrubland cover in the U.S. As previously discussed, the 1992 and 2001 NLCD has been used to estimate total rangeland (grassland-shrubland) cover (Heinz 2002 and 2008) (Fig. 3.1). An updated National Land Cover Database (2006 NLCD) is being produced using data from the 2001 NLCD and 2006 Landsat imagery (Xian et al. 2009).The development of methods to map land cover change at continental scales using moderate spatial resolution imagery such as available from the Landsat satellites is an active area of research. For example, the National Aeronautics and Space Administration (NASA) Landsat Ecosystem Disturbance and Adaptive Processing System program is conducting research to develop algorithms that can be extended in time and space to map forestland cover change for North America (Masek et al. 2008).

DeFries et al. (1998) began development of a remote sensing-based data set that could detect changes in land cover overtime using the International Geosphere-Biosphere Programme (IGBP) definition of land cover types. This concept has been extended to MODIS (Reeves et al. 2001; Zhang et al. 2000), which has been functional since July 2000. Value-added algorithms developed for MODIS-generate land cover characteristics (Justice et al. 2002), including fire anomalies, land cover conversion, and vegetation continuous fields (e.g., phenology, Zhang et al. 2009; biomass, Baccini et al. 2004). The MODIS Land Cover Type product (MCD12Q1) contains multiple classification schemes (USGS 2010b). The primary land cover scheme identifies 17 land cover classes defined by the IGBP, which include 11 natural vegetation classes, three human-altered classes, and three non-vegetated land classes. Evaluation of the primary land cover scheme identified that a portion of the cropland/natural vegetation mosaic cover type will also contain an unknown proportion of rangeland (Friedl et al. 2002). The MODIS Terra + Aqua Land Cover Type Yearly L3 Global 500 m SIN Grid product incorporates five different land cover classification schemes, derived through a supervised decision-tree classification method: IGBP global vegetation classification scheme, University of Maryland scheme, MODIS-derived LAI/fPAR scheme, MODIS-derived Net Primary Production scheme, and Plant Functional Type scheme.

A comparison of the estimates of rangeland area from the 1992, 2001, and 2006 NLCD (Landsat imagery with 0.09 ha spatial resolution), MODIS Global Land Cover Product (100 ha spatial resolution), and NRI (ground survey point sample on non-federal lands) would be informative. The NLCD and MODIS data sets have the advantage of providing a map product that is needed for other SRR criteria and indicators. However, the maps will likely have omission and commission errors, and accuracy assessment of the products are needed to calculate unbiased estimates of the area of rangeland. The NRI estimates of the area of rangeland should be unbiased but are only available for non-federal lands (Table 3.2). However, the NRI estimates offer the opportunity to assess the accuracy of satellite thematic classifications of rangeland area or change in the same way the FIA and Southwest Regional GAP Analysis Project (Lowry et al. 2007) field data were used to look at the accuracy of MODIS-derived continuous forest cover (White et al. 2005). This type of comparison would identify the most efficient method to assess land area change in rangeland. Other indicators may require a different approach; Thematic Mapper (TM) imagery may be better for calculating rangeland fragmentation than a map from MODIS imagery.

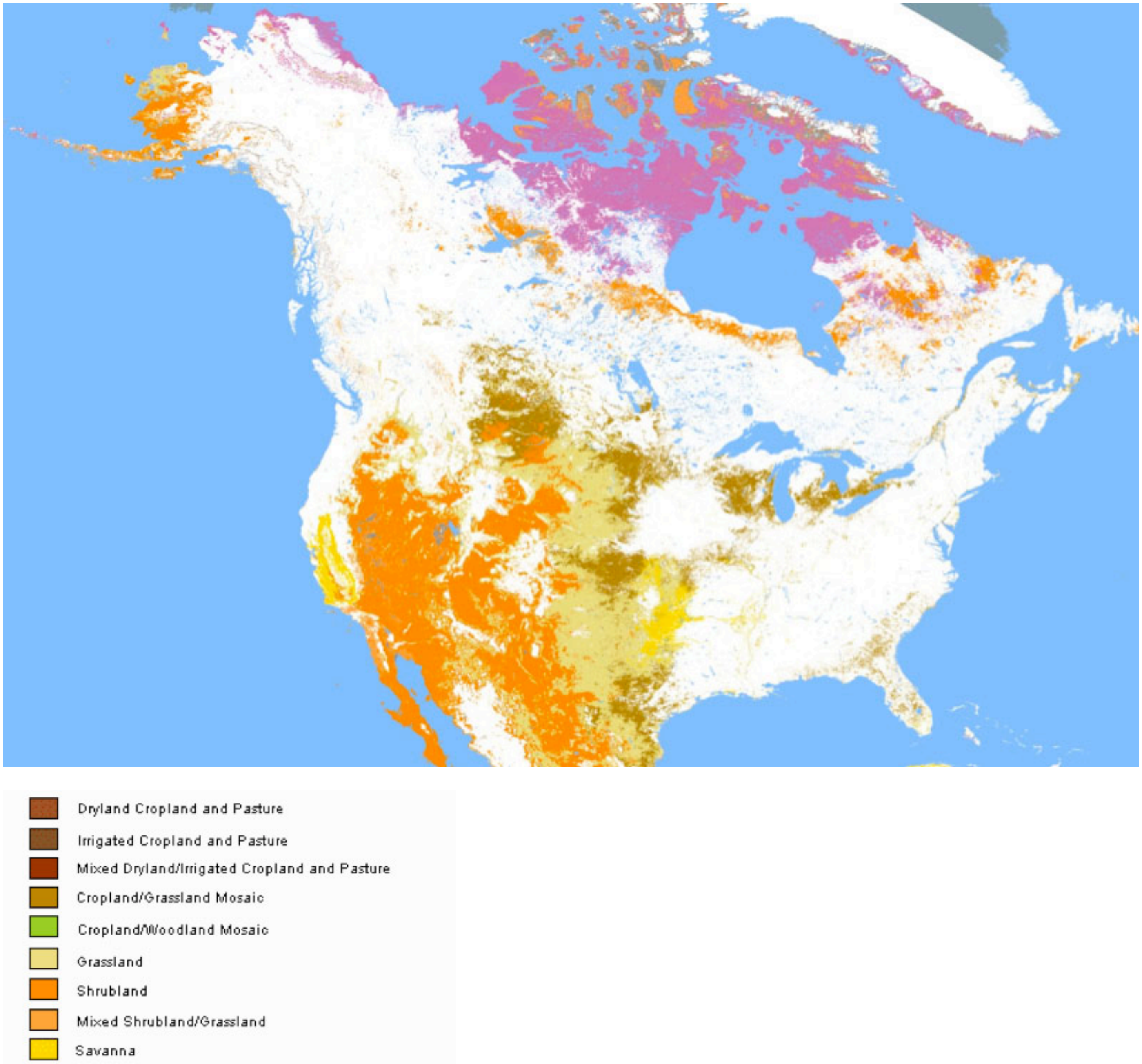

Figure 3.1. Extent of land area in rangeland as determined using remote sensing data. Source: Adapted from http://www.nationalatlas.gov/landcvm.html USGS 1992 and 1993 AVHRR 1-km U.S. land cover (USDI 2009).

Clarity to Stakeholders

Total area of rangeland and changes in the total area of rangeland would likely be one of the more easily understood and accepted indicators by the public. The possibility of mapping rangeland area and change would enhance understanding by the public.

Rangeland Area by Plant Community

Description and Importance of the Indicator

This indicator describes rangeland plant communities and their area at any given time, with the difference between times being a reflection of temporal changes. This indicator has a classification component—how stakeholders name and/or describe the plant community—and an inventory component—where they are found and what area they cover. This indicator is the hierarchical subcomponent of the "Extent of Land Area in Rangeland" indicator.

Plant communities are loosely assembled collections of plant species (Mueller-Dombois and Ellenberg 1974), with the mix of species affecting community structure and function and ultimately its capacity to support a wide range of plants and animals including rare, threatened, and endangered species. Description and classification of plant communities are challenging because the distribution of plant species over time and space is influenced by many factors operating at a number of scales. Classification systems are artificial constructs developed to simplify the variability of vegetation; therefore, numerous methods to classify vegetation have been developed (Whittaker 1973; Mueller-Dombois and Ellenberg 1974; Shiflet 1994; ESA 2004; Grossman et al. 2008).

Vegetation can be described in terms of potential vegetation, existing vegetation, physiognomy, floristics, or varying combinations of these descriptors. Resource conservation and land management agencies and organizations have often developed classification systems that facilitate decision-making for resource management and planning. The Ecological Site classification system is a single level classification system developed by the NRCS and used by both the NRCS and the U.S. Department of the Interior (USDI) Bureau of Land Management (BLM) (USDA NRCS 2010b) and now with a recent memoranda of understanding, the USDA Forest Service (Brown and Bestelmeyer 2008). Bestelmeyer et al. (2009) noted that ecological site classifications are based on the premise that difference in potential plant communities and their resilience are governed by subtle differences in soil, geomorphology, and climate. Knowing the suite of potential plant communities possible at a given site can help place the existing vegetation in a historical and environmental framework. Other federal agencies (U.S. Fish and Wildlife Service [FWS], U.S. Geological Survey [USGS], Department of Defense) and non-governmental organizations (among them, The Nature Conservancy [TNC]) have developed land and plant community classifications for institution specific management and planning needs. The challenge in developing a nationally consistent vegetation classification system is to recognize the role that these historic systems have played in management and planning decisions and to identify methods to continue to provide such information to meet management needs.

A fundamental goal of SRR is to facilitate the adoption of standardized assessment and monitoring technologies by all rangeland resource agencies and users in order to enhance interpretation of these data regardless of land ownership or stewardship responsibilities. To accomplish this goal and to enhance the utility of this indicator, a nationally consistent definition of rangeland ("Extent of Land Area in Rangeland" indicator) is needed as well as accepted definitions and descriptions of associated rangeland plant communities ("Rangeland Area by Plant Community" indicator). Descriptions must be clear and complete so resource managers, scientists, and technicians can unambiguously identify the specific plant communities occupying any given rangeland. Further, a consistent classification system should be implemented across the United States within the context of an inventory system that samples plant communities on rangeland. Technology is available to perform a national inventory and monitoring program for rangeland plant communities and to enhance these direct measurements with a probability-based sample design. The integration of remote sensing, abiotic data, GIS technologies, and ground sampling in a probability-based sampling design would capitalize on the strengths of each approach (e.g., Franklin et al. 2000). The challenge is to recognize the strengths of all assessment and monitoring approaches and then use the best combination of them.

The varieties of rangeland vegetation reflect the variety of benefits and values that rangelands provide. The extent of these communities indicates the current capability of rangeland to produce these benefits and values for society. Changes in certain plant communities could result in changes in resource outputs, ecosystem services, non-market values, and habitats for plant and animal species. Examples of endangered or critically endangered rangeland ecosystems include the native shrub and grassland steppe in Oregon and Washington, the Palouse prairie in eastern Oregon and Washington, and the tallgrass prairie of the eastern Great Plains (Flather et al. 1999; Noss et al. 1995). Presence of a plant community can also serve as a loose proxy for environmental characteristics, disturbances, and ecosystem processes. Changes in plant communities over time may suggest changes in underlying environmental factors such as climate and nutrient availability, changes in ecosystem functioning, or changes in disturbances. Flather and Sieg (2000) reported that the simplest measure of ecosystem diversity is the number and area of rangeland plant communities that occur nationally. They state that maintaining a sufficient area of each plant community is necessary to sustain ecosystem components and processes, as well as the species dependent on them. Information on the number and extent of rangeland plant communities over time is fundamental for resource management and planning decisions, as well as providing the basic information on vegetation for scientific research. Further, this information is critical to ensuring the sustainability of rangelands.

Geographic Variation

While different plant communities will occur in different regions, if communities are classified and named using the same protocols and methodology, this indicator is useful in and across different regions.

Scale in Time and Space

If a standard classification system of rangeland plant communities is nationally accepted, it will be necessary to define the spatial scale and hierarchal level within the classification system when indicator data are collected. This is because the field implementation of the definition is influenced by spatial scale. Estimations of the areal extent of plant communities through either ground-based inventories or remotely sensed techniques are often less sensitive than desired, but as technology advances, we may be able to improve our ability to determine plant communities more efficiently, in a less costly manner, and with greater spatial resolution. Granted, direct discrimination of the taxonomic composition of rangeland vegetation using satellite data have proven quite elusive. Still, newer sensors of high spectral and spatial resolution may dramatically improve our capability to remotely determine botanical composition. That said, of far greater promise is the process of context modeling. Context modeling technology predicts the taxonomy of vegetation from remotely sensed physiognomic and structural vegetation maps in conjunction with other landscape variables such as soil type and elevation within a geographic information system (Franklin et al. 2000; Wulder et al. 2008; see Guisan and Zimmermann 2000 for cautions).

Data Collection and Availability

In terms of the classification component and the inventory component of this indicator, the data availability is categorized as both B and C (Table 3.1, Appendix 1-E). Standardized methods and procedures for data collecting and reporting exist at the regional-national level, but useable data set(s) do not exist at the regional-national level. There is no single agency responsible for classifying, describing, and/or mapping the vegetation of the United States (FGDC 2008), and there are many agencies for which information on vegetation is critical and, therefore, have been developed independently at national or regional levels. Hence, some data set(s) exist at the regional-national level, but methods and procedures are not standardized at the regional-national level.

In 2008, Version 2 of the U.S. National Vegetation Classification Standard (NVCS) was formally approved by the Federal Geographic Data Committee (FGDC 2008; Jennings et al. 2009; Faber-Langendoen et al. 2009). The development of this revision occurred through a partnership of the Ecological Society of America (ESA) Panel on Vegetation Classification, NatureServe (http://www.natureserve.org/. Accessed 15 November 2008), and federal partners of the FGDC. Critical changes from Version 1 include a restructuring of the overall hierarchy, development of new standards for the lower levels of the classification (alliance and association), and the formation of a dynamic approach to maintaining the classification (Faber-Langendoen et al. 2009). Perhaps the most important revision is the development of a process, referred to as "successive refinement," to create a consistent national vegetation classification. Vegetation types must be defined and characterized using appropriate data where the classification and data are publicly accessible. The classification system is dynamic in that the content will evolve as data continue to be collected, analyzed, and correlated over time and new vegetation types are defined and previously defined types refined. Developing and revising these plant communities under the NVCS will be a peer-reviewed process. FGDC (2008) notes that the standard shall be followed by all Federal agencies for vegetation classification data collected directly or indirectly (through grants, partnerships, or contractors) using federal funds. Widespread use of NVCS by county and state governments, research institutions, and the private sector could facilitate information needs on vegetation across ownerships and landscapes.

The National Vegetation Classification (NVC) has eight levels in the hierarchy for natural and cultural vegetation with differently defined criteria for natural versus cultural. Cultural vegetation is defined as "vegetation with a distinctive structure, composition, and development determined by regular human activity" (FGDC 2008). It includes one or more physiognomic and structural attributes, such as growing in rows, substantial cover of bare soil for significant periods of the year, highly-manipulated growth forms usually determined by mechanical pruning or mowing, and/or species not native to the area intentionally introduced to the site by humans. The upper levels of the hierarchy for natural vegetation are based on broad growth form patterns that reflect ecological relationships (Faber-Langendoen et al. 2009) (Table 3.3). Physiognomy (life form, cover, structure, leaf type) plays a predominant role in Levels 1-3, whereas both floristics and physiognomy influence the criteria of the middle levels 4-6. The role of floristics increases as one steps down into the hierarchy. The upper physiognomic levels of the NVCS hierarchy are based on factors that could be discernible from aerial photography or fine spatial resolution satellite imagery.

Table 3.3 Summary of NVC-revised hierarchy levels and criteria for natural vegetation (FGDC 2008)

Hierarchy level	Criteria
Upper	Physiognomy plays a predominant role.
L1 – Formation Class	Broad combinations of general dominant growth forms that are adapted to basic temperature (energy budget), moisture, and substrate/aquatic conditions.
L2 – Formation Subclass	Combination of general dominant and diagnostic growth forms that reflect global macroclimatic factors driven primarily by latitude and continental position, or that reflect overriding substrate/ aquatic conditions.
L3 – Formation	Combinations of dominant and diagnostic growth forms that reflect global macroclimatic factors as modified by altitude, seasonality of precipitation, substrates, and hydrologic conditions.
Middle	Floristics and physiognomy play predominant roles.
L4 – Division	Combinations of dominant and diagnostic growth forms and a broad set of diagnostic plant species that reflect biogeographic differences in composition and continental differences in mesoclimate, geology, substrates, hydrology, and disturbances regimes.
L5 – Macrogroup	Combinations of moderate sets of diagnostic plant species and diagnostic growth forms that reflect biogeographic differences in composition and subcontinental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbances regimes.
L6 – Group	Combinations of relatively narrow sets of diagnostic plant species (including dominants and co-dominants), broadly similar composition, and diagnostic growth forms that reflect regional mesoclimate, geology, substrate, hydrology, and disturbance regimes.
Lower	Floristics plays a predominant role.
L7 – Alliance	Diagnostic species, including some from the dominant growth form or layer, and moderately similar composition that reflect regional to subregional climate, substrates, hydrology, moisture/ nutrient factors, and disturbance regimes.
L8 – Association	Diagnostic species, usually from multiple growth forms or layers, and more narrowly similar composition that reflect topo-edaphic climate, substrates, hydrology, and disturbance regimes.

Table 3.4. Hierarchy for natural vegetation with example (from FGDC 2008)

Hierarchy for Natural Vegetation	
Upper Levels	
1 – Formation Class	Scientific Name: Mesomorphic Shrub and Herb Vegetation Colloquial Name: Shrubland and Grassland
2 – Formation Subclass	Scientific Name: Temperate and Boreal Shrub and Herb Vegetation Colloquial Name: Temperate and Boreal Shrubland and Grassland
3 – Formation	Scientific Name: Temperate Shrub and Herb Vegetation Colloquial Name: Temperate Shrubland and Grassland
Mid Levels	
4 – Division	Scientific Name: ***Andropogon – Stipa – Bouteloua*** Grassland and Shrubland Division Colloquial Name: North American Great Plains Grassland and Shrubland
5 – Macrogroup	Scientific Name: ***Andropogon gerardii – Schizachyrium scoparium – Sorghastrum nutans*** Grassland and Shrubland Macrogroup Colloquial Name: Great Plains Tall Grassland and Shrubland
6 – Group	Scientific Name: ***Andropogron gerardii – Sporobolus heterolepis*** Grassland Group Colloquial Name: Great Plains Mesic Tallgrass Prairie
Lower Levels	
7 – Alliance	Scientific Name: ***Andropogon gerardii – (Calamagrostis canadensis – Panicum virgatum)*** Herbaceous Alliance Colloquial Name: Wet-mesic Tallgrass Prairie
8 – Association	Scientific Name: ***Andropogon gerardii – Panicum virgatum – Helianthus grosseserratus*** Herbaceous Vegetation Colloquial Name: Central Wet-mesic Tallgrass Prairie

The floristic levels of the classification hierarchy require more detailed field plot data to characterize the composition, structure, and cover of the vegetation. An example of the hierarchy for a grassland type is shown in Table 3.4. As identified by FGDC (2008), the initial NVC types are the current set of provisional NVC alliances and associations for natural vegetation (FGDC 1997), upper-level types developed by the Hierarchy Revision Working Group (Faber-Langendoen et al. 2009), and cultural vegetation types developed by USDA NRCS (2003). The original list of plant communities published by TNC, in conjunction with the Natural Heritage Network (Anderson et al. 1998), provided a comprehensive compilation of literature and field observations for each community. This list is now maintained by NatureServe. To date, the number of NVC nationally described associations is 5,516 (NatureServe 2008). Data to define new vegetation types must be archived and publicly accessible (Jennings et al. 2009). The ESA Panel on Vegetation Classification maintains VegBank as a repository to facilitate archiving, discovering, viewing, citing, and disseminating plot data (Duke et al. 2006), and the archive meets FGDC-recognized standards (Jennings et al. 2009). FGDC (2008) states that a vegetation classification system is not synonymous with a map legend. Tart et al. (2005) state that vegetation classification must be done first to identify the entities to be mapped.

Several projects have attempted to use Version 1 of the NVC to map vegetation (Comer et al. 2003). The USGS National Gap Analysis Program (GAP) is a first attempt to map existing rangeland vegetation of the nation using floristically defined classes and a common vegetation classification system. State GAP projects attempt to map existing vegetation at the alliance level of the NVCS using Thematic Mapper imagery and ancillary data with a per-class accuracy of 80 percent or greater (Fig. 3.2). The USGS/NPS Vegetation Mapping Program is using manual interpretation of aerial photography to map vegetation of National Parks at the alliance and association levels of the NVCS with a classification accuracy goal of 80 percent for each map class. However, attempts to attain the desired classification categories and accuracy have proven difficult. Mapping at the alliance level includes challenges such as not all alliances occur in large and distinctive patches, many alliances comingle in small areas, and some alliances remain indistinguishable using remotely sensed imagery (Comer et al. 2003). Mapping projects have often used a broader classification such as ecological systems (Comer et al. 2003) and associated the alliance information with the mapping unit.

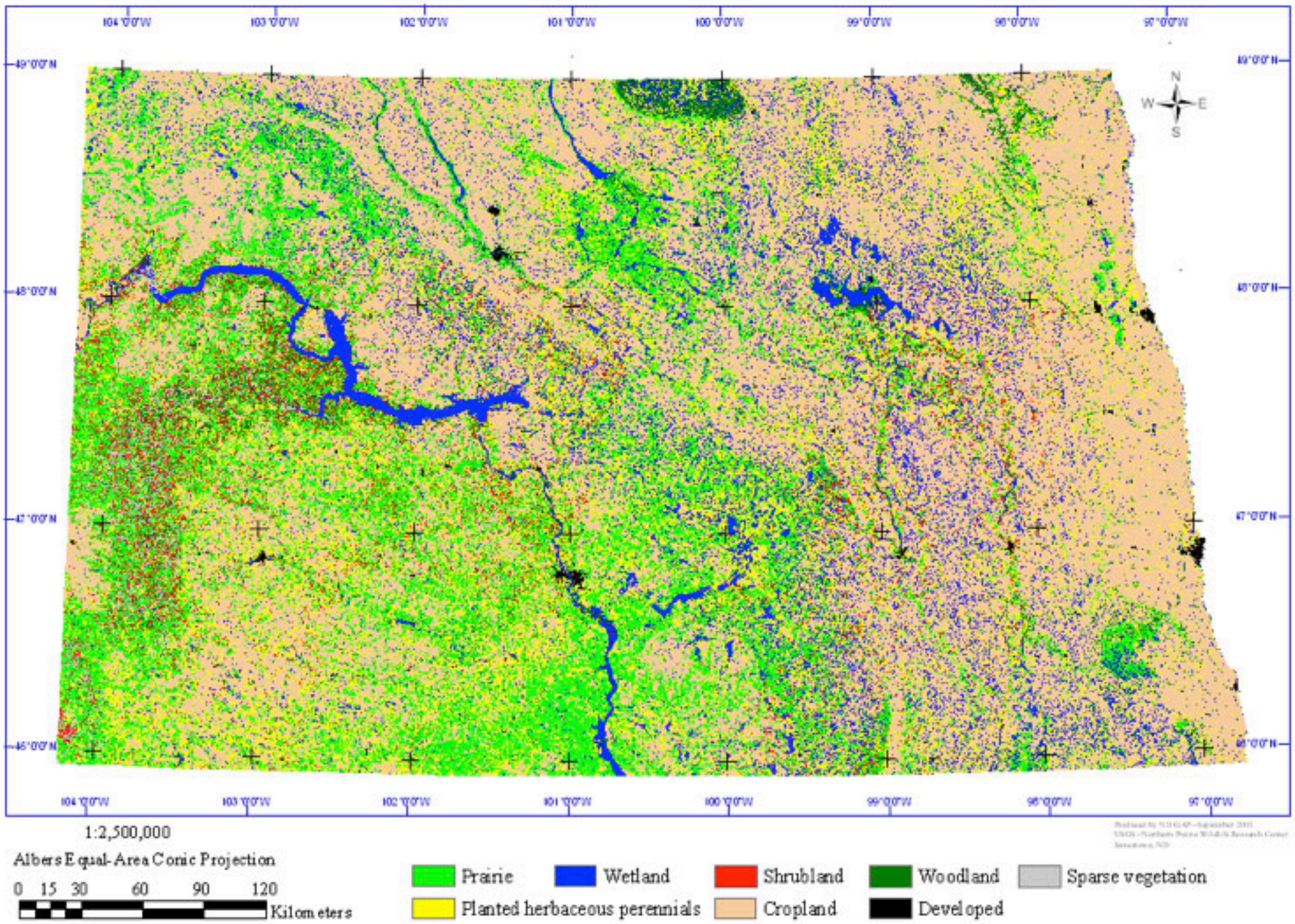

Figure 3.2. North Dakota Gap Analysis land cover map, circa 1997. Eight general land cover categories at the upper level of the land cover classification system (Strong et al. 2005).

The NVC describes existing vegetation. Historically, vegetation management on rangeland has depended upon ecological sites or similar potential-based land classification systems to provide information on the ecological integrity of the management unit (Brown and Bestelmeyer 2008; Bestelmeyer et al. 2009). The National Vegetation Classification emphasizes vegetation traits, whereas ecological sites bring in the additional influential factors associated with climate, geomorphic setting, and soils. For example, an NRCS Ecological Site, as defined in Boltz and Peacock (2002), is the product of all environmental factors responsible for its development. As such, an NRCS Ecological Site description attempts to incorporate the effects of soils, hydrology, herbivory, and disturbance regime on vegetation community (Ecological Site Information System, USDA NRCS 2010b). Soil series and slope are the primary variables for determining, correlating, and differentiating NRCS Ecological Sites. Brown and Bestelmeyer (2008) describe the many challenges that face the ongoing and future development and application of ecological sites including the influence of invasive species and climate change on individual ecological site dynamics and the possibility that interactions among individual plant communities in a landscape context may be just as important as the interactions of species within the plant community. Further, given the widening interest in ecological sites, assumptions underlying ecological site behavior associated with livestock grazing may no longer be valid or may be too limited to meet the increasing diversity of users (foresters, wildlife biologists, hydrologists). Opportunities may be present as scientists and managers refine current thinking on ecological sites to capitalize on the data collection and classification standards outlined in the National Vegetation Classification. The challenge within the rangeland community will be to merge these efforts so that there is the capacity and capability to compare vegetation data across temporal and spatial scales and to describe our understanding of plant communities and landscapes so that this information forms the platform for policy and management decisions.

Clarity to Stakeholders

While detailed understanding of this criterion by the public is questionable, use of the National Vegetation Classification has been attempted by many groups interested in rangeland conservation, such as the state GAP projects and The Nature Conservancy. The ESA Panel on Vegetation Classification efforts to establish descriptions for alliance and the VegBank database have also broadened the awareness of these approaches to vegetation classification. Although rangeland management has focused on ecological site, it may be that the public may have more of an awareness of existing vegetation and concern for changes in existing plant species and communities over time.

Number and Extent of Wetlands

Description and Importance of the Indicator

The indicator relates to abundance of wetlands in the rangeland landscape. Wetlands for this indicator include depression (e.g., prairie potholes and playas) and slope wetlands but do not include riverine or floodplain wetlands that are covered under the "Extent and Condition of Riparian Systems" indicator. Wetlands are transitional lands between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water. We have defined "wetland" as having one or more of the following three attributes: 1) the land at least periodically supports predominately hydrophytes, 2) the substrate is predominately undrained hydric soil, and 3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin et al. 1979).

This indicator measures the number and total area of wetlands within all or portions of the rangeland system. The metric may be either a) numbers of individually identifiable wetlands and acreage for a particular region, or for the entire rangeland region, or b) numbers and percent of landscape occupied by wetlands. Most wetlands occurring on rangeland will fall into the riverine, lacustrine (subsystem Littoral), or palustrine systems. They can be further described by class and subclass as well as by modifier for dominance type (vegetation), water regime, water chemistry, and soil (order or suborder as well as hydric criteria). Within the Cowardin et al. (1979) classification system, riverine systems are distinguished from riparian areas—the riverine system is bounded by the channel or stream bank while riparian areas typically begin at the stream bank. Within this criterion, riparian condition and extent are treated as a separate indicator (see discussion in "Extent and Condition of Riparian Systems").

Wetlands are a unique feature of rangeland in which maintenance of biodiversity requires connection among many wetlands as well as linkages to neighboring uplands. Reduction of wetland areas, often a consequence of hydrological or land-use changes, reduces the potential for sustaining the diverse assemblage of rangeland organisms that depend on wetlands for all or part of their life cycles. Wetlands also offer feeding sites for migratory waterfowl and other species, a connection that may be used for evaluating functionality of wetlands. Wetlands also function as buffers or filters of runoff, helping to maintain water quality in aquatic systems.

Geographic Variation

This indicator can be measured at a local, state, or regional scale. The presence of wetlands is connected directly to the hydrogeomorphic characteristics of the regional landscape. For example, prairie pothole wetlands, which are depressional, are found primarily in the region of the Dakotas. Vernal pool wetlands, also depressional, occur within portions of California (and other areas in the United States). Playas and mineral soil flats are found in the arid Southwest, and coastal wetlands and estuarine fringe wetlands are found along low oceanic coast lines. Recognition of these regional and hydrogeomorphic differences can be included in presentation of the indicator.

A wetland indicator can also be developed relative to the different climatic regimes often associated with different regions of the country's rangeland. If response to changing climate is an important factor in rangeland sustainability, wetlands may be more sensitive to changes in many hydrological components of climate than other indicators. The timing of a wetland inventory is important so that the data can be placed in the context of seasonal distribution of precipitation as it normally occurs and in the context of the natural variability of climate.

Changes in wetlands area can be associated with regional hydrogeomorphic characteristics and regional climate. For example, wetland areas in the Southwest and in the Southern Great Plains are closely tied to changes in water availability (e.g., groundwater depletion, water diversion), whereas in other regions, such as the Northern Great Plains, natural hydrologic variability strongly influences changes in wetland area. Human activities alter wetlands on some scale in most regions.

Scale in Time and Space

The spatial scale of wetlands ranges from tens of meters to several kilometers. If wetland delineation is done on an individual wetland basis, the data can be scaled up to any spatial scale desired, whereas wetland identification done by satellite on a regional basis may not be able to be scaled down to a local level. Changes in wetland numbers and areas can occur in decadal or smaller time frames, time frames sufficiently short to allow measurements to be used for management purposes.

Data Collection and Availability

The data for this indicator are best represented by A (Table 3.1, Appendix 1-E). Methods and procedures exist at the regional-national level for data collecting and reporting, and data sets of useable quality exist at the regional-national level. The data set being developed by the FWS under its National Wetlands Inventory (NWI) Program may be the most comprehensive and applicable to the Sustainable Rangelands project (FWS 2010a).

In 1982, the NWI produced its first estimate of the status of the nation's wetlands and wetland losses. The Emergency Wetlands Resources Act of 1986 (Public Law 99-645, 100 Stat. 3582) required the FWS to complete mapping of wetlands in the contiguous United States and, as soon as practicable, maps of Alaska and other noncontiguous portions of the United States and produce, by September 30, 1990, and at 10-year intervals thereafter, reports to update and improve in the 1982 "Status and Trends of Wetlands and Deepwater Habitat in the Coterminous United States, 1950s to 1970s." The NWI Program has focused on map or digital databases of wetlands and reporting on national wetland trends using a probability-based sampling design.

Using data from 3,635 four-square mile plots, the National Wetland Status and Trends Study analyzes the trends of major wetland types (Tiner 2009). Updates on status and trends of wetlands were produced in 1990 (Dahl and Johnson 1991), 2000 (Dahl 2000), and 2006 (Dahl 2006). For each plot, aerial imagery is interpreted and annotated in accordance with procedures published by the FWS. The results are compared with previous era imagery, and any changes are recorded. The differences between the data sets are analyzed, and a statistical estimate of the change is produced.

One hundred percent coverage for wetland mapping by the FWS does not exist (Tiner 2009), but the mapping continues and eventually all rangeland areas will be covered. It is unknown whether remapping will occur on a regular basis to allow for comparisons of changing wetland coverage. To date NWI, maintained by the National Wetlands Inventory Center, has mapped 90 percent of the lower 48 states and 34 percent of Alaska. About 60 percent of the lower 48 states and 27 percent of Alaska are digitized. Examples of the protocols used are presented in Dahl and Bergeson (2009). Online mapping capability is available on its website (FWS 2010b). The Federal Geographic Data Committee (FGDC Wetlands Subcommittee 2009) recently adopted the techniques used by the NWI as the federal wetland mapping standard, thus insuring that all federally funded wetland mapping can be added to the NWI's wetlands master geospatial database (Tiner 2009).

Baseline, or reference, conditions published in "Status and Trends of Wetlands in the Conterminous United States 1998-2004" (Dahl 2006) may be useful for future evaluation of wetland changes (Fig. 3.3). The report provides the most recent and comprehensive estimates of the current status and trends of wetlands in the 48 conterminous United States on public and private lands. Ninety-five percent of the nation's wetlands are freshwater; this number includes upland wetlands associated with rangelands. A major finding of the report is that the nation's estimated wetlands showed a 0.2 percent increase in freshwater wetlands between 1998 and 2004 compared to a continued declining wetland loss in the prior decade. Urban and rural development account for most recent freshwater wetland losses, while agricultural lands and rangelands experienced wetlands gains, in part through management or modification of shrublands and prairies (Dahl 2006).

The NRCS NRI also inventories wetlands using a statistically based sample of land use and natural resource conditions and trends on U.S. non-federal lands (USDA NRCS 2010a). Analyses of the inventory results over time provide data on land use, soil erosion and soil quality, water quality, wetlands, and other issues regarding the conservation and use of natural resources (USDA NRCS, not dated). See Table 3.5 for NRI information that can be found online.

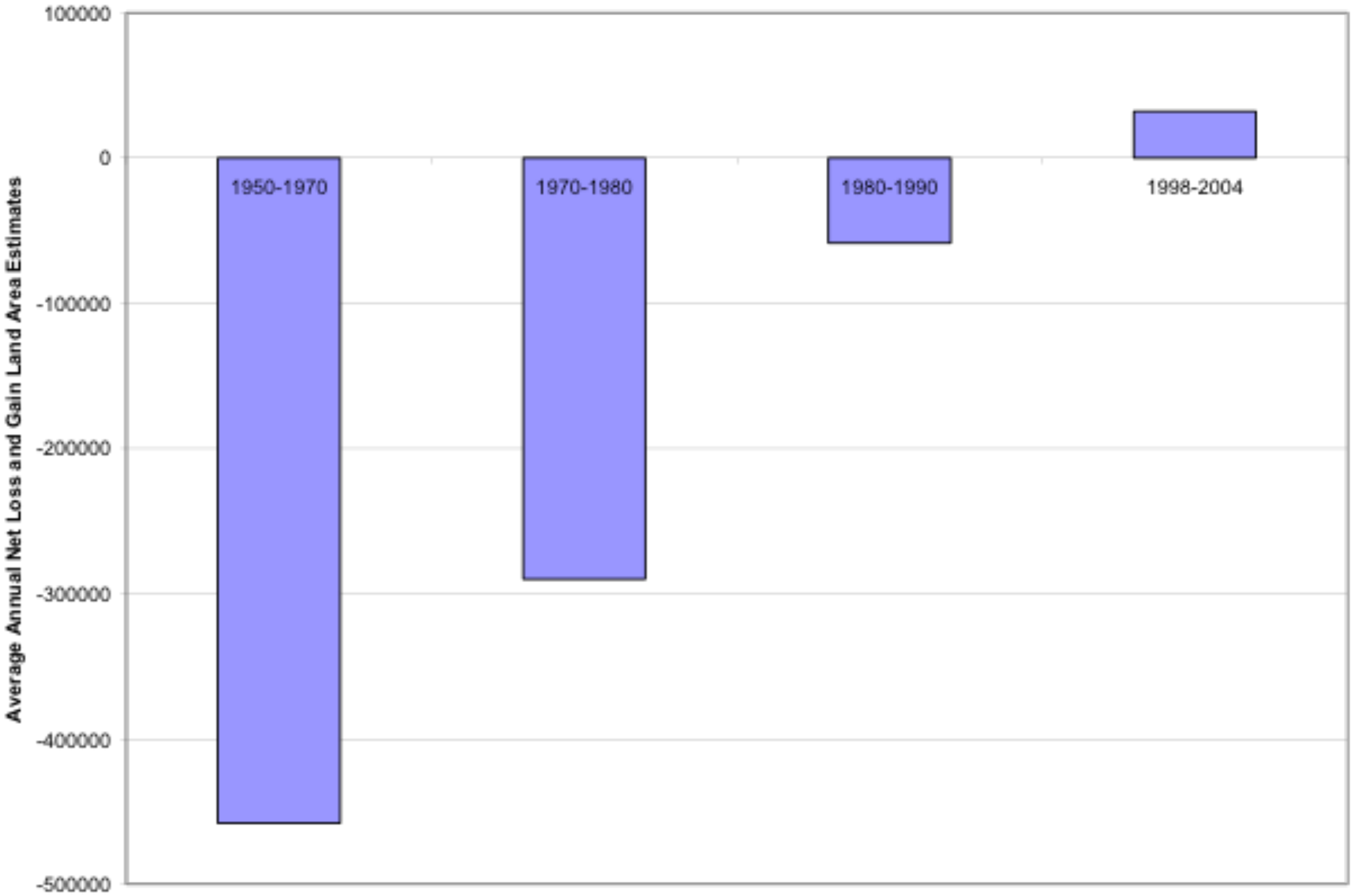

Figure 3.3. Average annual net loss and gain estimates for the conterminous United States, 1954-2004. These data, taken from Dahl (2006), indicate that wetland area gains were achieved through restoration and creation. The Dahl (2006) report does not draw conclusions regarding trends in the quality of the nation's wetlands.

Table 3.5. Online resources from the National Resources Inventory.

Data Resources	http://www.nrcs.usda.gov/technical/dataresources/ Links to NRCS base map coverages, status maps, the NRI database, and databases on soil, water and climate, plants for conservation, and other subjects. This site is a node of the National Spatial Data Infrastructure.
NRCS Geospatial Data Gateway	http://datagateway.nrcs.usda.gov/data.html Provides natural resources or environmental data at anytime, from anywhere, to anyone. Data themes listed on the Gateway Data Management page include orthoimagery, soils, cultural, and demographics (census tract boundaries, census of population and housing, census of agriculture, economic census), governmental units and place names, elevation, hydrography, cadastral, transportation (roads), Digital Raster Graphic (DRG) Scanned USGS quads, land cover/vegetation/plants, watershed boundaries (10-12 digit hydrologic units), wetlands, wetland and floodplain easements, climate (precipitation and temperature), and flood hazards
Imagery	*Aerial Photography*: http://www.apfo.usda.gov/ *Orthoimagery*: http://www.ndop.gov/index.html The NRCS participates in the National Digital Orthophoto Program, which serves as a focal point for accessing aerial and orthophoto imagery.

Although the NRI coverage does not include federal lands (USDA NRCS 2010a), the data may be sufficiently focused on those lands where land-use change is most likely to allow interpretation of wetland change, especially when those data are combined with NWI information. Within the NRI, wetlands are present as an attribute that may occur on all other land cover/use categories, so the data can be queried by land cover/use (e.g., rangeland) for wetland estimates by any category. Each NRI sample point has multiple attributes (soil map unit component, soil descriptions, land cover/use, wetland type, etc.) associated with it for many kinds of analyses. Additionally, state, administrative region, ecoregion, and other geographically defined areas of interest can be used to summarize data within the NRI. An additional advantage is that since 1997 the NRI has gone to an annualized inventory, with annual reports beginning with a summary report in 1997 (revised in 2000). The NRCS has made maps of the area of non-federal wetlands in 1992 and 1997 available on the web (USDA NRCS 2010c)).

Flather et al. (1999) analyzed wetland trends from 1982 to 1992 using the NRI data and found a decline (70 percent) in the rate of wetland loss between the mid-1970s and mid-1980s similar to the 2000 FWS report (Dahl 2000). Zedler and Kercher (2005) evaluating wetland status, trends, and ecosystems services found similar changes. During the 1982-1992 period, the primary cause of wetland conversion on non-federal lands was urban development. Data from the 2006 FWS report (Dahl 2006) show similar losses to urban development. However, this report indicates an overall gain of 0.2 percent in freshwater wetlands in the 1980-2004 period.

The indicator can be monitored with existing remote sensing capabilities (see NWI above). These monitoring data are repeatable and can be collected over time to present a picture of changing abundance of wetlands in the rangeland landscape. If NWI was to be repeated periodically and compared with NRI data, a more complete picture of changing wetland abundance may emerge. The probability-based sampling design allows for calculation of errors associated with each measurement in time. Tiner (1997) points out that wetlands can be missed when using remote sensing because wetlands with similar spectral signatures as non-wetlands might not be identified as separate from the surrounding vegetation. Accuracy of NWI is based on how much of the area is ground-truthed (e.g., Kudray and Gale 2000).

The FGDC in 1996 passed standards for classification of wetlands and deepwater habitats of the United States (FGDC Wetlands Subcommittee 2009). These standards provide specific ecological and hydrological information for the identification, classification, and mapping of wetlands in the United States and its territories. Adoption of these FGDC standards will not change the current status of NWI maps produced by the FWS.

Clarity to Stakeholders

Stakeholders understand what wetlands are and that wetlands in the rangeland landscape have been greatly reduced in the 20th century. Consequently, an indicator that simply presents the number and total area of wetland for selected spatial scales (e.g., regions or states) will be understandable to stakeholders and the public. Data from the FWS NWI and from the NRCS NRI are also readily available to stakeholders and the public over the Internet. NatureServe Explorer (http://www.natureserve.org/explorer/. Accessed 20 April 2011) provides users with the ability to search for wetland communities within other plant communities.

Fragmentation of Rangeland and Rangeland Plant Communities

Description and Importance of the Indicator

This indicator is defined as the breaking up or loss of connectivity of rangeland or of a rangeland cover type. A cover type is a category within a classification scheme that distinguishes among the different habitats, ecosystems, or vegetation types on a landscape (see discussion above of "Area of Rangeland by Plant Community" indicator). While designation of a patch is subjective (McGarigal and Marks 1995), a patch is usually a discrete scale-dependent entity of interest (such as a cover type) used to categorize landscape heterogeneity (Pickett and Cadenasso 1995). Landscapes are characteristically a mosaic of heterogeneous patches, and this is true of rangeland (Senft et al. 1987; Belsky 1989; Coughenour 1991; Friedl 1994; Washington-Allen et al. 2008). For our purposes, a patch or cover type has both regional and national spatial extents delineated both by total rangeland area and rangeland plant communities. Using such information, fragmentation has been observed in rangelands over time (Fig. 3.4).

Fragmentation has been shown to impact plant and animal species and ecosystem function in western ecosystems. For example, in one of the first applications of diversity metrics at the landscape scale, Romme and Knight (1982) demonstrated the impacts of fire patch dynamics on different forest stand ages and associated bird species. While fragmentation studies have a long history in forested ecosystems, recent research has also described fragmentation as an interruptive process affecting the sustainability of rangeland ecosystems (Ludwig and Tongway 1995; De Soyza et al. 2000; Flather and Sieg 2000; Wu et al. 2000; Washington-Allen 2003; Peters et al. 2006; Rietkerk et al. 2004; Ludwig et al. 2007; Hobbs et al. 2008; Okin et al. 2009; Ravi et al. 2009). Fragmentation of community types is particularly critical for wildlife and some plant populations; sufficient habitat and niche size is required to sustain breeding, rearing, feeding, and shelter needs (e.g., Romme and Knight 1982). In addition, fragmentation, and thus loss of connectivity, can also affect the maintenance of ecosystem processes, in particular fire regimes and hydrological and biogeochemical processes (Romme and Knight 1982; Wu et al. 2000; Peters et al. 2006; Rietkerk et al. 2004; Okin et al. 2009; Ravi et al. 2009). Fragmentation measures the size of contiguous areas, spatial organization, and community type dispersion. These factors are important descriptors in terms of grazing use, habitat and niche, and ecosystem services. Recently, fragmentation of rangeland ecosystems has been shown to impact the social and economic systems associated with those arid and semiarid lands (Galvin et al. 2008; Hobbs et al. 2008).

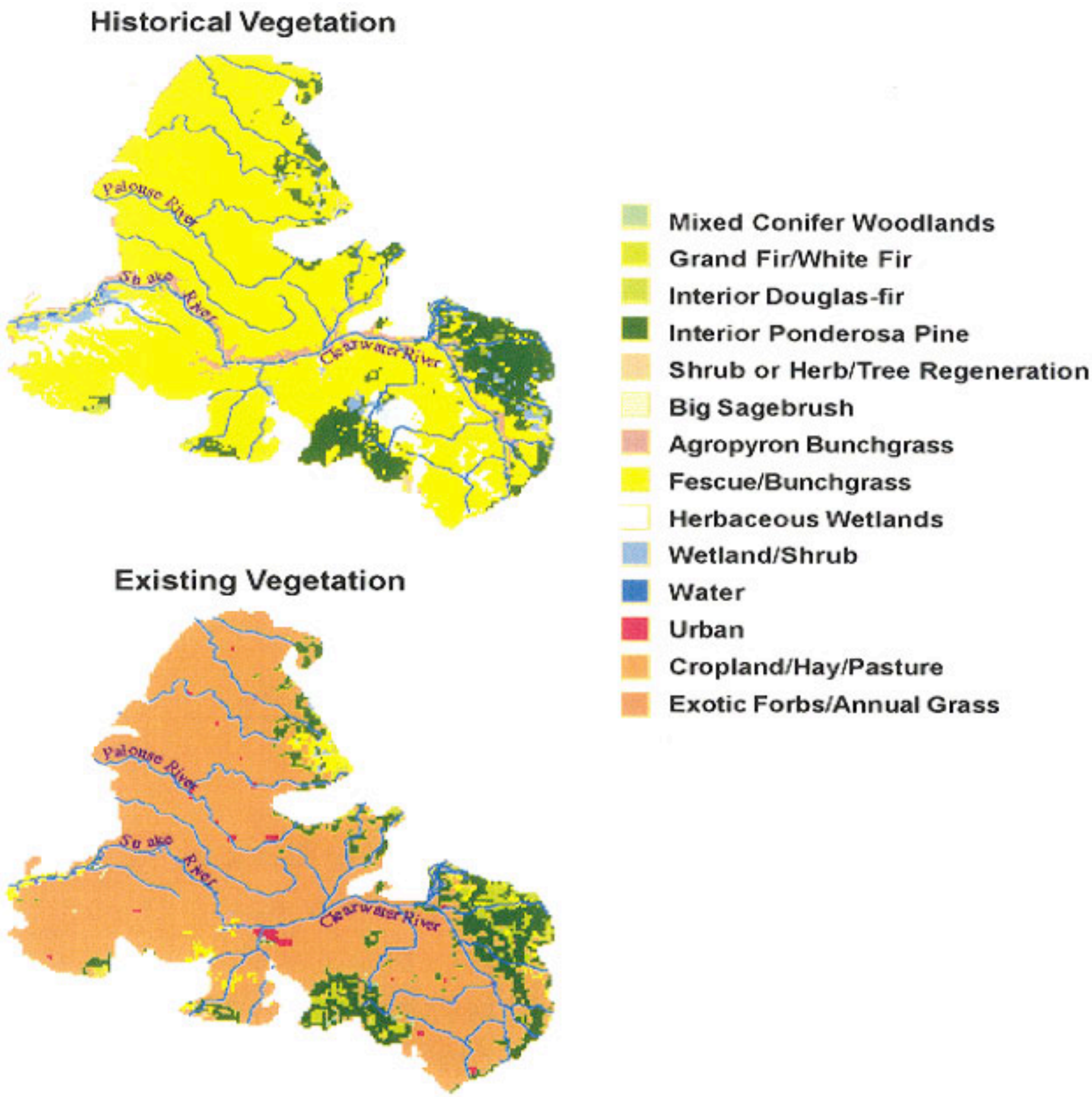

Figure 3.4. Fragmentation in rangeland vegetation communities. Palouse Prairie historical vegetation cover (circa 1900) and existing vegetation (circa 1990). Source: Quigley and Arbelbide 1997; Black et al. 1998.

Geographic Variation

The indicator would be meaningful in different regions. The changes in this indicator are nested within the total rangeland area of a region (see "Extent of Land Area in Rangeland" indicator) and within plant communities in the region (see "Area of Rangeland by Plant Community" indicator). The geographic extent may or may not change with loss or extinction of patches if the plant community shifts to another rangeland plant community. For example, ecological responses to abiotic or biotic changes at the local spatial scale, such as a shift to another plant community due to plant invasions, may not be apparent at the landscape scale where the total rangeland areal extent may not have been altered. However, at the local scale, fragmentation may have occurred. Thus, it is meaningful to speak of fragmentation of total rangeland area of a region and also fragmentation of particular plant communities.

Scale in Time and Space

Fragmentation has the capability of capturing spatial heterogeneity at varying spatial and temporal scales because it can be viewed hierarchically (Pickett and Cadenasso 1995). Fragmentation is a scale-dependent phenomena. For example, Washington-Allen (2003), Peters et al. (2006), Okin et al. (2009), and Ravi et al. (2009) demonstrated the effects that climate change, wind and water erosion, fire, and grazing have and could have on increasing bare ground patch connectivity, which can lead to loss of vegetation patch self-organization and increased dispersal across the landscape. Further, Fuhlendorf et al. (2002) demonstrated the importance of evaluating multiple scales (extents) when investigating relationships between landscapes and wildlife populations. They also demonstrated that changes in landscape structure over several decades influenced the lesser prairie-chicken, more so than the current landscape structure. They suggest that species exhibiting high site fidelity may show a lagged response to changes in landscape structure when compared to species that do not exhibit site fidelity. Scale in time and space are important considerations when exploring the impacts of fragmentation on rangeland.

Data Collection and Availability

The data currently available for this indicator are best represented by C (Table 3.1, Appendix 1-E). Some data set(s) exist at the regional-national level, but methods and procedures are not standardized at the regional-national level. Data sources for the analysis of fragmentation include federal agency repositories such as USGS (satellite imagery, digital elevation models, GAP analysis map data layers of land ownership, vegetation, and species distribution, and the NLCD), the Forest Service (LANDFIRE land cover map derived from 30-m Landsat data and associated 200,000 or more rangeland field data plots), the U.S. Environmental Protection Agency (EPA), and U.S. Census Bureau. Rangeland and rangeland community data sets identified in the "Extent of Land Area in Rangeland" and "Area of Rangeland by Plant Community" indicator sections could be used to calculate fragmentation matrices for rangeland.

In order to quantify fragmentation, metrics have been developed that identify the kinds of patches (e.g., cover type) and measure the size and area occupied, density, shape, connectivity, dispersion or clumping, number of patches, and the distance between patches (McGarigal and Marks 1995; Wu et al. 2000; Turner et al. 2001; Washington-Allen 2003). These metrics either directly analyze digital data or thematically/categorically classified digital data in one of two formats – raster or vector. Direct analysis have used such methods as lacunarity analysis (Wu et al. 2000) or Fourier analysis (Ares et al. 2003) with high resolution aerial photography and satellite imagery (1-m pixel resolution) including activity radar. The thematic data are usually imported to a spatial analysis program such as FRAGSTATS (McGarigal and Marks 1995). Table 3.6 lists indicators that have been used to measure fragmentation. Mean nearest neighbor is the distance (in meters) to the edge of the nearest neighboring patch of the same type. A small nearest neighbor standard deviation (NNSD) relative to the mean implies a homogenous distribution of patches across landscapes, whereas a large NNSD relative to the mean indicates a more heterogeneous distribution of patches (McGarigal and Marks 1995). Contagion measures the probability that two randomly chosen adjacent raster cells belong to different classes. Interspersion and Juxtaposition (IJI) is a measure of interspersion that is somewhat different from contagion because it measures individual patch types, and contagion measures individual pixels. IJI measures the juxtaposition of a focal patch type from all other types at the landscape and individual class type scales. IJI ranges from 0 to 100 percent with low values indicating low interspersion and high values indicating high interspersion or even distribution throughout a landscape (McGarigal and Marks 1995).

The Heinz Center (Heinz 2008) used the NLCD 2001 to aggregate selected cover types into a grassland-shrubland category. This analysis compared changes in grassland-shrubland core patch size between the West Coast, Southwest, and Rocky Mountain regions in the conterminous U.S. Core grassland or shrubland are patches of 0.1 ha that are surrounded by greater than 90-percent grassland or shrubland and other natural cover types. Heinz (2008) found that 22 percent of core shrubland was in patches of greater than 259 km^2 (or 100 square miles) compared to core grassland (13 percent within such patches). The West Coast, Southwest, and Rocky Mountain regions were dominated mostly by shrubland patches greater than 259 km^2 in size.

Another example of the use of such data to explore the impact of fragmentation on rangelands is the Rural Land Fragmentation Project in Texas. This study examined the status and recent changes in ownership size, land use, and property values of private farms, ranches, and forest lands in Texas (Wilkins et al. 2003). Data were from the U.S. Census Bureau, the USDA NRI, and the Bureau of Economic Analysis' Regional Economic Information System. Base maps of Texas were obtained from the Texas Natural Resources Information System. Changes in the size of the operation (e.g., ranch, farm) indicated that the amount of land in mid-size farms and ranches (500 to 2,000 acres) declined and resulted in mid-sized ownerships being fragmented into smaller ownerships. They suggested that over the next two decades, land in the south, central, and east-central portions of Texas would become increasingly fragmented, in contrast to trends suggesting that ownerships on the High Plains would increase in size. Coincident with these changes in ownership size were changes in native vegetation. Areas remaining in large ranches were more likely to stay in native vegetation, in contrast to smaller operations where conversions to non-native pastures was more likely. They noted that the ecological region strongly influenced these trends. They concluded that not only is native rangeland lost through conversion to improved pastures, but that the remaining native rangeland habitats are fragmented into increasing smaller patches as fragmentation progresses. The 2005 Land and Water Conservation plan (Texas Parks and Wildlife Department 2005) measured fragmentation by examining the division of single ownership parcels over time (Fig. 3.5). This index was combined with the percent of land converted to urban uses, population growth, and other metrics to assess the growing demand on land and water resources.

Table 3.6. The landscape metrics from the spatial analysis program FRAGSTATS (McGarigal and Marks 1995) that can be used to quantify landscape fragmentation.

Metric	Measure
Nearest Neighbor (meter)	Distance to nearest neighbor patch edge
Nearest Neighbor Standard Deviation	Dispersion of patches
Patch Number (PN)	Number of patches in landscape or the number of patches per class
Mean Patch Size (MPS)	Mean area of patches in landscape or the mean area of patches per class
Contagion (%)	Clumping, adjacency, and dispersion of pixels
Interspersion and Juxtaposition (IJI, %)	Interspersion and adjacency of patches

Flather and Sieg (2000) described the need to refine the use of remotely sensed satellite imagery to quantify fragmentation on rangeland and to identify the specific agents of fragmentation, such as intensive land uses, roads, and concentrations of exotic species. Such work is still needed. Thayn et al. (2008) establish that spatial pattern metrics are better predictors of rangeland stocking rates than spectral diversity metrics for Kansas grasslands. Ludwig et al. (2007) establish the link between landscape structure and function and the potential for landscapes to lose, or "leak," soil sediments. Such research establishes the potential for a new index for monitoring the health of rangelands using remotely sensed information. Hobbs et al. (2008) explore the ways in which humans contribute to fragmentation of rangelands, such as through fencing and potential adaptations that can mitigate harmful outcomes.

Clarity to Stakeholders

The public has been informed of the general subjects of habitat loss and species extinction and is more likely to associate the concept of fragmentation with forested habitat and the consequences of timber harvesting and land-use change on forested habitat. However, recent research (e.g., Galvin et al. 2008) and the widely accessible Heinz report (Heinz 2008) have quantified and demonstrated the implications of fragmentation in rangelands. Further, public support for the establishment of public lands and private conservation reserves indicate an understanding of the importance of rangeland habitat. The use of many easily calculated metrics could confuse the concept of fragmentation. Thus, it will be important to use metrics of fragmentation where they convey additional ecological information about underlying processes.

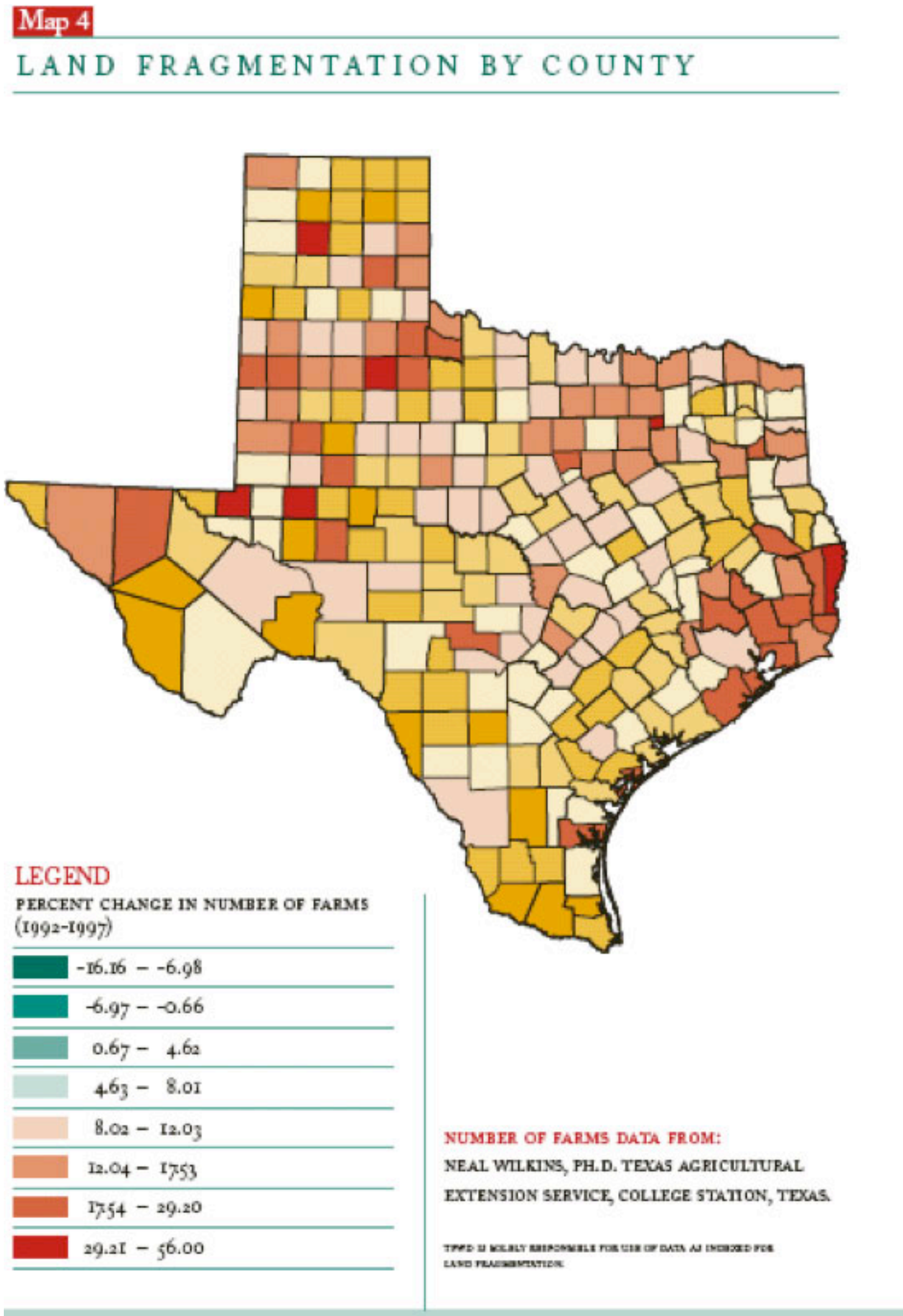

Figure 3.5. Fragmentation map by county of Texas where fragmentation was estimated by the change in the number of ranches over time, division of single parcel into one or more parcels (Texas Parks and Wildlife Department 2005).

Intensity of Human Uses on Rangeland

Description and Importance of the Indicator

This indicator provides a surrogate measure of intensive human uses of rangeland through the use of road density measures and housing densities. Many intensive uses of rangeland are often not represented in land cover maps because of their small individual spatial extents. Examples of these types of land uses of rangeland include low-density rural housing developments, power lines, off-road vehicle (ORV) uses, mines, and oil and gas wells, along with their associated transportation infrastructure. Although these activities have small individual spatial extents, their ecological impacts at both local and landscape scales and their cumulative impacts can be significant (Theobald et al. 1997; Forman and Alexander 1998; Leu et al. 2008). Recent examples of the use of road and housing density measures to examine land-use dynamics include those by Imhoff et al. (2000), Theobald (2001, 2003), Sanderson et al. (2002), Imhoff et al. (2004), Dale et al. (2006), and Radeloff et al. (2010).

The processes of land-use change are reasonably well understood and flow predictably from population growth, household formation, and economic development (Heimlich and Anderson 2001; Leu et al. 2008). Pressures on the interface between rural and urban landscapes are expected to increase from both rural and urban populations (Brown et al. 2005; Hansen et al. 2005; Theobald and Romme 2007). New technology lowers the cost of communication and transportation, resulting in higher land prices farther out into rural areas. As access to urban centers through communication and transportation technology increases, the development value of rural land exceeds the value for agricultural purposes. To adapt to rising land values and increasing contact with new residents, traditional rangeland users may change their operations to fit an urbanizing environment. This may include selling properties for development purposes or discontinuing their activity.

The potential ecological impacts of intensive human uses of rangeland include loss and fragmentation of rangeland, rangeland plant communities, and open space (Theobald et al. 1997), reduced primary and secondary productivity and biodiversity (Forman and Alexander 1998; Imhoff et al. 2004), increased soil disturbance and susceptibility to wind and water erosion (Iverson et al. 1981), disruption of material flows and ecological processes in the landscape (e.g., groundwater flow), fire spread (Forman and Alexander 1998), and enhanced opportunities for successful establishment of invasive plants and animals. The ecological impacts of intensive human uses of rangeland extend beyond the footprints of the land uses and vary with the spatial location and pattern of the intensive land uses (e.g., Leu et al. 2008).

Geographic Variation

Intensive human uses of rangeland are ubiquitous, and, thus, the indicator is meaningful in all geographic areas. Theobald (2003) examined spatial variability in "roadedness" in an assessment of the risk of habitat loss caused by development in Colorado. The proportion of the landscape impacted by roads varied widely among watersheds ranging from a low of 6.1 percent to high of 40.9 percent. The range of "roadedness" was even greater among counties. The relationship between percent roaded and the proportion of public land by county was weak. Three rangeland types, xeric upland shrub, tallgrass prairie, and foothills/mountain grasslands, were identified as threatened by forecasted development in 2020. They concluded that the "roadedness" and housing density indicators were useful for characterizing potential impacts from activities associated with human land use and for prioritizing where conservation efforts would be most effective. Sparsely populated states can be highly fragmented by roads. For examples, 90 percent of North

Dakota's land area is within 0.805 km (0.5 miles) of road, 99 percent is within 3.28 km (2 miles) of a road, and the maximum distance from a road is 4.82 km (3 miles; Fig. 3.6).

Scale in Time and Space

Interpreting "roadedness" and housing density images in the context of rangeland requires a spatially explicit map of rangeland or rangeland vegetation types. The need for such a map is discussed under the "Extent of Land Area in Rangeland" and "Area of Rangeland by Plant Community" indicator sections above and is likely needed by other criteria within the SRR as well. A "roadedness" image could be generated and intersected with a rangeland map, which would allow the amount of roads in rangeland or rangeland types to be calculated and the data aggregated by watershed, county, or other analysis units. Interpretation of the housing density image is more difficult because individual housing units are not spatially-explicit, which prevents determining if specific housing units occur within land designated as rangeland. Alternatively, the proportion of rangeland or rangeland types in different housing density classes (i.e., urban, suburban, exurban, and rural) could be tabulated and aggregated by county (Theobald 2001). Provided road and housing unit data are updated to reflect changes with time, the indicator could be used to examine trends in intensive human land uses of rangeland.

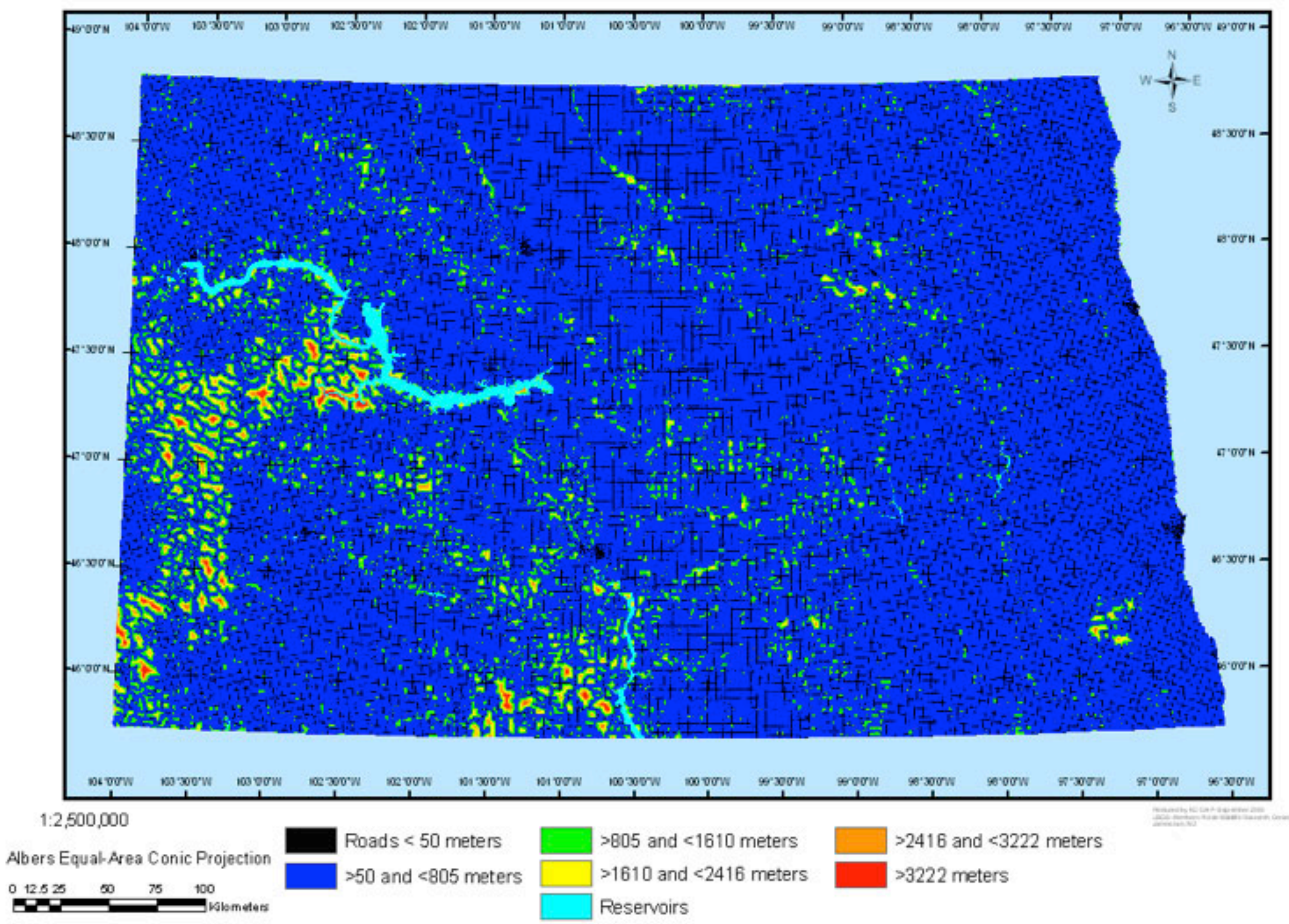

Figure 3.6. Distance from roads and trails in North Dakota. Road data from North Dakota Department of Transportation GIS Base Map Data version 1.0.

Data Collection and Availability

The data currently available for this indicator are best described by A (Table 3.1, Appendix 1-E). Methods and procedures for data collecting and reporting exist at a regional-national level, and data sets of useable quality exist at the regional-national level. This indicator would use digital road and housing data in a geographic vector model format within a GIS to calculate the density and spatial pattern of roads and housing units. Road density (km/km^2) is an overall index that averages patterns over an area. Road effects vary with road width and type, traffic density, location and spatial pattern (Forman and Alexander 1998). Because digital road data are spatially explicit, a "roadedness" image can be constructed that incorporates these factors (Davis et al. 1996; Stoms 2000). A "roadedness" image is constructed by buffering road arcs with a buffer width related to the class of road, e.g., a freeway is given a greater buffer width than an unimproved soil road.

Digital housing data are available for the nation in census block groups and blocks that are subdivisions of the familiar census tract (Theobald 2001). Although the census data are available at a relatively fine spatial grain for the nation, the location of individual houses is not spatially explicit. A housing unit density can be calculated for each polygon (block group and blocks) in the census data. Interpreting the "roadedness" and the housing density images in the context of rangeland requires a spatially explicit map of rangeland or rangeland types (see discussion of the "Extent of Land Area in Rangeland" indicator above). Roadedness, imperviousness, housing, and population density images have also each been derived from the Defense Meteorological Satellite Program (DMSP) night lights digital data (Elvidge et al. 1997; Imhoff et al. 1997; Sutton et al. 1997). The DMSP night lights time series is available from 1992 to 2003 (NGDC 2008).

The U.S. Census Bureau TIGER (Topologically Integrated Geographic Encoding and Referencing) and the National Imagery and Mapping Center databases are the most current sources of national data for roads and housing units. The USGS 1:100,000 scale Digital Line Graphs (DLG) were the initial source used to create most of the transportation lines in the TIGER database. Most of the 1:100,000 scale DLGs were constructed in the 1980s and have not been updated. The U.S. Census Bureau uses various internal and external procedures to update the TIGER database. There are issues with the completeness and location accuracy of the updated TIGER database (U.S. Census Bureau 2002). In preparation for the 2010 census, the U.S. Census Bureau and the USGS initiated discussions about the construction of spatially explicit road and structural data with 7.6 m positional accuracy (Broome and Godwin 2003). If road omissions in the TIGER database are identified as a serious problem, additional road data might be acquired from state departments of transportation, federal agencies (e.g., the USDA Forest Service), and local governments. However, the work required to prepare the road data for analysis would increase substantially. The road data do not provide information about ORV use on rangeland.

Clarity to Stakeholders

Roads and houses are common objects familiar to everyone. Consequently an indicator that presents the density of roads and houses will be understandable to stakeholders and the public.

Integrity of Natural Fire Regimes Across U.S. Rangeland

Description and Importance of the Indicator

This indicator, "Integrity of Natural Fire Regimes," spatially and temporally quantifies acres of rangeland burned annually. Analysis of this indicator requires a nationally accepted standard for reporting fire statistics. Burned acres would be identified annually by both location and season. This is necessary because frequency, intensity, seasonality, and type of fire depend on weather and climate in addition to the ecosystem structure and composition (Dale et al. 2001). Areas of both natural and prescribed (i.e., planned ignition) fires would be tracked.

Fire is a key ecological driver in many rangeland ecosystems, facilitating nutrient cycling, promoting recruitment of native grasses and forbs, and limiting encroachment of woody species. The dynamics of fire in rangeland ecosystems historically varied across the United States in terms of how frequent the fires were, the season that fires occurred, and the intensity and severity of the fires. In the desert grasslands of southwestern United States, highly variable rainfall coupled with a lack of fine fuels may have limited fire (Archer 1994). Regional climatic conditions such as the periodic meso-scale phenomena of El Niño-Southern Oscillation have been correlated with fire occurrence in the more mesic southwestern ecosystems (Swetnam and Betancourt 1990). Across the Central Great Plains, periodic fire was important for maintaining ecosystem structure and function (Engle and Bidwell 2001), and pre-European human management of fire to attract large grazers was an important component in the landscape dynamics there (Biondini et al. 1999). Fire return intervals may have varied from 7 to 30 years across the Great Plains (Brown and Sieg 1996; Perryman and Laycock 2000).

For many rangeland ecosystems, the introduction of domestic grazers, invasive species, conversion of rangeland to cropland, urbanization, fire suppression, and fragmentation of rangeland have significantly altered the natural fire regimes as well as landscape composition and structure (NRC Committee on Rangeland Classification, Board on Agriculture 1994; McPherson and Weltzin 2000; Rueth et al. 2002). Domestic livestock and wild ungulates graze a majority of both private and public rangeland in North America, altering the seasonal patterns of fine fuels availability (live and dead biomass), as well as species and physiognomic composition of vegetation on the landscape (Washington-Allen 2003). In many southwestern ecosystems with a history of frequent fire, the removal of fine fuels (grasses and forbs) by livestock and the resulting increase in bare ground caused a greatly extended fire-free interval (e.g., Savage and Swetnam 1990; Madany and West 1983).

In Texas, a combination of factors (reduced grass cover, fewer fires, a reduction in available moisture in the topsoil, and a change in rainfall patterns) over the past 100 to 200 years resulted in a shift from savanna with only scattered trees to a subtropical thorny woodland (Archer 1989). Throughout much of the Intermountain West, fire return intervals have decreased as a result of the livestock-facilitated invasion of cheatgrass. Because native sagebrush steppe communities do not have long evolutionary grazing histories of domestic livestock, do not survive the frequent fires facilitated by cheatgrass, and do not disperse effectively, the system moves toward a cheatgrass monoculture devoid of biodiversity or economic value (West and Young 2000). Indeed, the large majority of the West's arid rangelands have fire regimes that have been significantly altered from their natural patterns.

Because fire is such a dramatic disturbance, changes in its frequency or intensity results in significant changes in nutrient cycling, species richness, ecological integrity, and carbon stocks. Monitoring the integrity of fire regimes promises to significantly inform evaluations of rangeland health.

Geographic Variation

The areal extent of fire in rangeland ecosystems would be meaningful in different regions. Understanding the implications of changes in the area of rangeland annually burned will also require an understanding of the role of fire in different ecosystems. The role of fire would vary in rangeland ecosystems across the United States.

Scale in Time and Space

The areal extent of rangeland burned on an annual basis is available from a variety of sources (see below) and can be analyzed across both spatial and temporal scales. Changes in a fire regime, either in frequency or severity, can result from both natural (e.g., climate) and anthropogenic sources (e.g., grazing management, fire suppression). As a result, measures of change in a fire regime reflect important ecological changes at multiple scales ranging from sites to regions. However, changes in fire regimes must be interpreted with respect to the plant community being described and the spatial scale at which it is mapped. Past attempts to map changes in fire regimes have been spatially coarse and have not allowed for the analysis of separate, smaller community types.

Data Collection and Availability

The data currently available on acres burned are best represented by C and D (Table 3.1, Appendix 1-E). Some data set(s) exist at the regional-national level, but methods and procedures are not standardized at the regional-national level. Information on the precise location and season of fires are metrics that are conceptually feasible or initially promising, but no regional-national methods, procedures, or data sets currently exist.

Wildfire statistics are available through the National Interagency Fire Center (NIFC) at national and state levels over periods ranging from 1983 to 2009; however, fine spatial scale information on the historical fires is not available (http://www.nifc.gov/nicc/index.htm. Accessed 30 January 2010). Coarse-scale, national-level data on fire occurrence were developed for the 1986-1996 period (Schmidt et al. 2002). The national fire occurrence database includes spatial layers of federal and non-federal fire occurrences, as well as vegetation layers (Küchler vegetation as well as current vegetation). Acres of fires within rangeland types could be assessed and mapped using such a system. However, these data represent a one-time coarse-scale assessment and mapping effort funded by the USDA Forest Service and the BLM, where data from several federal agencies and state agencies were compiled to produce a geographic information database (see also Brown et al. 2002). Schmidt et al. (2002) note that there are several potential problems with the fire occurrence data set, such as missing records, duplicate fires where the same fire may have been reported on federal and on non-federal lands, approximate locations of fires where county was the finest spatial identifier, and unreported fires. The most appropriate use of such an occurrence data set, according to the authors, is in illustrating trends in fire occurrence. Bartlein et al. (2008) used the database to assess the temporal and spatial structure of wildfires across the western United States. A national standardized reporting method is needed for all jurisdictions so that fire reporting at the national level can be dependable and consistent.

LANDFIRE, also known as Landscape Fire and Resource Management Planning Tools Project, is an interagency mapping project producing nationally consistent and comprehensive maps and data of vegetation, fire, and fuels characteristics (http://www.landfire.gov/index.php. Accessed 2 February 2010). Partners include the USDA Forest Service and the USDI. The principal purposes of the LANDFIRE Project are to: 1) provide national-level, landscape-scale geospatial products to support fire and fuels management planning, 2) provide consistent fuels data to support fire planning, analysis, and budgeting to evaluate fire management alternatives, 3) provide landscape-scale, cross-boundary strategic products for fire and land management activities, 4) supplement planning and management activities, including monitoring, that require consistent vegetation data, 5) supplement strategic and tactical planning for fire operations, and 6) supplement and assist in a variety of activities such as the identification of at-risk areas due to accumulation of wildland fuel, the prioritization of national hazardous fuel reduction projects, and modeling of real-time fire behavior to support tactical decisions to ensure sufficient wildland firefighting capacity and safety . LANDFIRE has produced geospatial data products that describe existing vegetation composition and structure, potential vegetation, historical fire regimes, and fire regime condition class (FRCC). Vegetation and disturbance dynamics models are used to simulate the historical vegetation reference conditions, and FRCC is the amount that current vegetation has departed from the simulated historical vegetation reference conditions (Rollins et al. 2006, 2007). Such information may provide insights into changes in fire regimes across the U.S., particularly as the information is updated over time.

Other methods of establishing acres burned annually are being developed. For example, using data from the MODIS project on NASA's TERRA satellite, scientists at the Goddard Space Flight Center are mapping fire activity worldwide (Kaufman et al. 1998). These data have been available since February 2000, can be summarized at a variety of geographic scales, and can be used to explore frequency and extent of fires (Fig. 3.7). Pu et al. (2007) used the Advanced Very High Resolution Radiometer (AVHRR) instrument to map fires on forest lands in North America. With additional information collected over time, these methods may begin to establish the spatial records of fire on rangelands. Eidenshink et al. (2007) reported on a six-year project whereby the Forest Service and USGS began mapping and assessing the burn severity for all large current and historical fires beginning in 1984. "Large" is defined as greater than 500 acres in the east and 1,000 acres in the western U.S. Landsat data will be used to assess burn severity and map the areal extent of the fire. As the fires are mapped, data become available on the web (http://www.mtbs.gov/. Accessed 20 April 2011). The intent of the project is to provide local, state, and federal land managers with information to evaluate the effectiveness of land management decisions and to establish a baseline from which to monitor the recovery and health of fire-affected landscapes over time (Eidenshink et al. 2007).

Clarity to Stakeholders

Total area burned is a concept readily understood by the public. Recent attention to large wildfires in the western U.S. has raised the level of discussion about the role of fire in ecosystems, but the importance of other measures (e.g., frequency, seasonality, severity, and intensity) are less well understood.

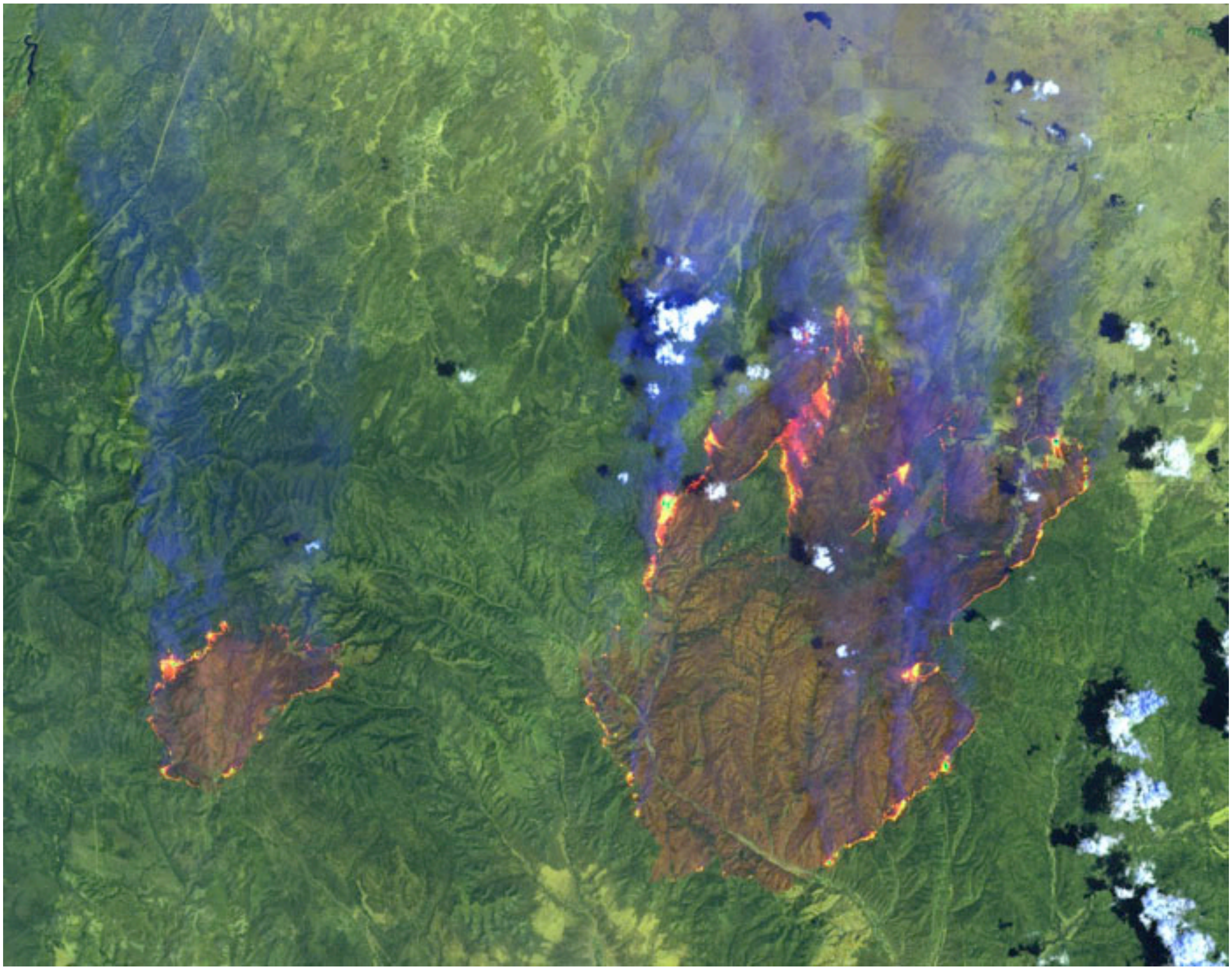

Figure 3.7. Area of Rodeo-Chediski Fire in Arizona on 28 June 2002, 18:06 UTC, identified using Landsat 7 ETM+ at 28 m resolution. From http://veimages.gsfc.nasa.gov//2936/Az_fires752.L720020621_lrg.jpg downloaded on 4 October 2010.

Extent and Condition of Riparian Systems

Description and Importance of the Indicator

This indicator measures the extent and condition of riparian plant communities along rivers and streams on rangelands. This indicator is separate from the "Number and Extent of Wetlands" indicator in that most riparian systems do not have all three attributes of a wetland (hydrophytic vegetation, hydric soils, and inundation frequency), and riparian systems have several distinct functions because they are primarily associated with lotic water in rivers and streams. This indicator is not a vegetation classification indicator but rather an indicator of vegetation condition or status regardless of composition.

The indicator will measure the status or condition of riparian vegetation on a linear basis measured in kilometers for 1st to 6th order streams within the rangeland regions. The status or condition may be evaluated on a quantitative basis using a numeric value. Possible numeric values could include a metric similar to the Index of Biotic Integrity (IBI) (Karr 1995), a hydrogeopmorphic (HGM) index (Brinson 1993), or a qualitative evaluation with a descriptor such as "fair condition" (e.g., Proper Functioning Condition [PFC]). No metric similar to the IBI has been thoroughly developed and tested, although several riparian researcher teams are working to create one that is ecologically-based and includes geomorphic, hydrologic, and biotic parameters. The HGM index is complex and has been applied to riparian areas only on a case-by-case basis. PFC is used by several agencies to evaluate riparian and stream bank conditions (Proper Functioning Condition Work Group 1993, 1994). By necessity, PFC depends on subjective evaluation by different personnel and is primarily based on physical parameters, which may limit its applicability on a national comparative basis. A quantitative index of condition built upon the concepts of PFC with more ecological parameters could perhaps become a measurement acceptable to most resource managers. When developed, an index score or indicator value (e.g., good or poor) will be applied to numbers of miles (or kilometers) of riparian community within a region. Riparian ecosystems respond to the "funnel effect" of changes in the associated upstream watershed. They respond readily to land use in adjacent floodplains but are very resilient and recover readily if perturbations are removed (Patten 1998). Riparian areas also function as buffers between the upland and the stream, helping to maintain water quality. They also control flood magnitudes and trap suspended sediment, altering channel configurations. Riparian ecosystems are used as habitat by a high percentage of animals for all or some portion of their life cycle and are known for supporting high biodiversity (Naiman et al. 1993). Consequently, sustainability of a watershed and all its components, including rangelands, can be evaluated in part through the condition of the riparian ecosystems within that watershed.

Geographic Variation

Riparian systems occur wherever there are streams and rivers. These systems tend to be linear, that is, following the course of the river, and are formed and maintained by similar hydrogeomorphic and biological processes throughout their range (Patten 1998; Scott et al. 1996). Consequently, an indicator metric or index developed for one region of the United States will be applicable to other regions.

Scale in Time and Space

Riparian systems can be related to watersheds, which can be aggregated into larger hydrological units. Measurements of riparian condition can be made locally or aggregated and evaluated on a larger scale such as a particular national forest, BLM unit, or region. The indicator relates to a system that is linear and characterized by disturbance (e.g., flooding). The temporal scale of riparian disturbance and resilience is normally within decades, and this is commensurate with the linear extent of the system, which is tens to hundreds of miles (or kilometers).

Data Collection and Availability

The data currently available for this indicator are best represented by C (Table 3.1, Appendix 1-E). Some data set(s) exist at the regional-national level, but methods and procedures are not standardized at the regional-national level. Several protocols exist that may be used on a local basis, e.g., the HGM index developed by U.S. Army Corps of Engineers (Brinson 1993; Smith 1993; Smith et al. 1995). Some protocols are generally used by several resource management agencies (e.g., PFC). The subjective nature of these data (e.g., PFC used by BLM and USDA Forest Service) could result in inconsistencies when aggregated and implemented at regional or national levels.

Clarity to Stakeholders

The importance of riparian systems is becoming more apparent to concerned stakeholders as issues with urban and agricultural intrusion into riparian buffer strips are often brought before city, county, and state planning entities. Riparian areas are also widely used by the public for recreational purposes, and the public recognizes their importance in maintaining the quality of rivers.

Area of Infestation and Presence/Absence of Invasive and Non-Native Plant Species of Concern

Description and Importance of the Indicator

Invasions of non-indigenous species can threaten native biodiversity, ecosystem functions, animal and plant health, and human economies (Carey 2003; Pimentel et al. 2005). Plant invasions are a serious threat to natural and managed ecosystems. The number of species involved and the extent of existing invasive species renders the problem almost intractable with the likelihood of the problem worsening in the future (Hobbs and Humphries 1995; Prentis et al. 2008; Crossman et al., in press). The optimal solution regarding invasive and non-native species is to prevent the introduction of these species into the ecosystem. However, in many rangeland situations, this option has already been lost, and a system must be developed to manage invaded areas, monitor exotic organisms, and attempt to minimize their impacts on other ecosystems. The proposed indicator is designed to track the area of infestation and the presence or absence of invasive or non-native species on rangeland over time. This information should help land managers to develop strategies to address the problem.

Biological invasions can be defined as the introduction, establishment, and spread of species outside their native range (Richardson and Pyšek 2006). Globally, "introduced species" are present in biological and geographic regions where they have not evolved and where they may be inadequately suited, but where potential exists for rapid adaptation (Richardson and Pyšek 2006; Facon et al. 2006; Novak 2007).

Invasive species typically have high reproductive rates, fast growth rates, and dispersal mechanisms that allow for swift movement across landscapes. Overall, these species have developed evolutionary-based adaptations that provide an added advantage in competing with other species (Prentis et al. 2008). Other non-native plant species, not officially defined as noxious or invasive, can also share some of these traits and can alter the functioning of rangeland ecosystems in ways similar to invasives. Hence, non-native species of concern are included in this indicator to be used at the discretion of those monitoring rangeland systems. Their inclusion provides the opportunity to monitor them through the indicator and to measure potential impacts they may be having on native rangeland systems. The implementation of this indicator requires that stakeholders define which species are to be monitored for their region. These species may be in addition to the federally designated species of concern in rangeland systems.

The indicator measures the area of infestation (acres/hectares) of identified invasive plant species to track their progress within the rangeland landscape over time. The areas of infestation can be inventoried or monitored at the county level and be scaled up to the state, regional, and national level. In association with the monitoring of infestation area, one could also develop a database that determines the presence or absence of an invasive or non-native species at both the state and county levels. This information would allow for efficient mapping to track the movement of identified species. Ultimately, the indicator can be used by policymakers and managers to monitor changes in the abundance and distribution of invasive or non-native species and make determinations on how to manage the species in question.

Invading nonindigenous species in the United States cause major environmental damages and losses adding up to more than $100 billion per year (Pimentel et al. 2000). There are approximately 50,000 foreign species in the U.S., and the number is increasing (Pimental et al. 2005). About 42 percent of the species on Threatened and Endangered lists are at risk primarily because of non-indigenous species (Pimentel et al. 2000). Invasive plant species make up approximately 10 percent of the 50,000 non-indigenous species in the U.S. that have escaped into natural systems (Morse et al. 1995). Non-indigenous, "weedy" species are spreading and invading approximately 700,000 ha/yr of U.S. wildlife habitat (Babbitt 1998). The 700,000 ha/yr of habitat refers only to wildlife habitat that is being lost. The total area of infestation due to invasive plants is much higher. Current rates of infestation on rangeland are increasing at approximately 14 percent per year (USDI BLM 1996). It is estimated that 100 million acres of land are moderately to heavily infested with non-native grasses such as cheatgrass, red brome, and medusa head (Westbrooks 1998).

One example of an invasive plant that is having significant impacts on natural ecosystems is purple loosestrife (*Lythrum salicaria*). Purple loosestrife, introduced in the early 19th century as an ornamental plant (Malecki et al. 1993), changes the basic structure of most of the wetlands it has invaded (Thompson et al. 1987) through altered decomposition rates and nutrient cycling and reduced wetland plant diversity and habitat suitability for specialized wetland bird species (Blossey et al. 2001). This plant alone is able to reduce critical habitat impacting 44 native plants and endangered wildlife species that rely upon native plants for survival (Gaudet and Keddy 1988). Loosestrife now occurs in 45 states (USDA Plants 2009). Other non-native grasses (*Aegilops cylindrical* – jointed goatgrass; *Bromus japonicas* – Japanese bromegrass, *Echinochloa crusgalli* – barnyard grass, etc.) have altered historical fire regimes in the Great Basin and at Hawaii Volcanoes National Park (Mack and D'Antonio 1998). Salt cedar (*Tamarix chinensis*, *T. parviflora*, and *T. ramosissima*) was introduced as an ornamental in the early 1800s and has spread into nearly every riparian community of the desert Southwest. Dense stands of salt cedar release salt accumulation from their tissues and make the site unsuitable for native species (Westbrooks 1998). Invasive species also have economic impacts on rangeland economic value and enterprise net returns (Masters and Sheley 2001).

"Healthy ecosystems" are often considered to be highly diverse. A system can have a high biological diversity but lack biological integrity if a number of exotic species make up a large proportion of the diversity (Karr and Dudley 1981). Ecosystem health can be assessed by the normality of the linked processes and functions that constitute ecosystems (Rapport 1995) and defined in terms of vigor, resilience, and organization (Mageau et al. 1995). A sure way to maintain ecosystem health is to maintain biological integrity (Karr 1995). The opposite is not necessarily true, however. Inclusion of multiple or even a single exotic species can influence the ecosystem functions and processes to the point that biological integrity can be lost and ecosystem health can be diminished.

Geographic Variation

The proposed indicator is meaningful throughout all regions of rangeland systems and could be integrated across regions to provide a national-level metric and standardized monitoring program. Many methods could be used to standardize the metric. One easy method would be to focus on the taxonomic relationships of the invasive or non-native plants. In such a manner, similar species could be tracked and compared across multiple scales. For example, plant species in the Poaceae family could be tracked together to determine the problems associated with invasive or non-native grasses both locally and at the regional to national scale. This arrangement could eliminate the comparison of “apples to oranges” in the plant world. Focusing on taxonomic criteria would allow distinct strategies to be developed for various problem species (grasses, forbs, shrubs, trees, etc.).

Scale in Time and Space

The indicator can be scaled from the local and county level up through the state, region, and national levels of reporting. County-level monitoring would most likely be used (and is being used) to develop a national database. The use of area as a monitoring metric allows for quantification across counties, states, and throughout the nation. Presence or absence is a measurement that could be used to develop maps and to track the plants at county and state levels. The presence or absence designation is not designed to implicate an area as “invaded” if only one or two plants are in a county. Instead, the presence or absence portion of the indicator is designed to monitor where problems have the potential to increase.

Data Collection and Availability

The data currently available for this indicator are best represented by C (Table 3.1, Appendix 1-E). Some data set(s) exist at the regional-national level, but methods and procedures are not standardized at the regional-national level. At this time, there are a multitude of invasive species databases (Table 3.7, Fig. 3.8). Several of these provide distribution information at various scales; however, most of them only include a list of the species. In order for data to be meaningful at a regional to national level, an effort would need to be made to develop a national framework of data collection similar to the FIA or NRI. At the very least, a set of national data standards and a consistent list of species should be developed that would allow data to be aggregated up from some common local level (e.g., county). At this time, an effort to standardize collection and analysis of invasive species information is being developed. According to Rita Beard, Invasive Species Coordinator, NPS, Fort Collins, CO (personal communication), a multi-agency task force is developing a scale-sensitive standardized monitoring system that is planned for implementation within the next five years.

Table 3.7. Selected invasive plant species databases (adapted from http://www.invasivespecies.gov).

Database name	Database host
APHIS Regulated Plant List http://www.invasivespecies.org/NewInitiatives.html	U.S. Department of Agriculture, Animal and Plant Health Inspection Service
Aquatic, Wetland and Invasive Plant Information Retrieval System (AIRS) http://plants.ifas.ufl.edu/	University of Florida, Center for Aquatic and Invasive Plants with Bureau of Invasive Plant Management, Florida Department of Environmental Protection Aquatic Plant Control Research Program, U.S. Army Corps of Engineers
CalWeed Database http://endeavor.des.ucdavis.edu/weeds/	California Department of Food & Agriculture; California Interagency Noxious Weed Coordinating Committee; Bureau of Land Management; University of California-Davis
Exotic Plant Database (The Florida Exotic Pest Plant Council [Florida EPPC]) http://www.eddmaps.org/florida/	Florida EPPC; Florida Department of Environmental Protection's Bureau of Invasive Plant Management
Federal and State Noxious Weeds in GRIN (Germplasm Resources Information Network) http://www.ars-grin.gov/npgs/html/taxweed.pll	U.S. Department of Agriculture, Agricultural Research Service, National Genetic Resources Program
Federal Noxious Weeds Database http://www.invasivespecies.org/fedweeds.html	U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Center for Plant Health Science and Technology
Global Compendium of Weeds http://www.hear.org/gcw/	U.S. Geological Survey, Hawaiian Ecosystems at Risk project (HEAR)
Global Invasive Species Database http://www.issg.org/ http://gisp.org/ Document7	Invasive Species Specialist Group (ISSG); Global Invasive Species Programme (GISP)
Hawaiian Ecosystems at Risk (HEAR) http://www.hear.org/	U.S. Geological Survey; University of Hawaii
Invasive and Exotic Species of North America – Invasive.org http://www.invasive.org/	A joint project between The University of Georgia – Bugwood Network and the USDA Forest Service
INVADERS Database http://invader.dbs.umt.edu/	University of Montana
Invasive Plants Atlas of the United States http://www.invasive.org/weedus/index.html	
USDA National Invasive Species Information Center http://www.invasivespeciesinfo.gov/plants/databases.shtml	General Database
USDA National Invasive Species Information Center http://www.invasivespeciesinfo.gov/plants/pubs.shtml	Publications
North American Weed Management Association http://www.nawma.org/	

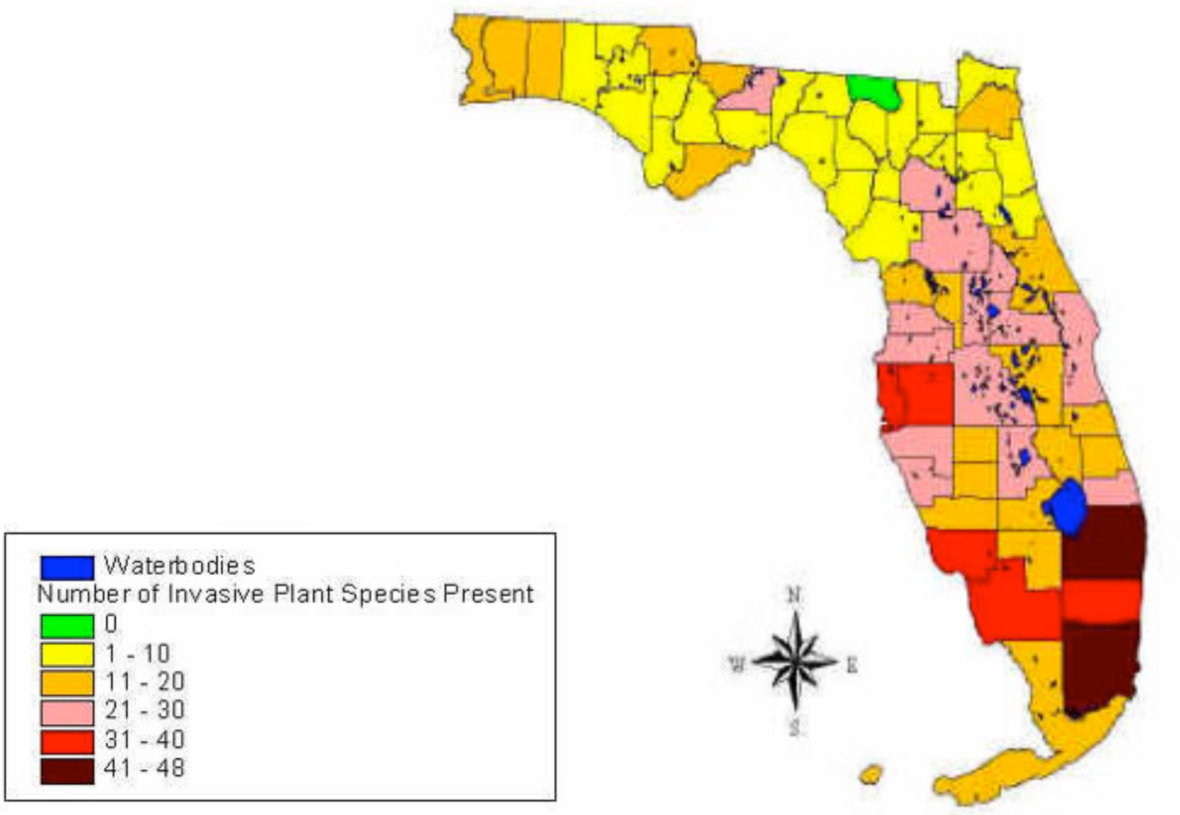

Figure 3.8. Example output from Florida Exotic Pest Plant Council's Exotic Pest Plant Database (http://www.eddmaps.org/florida/).

A standardized mapping procedure is also being proposed for each entry into the national-level data system (North American Weed Management Association 2002). Also, a National Early Warning and Rapid Response System for Invasive Plants in the United States has been proposed (FICMNEW 2002).

The University of Montana has developed the INVADERS database, which is a comprehensive database of exotic plant names and weed distribution records for six states in the Pacific Northwest (University of Montana 2008). Within this database, the spatial and temporal spread of weeds can be displayed using information on the historical distribution of the species. The database also contains a listing of all noxious weed species in the United States. The design structure is such that the database could be expanded to cover additional areas in the United States. Weed managers are invited to cooperate.

For the purpose of this indicator, the working group does not intend to develop a threshold value of area of infestation within an ecosystem. This will require local stakeholders to develop the levels to be monitored. The value of the indicator would be in the periodic resampling of the metric to develop trend data showing spread or decline of invasive or non-native species. The metric should be established to be repeatable, reliable, and accurate over time.

There are many potential uncertainties that have to be addressed in the development of a comprehensive invasive plant database program. These include, but are not limited to, misidentification of specimens, presence versus population estimates, irregularities in data collected, etc. The North American Weed Management Association (2002) is addressing these and other standardizing factors that could be used to reduce the level of uncertainty in the development of a national invasive database system.

Clarity to Stakeholders

Through a multitude of educational efforts, the impacts of invasive and non-native species are becoming increasingly well understood by the public. However, it will be necessary to continue educational activities to increase awareness and provide further understanding. The indicator itself is fairly straightforward and should be understood by the public.

Number and Distribution of Species and Communities of Concern

Description and Importance of the Indicator

This indicator measures the numbers and geographic ranges of rare or "at-risk" species that occupy rangeland habitats for a significant portion of their life cycle, as well as the presence and extent of rangeland plant communities of concern. Trends in the number of at-risk species and communities help identify potential loss of historical and natural rangeland ecological functioning, as well as the loss of associated values and benefits. This indicator is analogous to the "canary in the coal mine" when measuring ecosystem stress.

This indicator is related to the "Rangeland Area by Plant Community" indicator. Rare and at-risk communities will be identified in that indicator but are also included in this indicator because of the legal and biological importance of rarity and threatened status.

This indicator measures the number and geographic ranges of at-risk species and plant communities. Species of concern include those identified by TNC at the G1, G2, or G3 level, species listed under the Endangered Species Act or identified as candidates for listing, or species otherwise identified as being at risk, e.g., International Union for Conservation of Nature (IUCN) categories. Communities include those identified as G1, G2, or G3 by TNC, as well as those identified by other organizations such as the World Wildlife Fund (WWF 1999).

There are several metrics that could be used to describe the indicator. For species, metrics include the number of species, the number of populations per species, the abundance (number of individuals) per population, and the geographic range. For communities, metrics include the presence and number of at-risk communities, the number of stands of each community, the size of the stands, and the geographic range of the community.

The concept of at-risk communities is less well-defined in the ecological literature than at-risk species. "Plant community" is defined in the "Rangeland Area by Plant Community" indicator section above. At a coarse scale, TNC community-level measure of rarity (G1-G5) can be used, as it is well defined and widely applied. Areal extent (e.g., hectares or km^2) is also relatively easy to determine. The status of particular stands is more difficult to determine. Loss of native species, spread of exotics, and changes of ecosystem-level attributes such as nutrient cycling or pollination function could be used but are not currently well-defined or standardized.

An increasing number of at-risk species or communities, or a decline in their ranges, generally indicates regional or landscape-level ecosystem instability or degradation and the potential loss of critical components to maintain ecosystem function. The number of at-risk species or communities in a region is not as responsive an indicator as some other indicators because a species or community is probably in serious trouble before it becomes recognized or listed as threatened. It should be viewed more as a trailing than a leading indicator of ecosystem stress. Population demography or community-level functional attributes are more responsive measures but are more difficult to obtain than simple counts of species and communities.

Geographic Variation

Measures of the numbers of at-risk species and plant communities can be easily aggregated and compared among areas. However, as larger areas and more complex biomes are likely to have more species and communities, including rare and at-risk species, the numbers of at-risk species and communities should be considered relative to the total number of rangeland species and communities. In order for comparisons to be meaningful, the metrics used to describe conservation status should be uniform across taxonomic groups and between regions. Metrics and assessment tools developed by the FWS, TNC, NatureServe, WWF, and the IUCN are recommended as they are widely used and are applicable to U.S. rangeland.

Scale in Time and Space

The distribution of at-risk species and communities at the landscape level is generally patchy. However, the basic metrics are generally scale independent and can be aggregated from the local (county) and regional (state) levels to the national level. This indicator will also be comparable over time, if the criteria and assessment methods do not change.

Data Collection and Availability

The data for this indicator are best characterized as A (Table 3.1, Appendix 1-E). Methods and procedures exist for data collecting and reporting at a regional-national level, and data sets of useable quality exist at the regional-national level. There are extensive data available on at-risk vertebrate and vascular plant species and many plant communities at the local, state, ecoregional, and national levels. Most federally listed species will have either recovery plans or other documents that indicate status and distribution (USDI FWS 2010c). Other at-risk species and community data are available through state-level heritage programs, TNC, and NatureServe. These programs include data on both population locations and often species and community status. However, data are scarcer for some vertebrate groups (e.g., fish, small mammals, reptiles) than they are for large mammals and birds. Generally, much less is known about other taxonomic groups, such as lichens, bryophytes, invertebrates, fungi, algae, and bacteria. The identification and description of rare plant communities is at an earlier stage of development than for species. However, TNC, NatureServe, and WWF have attempted designations of rare communities. Some states also have relatively detailed community classifications and status. For example, the California Native Plant Society has published a list of plant communities at the alliance level, and it includes information on their status within the state (Sawyer and Keeler-Wolf 1995)

Although subjective judgment is often used in determining rarity, there are guidelines and extensive research available that can make these indicators both repeatable and reliable. Vascular plants and vertebrate animals have received closer scrutiny than other species, and charismatic species sometimes receive special emphasis, increasing the bias and decreasing the accuracy of the indicator. However, the numbers and ranges of at-risk species and communities remain valid despite these concerns because they measure the potential loss of critical rangeland components.

Clarity to Stakeholders

The concept of threatened and endangered species and communities is understood, and it forcefully communicates threats to rangeland sustainability. Almost everyone is familiar with endangered species through news reports. The concept of rare plant communities is understood in a very general sense by the public (e.g., loss of tropical rainforests), but a more detailed understanding is not widespread.

Population Status and Geographic Range of Rangeland-Dependent Species

Description and Importance of the Indicator

This indicator measures the population levels (abundance) and the current geographic ranges of rangeland-dependent plant and animal species, monitored across their known range. Species should be dependent on rangeland for most if not all of their life cycle, i.e., permanent residents. One cannot generally use the population level or range of one species to reliably infer traits about another species, so single species are not always useful as representatives of other species or communities. However, it is not possible to monitor the population levels and ranges of all species of animals, plants, and microorganisms, so some species must be selected for monitoring. If the selected species include keystone species and those that are sensitive to particular threats, such as overgrazing, irreversible soil erosion, or fire, and if the species are diverse with respect to their taxonomy, habitats, trophic levels, ranges, and life strategies, the indicator will have a higher likelihood of detecting trends in range ecosystems.

This indicator measures population levels (abundance) of rangeland-dependent species and the geographic area of their current ranges (Fig. 3.9). This indicator combines elements of the Montreal Process forest indicators 6, 8, and 9 (Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests 1995). To a certain extent, it also measures genetic diversity on rangeland (for an alternative view see Flather and Sieg 2000). A reduction in the geographic range of a species often results in the loss of subspecies and locally adapted populations. It is a leading indicator of ecosystem stress and will respond to impacts before the indicator measuring the number of at-risk species. Stressed species will likely exhibit the stress through reduced population sizes, reduced geographic range or both, which will be detected by this indicator.

Rangeland-dependent species include widespread common plants and animals such as big sagebrush (*Artemisia tridentate)* or greater sage-grouse (*Centrocercus urophasianus*), or species from particular kinds of rangeland, such as saguaro cactus (*Carnegiea gigantea*) in the Sonoran Desert. Species may be categorized as umbrella, keystone, or guild indicator species (Landres et al. 1988; NRC 1986). The species thus categorized can indicate one of three factors: levels of contaminants in an ecosystem, changes in other species in the same guild, or changes in habitat quality that affects other species as well. An alternative to the use of particular species is to use community-level or ecosystem processes such as trophic relationships or species diversity as indicators of ecosystem function (Launer and Murphy 1994; Williams and Gaston 1994). The selection of the kinds of species or community-level attributes to measure is problematic for a variety of reasons (Landres et al. 1988). In the case of either species or ecosystem functions, ecological theory does not have the ability to precisely define the nature or quantity of species or community responses needed to maintain all the native elements of a regional biota or landscape.

At the species level, two terms are widely used: "indicator species" and "umbrella (keystone) species." Indicator species are those that are representative of a particular ecological guild, trophic level, or ecosystem function. Indicator species do not necessarily have direct interactions or causal relationships with the species or groups they are supposed to represent. Umbrella or keystone species are over-arching species that need to exist in a community for a variety of other species to be present and persist as well. Implied in this are more direct causal linkages between an umbrella species and other species. For example, the presence of breeding woodpeckers in forested communities, through their propensity for cavity excavation, allows the presence of a wide variety of secondary cavity-nesting species. Another well-known indicator is the prairie dog, which is a keystone species because of its abundance and colonial and burrowing instincts. Many other rangeland species depend on the existence of the prairie dog colonies, such as black-footed ferrets, burrowing owls, and various plants, raptors and reptiles. More recently, Lambeck (1997) introduced the term "focal species," defined as a multiple-species umbrella. He provides a conceptual model for selecting focal species. Although his emphasis was on rare and declining species in fragmented habitats, the method is also applicable to more common species.

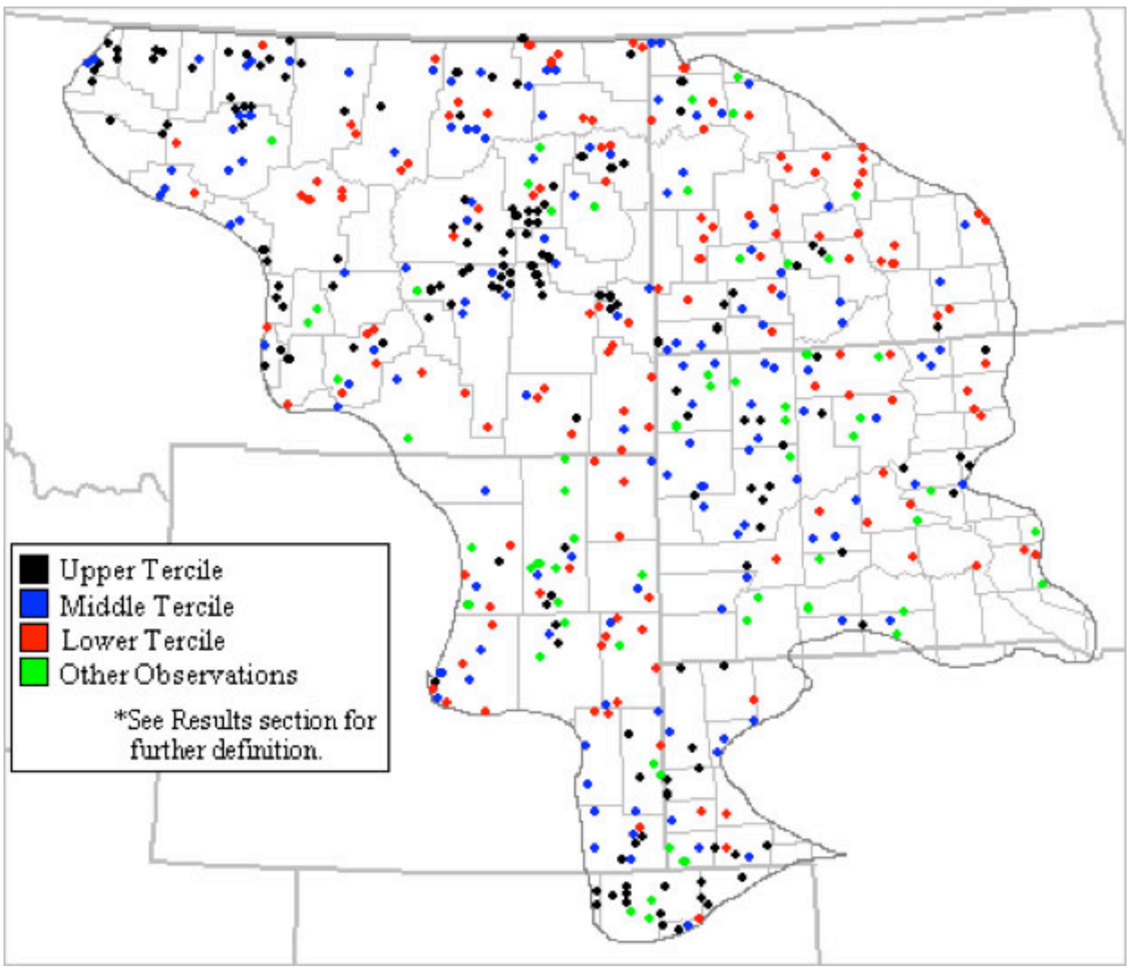

Figure 3.9. Population status and geographic range, breeding distribution of horned lark, a species dependent upon rangeland habitat in northern Great Plains. Source: Kantrud (1982).

Landres et al. (1988) point out the many pitfalls in using guild indicator species, suggesting that the method should be abandoned. If a species is to be used as an indicator of habitat change or quality, it must have a demonstrated relationship with the habitat attributes of interest. Because of the complex and multiple causality in natural ecosystems, it may prove difficult, if not impossible, to find a species that can be used to indicate habitat quality for any other species or group. Because of these problems, this indicator focuses on types other than guild indicator species and includes both "typical" representative rangeland-dependent species and umbrella species that are critical for maintaining subsets of a regional rangeland biota. Recognizing that we cannot monitor all species, some species selection is necessary. Careful selection of species can increase the likelihood of detecting threats to sustainability, but we cannot claim that the selected species are indicator or representative species.

Geographic Variation

Because of the wide diversity of vegetation on rangelands, any regionally-restricted rangeland species will not be a useful indicator outside the regional level (e.g., ecoregion or province). This makes it difficult to compare groups of species across various regions and at the national level, but trends in range and abundance can be compared in the abstract across regions and at the national level. For example, is there a widespread decrease in rangeland species, or are the decreases occurring primarily in particular areas or with particular types of species? The numbers of species can be aggregated from the local to the regional level.

Scale in Time and Space

The distribution of species and communities at the landscape level is often patchy. However, the population levels (abundance) of rangeland-dependent species, as well as trends in the geographic area of their current ranges can be aggregated from the local (county) to regional (bioregion, state) levels. It will be more problematic to aggregate this data to the national level. This indicator will be more meaningful if species trends can be extrapolated into the past to measure the loss of populations and contraction of geographic range over time up to the present. The basic metrics are population locations and overall status for representative species, repeated over space and time. This indicator will be comparable over time if the criteria and assessment methods do not change.

The number and geographic range of species in a region is a more responsive indicator than the number of at-risk species or communities. If a wide enough variety of species from different trophic levels and taxonomic groups are included, there is a greater probability of detecting early changes in communities and ecosystems that could lead to loss of function and sustainability.

Data Collection and Availability

The data for this indicator are best characterized for some vertebrate and vascular plant species as both A and C (Table 3.1, Appendix 1-E). Methods and procedures for data collecting and reporting exist at the regional-national level, and data sets of useable quality exist for some species at the regional-national level. Although data set(s) exist for many other species at the regional-national level, methods and procedures are not standardized at the regional-national level.

Data are available for a wide variety of vertebrate and vascular plant species that could be selected as representative or umbrella species. The data are primarily in the form of either local-focused research or as annual or other temporal counts of species abundance, such as the North American Breeding Bird Survey of the USGS (Sauer et al. 2002), the Christmas Bird Count of the Audubon Society (http://www.audubon.org/Bird/cbc/), the North American Waterfowl Breeding Population Survey (http://www.fws.gov/birddata/databases/mas/maydb/html), the Great Plains Flora Association county-level distributional data (Great Plains Flora Association 1977), and others.

Less is known about other groups, including invertebrates, reptiles, small mammals, bryophytes, fungi, algae, and bacteria. Lichens are known to respond to air pollution, and extensive research on their uses as indicators is available. Much of the available species-specific data are from local research sites that have little applicability at broader scales. Because of the site-specific nature of much of these data, it will be difficult to synthesize the available research and aggregate for regional or national assessments.

Species are typically characteristic of a particular climatic region; they are, therefore, extremely useful at the regional level. There are many different classifications of regional vegetation that local data could be aggregated toward, including but not limited to those developed by Brown et al. (1980), McLaughlin (1989), and Bailey (1995). However, the data cannot be easily aggregated beyond the regional level, as species-level comparisons are largely invalid across biome or ecoregional boundaries. However, patterns of similar species-groups (e.g., neotropical migrant birds) can be compared across regions.

Clarity to Stakeholders

Most people readily understand the concepts of population size, trends in abundance, and changes in geographic ranges of species. Rangeland-dependent as a concept may be less well understood by the public, except for a few large game or threatened species like the black-footed ferret, primarily because the public tends to lack the detailed ecological background needed to evaluate the concept.

Summary

The 10 indicators described here will contribute to a national system of monitoring the health and sustainability of U.S. rangelands. As noted in the “Soil and Water Conservation on Rangelands” criterion section, there is some overlap in indicator identification between the criterion groups. Integration, both within the SRR and between the various Roundtables (Forest, Mineral, Water), is critical to develop a suite of indicators that effectively and efficiently captures the factors necessary to monitor rangeland sustainability.

In the course of identifying key indicators of rangeland sustainability, we have also identified challenges for the rangeland scientific community. Measuring trends in the area of rangeland plant communities provides important information on the diversity of rangeland ecosystems and can serve as a loose proxy for environmental characteristics, disturbances, and ecosystem processes on rangelands. To be successful, a nationally accepted operational definition of rangeland and a standardized approach to classifying vegetation are needed, in addition to standardized inventory methodologies. The NVCS (FGDC 2008) and the Ecological Site Inventory (USDA NRCS 2010b) are two approaches moving toward standardized classification systems. Neither has had extensive implementation across a diversity of landowners. However, the collaboration efforts underway to improve the inventory, monitoring, and data management for these approaches should be encouraged.

The Federal Interagency Committee for the Management of Noxious and Exotic Weeds continues to refine and revise the development of a national invasive species database. This significant undertaking requires continued cooperation across political as well as scientific boundaries, as well as the necessary funding to bring such a massive undertaking to fruition. A centralized database is also needed with a query mechanism that will provide for the needs of managers fighting the problems in the field. Standardization of the data collected is the first step towards realizing a fully functioning program.

Enhanced spatial data would improve indicators. In addition to roads and residential land use, there are a number of additional uses of rangeland (e.g., commercial- and industrial-related land uses, oil and gas wells, wind energy developments, power lines, off-road vehicle uses) that would be useful but are more challenging to incorporate into the "Intensity of Human Uses on Rangeland" indicator. The development of spatially explicit data for human structures would be a significant improvement beyond the existing census block group data.

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