Grasslands and Shrublands

Area of Grasslands and Shrublands

The Indicator

This indicator reports the acreage of grasslands and shrublands using land cover data based on satellite measurements from the National Land Cover Dataset (NLCD). For this indicator, pastures and hay-lands were included; however, they were included within farmlands for that system's extent indicator (p. 191) and the national extent indicator (p. 40). Pastures and hay-land are included in this indicator because many fall within the description of grasslands and shrublands given in the introduction of this chapter, and because it is not clear how well the satellite data distinguish them from less-managed grasslands. (Note that in the NLCD the classification "pasture/hay" is defined as areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.)

The U.S. Department of Agriculture Economic Research Service (ERS) has carefully tracked changes in different land uses over the past 50 years in its "Major Uses of Land" series (see http://www.ers.usda.gov/data/majorlanduses/). Its accounting for cropland and forest land is consistent with the approach taken in this report, and its trend in urban area was adopted for comparison purposes (see national extent indicator, p. 40). However, the ERS category that is closest to the definition of grasslands and shrublands used in this report is "grassland, pasture and range." This category, which included 578 million acres for the lower 48 states in 1997, is inconsistent with the definition used in this report because land is included based on grazing activity rather than on the land cover classification; there was no obvious way to reconcile the differences in definition adequately so that the ERS data could be used to track trends in grasslands and shrublands.

The extent of grasslands and shrublands (shown in this indicator) is a key aspect in understanding this ecosystem. Additional indicators in this chapter provide information on other key parameters. In addition, there have been attempts to provide overall ratings of the "ecological condition" or "health" of these lands. One potential measure of ecological condition is seral stage. The concept of rangeland health has been addressed by the National Academy of Sciences (Committee on Rangeland Classification 1994). However, ecological condition is expressed differently at multiple scales, including sites and landscapes, and presently does not lend itself to synthesis at a national scale. Aggregation of site-level rangeland condition data to a national assessment is particularly problematic (Mitchell 2000).

The Data

Data Source: The data for the lower 48 states are from the NLCD, which has a resolution of approximately 30 meters on a side. The NLCD is a product of the interagency Multi-Resolution Land Characterization (MRLC) initiative (see the technical note for the national extent indicator, p. 207).

Data for Alaska are from a vegetation map of Alaska by Flemming (1996), based on Advanced Very High Resolution Radiometer (AVHRR) remote-sensing images with an approximate resolution of 1 kilometer on a side. The following groupings of classes were used (see http://agdc.usgs.gov/data/projects/fhm/#G [Statewide Vegetation/Land Cover] and the technical note for the national extent indicator, p. 207). Briefly, the following are Flemming's (1996) classes that were included within grasslands and shrublands: alpine tundra & barrens (#3); dwarf shrub tundra (#4); tussock sedge/dwarf shrub tundra (#5); moist herbaceous/shrub tundra (#6); wet sedge tundra (#7); low shrub/lichen tundra (#8); low & dwarf shrub (#9); tall shrub (#10); and tall & low shrub (#23).

Presettlement estimates of grass/shrub land cover were derived from data provided by Richard J. Olson, Oak Ridge National Laboratory (personal communication). These data were first published in Klopatek et al. (1979). This dataset provided potential area of Kuchler vegetation types. A set of Kuchler vegetation types provided by the Vegetation/Ecosystem Modeling and Analyis Project (VEMAP) program (http://www.cgd.ucar.edu/vemap/lists/kuchlerTypes.html) was used to select a set of grassland and shrubland vegetation types from Klopatek et al. (1979). While there are minor differences between the Kuchler naming conventions in the Klopatek et al. (1979) and VEMAP lists, the overall suite of vegetation classes matches quite well, and the resulting estimate is considered reasonable.

Data for recent changes in "non-federal grasslands and shrublands" are from the U.S. Department of Agriculture A Natural Resources Conservation Service National Resources Inventory (NRI) program. NRI uses the term "rangelands," which is consistent with our definition of grasslands and shrublands, except that the NRI data used here do not include pasture or lands enrolled in the Conservation Reserve Program. Data from 1982, 1992, and 1997 are derived from the NRI Summary Report (revised December 2000), tables 5 and 8. See http://www.nhq.nrcs.usda.gov/NRI/1997/national_results.html.

Data Limitations/Caveats: In the discussion section of the indicator text, an attempt was made to place bounds on the loss of grasslands and shrublands since the time of European settlement. This was done to give the reader a sense of the change; however, this estimate should be interpreted with caution. There are two caveats in particular. The satellite data used to estimate the acreage of pasture do not indicate whether or not the land is heavily managed (i.e., plowed and seeded). Depending upon the division of pastures between relatively heavily managed and relatively lightly managed (i.e., more natural in character), grasslands converted to pasture could represent a significant addition to the estimates of area converted. Also, a considerable amount of the land that is now classified as pasture is located in the East and was probably forest. Hence, to say that grasslands and shrublands declined 40 to 140 million acres since European settlement ignores the fact that more of the original grasslands and shrublands may have been lost but these losses were offset by gains in eastern pastures.

Data Access: Please see the information contained within the technical note for the national extent indicator (p. 207).

References

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Mitchell, J.E. 2000. Rangeland resource trends in the United States: A technical document supporting the 2000 USDA Forest Service RPA Assessment. Gen. Tech. Rep. RMRS-GTR-68. Rocky Mountain Research Station, Fort Collins, CO.

Land Use

The Data

Data Source: Data on Conservation Reserve Program (CRP) lands are from the USDA Farm Services Agency (FSA), which manages CRP signups and contracts.

Data Manipulation: Reported here are lands in the following "practice" categories: Introduced Grasses (CP1), Native Grasses (CP2), Wildlife Habitat (CP4), Grass Waterways (CP8), Established Grass (CP10), Wildlife Food Plots (CP12), Filter Strips (CP13), Contour Grass (CP15), Snow Fences (CP17), Salt Tolerant Vegetation (CP18), Alternative Perennials (CP20), Filter Strips (CP21), Cross Wind Strips (CP24), and Declining Habitat (CP25). The figure of 29 million acres (29.37 million acres) reported here is based on data reported at http://www.fsa.usda.gov/crpstorpt/04approved/r1pracyr/r1pracyr2.htm (report MEPRTK-R1, April 30, 2001, last accessed 10/15/01). Data from each of these practice categories were summed for all contracts active at the time the report was prepared.

This report provides information on cover practices for contracts beginning in each program year since CRP was implemented (1987). However, the report generally provides information only for contracts that begin in a specific year, not those that are active in a specific year. Therefore, it is not possible to develop time trend information for cover practices active in any given year. The exception to this statement is that the report does provide a summary of cover practices for all currently active contracts, and this summary provided the figure of 29.37 million acres.

The Data Gap

For this indicator to be reported on effectively at a national level, a standardized set of definitions and criteria for classifying land uses is needed. Following are possible components and approaches to be incorporated into such definitions.

Livestock Raising: Federal land managers report the allowable stocking rate in Animal Unit Months (AUMs) for individual livestock allotments. In theory, the number of animal units per acre could be calculated. However, research should be done to understand how well allowable stocking rates reflect actual rates of use. In addition, we are aware of no source for consolidated information on acreage used for livestock raising on private lands.

Intensive Recreation: This category is intended to describe areas whose major purpose is recreational use, and where such use is significant enough to generate changes in the condition of the area. To adequately report on such areas, a definition needs to be devised based on factors such as levels of recreation use or number and type of recreational facilities in an area.

Energy and Mineral Development: As with recreation, adequate reporting on areas used for energy and mineral development requires a definition that accounts for the areas directly affected (e.g., drilling pad area, mine pits, tailings ponds) as well as nearby areas with visual, noise, dust, and other impacts.

Rural Residences: As with other categories, adequate reporting of this indicator component would require adoption of thresholds that identify a class of lands with low-density rural residence development. These areas are less dense than what most people would consider "suburban" but would have to be distinguished in some manner from truly rural, very low density development. The target for this component is often described as "ranchette" development.

"Protected Areas": Identifying protected areas will require adoption of a standard that distinguishes certain public or private lands based on their legal status or management practice; lands that are managed primarily in order to maintain biodiversity and natural processes should be included. Several categorization approaches have been developed including the World Conservation Union's six-category approach (see http://wcpa.iucn.org/wcpainfo/protectedareas.html) and the Gap Analysis Program's management status four-category scheme (http://www.gap.uidaho.edu/). A dataset being developed for this purpose will report the acreage of lands according to a system of categorizing management intensity developed by the U.S. Geological Survey Gap Analysis Program (see http://www.gap.uidaho.edu/handbook/Stewardship/default.htm). This database is currently under development by the Conservation Biology Institute in conjunction with the USDA Forest Service; see http://www.consbio.org/cbi/what/pad.htm.

In addition to developing definitions for these categories, mechanisms should be developed for the accounting of the acreage in each category and changes in these areas over time.

Area and Size of Grassland and Shrubland Patches

The Indicator

This measure would report the percentage of grasslands and shrublands in patches of different sizes. Patch sizes and percentages would be reported separately for grasslands and shrublands. The patch sizes for this indicator are as follows: less than 10 acres, 10–99 acres, 100–999 acres, 1000–9,999 acres, and 10,000 acres or greater.

Species and ecosystem processes are sensitive to spatial heterogeneity. Landscape diversity is an important component of species diversity, habitat conservation, and human health. While much research has been undertaken to determine these relationships in forested ecosystems, there is general agreement among grass/shrub experts that such spatial patterns are important in grasslands and shrublands as well. For example, in the sagebrush/grassland mosaic of western intermountain basins, fuel buildup after a period of minimal grazing and sufficient rainfall creates highly flammable conditions. When a fire does occur, the sagebrush is greatly reduced in abundance because it cannot sprout, unlike nearly all the grassland plants. Grassland expands, reducing the area of habitat for sagebrush-dependent species.

The Data Gap

High-quality satellite data provide an excellent baseline to assess future changes in patch sizes. Many of the indicators in this report are based on data from the National Land Cover Dataset, produced by a federal interagency consortium including the U.S. Geological Survey, the USDA Forest Service, the National Oceanographic and Atmospheric Administration, and the U.S. Environmental Protection Agency (see http://www.epa.gov/mrlc/nlcd.html and the technical note for the national extent indicator, p. 207). It is expected that satellite data will be used for this indicator.

However, the software currently available for analyzing patch size characteristics was developed for use on relatively small landscape areas. It is not designed, and cannot be used, to process datasets as large as are required for this indicator. An alternative approach involves analyzing patch characteristics for smaller landscape areas (such as 7.5 x 7.5 km), then combining the statistics on these many individual areas to describe much larger areas, such as ecoregions. However, in this approach, any patch that crosses the boundary of one of the 7.5 by 7.5 km squares is not accurately represented, because a portion is in one square and a portion is in the adjoining square. This is referred to as a right-censored distribution and will provide consistent underestimates of the number of larger patches.

In addition, the indicator should distinguish between lands that have been altered (e.g., cultivated and seeded for pastures) and more "natural" lands; only patches of the more natural grasslands and shrublands would be included.

References

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Nitrate in Groundwater

The Indicator

The sources cited below provide additional information regarding the choice of nitrate as an appropriate and sensitive indicator of ecological condition (Smith et al. 1997), how vegetation composition, activity, and management affect nitrate concentrations in soil water, seeps, and streams (Ramundo et al. 1992, Tate 1990), and the relationship between soil texture and types and abundance of carbon sources (Nolan and Stoner 2000).

The Data Gap

Data on nitrate concentration in groundwater need to be collected and reported in a consistent fashion across a broad and representative set of grassland and shrubland areas. Nitrate measurement is simple, straightforward, and largely unchanged since measurements began more than 100 years ago. Because many usable wells already exist, on both public and private lands, the cost of sampling and analysis is the primary factor limiting current efforts.

In addition, careful searching of federal, state, county, municipal, and private records could produce a valuable historical archive that would serve as a baseline against which to compare current conditions.

The technical note for indicators describing nitrate concentrations in forested, farmland, and urban/suburban areas (see p. 232) provides information on the U.S. Geological Survey

National Water Quality Assessment program, which is a potential future source of data for this indicator.

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Carbon Storage

The Indicator

This indicator seeks to track long-term changes in carbon sequestration in grasslands and shrublands. Measurements of this indicator through time can provide information on whether the ecosystem is a net source or a net sink of atmospheric carbon dioxide. An ecosystem accruing carbon is one contributing to a reduction in greenhouse gases. White et al. (2000) have estimated that grassland ecosystems worldwide store an amount of carbon that is about half of that stored by the world's forests and roughly equivalent to that stored by agricultural systems.

An ecosystem not changing in carbon content, but also not producing high inorganic nitrogen exports, is likely a late-successional, mature system possessing high biotic diversity. Systems containing high amounts of carbon are often associated with high levels of ecosystem services (i.e., responsible for clean air and clean water).

The minimum data that are required for this indicator are percentage soil organic matter (SOM) in surface soil layers and carbon stored in plant material, estimated on an area basis. Soil measurements provide an excellent index of both potential soil fertility and nitrogen storage. Soil carbon storage is the net accumulation of (mostly dead) plant matter. It represents the net accumulation of carbon inputs (plant production) minus all sources of organic carbon loss. Changes in soil carbon storage can be caused by changes in climate, changes in atmospheric chemistry, or changes in the abundance and species composition of the vegetation. Plant carbon storage varies annually while soil carbon storage changes at longer time scales.

The Data Gap

Data are not currently available to provide systematic monitoring and reporting of soil and vegetation carbon. There are, of course, many research sites at which such information is collected. Soil carbon can be found at substantial depths, although routine sampling of soils to such depths is uncommon. A variety of available models can estimate total soil carbon storage from surface measurements of SOM and estimate plant carbon from above-ground vegetation measurements. However, there is a serious concern about the use of single-point estimates to represent large areas. Some procedures for establishing the representativeness of sites will be required. Intensive, long-term data are available from the Long Term Ecological Research (LTER) sites, including those in Alaska, Michigan, Minnesota, Kansas, Colorado, and New Mexico (there are two sites in New Mexico). Such sites could provide substantial validation for more widely dispersed measurements. Relatively long-term alpine and arctic tundra SOM data are available from LTER sites as well. See http://lternet.edu/sites/ for additional information and links to the LTER network.

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Number and Duration of Dry Periods in Grassland and Shrubland Streams

The Indicator

This indicator has two aspects: (1) the percentage of streams with at least one day of no flow (also referred to as zero flow) in a year and (2) for sites with at least one day of zero flow, the duration of zero flow events, compared to a long-term average (50 years in this case). Together, these two variables help describe both the frequency and duration of zero-flow events. Changes in either of these could have significant effects on aquatic and riparian species.

Relatively intact/undisturbed watersheds (including their upland, riparian, and wetland components) are capable of maintaining the maximum duration of streamflow their climates will support. When soil conditions and the kinds and proportions of vegetation promote the infiltration of moisture falling in the watershed, and when evapotranspiration and groundwater recharge are in balance, rapid loss of moisture to overland flow is minimized and long-duration, frequently perennial (i.e., year-round) flow is maintained. Intact riparian areas and wetlands are capable of retaining water during high-flow periods and metering out stored moisture during periods of low flow—further supporting longer duration, or perennial flow.

Conversely, the increase of impervious surfaces through soil compaction or development and/or the loss of protective vegetation result in increased overland flow and rapid runoff events—depleting moisture storage to maintain long-duration flows. Improved management of grazing that promotes stream-side vegetation can lead to increased stream flow. In contrast, moisture loss from excessive evapotranspiration caused by plant community imbalances can also reduce the amount and duration of stream flow—this is attributed to encroachment of pinyon-juniper woodlands, Western juniper, and other species that are not actively managed.

Changes in annual weather patterns or long-term climatic changes also influence streamflow quantity and flow duration.

The Data

Data Source: Data reported here are from the U.S. Geological Survey (USGS) stream gauge network. USGS has placed stream gauges and maintained flow rate records throughout the United States since the end of the 19th century.

Data Collection Methodology: Stream gauging data are collected using standard USGS protocols.

Data Manipulation: The goal of the initial data manipulation was to identify stream gauges in watersheds where more than 50 percent of the land cover is grassland or shrubland. Each site was referenced to a watershed cataloguing unit (known as a 4-digit Hydrologic Unit Code, or HUC4) using latitude and longitude. Grassland and shrubland were defined using the National Land Cover Dataset (see http://www.epa.gov/mrlc/nlcd.html) using land cover categories 51 (shrubland), 71 (grassland/herbaceous), and 31 (bare rock, sand, clay) (see http://www.epa.gov/mrlc/classes.html and the technical note for the national extent indicator, p. 207). The HUC4s were also paired with their corresponding ecoregions (see below for description of the ecoregions used). Only sites with greater than 50% grass/shrub cover were used in the analysis.

The number of sites with at least one no-flow day in a year was determined for each water year from 1950 to 1999. The corresponding percentage value for that year was also calculated as 100 x (number of sites/total sites). The percentage values were then averaged over each decade (i.e., 1950s, 1960s, 1970s, 1980s, and 1990s). This procedure was followed for all sites with greater than 50% grassland/shrubland cover as well as for each ecoregion.

For the analysis of duration of zero-flow, only sites with at least one no-flow day in each decade between October 1, 1949, and September 31, 1999, were considered. The analysis determined whether there was a substantial increase, substantial decrease, or minimal change in the number of no-flow days, compared to the long-term (50-year) average for each stream. These categories are defined by the percent change in average zero-flow days, as compared to the long-term average, on a stream-by-stream basis. Thus, a "substantial increase" is defined as an increase of more than 100 percent in the duration of zero flow, or a change from perennial (no zero-flow) to intermittent. Likewise, a "substantial decrease" is defined as a decrease of at last 50 percent in the duration of zero flow, or a change from intermittent to perennial. "Minimal change" is defined as anything between a 100% increase and a 50% decrease.

Ecoregions: This indicator is reported using an ecoregional approach developed by the USDA Forest Service (Bailey 1995). The Bailey system has several levels into which the United States may be divided, based on dominant biological and physical attributes. The scheme has three domains, 13 divisions, and 52 provinces. We have chosen to report this indicator on the basis of divisions. We selected three major suites of Bailey's divisions:

- *Desert shrub ecoregion*, composed of the following Bailey's divisions: 320 (tropical/subtropical desert division), M320 (tropical/subtropical desert division—mountain provinces), 340 (temperate desert division), M340 (temperate desert division—mountain provinces)
- *Grassland/steppe ecoregion,* composed of the following Bailey's divisions: 250 (prairie division), 330 (temperate steppe division), M330 (temperate steppe division—mountain provinces), 310 (tropical/subtropical steppe division)
- *California/Mediterranean,* composed of the following Bailey's divisions: 260 Mediterranean division, M260 (Mediterranean division, mountain provinces)
  See http://www.fs.fed.us/colorimagemap/ecoreg1_divisions.html for full definitions and a map showing the individual divisions.

Data Access: The data records used in this study are available on the Internet in the form of daily streamflow values reported as the average volume of water per second over a 24-hour period (http://water.usgs.gov/nwis/discharge).

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Depth to Shallow Groundwater

The Indicator

Shallow aquifers, or deeper regional aquifers where shallow aquifers do not exist, are often the water source for the maintenance of riparian and wetland ecosystems (Dawson and Ehleringer 1991, Flanagan et al. 1992). Shallow groundwater is being increasingly withdrawn for agriculture, urban expansion, and mining. Reduction in stream flows, which maintain shallow alluvial aquifers, by dams or other activities also reduces the level and availability of this important water source (Shafroth et al. 2000). In addition, deep-rooted plants, such as pinyon-juniper and Western juniper, are capable of lowering shallow aquifers in the process of transpiration.

Declining groundwater has been shown to affect riparian ecosystems through a reduction of (1) the shallow water table necessary for recruitment of riparian species and (2) long-term maintenance of established woody riparian vegetation. Urban development may tap shallow groundwater associated with river basins, which can cause a gradual decline in associated riparian forests (Stromberg et al. 1992). Gravel mining may alter the natural gravel deposits along rivers, causing shallow groundwater to recede, affecting established riparian vegetation (Scott et al. 1999).

Streams in arid climates, affected by withdrawal of groundwater inputs, also show declining vigor of riparian vegetation as both the alluvial groundwater level declines and stream flow is reduced (Stromberg et al. 1996). Shallow groundwater decline is often a long-term phenomenon because it is usually caused by a gradual withdrawal of water from the shallow aquifer which may continue to be recharged, although inadequately, by stream inflows or from deeper aquifers. If the source of water replacement is affected, shallow aquifers, which are the primary water source for springs, seeps, wetlands, potholes, and riparian areas and which in some cases support declining ecosystems, will thus not be replenished.

Shallow groundwater depths are often used to determine long-term cumulative effects of groundwater withdrawal by agriculture, mining, or urban expansion. Urban expansion in the Great Basin has resulted in water claims on both shallow and deep aquifers. Modeling of this potential withdrawal shows that the shallow water table may decline by 1–3 m (Schaefer and Harrill 1995), a result that would drastically impact the isolated desert springs, the only water source for domestic livestock and wildlife in these areas. Decreasing aquifer volumes and dropping water tables also add to energy costs of water withdrawal, sufficiently so to cause decline or termination of regional agriculture in arid regions of the United States.

The technical note for Number and Duration of Stream Flow (immediately preceding this technical note) also provided relevant perspective on the interaction between groundwater, surface water, and land use.

The Data Gap

Although depth to deep groundwater or the regional aquifer is regularly measured in monitoring and functioning wells across the country and the data are reliable and maintained by appropriate agencies, these data have not been integrated either for the grassland/shrubland region or nationally (see groundwater indicator in freshwater chapter, p. 151; and USGS 1997).

Data on shallow aquifers are quite limited. Depths for shallow aquifers (e.g., groundwater under riparian communities) and deeper regional aquifers are usually treated separately. The limited shallow aquifer data from the U.S. Geological Survey and many academic and agency research projects dealing with rivers and adjacent floodplains (see citations above) may also be good sources for regional shallow groundwater data.

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At-Risk Native Species

See the technical note for the core national at-risk species indicator (p. 214).

Non-native Plant Cover

The Data Gap

Data from various sources must be evaluated and synthesized to provide regional and national estimates of the area occupied by non-native plant species. There are numerous federal, state, and local government programs that collect relevant information, plus important efforts in nongovernmental organizations and academic institutions that could contribute to reporting on this indicator.

A recently established consortium includes representatives from the U.S. Geological Survey, the U.S. Fish and Wildlife Service, National Aeronautics and Space Administration, USDA Forest Service, The Nature Conservancy, Colorado Natural Heritage Program, USDA Animal Plant and Health Inspection Service, National Park Service, Bureau of Land Management, Colorado State University, the Biota of North America program (University of North Carolina), and others. This initiative, titled "One if by Land, Two if by Sea," will attempt to better coordinate and synthesize existing data on non-native species in the United States. Coordination for this initiative is being provided by Tom Stohlgren, USGS Natural Resources Ecology Laboratory, Colorado State University, Fort Collins, CO 80523, tom_stohlgren@USGS.gov.

Many agencies of the Departments of Interior and Agriculture, as well as state and local governments, nongovernmental organizations, and universities, collect important data on invasive plants in grassland and shrubland regions. Several examples of such programs are listed below.

The USDA Forest Health Monitoring program (http://www.na.fs.fed.us/spfo/fhm/), for example, collects plant cover data in forests throughout the United States, and the program is expanding to include grasslands and shrublands in some areas.

- U.S. Department of Agriculture's Center for Plant Health Science and Technology, a part of the Animal and Plant Health Inspection Service's Plant Protection and Quarantine program, maintains the Federal Noxious Weeds Database, which provides descriptive and some distributional data on many recognized invasive plants (see http://www.invasivespecies.org/fedweeds.html). The distribution data for the Federal Noxious Weeds Database (which provides data up to 1999) are from the Synthesis of the North American Flora by John Kartesz (North Carolina Botanical Garden, University of North Carolina) and Christopher Meacham (Jephson Herbarium, University of California, Berkeley). The Synthesis is available as an interactive database on CD-ROM (see http://www.bonap.org/synth.html for ordering information). It provides information at state level, although the program from which it was generated also maintains county-level data for 44 states (see www.bonap.org/summary.html).

- The University of Montana maintains the INVADERS database, which covers five northwestern states (Oregon, Wyoming, Montana, Idaho, and Washington) with information at county level. INVADERS may be accessed at http://invader.dbs.umt.edu/.
- The U.S. Geological Survey has initiated the Southwest Exotic Plant Mapping Program, or SWEMP, which is designed to develop a regional database of exotic plant distributions for the Southwest (Arizona, New Mexico, and Colorado Plateau portions of Utah and Colorado). Some data are available at http://wapiti.wr.usgs.gov/swepic/.

Standardized field techniques should be adopted to create comparable data that can be synthesized. These extensive field datasets must be linked to high-resolution maps of vegetation, soils, topography, and land use to achieve reliable national coverage.

Population Trends in Invasive and Non-Invasive Grassland/Shrubland Birds

The Indicator

This indicator reports the change in population of invasive and native, non-invasive grassland/shrubland birds. The invasive birds include both non-native birds and some native birds that spread aggressively because of a favorable change in conditions. The non-invasive birds are native birds that depend on high-quality native grasslands and shrublands.

There was some interest in separating the groups of this indicator by native/non-native; however, given the low number of birds involved, a decision was made to maximize the number of species in each group to improve the statistical reliability of the results. Thus, both natives and non-natives were included in the invasive category.

The Data

Data Source: This indicator incorporates population trend estimates for 15 invasive non-native and 35 native grassland bird species. Estimates are based on data collected for the North American Breeding Bird Survey (BBS), and were obtained from the Patuxent Wildlife Research Center (PWRC), United States Geological Survey, U.S. Department of the Interior. Trends were estimated for BBS Physiographic Strata (regions) 6–8, 32–56 and 80–91, in seven 5-year intervals from 1966 to 2000 (http://www.mbr-pwrc.usgs.gov/bbs/physio.html).

Following is a list of the invasive species included in this indicator and the reason the species is considered invasive: American crow, habitat conversion to agriculture; American robin, habitat fragmentation due to suburban development; black-billed magpie, habitat conversion and fragmentation; bronzed cowbird, forage in association with livestock; brown-headed cowbird, forage in association with livestock; cattle egret, Old World native, habitat conversion to agriculture, and forage in association with livestock; common grackle, habitat fragmentation and conversion to agriculture; European starling, Old World native; gray partridge, Old World native, habitat conversion to agriculture; great-tailed grackle, habitat conversion to agriculture; house finch, habitat fragmentation due to suburban development; house sparrow, Old World native; mourning dove, habitat conversion and fragmentation; ring-necked pheasant, Old World native, habitat conversion to agriculture; and rock dove (domestic pigeon), Old World native, habitat conversion, and fragmentation.

Native, non-invasive species, which are restricted to those native species known to be dependent upon relatively intact and high-quality native grasslands and shrublands, included Baird's sparrow, black-throated sparrow, LeConte's sparrow, bobolink, loggerhead shrike, Brewer's sparrow, long-billed curlew, burrowing owl, McCown's longspur, Cassin's sparrow, mountain plover, chestnut-collared longspur, northern harrier, common nighthawk, prairie falcon, dickcissel, sage grouse, eastern meadowlark, sage sparrow, ferruginous hawk, sage thrasher, golden eagle, savannah sparrow, grasshopper sparrow, sharp-tailed grouse, greater prairie chicken, Sprague's pipit, Henslow's sparrow, Swainson's hawk, horned lark, upland sandpiper, lark bunting, vesper sparrow, lark sparrow, and western meadowlark.

Data Collection Methodology: The BBS is jointly coordinated by the PWRC and the Canadian Wildlife Service, Environment Canada. It is conducted along randomly located routes on secondary roads throughout the contiguous United States and southern Canada. Routes are 24.5 miles long, with 50 survey points at 0.5-mile intervals. Observers survey each route annually during June (May in some southern states and desert areas). At each survey point, the observer counts all birds seen or heard within a 0.25-mile radius during a 3-minute census. The first BBS routes in 1966 were run only east of the Mississippi River. The BBS was extended to the central United States in 1967, with full coverage of the contiguous United States by 1968. The number of BBS routes has increased over time, so recent years provide more comprehensive data than early years. Summaries of the BBS methodology are provided by Peterjohn and Sauer (1993) and Sauer et al. (2000a,b), and a review of the program is provided by O'Connor, et al (2000).

Data Manipulation: W. Mark Roberts, an independent researcher, obtained trend estimates (change in population size as a percentage per year) for each species in each physiographic stratum (region) and time interval from a server program provided by John R. Sauer at PWRC (http://www.mbr-pwrc.usgs.gov/bbs/trend/tfmb.html). The program uses an "estimating equations estimator" (described in Link and Sauer 1994) to calculate each stratum's trend estimate from individual route data. Dr. Roberts performed subsequent manipulations: To reduce the influence of less reliable estimates, each stratum estimate was weighted toward the survey-wide estimate, proportionately to the variances of both estimates. Weighting used an empirical-Bayes formula (Equation 1 in Link and Sauer 1996). The mean of the variance-weighted stratum estimates was calculated for each species and time interval. The summary indicator is the proportion of species with positive (increasing) mean variance-weighted estimates. To compare native with invasive birds, Yates-corrected Chi-square statistical tests were performed on the frequencies of positive and negative mean variance-weighted estimates.

Data Quality/Caveats: Bird species differ in habits, habitat, abundance, and range, all factors that may bias trend estimates for certain species more than for others (see Droege 1990 and http://www.mbr-pwrc.usgs.gov/bbs/introbbs.html). The BBS methodology and data have been subjected to peer review, results of which are available at http://www.mp2-pwrc.usgs.gov/bbs/

bbsreview/. The trend analysis program (Sauer and Hines 2001) and manipulations performed by Dr. Roberts are based on peer-reviewed methodology. Output of these manipulations has not, however, been independently verified.

Data Access: Trend estimates are the output of a draft program (http://www.mbr-pwrc.usgs.gov/bbs/trend/tfmb.html), placed on the PWRC server but not linked to public pages. Though accessible without charge, this program should not be used without permission from John R. Sauer at PWRC.

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Fire Frequency

See the technical note for the forest fire frequency index indicator, p. 243.

Riparian Condition

The Indicator

The indicator would report on the ecological integrity or health of riparian ecosystems, including both physical and biological factors.

The number and quality of streams and rivers and their associated riparian areas are a function of watershed conditions. Consequently, the condition of riparian areas may be useful as an indicator of ecological alterations of grassland and shrubland watersheds. For example, if land cover is altered, the stream flow may also be altered, changing the geomorphology of the river channel and influencing riparian dynamics. Regulation of rivers by dams and other flow-altering devices also influences downstream conditions, including streambank erosion and river meandering, sediment aggradation and seedbed development, and natural recruitment of riparian vegetation. Local land use within a floodplain, such as agriculture, grazing, and urbanization, may also greatly influence the condition of riparian ecosystems. In turn, riparian systems also influence hydrogeomorphic processes by trapping sediment and modifying flood flows and groundwater recharge.

The Data Gap

Several measures are being used nationally, but no "simple" index has received general acceptance among the research community. An appropriate "Index of Riparian Integrity" still needs to be fully developed. Several federal agencies use a combined qualitative metric called Proper Functioning Condition (PFC) when evaluating riparian systems (see Bureau of Land Management 1993). However, PFC is primarily hydrogeomorphic and includes little of the biological conditions such as species composition, age classes, understory condition, canopy condition, and successional processes. Another methodology developed in the past few years is the Hydrogeomorphic Methodology (HGM) (Brinson 1996, Smith et al. 1995). This methodology uses a complex of indices for hydrology, geomorphology, land use, biology, and other aspects to create a single index for the riparian system. It is complex, but a simplified version might be developed for broad-scale application. Yet another, simpler method is one that relies on satellite data (Iverson et al. 2001).

Aspects of the riparian condition that can be measured on a regional basis and that should be considered in any multi-metric index include hydrology (e.g., relationship to natural flow patterns), geomorphology (e.g., stream sediment transport), and biology (e.g., canopy cover condition; percentage of potential recruitment or successional measures; canopy diversity, or coverage of point bars). Many of these aspects either are being measured now or could be measured as part of a national riparian evaluation system.

Once an index is developed, it would be applied within a sampling design that would allow estimation of the conditions on all streams within a region. Thus, for example, such an approach might provide estimates of the number of miles of stream with "riparian condition index" that is "high," "medium," or "low," each of these being within a selected numerical range of the index.

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Production of Cattle

The Indicator

This indicator reports on the U.S. cattle and calf inventory not at feedlots in July of each year. It is assumed these cattle are grazing on grasslands and shrublands (including pasture) because they are not at feedlots. Note that cattle will spend some time during the summer months in woodlands or forests if they are available; it is uncertain how this complication would affect the data reported here.

The Data

Data Source: Data presented here are from the U.S. Department of Agriculture National Agricultural Statistics Service (NASS). NASS conducts annual surveys of livestock herd sizes during January and July.

Data Manipulation: Cattle numbers on grasslands/shrublands were estimated by subtracting the number of "cattle on feed" from total cattle ("all cattle") numbers in July. Total cattle numbers include cows that have calved, bulls, heifers, steers, and calves. Most calves have not weaned by July; however, increased forage consumption by lactating cows compensates for this apparent overcounting of animals. The number of cattle on feed includes steers, heifers, cows, and bulls.

In winter, some cattle are placed on croplands to consume plant products and seeds left behind. More important, the quantity and quality (digestibility and amount of protein) of grass plants decline substantially in winter, so the forage supply on grasslands and shrublands is inadequate. Thus, in many parts of the country, ranchers must feed hay to cattle in winter.

Data Caveats/Quality: It is known that cattle will spend some time during the summer months in woodlands and forests. The effect that this caveat might have on the indicator is unknown.

Another caveat involves the fact that the indicator reports the number of cattle rather than the weight of cattle. The average weight of cattle may change over time, so the same herd size may involve more or fewer pounds of livestock. If such changes occur, this indicator may over- or under-represent the production of livestock.

Data Availability: These data are available at http://www.nass.usda.gov:81/ipedb/cattle.htm. This site allows the user to retrieve selected data for selected years from the NASS database. To obtain the total cattle July inventory, select "Inventory by Class, July 1" for years of interest. To obtain data on cattle on feed, select "cattle on feed, July 1" (data availability begins in 1994). In obtaining the data reported here, the "cattle on feed" data were subtracted from the "cattle and calves-all" column of the cattle inventory data set. These data were accessed October 25, 2001.

Data from the July inventory are available for a longer time series than is presented here, but comparable data on cattle on feed are not. In addition, data from the January inventory are available for both the total inventory and cattle on feed. However, these data are not believed to represent cattle on grasslands and shrublands, and thus are inappropriate for this indicator.

Data on the value of the U.S. cattle inventory are from NASS, 2000 Agricultural Statistics (www.usda.gov/nass/pubs/agr00/00_ch7.pdf).

Data on longer term trends in cattle inventory are from the NASS database Web site noted above. The January cattle inventory was inspected for the period from 1960 to 2000 and showed a high of 132 million in 1975. As noted, this inventory is not comparable to the July inventory, and can be used only to suggest long-term trends in cattle herd size.

Recreation on Grasslands and Shrublands

There is no technical note for this indicator.