Rangeland CEAP

An Assessment of Natural Resources Conservation Service Practices

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On The Ground

- The Conservation Effects Assessment Project (CEAP) is a multi-agency effort to quantify the environmental effects of conservation practices and programs and develop the science base for managing the agricultural landscape for environmental quality.
- The rangeland CEAP review evaluated the scientific literature on seven core NRCS conservation practices: prescribed grazing, prescribed burning, brush management, range planting, riparian herbaceous cover, upland wildlife habitat management, and herbaceous weed control.
- The scientific literature "broadly supports" the reviewed rangeland conservation practices standards; however, there is a disjunct in integrating science and field-based knowledge so that managers and conservationists can fully understand the individualistic dynamic aspects of rangeland conservation practices.
- The CEAP synthesis establishes a precedent for partnerships among scientists, land managers, conservation specialists, and policymakers to provide NRCS with useful, current, science-based information for rangeland conservation practices.

Keywords: Conservation Effects Assessment Project, prescribed grazing, prescribed burning, brush management, range planting, riparian hernaceous cover, upland wildlife management.

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The Soil Conservation Act of 1935 provided the authority to prevent and manage soil erosion on croplands, grazing lands, and forestlands in the United States. The Act also authorized the Soil Conservation Service, renamed the Natural Resources Conservation Service (NRCS) in 1994 to convey the broader scope of the agency's mission—to carry out conservation measures and assist landowners in this process. This legislation and other related laws tasked NRCS with assisting owners and operators in planning and applying conservation programs.

Today, science-based information is needed to develop and assess the effectiveness of NRCS management practices and conservation programs. In 2003, in the interest of government accountability, Congress and the Office of Management and Budget requested information from the U.S. Department of Agriculture (USDA) about the effectiveness of its conservation programs. In response, the Conservation Effects Assessment Project (CEAP) was initiated by NRCS to provide quantitative information about the environmental impacts of its conservation practices on agricultural lands within the contiguous 48 United States. The CEAP is a joint effort of the NRCS, Agricultural Research Service (ARS), National Institute for Food and Agriculture, other federal agencies, and university scientists to quantify the environmental effects of NRCS conservation practices and programs and develop the science base for managing the agricultural landscape for environmental quality. Initially focused on croplands, the CEAP effort has been expanded to include wildlife, wetlands, pastures, and rangelands. Project findings have been used to guide USDA conservation policy and program development that will assist conservationists, farmers, and ranchers with informed conservation decisions.

The CEAP Process

The rangeland CEAP effort began in 2006 to 1) assess and quantify the impacts and effects of conservation practices on environmental quality at national, regional, and watershed scales; 2) strengthen the scientific basis associated with conservation programs and enhance environmental quality of managed lands; and 3) provide a solid scientific foundation for NRCS conservation practices.[1]

The first comprehensive review of literature to describe the benefits of NRCS conservation practices was on croplands,[2] for which a special issue of the *Journal of Soil and Water Conservation*[3] was developed with 35 articles on the impacts of conservation on croplands. The subsequent CEAP literature synthesis on rangelands was conducted in phases. The first phase and publication, *Environmental Effects of Conservation Practices on Grazing Lands*,[4] developed by the Water Quality Information Center at the National Agricultural Library in 2006, is a bibliography of recent scientific literature covering environmental effects of conservation practices on grazing lands (Fig. 1). The 1,303 citations in the bibliography are categorized for pastureland or rangeland and are organized as to effects on soil and water, fish and wildlife, and plant ecology and biodiversity. Documents are cited from the published literature from 1980 through early 2006, and each entry includes an abstract, URL to download the article when available, and source database of information (e.g., AGRICOLA, CAB International, etc.). Current dynamic literature searches are also available for retrieving more recent literature that addresses both policies and on-the-land conservation systems that foster practical and environmentally sound practices through the National Agricultural Library, Water Quality Information Center website.[i]

The second phase of the literature review process was a synthesis to evaluate the scientific basis for the purposes and objectives of the NRCS National Conservation Practice Standards.[5] NRCS practice standards are developed at the national and state levels and contain information on the purpose, conditions for practice application, criteria for the selection of the practices to address identified resource concerns, design considerations, plan and specification requirements, and operation and maintenance of the practices. National Conservation Practice Standards are not used to specifically plan, design, or install on-the-ground conservation practices, but they serve as a guide for state standards which are designed to meet all federal, state, and local criteria. State standards are more specific to the region, locally relevant, and contain technical details. National and state conservation practice standards are presented in alphabetical order by practice name, and are available on the NRCS website.[5]

For the CEAP synthesis, 40 rangeland scientists provided rigorous external review of the scientific literature to determine if published experimental evidence supported, refuted, or was insufficient to assess conservation outcomes. The 429-page rangeland CEAP literature synthesis, *Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge Gaps*,[6] (Fig. 2) evaluates seven core NRCS rangeland conservation practices:

1) prescribed grazing (NRCS Practice Code 528);
2) prescribed burning (338);
3) brush management (314);
4) range planting (550);
5) riparian herbaceous cover (390);
6) upland wildlife habitat management (645); and
7) herbaceous weed control (315).

[i]Dynamic literature searches of the CEAP bibliography are available online at http://www.nal.usda.gov/wqic/Bibliographies/ceap-dynamic.shtml.

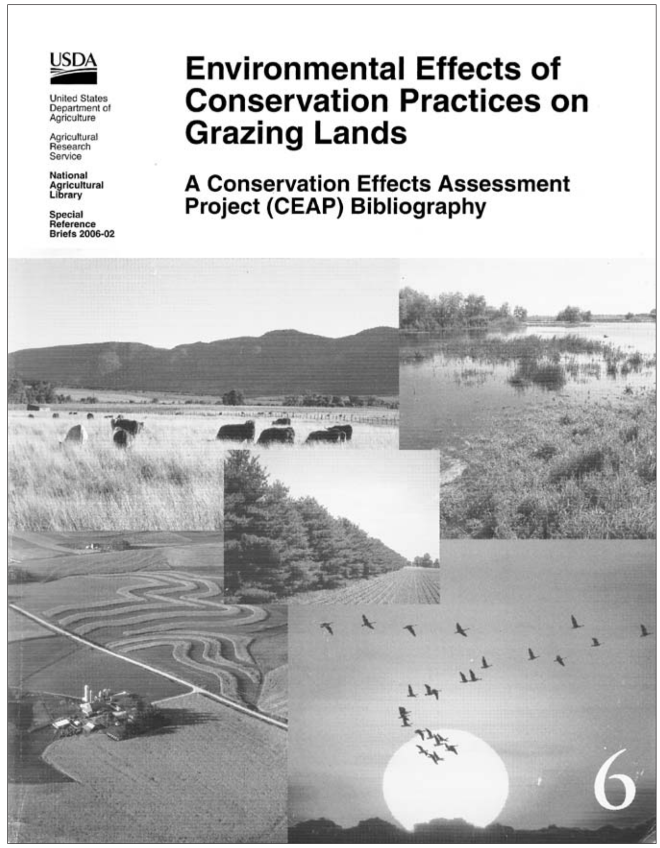

Figure 1. *Environment Effects of Conservation Practices on Grazing Lands* (bibliography).

While the CEAP synthesis also focused on two crosscutting issues, landscape analysis and socioeconomics and ecosystem services (important components of future conservation planning), we chose not to address these issues in this article.

Each of the seven CEAP chapters includes a description of the core NRCS practice standard, its purposes and benefits, evidence-based information (positive, negative, tradeoffs, and risks), identification of knowledge gaps, recommendations for future modifications, and a summary and conclusions. A summary of the CEAP findings can be found in the document's Executive Summary.[6] In this article, we present original syntheses of each of the seven CEAP chapters, including the results of how well the scientific literature supported each of the NRCS conservation practice standards, and then discuss how NRCS is building on the results.

Assessment of Rangeland Conservation Practices

Prescribed Grazing

Prescribed grazing, as defined in the NRCS practice standard, is managing the harvest of vegetation with grazing and/or browsing animals. "Prescribed grazing involves a continuum of management activities" that are described in the standards'

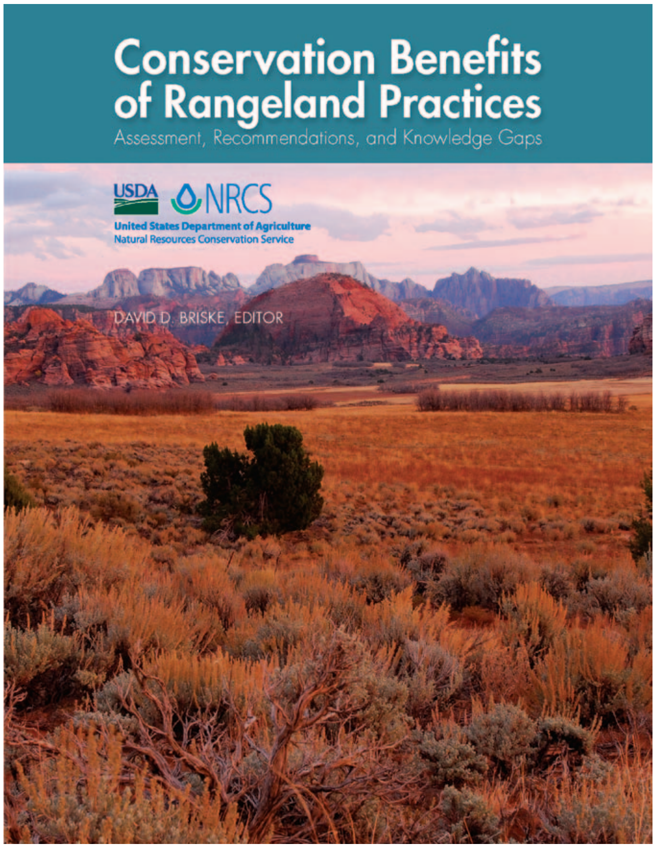

Figure 2. *Conservation Benefits of Rangelands Practices: Assessment, Recommendations, and Knowledge Gaps.*

list of purposes.[7] The purpose of prescribed grazing is intended to improve or maintain ecosystem services (i.e., desired species composition, quantity and quality of forage, surface and/or subsurface water quality and quantity, riparian and watershed function, reduction of soil erosion, maintenance or enhancement of wildlife habitat, and maintenance of fine fuel loads). The chapter authors[7] concluded that "published experimental evidence relevant to grazing management broadly supports the overall USDA-NRCS approach to prescribed grazing and validates the ecological foundations of many of the purposes addressed in this conservation practice standard. Inferences drawn from these experimental data indicate that the NRCS conservation purposes addressing prescribed grazing can potentially be realized, if implemented appropriately."[7] Stocking rate and livestock distribution are important variables that influence conservation objectives in grazed ecosystems and guidelines for balancing forage production with animal demand should include the following contingencies: forage inventories, analysis of seasonal growth curves, and drought management plans.

The science pertaining to prescribed grazing is not without knowledge gaps because research to date has emphasized plant and animal production responses, while the responses of other ecosystem services (e.g., species diversity, carbon sequestration) have been investigated to a much lesser extent.[7] This emphasis on plant and animal production responses to grazing provides a "narrow foundation on which to assess ecosystem services and environmental quality in grazed ecosystems."[7] In future syntheses and amendments to our knowledge of prescribed grazing, more attention and review is needed on plant functional groups, soil health, biodiversity, carbon balance, drought dynamics, hydrology, and spatial heterogeneity of rangeland landscapes. The authors of this chapter[7] conclude the following:

1) greater emphasis is needed to support training in management skills and management effectiveness beyond the initial financial investment for producers,
2) a precedent of frequent follow-up and monitoring needs to be established to assess both short- and long-term responses that can directly support adaptive management and optimize the economics of the conservation investment,
3) future revisions of the NRCS standard should incorporate the CEAP prescribed grazing recommendations that focus on environmental quality, ecosystem services, and societal benefits, and
4) future revisions to the prescribed grazing standard should include the most current technical information and references to support the agency's application of rangeland conservation planning.

Prescribed Burning

The USDA-NRCS definition of prescribed burning is controlled fire applied to a predetermined area. Its purposes are to control undesirable vegetation; prepare sites for harvesting, planting, or seeding; control plant disease; reduce wildfire hazards; improve wildlife habitat; improve plant production quantity and/or quality; remove slash and debris; enhance seed and seedling production; and facilitate distribution of grazing and browsing animals. The chapter authors[8] found that the general nature of the standard's purposes was difficult to assess through the scientific literature and opted to evaluate prescribed fire effects on plants, soil, water, wildlife, arthropods, livestock, fire management, fire behavior, smoke management, socioeconomics, air quality, fire history, and human health. One major finding was that most research on prescribed burning is not specific to management applications and management recommendations. Rather, the vast majority of scientific evidence addressing fire in rangeland ecosystems points to the "need to continue and restore fire regimes with conservation programs."[8] We do know that fire effectively controls many invasive woody plants that have a negative competitive effect on herbaceous understory species. In situations where herbaceous plants respond negatively to fire and postfire conditions, the effect usually persists for only 2 to 3 years.[8]

Application of prescribed fire has met with challenges because of social concerns, legalities among municipalities, air quality impacts, and fear of litigation in case of accidents. "Incorporation of prescribed burning into conservation programs must include an understanding of the dynamic role that fire plays in most rangeland ecosystems."[8] NRCS should also be proactive in promoting and supporting rangeland fire research and engage the scientific community and other federal agencies to develop management tools.[8]

Herbaceous Weed Control

The USDA-NRCS herbaceous weed control standard definition is the removal or control of herbaceous weeds including invasive, noxious, and prohibited plants. NRCS requested that the chapter authors[9] assist in developing a new set of practice standards in parallel with their review of the effects of this practice. The purposes of herbaceous weed control are to protect noninfested rangeland; enhance quality and quantity of commodities, including forage for livestock; control undesirable vegetation; create desired plant communities; change underlying causes of weed invasion; restore desired vegetative cover; maintain or enhance wildlife habitat; protect life and property from wildfire hazards; and minimize negative impacts of pest control on soil, water, air, plant, and animal resources.

The interrelationships of ecosystem components and climate are complex on rangelands and vegetation response to herbaceous weed control and management is often difficult to predict. Ecological Site Descriptions with fully developed state-and-transition models that emphasize ecological processes and integrated systems approaches can provide a "viable framework" for invasive plant management.[9] To foster improved invasive plant management, the chapter authors[7] recommend the following:

1) improving and standardizing data collection and degree of risk for better management decisions;
2) accelerating science-based management of threatened and/or invasive-dominated rangelands;
3) developing and implementing a comprehensive education, technology transfer, and preventative warning system; and
4) developing ecologically based management systems for invasive plant management.

This chapter concludes that 1) herbicides provide "short-term control of invasive weeds"; however, without additional management practices, weeds return; 2) positive effects of biological control are rare; 3) grazing management is emerging as a practicable weed management method, but knowledge on timing, intensity, frequency of grazing, and class of livestock is limited to a few invasive plant species; and 4) studies pertaining to prevention strategies are virtually nonexistent.[9] The chapter authors[9] found that herbaceous weed management strategies are often associated with a high ecological risks and high risks of failure. More research is needed to develop effective and predictable techniques for invasive plant control.[9] However, more research alone will not solve the problem. New methods of conducting research that use adaptive management strategies and include long-term monitoring to document the effectiveness of treatments are needed. The most effective approach is early detection where eradication may be possible, but it is only infrequently implemented.

Range Planting

NRCS defines range plantings as the establishment of adapted perennial or self-sustaining vegetation such as grasses, forbs, legumes, shrubs, and trees. The purposes of the range planting standard are to restore a plant community similar to the Ecological Site Description reference state for the site or develop another desired plant community; provide or improve forages for livestock; provide or improve forage, browse, or cover for wildlife; reduce erosion by wind and/or water; improve water quality and quantity; and increase carbon sequestration. The chapter authors[10] point out other purposes for range plantings that are not mentioned in the standard, for example, reduction of weed impacts on increased fuel loads and contiguous and homogeneous fine fuels that increase wildfire hazards.

NRCS range planting recommendations may vary from seeding the entire area to overseeding or spot-seeding depending on local conditions. To meet overall management objectives, range plantings are often integrated with other conservation practices such as brush management, prescribed grazing, prescribed burning, upland wildlife management, herbaceous weed control, and grazing land mechanical treatments.

The chapter authors[10] found that "virtually no refereed journal literature directly linked NRCS rangeland seeding conservation practices to specific conservation effects." They did determine that the scientific literature generally supports conservation practice recommendations for seeding rangelands.[10] One of the most problematic variables in rangeland plantings is the stochastic nature and variability of weather. Recommendations to improve this conservation practice include the following:

1) incorporating low-resolution weather forecasts and modeling into the planning process to increase the probability of success, especially if seeding decisions in the fall are linked to projected climatic conditions throughout the winter and spring following seeding;
2) effectively documenting site conditions and climatic variability, as well as information about monitoring results, and evaluating unsuccessful or partially successful applications to determine cause, if possible;
3) developing new and innovative approaches for validation and testing Ecological Site Descriptions and associated state-and-transition models before they can be used to form the bases of range planting conservation practices;
4) including more references pertaining to ecologically based technical literature to guide planning decisions;

5) modifying the practice standard to provide guidance on appropriate use of adaptive management to increase the success rate of plantings; and
6) adopting protocols to ascertain revegetation and restoration success through monitoring.

Brush Management

The brush management standard is defined as the management or removal of woody (non–herbaceous or succulent) plants including those that are invasive and noxious. The purposes of this practice are to create a desired plant community consistent with the ecological site; restore or release desired vegetative cover to protect soils, control erosion, reduce sediment, improve water quality, or enhance stream flow; maintain, modify, or enhance fish and wildlife habitat; improve forage accessibility, quality, and quantity for livestock and wildlife; and manage fuel loads to achieve desired conditions. The chapter authors[11] found the following:

1) brush management is essential for maintaining grassland and savannah ecosystems;
2) grass response to woody plant removal varies, but it is pronounced 2 to 5 years after the treatment;
3) hydrological processes may be enhanced but not assured and are dependent on geology and climate;
4) wildlife species and habitat response (plant functional groups and species) are site-specific and little information is available for nongame species; and
5) economics of brush management cannot be based solely on improved livestock and wildlife response—other ecosystem services such as maintaining biodiversity should be considered in estimating benefits.

Upland Wildlife Habitat Management

Many land management applications on rangelands are used to enhance wildlife populations and habitats; however, wildlife response is species-specific because of the varied habitat types they utilize.[12] If prescribed grazing is applied correctly, wildlife habitat can be maintained or enhanced, but the frequency, timing, and intensity of livestock grazing may need to be altered to optimize benefits to wildlife.[12] The NRCS definition for upland wildlife habitat management is to provide and manage upland habitats and connectivity within the landscape for wildlife. Its purpose is to treat upland wildlife habitat concerns identified during the conservation planning process so that the wildlife that inhabit these uplands during a portion of their life are able to move as they need and have shelter, cover, and food in the proper amounts, locations, and times needed to sustain them.

This CEAP chapter is centered on the effects of grazing and to a lesser extent on other conservation practices on wildlife. The chapter authors found that very few studies have examined the effects of conservation practices on habitat heterogeneity and wildlife.[12] There is a repetitive theme in the literature: livestock grazing can have positive, negative, or neutral effects on unique wildlife species depending on the timing and intensity of grazing, and combinations of different classes of livestock. The literature is clear about the negative effects of overgrazing on wildlife for some species. However, light to moderate grazing has been shown to promote plant species diversity in rangeland ecosystems[13–17] and have positive impacts for some wildlife species.

Overall, rangeland conservation practices have great potential for upland wildlife species; however, many knowledge gaps remain regarding wildlife responses to conservation practices and additional experimental research is warranted. These knowledge gaps are centered on the lack of experimental research on conservation effects on upland wildlife. Specifically, research addressing wildlife responses to grazing practices, energy development impacts, and landscape patterns and modifications is needed. The chapter authors recommend that researchers collaborate with land management agencies to foster large-scale long-term studies that integrate wildlife responses at a landscape scale.[12]

Riparian Management Practices

There are more than 40 conservation practices that have applications to riparian ecosystems. The chapter authors[18] focused their review on 20 of these practices and evaluated 21 separate hypotheses. The practice standards reviewed identified the following ecosystem services and benefits: 1) provision of high quality and abundant fish and wildlife habitat; 2) maintenance and improvement of water quality and quantity; 3) maintenance of stable stream banks and riparian soils supporting flood and pollutant attenuation; 4) sequestration of carbon; and 5) improvement and/or maintenance of biodiversity. Scientific evidence supporting riparian practice benefits are inconclusive; however, "there are several practice benefits that are well documented."[18] The chapter authors found weak or inconclusive evidence for seven of their hypotheses, including the notions that uncontrolled riparian grazing decreases habitat for riparian mammals and sage grouse, woody plant control decreases undesirable species, prescribed fire increases the diversity of flora and fauna, upland woody plant management decreases erosion and increases stream flow, and carbon sequestration can be enhanced through establishment and maintenance of woody species. The authors also reported that there was weak or inconclusive evidence that establishment of herbaceous species with high root mass or deep tap roots increased carbon sequestration.[18]

The chapter authors did find scientific evidence to support the following:

1) reduced livestock densities and residence time can reduce nutrient and pathogen loading in the water;
2) grazing does not decrease habitat quality of waterfowl—the exception being heavily grazed areas;
3) where grazing alters riparian habitat structure and composition, shifts can occur from riparian obligate dominance to riparian generalist species;

4) grazing effects on reptile populations are inconclusive, but diversity and abundance of macroinvertebrates seem to be unaffected;
5) salmonid habitat and populations may be decreased by long and poorly timed grazing;
6) prescribed fire can be useful in suppressing some species of woody plants; however, site recovery depends on the pre-burn levels of desirable species and adequate water tables;
7) species composition, cover, productivity, and root mass have been shown to positively respond to effective riparian grazing management, and as a result, stream channel, riparian soil stability, and riparian habitats are enhanced, supporting reduced flooding and pollutants downstream; and
8) riparian management that fosters woody plant cover can moderate stream temperatures, but this finding is conditional and dependent on site conditions and inherent woody plants.

In summary, the implications of riparian management practices support maintenance and recovery of riparian habitat structure, function, and pollution abatement by employing grazing management practices such as season of use, and intensity, and duration of use by large herbivores.

Conclusion and Future Perspectives

The NRCS uses science-based technology to provide conservation planning and assistance to land owners and land operators to maintain productive lands and healthy ecosystems. Evaluating the existing scientific literature on the effectiveness of NRCS rangeland conservation practices is an important first step as it provides a valuable source of information about what we know and what we don't know. The CEAP synthesis will serve as a "living document" that can be updated as new scientific information is available.[6]

This comprehensive literature synthesis of peer-reviewed scientific research "broadly supports" many of the NRCS Conservation Practice Standard purposes.[6] Importantly, the CEAP chapter authors collectively identify a lack of existing research that specifically applies to conservation practices as a common theme. The research community has not often conducted long-term studies (>10 years) to document ecosystem outcomes, including both ecosystem goods and services derived from implementing conservation practices. Similarly, the USDA has not emphasized or funded either short- or long-term monitoring investigations following the implementation of conservation practices because the benefits were assumed to be self-evident or too costly or difficult to obtain. A disjunct exists about benefits and various aspects of implementation of NRCS National Conservation Practice Standards and the types of research conducted by the research community.

The rangeland CEAP authors[6] noted that research methodologies and application of conservation planning and management use distinct styles of inquiry, and integrating these alternative approaches is not always clear-cut. Science emphasizes hypothesis testing, experimental design, and data analysis, often in a short time framework. In contrast, conservationists and land managers evaluate conservation responses mostly by observation and qualitative indicators, and, if time allows, some field-based quantitative measurements. Conservation management decisions often occur on longer time frames and larger spatial scales than most scientific experiments. There is merit to both lines of inquiry and approaches are desperately needed to integrate these two information sources to more effectively inform management and conservation programs. Science must be incorporated when available; similarly, managers and policymakers must inform the research community of their needs so that relevant and timely experimental information can be produced. Conservation activities must be adaptive to address local conditions and circumstances and to allow managers to constantly learn and adapt management actions based upon previous successes and failures.

The CEAP synthesis of seven NRCS rangeland conservation practices provided an in-depth review of the scientific literature, noting conclusive and inconclusive information, gaps in knowledge, and recommendations. When science-based evidence for conservation practice standard purposes and objectives are not available, NRCS must rely on interpretation of published information or subjective evidence until quantitative data are available. At present, NRCS uses supplemental information such as information sheets, physical effects worksheets, job sheets, and network effects diagrams to support the planning, decision process, and application of conservation practice standards when knowledge gaps exists in the literature.

Moving Forward

NRCS conservation planning relies on multiple conservation practices—tools from which land managers can choose to best achieve their natural resource management goals. In order to successfully meet resource management objectives that are ecologically sound, NRCS uses a resource management system approach that combines a variety of conservation practices to address multiple resource concerns and meets or exceeds the quality criteria (for soil, water, air, plants, and animals) of the identified resource concerns as described in the NRCS *Field Office Technical Guide*.[19] For NRCS, conservation planning is a dynamic comprehensive nine-step process starting with identifying problems and opportunities, determining objectives, inventorying resources, analyzing resources, formulating and evaluating alternatives, making decisions, and implementing and evaluating the plan.[20] Several CEAP authors stressed that the professional experience of conservation professionals and land managers is an important source of knowledge regarding practice effectiveness (adaptive management). The nine steps of planning used by NRCS are a form of adaptive management and learning from others is often necessary to produce positive results.[18] However, to benefit from and promote further development of adaptive management, a new procedure will need to be designed and implemented by NRCS to define what critical information is required to be captured and how to evaluate and disseminate the information resulting from the successes and failures of previous conservation practices. This new procedure must be able to integrate science and management information and be sufficiently robust to support the diverse needs of complex adaptive systems. Conservation practice standards that possess the capacity to interface with existing USDA databases and management protocols would provide a more comprehensive platform from which to select, design, implement, and evaluate conservation practices on rangelands. These data-derived conservation programs would provide the capacity to more effectively target specific conservation practices on the landscape, enhance the probability of successful conservation outcomes, evaluate cost effectiveness, and address benefits to ecosystem services. Such a comprehensive platform must coexist in the presence of trust-based professional relationships between NRCS conservationists and producers in order to truly foster those successful conservation outcomes.

Rangeland CEAP is now at the juncture where the next phase will require integration of science-based knowledge with natural resource management systems to assess the benefits of conservation, including both ecosystem goods and services. A challenge to NRCS is how to capture lessons learned from the CEAP process to guide NRCS conservation activities in the future and achieve optimal environmental benefit for funds expended. Natural resource conservation activities are vital to the future of the nation and the USDA conservation activities will continue to focus on fiscal responsibility, accountability, and environmental and scientific soundness. Assembling baseline knowledge of rangeland conservation principles can be used to inspire innovation in the design and implementation of future USDA policies and programs, guide research directions, and provide a blueprint for the delivery of science-based cost-effective conservation programs to land management agencies and producers.[21]

Application of individual conservation practices and resource management systems are expected to have a significant lag affect and yield their results very slowly because these practices involve the alteration of water and chemicals, sediment movement, and recruitment of new plant community assemblages.[22] They also involve changing the way producers think about, value, and manage their operations—ways of thought that are often adhered to for social and/or economic reasons. Quantifying the effectiveness of conservation on annual basis can be further confounded by interannual variation in weather (e.g., droughts and exceptionally wet years), making it difficult to develop socially acceptable and cost-effective monitoring systems for reporting annual benefits. Quantifying and reporting conservation effectiveness must be done in a longer timeframe (e.g., 3 to 5 years). By the time rangeland landscape deterioration is detected using currently available tools, rangeland ecosystem function may have already been compromised.[23] Therefore, resource managers should consider the probability and/or frequency of extreme climatic events (>10-year precipitation event or extended drought), plus their vulnerability to these, in conjunction with the current condition of the ecological site when assessing the site's ability to respond to conservation practice application and management.[24] For example, the hydrologic benefits of conservation practices for a site should be considered in a probabilistic framework that measures the vulnerability of a site over a range of climatic, vegetation, and surface conditions that lead to changes in runoff and erosion when considering that practice.[25] Restoration of degraded rangelands that are impacted by invasive weeds is extremely difficult and only successful about 20% of the time when nonnative adapted species are used. When only native plants are used for restoration of sites that have become dominated by invasive weeds, the probability of success is even less.[9] It is clear from the CEAP literature synthesis that more research is necessary if the anticipated benefits of invasive plant management are to be realized.[9] More research is needed to quantify reoccurrence probabilities from different extreme climatic events to be able to implement a risk or vulnerability assessment approach for estimating benefits of conservation on rangelands, and to assist in adaptive management decisions. Documenting the effectiveness of the conservation efforts may take decades to emerge to the point of being able to statistically quantify cause and effect.

Historically, natural resource research has focused on short-term challenges, with less attention and fewer resources devoted to long-term and fundamental research and this has made it difficult to document benefits of conservation that may take a decade to be realized. Also, very few rangeland research efforts have sought to incorporate the "human factor" that is key to making long-term changes in management or practice application successful. This paradigm of funding short-term research is beginning to change. Recently USDA announced the establishment of the Long-Term Agro-Ecosystem Research Network (LTAR) to provide a long-term platform for research on sustainability of US agricultural systems (e.g., cropland and rangelands) from ARS benchmark experimental watersheds and experimental ranges.[26,27] The LTAR network will provide the foundation to conduct transdisciplinary science over decades in different regions of the nation and provide a means of enhancing the sustainability of agro-ecosystems goods and services. This new network will complement the National Science Foundation's ecological networks such as Long Term Ecological Research Network and the National Ecological Observatory Network. These research networks will hopefully address, in part, what new technologies and monitoring systems are needed to observe and measure the important abiotic and biotic variables of rangeland systems in a cost-effective and timely manner to meet the needs of adaptive management required of producers and federal and state agencies at local, regional, and national scales.

The CEAP rangeland synthesis establishes a precedent for formalized ongoing partnerships among scientists, land managers, conservation specialists, and policymakers. These partnerships can assist NRCS in providing the most up-to-date science-based information for rangeland conservation practice standards. NRCS is developing a process to review all its grazing land conservation practices based on the findings in the CEAP synthesis, along with additional published material, to define quantitative metrics to evaluate the impacts of both individual NRCS conservation practices and suites of conservation practices (e.g., resource management systems). To document the impacts of its conservation practices, NRCS is investigating options for implementing a producer monitoring system and associated data management systems to quantify ecosystem impacts and provide the foundational data for modifying conservation practices in the future to achieve the desired targeted benefits.

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