Executive Summary: New Foundations for Conservation Standards[1]

C. Jerry Nelson, David J. Barker, Lynn E. Sollenberger, and C. Wesley Wood

THE CEAP INITIATIVE

Forage, grasslands, and grazing lands constitute more than two-thirds of agricultural land in the USA, where they contribute to food production and provide several ecosystem goods and services. Increasing and sustaining provision of these goods (e.g., wildlife and aesthetics) and services (e.g., conserving and protecting soil, water, and air resources) usually requires public funding and makes government agencies responsible and accountable for the investments. The Conservation Effects Assessment Project (CEAP) is a multiagency effort begun in 2003 to evaluate published research to determine if outcomes desired from conservation practices used by private landowners are supported by science. Results from CEAP will help policy makers and program managers implement existing conservation programs and design new ones to meet national goals more effectively and efficiently. In addition, CEAP identified gaps in scientific knowledge and recommended ways to build a timely science base for meeting simultaneous goals of production and conservation, and providing other ecosystem services expected by the public.

"Results…will help policy makers and program managers implement existing conservation programs and design new ones to meet national goals"

Previous CEAP assessments focused on cropland, wetlands, and wildlife. The grazing lands assessment was partitioned into rangelands, located primarily in the west, and pasture/hayland, located primarily in the east. For the pasture/hayland effort, teams of prominent scientists with expertise related to four selected conservation standards were formed in 2008 to search thoroughly, compile, interpret, and synthesize the scientific literature regarding its support of production and environmental outcomes. Natural Resources Conservation Service (NRCS) advisory personnel were associated with each team to clarify practical aspects of describing, designing, and installing the practice. Dr C. Jerry Nelson served as Academic Coordinator of the project and editor of the publication. The procedure was similar to that used by literature

[1]Excerpt from Nelson, C.J. (ed.) 2012. *Conservation Outcomes from Pasture and Hayland Practices: Assessment, Recommendations and Knowledge Gaps*. Allen Press, Lawrence, KS.

“This effort now provides a solid framework for evaluating the current situation, and for focusing, designing, implementing, and justifying future iterations”

synthesis teams for the rangeland CEAP assessment (Briske, D.D. [ed.] 2011. Conservation benefits of rangeland practices: Assessment, recommendations, and knowledge gaps. Allen Press, Lawrence, KS.)

The book contains an introduction, four chapters of in-depth assessment of a specific practice, and another chapter on synthesis and perspectives. Chapters on practice standards include:

- Planting for Hay, Silage, and Biomass (Code 512, 2010 edition)
- Prescribed Grazing (Code 528, 2007 edition)
- Forage Harvest Management (Code 511, 2008 edition)
- Nutrient Management (Code 590, 2006 edition)

Each writing team answered the basic questions of 1) does the literature document that the practice accomplishes its goals; 2) if so, how effectively does it work; 3) if not, why not; and 4) how can the practice be improved? Areas needing some or additional research were pointed out. Each chapter was reviewed by the academic coordinator and U.S. Department of Agriculture–Agricultural Research Service (USDA-ARS) liaison to ensure the review was comprehensive and had addressed the purposes and criteria. Revisions were reviewed by the academic coordinator, two peer experts not related to the CEAP effort, and by at least two NRCS practitioners. In each case the authors addressed all issues raised by reviewers.

The search, review, and evaluations were rigorous, thorough, and comprehensive, going well beyond any previous assessments of pasture and hayland practices for conservation purposes. This effort now provides a solid framework for evaluating the current situation, and for focusing, designing, implementing, and justifying future iterations and assessments of conservation practice standards for pastures and haylands. This Executive Summary highlights overarching assessments and recommendations by the writing teams. These assessments are supported by detailed analyses recorded in the book chapters and summarized in tables published within the Executive Summary.

CURRENT STATUS OF SCIENTIFIC KNOWLEDGE

Agriculture in the USA is continuing to change rapidly from nature-integrated, family-centered operations to dominance of large-scale operations using a corporate or industrial model. Farm size, machinery size, and land prices are increasingly based on crop production that depends on industrial inputs ranging from cultivars to chemicals. Gradually, natural grasslands, hay fields, and woodlands have been converted to large-scale monoculture crop production in large fields, which has displaced desirable habitat for wildlife and reduced plant biodiversity that provide natural abatement of potential risks to the environment. Credibility of agriculture is being questioned, because the general public often identifies large-scale, corporate farms with a business interested mainly in profit, having only a marginal interest in ecosystems, and increasing use of nonfamily employees who may be exploited.

"future research… needs to be broader in scope, more complex, more interdisciplinary, and longer term."

Research Needs Are Broader in Context

Current and future research for pastures and hay fields needs to be broader in scope, more complex, more interdisciplinary, and longer term. Experimental methods, focused largely on a specific hypothesis with rigorous protocols to ensure appropriate measurements for 2–4 yr, are used to answer input–output questions. In contrast, conservation questions, especially with pastures and haylands, involve nature and natural settings, usually have several animal and plant variables, allow less experimental control, and must be conducted for longer time periods, in many cases for 10 or more years. Change toward the ecological equilibrium of a pasture treatment or among perennial forages in mixtures takes time before that endpoint, the key objective, can be evaluated. Cooperation with ecologists and social scientists is needed to research these multiple outputs to answer complex management questions for pastures and haylands.

Expectations of Agriculture Go Beyond Food Supply

Food supply has traditionally been the major expectation from agriculture, but that food must also be safe, healthy, and have a desired taste. Public interest and pressure includes recognizing animal rights, managing livestock waste, improving water quality of streams and lakes, and conserving soil and biodiversity. Although acceptance and use of biotechnology and genetic engineering of crops by U.S. farmers and consumers occurred rapidly, demand for organic products also increased, especially among high-income families. Some prefer "natural" foods that are different from organic foods and are labeled "locally produced," "grass-fed," "hormone-free," or "free-range," for example, or have other value-added traits. New research will require cooperation with social scientists so human elements of both consumers and producers receive appropriate attention and understanding as changes occur.

These concerns also point toward greater use of hayland and animal manures in crop rotations and use of more pastureland for meat and milk production.

Private Industry Brings Mixed Reactions/Emotions

Amalgamation or connectivity among agricultural industries has brought new technologies that are adopted rapidly by crop farmers, giving the public perception of industrial control of agriculture. The private sector greatly influences machinery, cultivars, chemical fertilizers, pesticides, and other technologies now used routinely in "conventional" agriculture. Research by private industry and patenting, including genetic engineering, have allowed private plant breeders to develop new cultivars with improved water-use efficiency, nutrient-use efficiency, herbicide tolerance, and disease and insect resistance of major crop plants. These methods and materials are usually adopted quickly, with the outcome being greater economic competitiveness of grain and row crops, higher land prices, and fewer rotations with forages and use of animal manures.

> "Local knowledge about climates, soils, plant species, and livestock needs is essential to provide credible guidance"

Public Support Is Needed for Pasture- and Hayland Issues

Conservation of natural resources will continue to be a national priority with additional state support. There are few technologies being developed by the private sector for forages aside from some seed supplies; seeding, harvest, and packaging machinery; fertilizers; and a few pesticides. Even so, significant management technologies such as rotational stocking, nutrient management, harvest management, and no-till seeding have emerged from public-sector research to improve yield and quality of pastures and hay fields while conserving resources. Private industry contributes machinery that helps implement conservation practices, but does little in areas where there is low or minimal potential for profit on their investment. Thus, enhanced public support will be needed for research, education, and incentives for volunteer adoption of needed practices.

A New Era Is Emerging for Pasture and Hayland

Forages are renowned for their capacity to reduce erosion, protect surface waters, provide low-cost feed, benefit crop rotations, support biodiversity, and provide sites to receive animal manures. There are hundreds of grass, legume, and forb species used for pasture and harvested forage. Each species has its own growth form, response to biotic and abiotic stresses, and conservation value. Pastures and forages provide good potential for erosion control on sloping and lower productivity sites, and are quality materials for riparian areas and waterways that reduce risks of plant nutrients, livestock wastes, and antibiotics as runoff pollutants. These diverse species support food chains and quality habitats for wildlife. Although the challenges are great, pastures and haylands can be managed to provide economic uses of these landscape positions while providing many ecosystem services that are valued by the public.

Summary

It is impossible to research the multiplicity of combinations of problems and potential solutions over the range of sites needing conservation practices. Thus, dependence is on basic research knowledge that is augmented by experience of the agency personnel at the local level. Local knowledge about climates, soils, plant species, and livestock needs is essential to provide credible guidance for implementation of the best practice, its maintenance, and its long-term effectiveness. Education of landowners is also critical for understanding the goals and ways adaptive management is used to maintain the area so it provides the greatest function. Modeling will help understand interactions among the biological, economic, social, and cultural expectations.

SUMMARY OF FINDINGS BY CONSERVATION PRACTICE

Each team evaluated the current level of research support for each purpose and its underlying criteria. Collectively, the team reached consensus and developed the suggestions reported in the individual chapters in the published book. The lead authors then gleaned these major findings from the chapters, integrated the assessments, and developed the tables and Executive Summary.

> "Site- and species-specific management during the first year is critical;"

PLANTING FOR HAY, SILAGE AND BIOMASS CHAPTER 2

This USDA–Natural Resources Conservation Service (NCRS) practice focuses on establishing adapted and/or compatible species, varieties, or cultivars of herbaceous species suitable for pasture, hay, or biomass production. Purposes include the following:

- Improve or maintain livestock nutrition and/or health
- Provide or increase forage supply during periods of low forage production
- Reduce soil erosion
- Improve soil and water quality
- Produce feedstock for biofuel or energy production

Key Synthesis Findings (from Table ES.1)

- Publications covered 162 grass, legume, and forb species, but more than 50% were on only 28 species. Research is needed on more species for specialized situations such as unknown dormancy conditions or unique establishment requirements.
- Adaptation to a wide range of conditions exists to provide species and management options for specific locations.
- Establishment is improved by using legume seed inoculated with the proper strain of rhizobia. Strains for some species differ in effectiveness, but may not be available. Rhizobia are not available commercially for less-common legume species.
- The best measure of seed quality is the germination test (percentage and date). Seed size and storage conditions are also important, but are not reported commercially.
- Phosphorus applications gave more consistent improvement in grassland establishment than did potassium or nitrogen. Specific responses depend on plant species, other nutrients, and competition from nonsown species. Recommendations for seeding-year stands differ from those for mature stands.
- Satisfactory establishment results from many methods of site preparation, planting methods, and species, typically with a direct relationship between cost and success. Best advice is from local specialists who adapt research to local conditions. Greater use of modeling may be warranted.
- Planting success depends on a period of favorable temperature and rainfall. Timely weather forecasting is advantageous.
- There is no benefit from sowing rates higher than those recommended by state agencies. Seeding rate should be adjusted to deliver seed on a pure-live-seed (PLS) basis.
- Seeding depth is critical; small seeds should be planted near the soil surface with adequate soil coverage. A general guide is to plant a seed no deeper than seven times its diameter.
- Site- and species-specific management during the first year is critical; species such as native warm-season grasses take more than 1 yr to be ready for their intended use. Seedling root growth is critical.
- Establishment is greatly improved by control of weeds or existing vegetation, but data were inconsistent as to the best method. Risk of runoff and soil erosion is greatest when there is little vegetation, and is extended with species that take more time to become established.
- There was little research on effects of establishment time or methods on water quality, soil erosion, gaseous emissions such as CO_2 or NO_X, other environmental factors, and food sources and habitat for wildlife.
- Few research studies consider establishment of biomass species other than those, such as switchgrass, that also can be forage or pasture crops.

"Recognizing and using adaptive management like weed control, fertilization, and cutting times will assist managers"

Implications: Generalized descriptions for forage and biomass planting are nearly impossible because of the almost infinite number of combinations of species, cultivars, planting methods, planting times, fertilizer regimes, seed coatings and treatments, climatic conditions, and final uses for the stand. Specifications to use local guidelines and expertise are warranted, because many of those guidelines have been researched locally. New species and new developments in cultivars, seed coating, fertilizer products, options for weed and pest control, and potentials for genetically modified forage and pasture plants suggest an ongoing need for continued research on establishment practices in each major climatic zone of the USA.

Establishment of forages for biomass harvesting, wildlife, erosion control, and water harvesting requires additional research, hopefully conducted with teams of ecologists and social scientists that support modeling to strengthen understanding relationships and transferability of information. Research is needed to determine when or at what stage plants are deemed to be established, and to quantify effects of establishment methods on runoff and erosion, wildlife food supplies, and time when the planting is ready for its intended use.

Research is needed on establishment on lower productivity and sloping soils that are often used for forage supplies and ecological benefits. Education of agency staff will help blend experience and science for planning and implementing the practice. Recognizing and using adaptive management like weed control, fertilization, and cutting times will assist managers correct emerging situations to minimize risk, ensure rapid and successful establishment, and provide maximum conservation benefit. This will require educational programs for managers focused on desired outcomes including forage supplies and other ecosystem services.

TABLE ES.1. Summary of purposes, criteria used for evaluation, and level of research support of Natural Resources Conservation Service Conservation Practice Standard for Forage and Biomass Planting, Code 512.

Purposes of the practice standard	Criteria used for assessing achievement of purpose	Support by research based on 350 scientific publications and 162 different species
Improve or maintain livestock nutrition and health	by establishing species and cultivars with greater production, and potential to increase animal intake	Species and cultivars differ in production and quality. But increased livestock production was assumed more likely from increased stocking rate than intake per head.
	by establishing species and cultivars with greater nutritive value (i.e., energy content, protein or mineral concentration)	A negative relationship often occurs between production and nutritive value. Less-productive species and cultivars (above) can have higher nutritive value.
	by replacing species with low nutritive value or with high levels of toxic compounds	Whether through complete stand replacement (e.g., full cultivation) or partial stand replacement (e.g., sod or no-till seeding), species with greater nutritive value can be introduced into grasslands.
	by establishing species and cultivars to provide nutrition during periods of feed deficit (e.g., extend forage production season)	Species and cultivars that are tolerant to cold can improve early-spring and late-autumn production, and those tolerant to heat and drought can improve summer production. Major species are characterized.
	by establishing species with wildlife benefits such as nesting habitat, cover, biodiversity, and insects	Wildlife species vary in nutritional and habitat requirements that cannot be met by any single forage species. Species-rich vegetation offers more benefits to wildlife than monocultures.

TABLE ES.1. continued.

Purposes of the practice standard	Criteria used for assessing achievement of purpose	Support by research based on 350 scientific publications and 162 different species
Provide or increase forage supply during periods of low forage production	by establishing species and cultivars with greater production potential	More productive species and cultivars can be harvested for hay or silage, for use during periods of low forage production.
	by establishing species with higher environmental tolerance (e.g., cold, heat, drought, pH, salinity)	Cold- and drought-tolerant species with greater forage production during feed-deficit periods can provide in situ grazing and reduce hay or silage feeding costs.
	by establishing annual forage crops to fill predicted feed deficits for harvest or grazing	Annual forage species can be planted into existing grassland, or as cover crops in grain systems, to provide forage for in situ grazing or for hay or silage harvest.
Reduce soil erosion	by establishing perennial species that provide year-round ground cover, and by avoiding cultivation	Perennial grasslands have year-round soil cover with lower rates of soil loss than bare soil and can be managed for improved persistence.
	by establishing species with improved adaptation and greater persistence	Stand longevity of new alfalfa cultivars with multiple insect and disease resistance may be more than double that of older cultivars.
	by using no-till methods for establishment to alleviate soil cultivation	Sod- and no-till seeding, especially with herbicide use for vegetation control, can successfully establish grasslands.
	by establishing plants with greater ground cover that reduces the rate of surface water flow	Plants with greater ground cover and denser vegetation have less runoff and higher water infiltration. Vegetation density is also affected by management.
Improve soil and water quality	by establishing species with vigorous root growth that ensures carbon sequestration and nutrient uptake	In general, grasses have dense, fibrous root systems, whereas legume root systems may include large taproots and crowns; rooting characteristics are affected by management as well as establishment practices.
	by establishing N-fixing legumes, thus reducing the need for fertilizer N	Legumes are relatively fast to establish, can be included in grassland mixtures, or can be no-till drilled (sod seeded) or broadcast seeded (frost seeded) into grass stands
	by establishing species that ensure efficient nutrient cycling, and support active populations of soil macro- and micro-organisms	Nutrient cycling and some soil microbial processes are impaired during establishment, but resume once the stand is established. Later on, nutrient cycling is affected significantly by forage removal as hay or silage.
	by reducing soil erosion	Where water quality is a critical issue, new seedings should use no-till methods or fast-establishing companion crops to avoid bare soil or reduce time of bare soil exposure.
Produce feedstock for biofuel or energy production	by establishing species and cultivars with high biomass potential	The most productive biofuel feedstocks (miscanthus and giant reed) can be established vegetatively with stems and/or rhizomes. Switchgrass can be established from seed.
	by establishing species and cultivars with unique characteristics for biofuel or energy production (e.g., low ash, high cellulose)	Species differ in concentration and types of structural and nonstructural carbohydrates for biofuel purposes. Several forage species have high ash content and may be less suitable for biofuel purposes than others.

"Grazing intensity…is the most important grazing strategy on pasturelands;"

This USDA-NRCS practice standard focuses on managing harvest of vegetation with grazing and/or browsing animals. The practice may be applied as a part of a conservation management system to achieve one or more of the following purposes:

- Improve or maintain desired species composition and vigor of plant communities
- Improve or maintain quantity and quality of forage for grazing and browsing animals' health and productivity
- Improve or maintain surface and/or subsurface water quality and quantity
- Improve or maintain riparian and watershed function
- Reduce accelerated soil erosion, and maintain or improve soil condition
- Improve or maintain the quantity and quality of food and/or cover available for wildlife
- Manage fine fuel loads to achieve desired conditions. Note: It was decided to not address this purpose, as it is covered in detail by the Rangeland CEAP assessment (D. D. Briske, 2011)

Key Synthesis Findings (from Table ES.2)

- Grazing practices have major influence on plant, livestock, water, soil, and wildlife.
- Grazing intensity (i.e., stocking rate or plant height) is the most important grazing strategy on pasturelands; and conservation plans should prioritize proper grazing intensity.
- Stocking method is useful for fine-tuning the system once appropriate grazing intensity is imposed. Rotational vs. continuous stocking positively affects forage accumulation and utilization as well as important measures of water quality.
- Adequate forage ground cover reduces runoff and improves water infiltration, wildlife habitat, avian nesting sites, and food supply for wildlife and livestock.
- Cograzing or grazing by one livestock species vs. another can be used to manipulate botanical composition of pastures, decrease abundance of unwanted plants, and create greater patchiness in plant height that improves wildlife habitat.
- Time scales for most pastureland research have been limited such that long-term changes in plant persistence, livestock diets, and effects on soil, water, and wildlife may be inadequately described.

Implications: Grazing intensity is the prescribed grazing strategy having greatest impact on plant, animal, soil, water, and wildlife. Thus, defining and achieving an optimal grazing intensity should be of highest priority in conservation planning and implementation. Although societal interest and emphasis on soil, water, and wildlife is increasing, there is a paucity of literature addressing effects of prescribed grazing on these ecosystem components. Future grazing studies on pastureland should be more comprehensive in scope, including these components in addition to plant and livestock measures, and be carried out over longer time periods to allow the full effects of prescribed grazing to be quantified. These data will provide the basis for development of effective pastureland ecosystem models.

A significant weakness of existing literature is the lack of consistent or standardized research protocols for measuring forage mass, accumulation, nutritive value, and species composition, especially in comparisons among stocking methods. There appears to be a significant future role for emphases including 1) use of prescribed grazing in adaptive management to correct undesirable trends in pastureland response and restore desired grassland condition; 2) better education of end users regarding implementation of prescribed grazing technology; 3) detailed monitoring and reporting of the impacts of implementation of prescribed grazing practices to use adaptive management more effectively to adjust the system to meet goals. Accumulation of monitoring data will also assist in future designs and education programs for landowners.

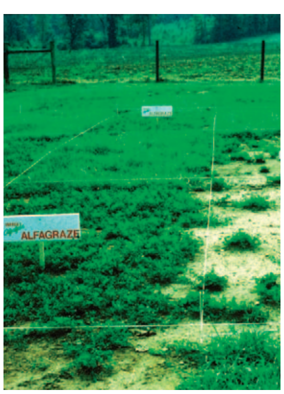

TABLE ES.2. Summary of purposes, criteria used for evaluation, and level of research support for Natural Resources Conservation Service Conservation Practice Standard for Prescribed Grazing, Code 528. Each criterion is evaluated for degree of research support from studies using five different grazing strategies.

Purposes of the practice standard	Criteria used for assessing achievement of the purpose	Support by research for each criterion (level of support in parentheses)[1]
Improve or maintain desired species composition and vigor of plant communities	by providing grazed plants sufficient recovery time to meet objectives	Stocking method (SS); season of grazing (SS)
	by improving or maintaining vigor of plant communities, especially key species	Grazing intensity (SS); stocking method (MS); season of grazing (MS); type and class of livestock (MS)
	by enhancing diversity of plants and optimizing delivery of nutrients to animals	Grazing intensity (SS); stocking method (WS); distribution of livestock (MS)
	by combining it with other pest management practices, which can promote community resistance to invasive weed species and enhance desired species	Grazing intensity (SS); stocking method (MS); season of grazing (MS)
Improve or maintain quantity and quality of forage for grazing and browsing animals' health and productivity	by reducing animal stress and death from toxic or poisonous plants	None documented
	by improving and maintaining plant health and productivity	Grazing intensity (SS); stocking method (MS); season of grazing (SS); type and class of livestock (MS)
	by basing management on target levels of forage utilization or stubble height as a tool to help ensure goals are met	Grazing intensity (SS)
	by locating of feeding, watering, and handling facilities to improve animal distribution	Distribution of livestock in the landscape (MS)
Improve or maintain surface and/or subsurface water quality and quantity, and riparian and watershed function	by improving or maintaining riparian and watershed function	Grazing intensity (SS); stocking method (MS); season of grazing (SS); distribution of livestock (MS)
	by minimizing deposition or flow of animal wastes into water bodies	Grazing intensity (SS); stocking method (WS); season of grazing (WS); distribution of livestock (SS)
	by minimizing animal effects on stream bank stability	Grazing intensity (WS); stocking method (MS); season of grazing (MS); distribution of livestock (SS)
	by providing adequate litter, ground cover, and plant density to maintain or improve infiltration capacity of the vegetation	Grazing intensity (SS); stocking method (MS); season of grazing (MS)
	by providing ground cover and plant density to maintain or improve filtering capacity of the vegetation	Grazing intensity (SS); stocking method (MS); season of grazing (MS)
	by minimizing concentrated livestock areas, trailing, and trampling to reduce soil compaction, excess runoff, and erosion	Grazing intensity (SS); stocking method (MS); season of grazing (MS)

TABLE ES.2. continued.

Purposes of the practice standard	Criteria used for assessing achievement of the purpose	Support by research for each criterion (level of support in parentheses)[1]
Reduce accelerated soil erosion, and maintain or improve soil condition	by reducing accelerated soil erosion	Grazing intensity (MS)
	by minimizing concentrated livestock areas to enhance nutrient distribution and improve ground cover	Grazing intensity (MS); stocking method (MS)
	by improving carbon sequestration in biomass and soils	Grazing intensity (MS)
	by application of soil nutrients according to soil test to improve or maintain plant vigor	Grazing intensity (MS)
Improve or maintain the quantity and quality of food and/or cover available for wildlife	by maintaining adequate riparian community structure and function to sustain associated riparian, wetland, flood plain, and stream species	Grazing intensity (SS); season of grazing (SS); distribution of livestock (MS)
	by providing for development and maintenance of the plant structure, density, and diversity needed for desired fish and wildlife species	Grazing intensity (SS); season of grazing (SS); type and class of livestock (MS); distribution of livestock (MS)
	by improving the use of the land for wildlife and recreation	Grazing intensity (SS); season of grazing (MS); distribution of livestock (MS)
	by avoiding any adverse effects on endangered, threatened, and candidate species and their habitats	Grazing intensity (MS); season of grazing (MS); distribution of livestock (MS)

[1]The five grazing strategies were grazing intensity, stocking method, season and deferment of grazing, type and class of livestock, and distribution of livestock in the landscape. SS = strongly supported; MS = moderately supported; WS = weakly supported; for grazing strategies not shown there was no support in the literature that this strategy affected the criterion in question.

FORAGE HARVEST MANAGEMENT CHAPTER 4

This USDA-NRCS practice standard focuses on timely cutting and removal of forages from the field as hay, green chop, or ensilage. The practice applies to all land uses where machine-harvested forage crops are grown. Purposes include the following:

- Optimize yield and quality of forage at the desired levels
- Promote vigorous plant regrowth
- Maintain stand life
- Manage for the desired species composition
- Use forage plant biomass as a soil nutrient uptake tool
- Control insects, diseases, and weeds
- Maintain and/or improve wildlife habitat

Key Synthesis Findings (from Table ES.3)

- Most research was on management with outputs of yield and forage quality. Only a few long-term studies evaluated effects on persistence or botanical composition.
- The State Agricultural Research System provides local research on cutting height and frequency for yield and quality of major forage species, generally when grown in monoculture.
- Adaptation of major species and their use characteristics have been researched at local levels.
- Ecosystem research has been focused on quantifying N and P losses from the field with implications for efficiency of nutrient use and improved water quality.
- Integrated pest management has emphasis on alfalfa insects and a few others like army worm. Most diseases are addressed with the use of genetic resistance. Biocontrol has been researched for a few insects and weed species with moderate success.
- Delaying first harvest of hay or hay-crop silage of many cool-season species favors success of ground-nesting birds; cutting 100 mm above soil level improves survival of turtles.

"Only a few long-term studies evaluated effects on persistence or botanical composition."

“Periodic monitoring of the practice and education of land managers will help understand challenges”

- Several warm-season native perennials are lauded for wildlife benefits because of growth habit, maturity, and provision of protection over the winter, but few research studies have quantified the superiority over other species.
- Allowing growth during fall improves overwintering success in northern environments.
- Growth habits of cool-season grasses in spring favor harvest for hay compared with summer when leaf growth favors grazing or accumulating forage for winter grazing.
- Legumes fix nitrogen for hayland that can be carried over for crop production.
- Principles for making and storing quality hay, haylage, and silage are well documented.
- Harvest and storage losses are well characterized for both hay crops and silages; strategies to minimize losses have been researched for most conditions.

Implications: Agricultural Experiment Stations have developed sound management practices for major species that are transferable among states. Managing for forage yield and quality is well known for major species, with less information available on stand longevity. There is growing awareness that wheel traffic damages plants and causes soil compaction, reducing production and persistence, especially for legumes, and may increase runoff. Similarly, key soil criteria, weather data, and life cycles of biota need to be incorporated into the research design, measurements taken, and interpretation of data to elucidate major interactions in such complex systems.

Long term research on pure stands and mixtures is needed to understand changes among component plant species and other biota over time. Further, interactions with forage management suggest one wildlife form may be enhanced at the detriment of another form. Specific wildlife types need to be evaluated to understand effects of field sizes, forage species, position on the landscape, and management practices on success of birds, small mammals, and other wildlife. Entomologists, plant pathologists, soil scientists, wildlife specialists, and ecologists need inputs to scale the research so results can be fitted into models for comprehensive ecosystem assessments. Periodic monitoring of the practice and education of land managers will help understand challenges, promote use of adaptive management to mitigate problems, and evaluate attempts to restore or maintain the practice for the stated goal.

TABLE ES.3. Summary of purposes, criteria used for evaluation, and level of research support of Natural Resources Conservation Service Conservation Practice Standard for Forage Harvest Management, Code 511.

Purpose of the practice standard	Criteria used for assessing achievement of the purpose	Support by research
Optimize yield and quality of forage at the desired levels	harvest at frequency and height to maintain healthy plant community as recommended by state extension service	Strong support on major species, limited on other species being used in special situations.
	harvest forage at stage of maturity for desired quality and quantity	Strong support on major species to optimize yield and quality.
	delay harvest if prolonged or heavy precipitation is forecast that would damage the cut forage	Moderate, need comparative data on rate of yield and quality change due to weather or later maturity.
	harvest silage/haylage crops within the optimum moisture range for the storage structure(s) being utilized	Strong support for haylage and silage crops over a range of moisture contents.
	use state extension service recommendations for optimum moisture content and how to determine moisture content	Strong support for optimum content, but comparison of methods for measurement needs research.
	treat direct-cut hay crop silage (moisture content > 70%) with chemical preservatives or add dry feedstuffs	Generally supported, research is variable on consistency of results achieved. Cost-effectiveness needs more research.
	invert swaths when moisture content is above 40% and rake hay at 30–40% moisture to maintain hay quality	Inverting assists the drying process, but leaf loss on some species can be high. Need research on different methods and cost effectiveness.
	bale field-cured hay at 15–20% moisture; bale at 20–35% moisture if it is to be dried by forced air	Strong support, but need more research on quality losses from field drying vs. costs for water transport and energy costs for forced-air drying.
	chop ensilage to a size appropriate for the storage structure that allows adequate packing	Strong support
Promote vigorous plant regrowth	cut plants at a stage or interval that provides adequate food reserves and/or basal axillary tillers or buds for regrowth or reproduction without loss of plant vigor	Strongly supported for upright perennial legumes and grasses. Moderate support for prostrate species that use leaf area to provide the major energy source.
	cut plants at a height that promotes vigor and health of the desired species	Strong support for low cutting of alfalfa for yield, but not for soil erosion and some wildlife.
Manage for desired species composition	harvest at the proper height and frequency to maintain desired species composition	Strong support on how height and frequency can affect species in the short term which would be useful as an adaptive management method.
	fertilize with appropriate minerals at the correct time in the growing season	Strong support for use of N, P, and K and time during the season to alter the botanical composition.

TABLE ES.3. continued.

Purpose of the practice standard	Criteria used for assessing achievement of the purpose	Support by research
Use forage plant biomass as a soil nutrient uptake tool	use a harvest regime that utilizes the maximum amount of available or targeted nutrients	Moderate research on use of forage plants to utilize excess nutrients in cropping systems
	when desired, select species that can maximize nutrient uptake	Variation in nutrient uptake among species is known, but balance is more critical than uptake of a single nutrient.
	use proper balance of nutrients such as nitrogen to avoid toxic plant material for animals	Strong research support on NO_3 and HCN challenges in grasses. Some research on N on alkaloids in some cool-season grasses.
Control insects, diseases and weeds	select harvest periods to control disease, insect, and weed infestations	Weak research support except for insects on alfalfa (weevils, potato leafhoppers).
	evaluate pest management options by planning conservation practice standard Pest Management (595)	Strong integrated pest management (IPM) research for alfalfa insects, but weak for other species, need more research.
	lessen incidence of disease, insect damage, and weed infestation by managing for desirable plant vigor	Strong support for maintaining plant vigor and competition to reduce challenges
Maintain or improve wildlife habitat	if suitable habitat for wildlife species is desired, appropriate harvest schedules(s), cover patterns, and plant height should be maintained to provide suitable habitat	Some support for delayed harvest of first cut for ground nesters and leaving stubble for winter cover and food source; raise cut height for turtles.
	avoid harvest and other disturbances during nesting, fawning, and other critical times	Some research indicates biomass crops will be harvested late and will provide habitat in summer and winter for some forms of wildlife.

"Most purposes were supported moderately to strongly by the U.S. scientific literature."

NUTRIENT MANAGEMENT CHAPTER 5

This USDA-NRCS practice standard focuses on managing the amount, source, placement, form, and timing of applications of plant nutrients and soil amendments. The practice applies to all lands where plant nutrients and soil amendments are applied. Purposes include the following:

- To budget and supply nutrients for plant production
- To utilize manure or organic byproducts as a plant nutrient source properly
- To minimize agricultural non-point-source pollution of surface and ground water resources
- To protect air quality by reducing nitrogen emissions (ammonia and NO_X compounds) and the formation of atmospheric particulates
- To maintain or improve the physical, chemical, and biological condition of soil

Key Synthesis Findings (from Table ES. 4)

- Most purposes were supported moderately to strongly by the U.S. scientific literature.
- Several emerging areas of nutrient management require further research and development to ensure sustained and environmentally conscious pasture and hayland production.
- Major concerns with manure or organic by-products are 1) uncertainty regarding phytoavailability of nutrients contained and 2) economic evaluations.
- Simulation models, coupled with rapid determination of pools and rates of mineralizable N and P, and phytoavailable K in organic nutrient sources, could be powerful decision support tools to help optimize nutrient management in systems.

- There are few data on costs, benefits, and cost effectiveness of available best management practices for retarding nutrient loss from pastures and haylands.
- A national P index is needed to predict losses of runoff P over a wide range of conditions.
- A national nitrate leaching index is needed that will accurately predict nitrate leaching losses over a wide range of conditions.
- Improved existing and new process models are needed to predict nutrient losses from divergent nutrient loadings, soil properties, and climatic conditions.
- Literature is scarce on reducing N emissions and formation of atmospheric particulates. Most U.S. research has been in the southeast; more is needed from other regions to fully evaluate effects of management on air quality.
- Less than 5% of N applied to U.S. pastures is lost to the atmosphere as gaseous N.
- Gaseous-N loss increases with increasing rates of applied N; losses are greater from organic-N sources than from inorganic-N sources.
- Pasture and hayland fertilization maintains or moderately improves soil organic matter concentration over the long term.
- Overapplication of N and P to pastures and haylands results in their buildup and may promote escape to surface and ground waters, and N escape to the atmosphere.
- Salt buildup in soils due to fertilization of pastures and haylands is typically of no consequence at current soil concentrations.
- Heavy metals accumulate in U.S. pasture and hayland soils where animal manures are applied, but at current soil levels do not influence pasture and hayland productivity.
- Long-term manure applications have a slight liming effect on pasture and hayland soils.
- No U.S. research was found relating soil physical properties to nutrient management of pastures or haylands.
- Current data are insufficient to interpret effects of nutrient cycling on pastures and interactions with grazing management and pasture fertilization.

"A national P index is needed to predict losses of runoff P over a wide range of conditions."

Implications: Most research is focused on plant productivity, usually of short duration, leaving a strong need for long term research regarding impacts of nutrient management on soil, water, and air quality. This need is particularly evident for pastures and haylands where manures and other organic by products are used as nutrient sources. Basic information and quick test methods for nutrient release from organic nutrient sources need to be developed and standardized

"Code 590 should be separated into one focused on traditional crops, mainly annuals, and one focused on pastures and hayland."

for use across the USA. Simulation models coupled with appropriate methods for rapid determination of pools and rates of mineralizable N and P, and phytoavailable K from organic nutrient sources, could provide powerful decision support tools to optimize nutrient management. Phosphorus and N are the most common nutrient related water pollutants.

A national P index and a nitrate leaching index would help planning by predicting runoff P losses and nitrate leaching, respectively, over a wide range of conditions. Moreover, improvement of existing and development of new process models could predict nutrient losses from divergent nutrient loadings, forage or pasture species, soil properties, and climatic conditions. Once nutrient losses are defined the appropriate management practice can be implemented and impacts on other ecosystem services can be determined.

Lastly, the practice standard revised in 2011 covers some of these issues and is an improvement. But the wide difference in management practices and expected outcomes strongly indicates that Code 590 should be separated into one focused on traditional crops, mainly annuals, and one focused on pastures and hayland. This would allow more specific coverage of nutrient management during establishment and maintenance of long-term stands for production, forage quality, persistence, and provision of ecosystem services. The focus on pastures should consider stocking rates and grazing methods that affect nutrient cycling and times available for nutrient applications. The focused practice standard could emphasize perennial crops grown on lower-productivity sites that have more risk of runoff, yet have more potential for wildlife and other ecosystem benefits. The code should include riparian areas and waterways and other critical sites where forages play major roles.

TABLE ES.4. Summary of purposes, criteria used for evaluation, and level of research support for Natural Resources Conservation Service Conservation Practice Standard for Nutrient Management, Code 590.

Purposes of the practice standard	Criteria for assessing achievement of the purpose	Support by the literature
Budget and supply nutrients for plant production	by developing a nutrient management budget using all potential sources of nutrients, including crop residues, legume credits, and irrigation water	Strong support for hayland, but need manure credits for pastures and research on phytoavailability.
	by establishing realistic yield goals based on soil productivity information, historical yield data, climate, management, and local research	Moderate support, more research needed on lower quality land sites.
	by specifying the source, amount, timing, and method of applying nutrients to each yield goal while minimizing movement of nutrients and other potential contaminants to surface or ground waters	Strong support for application ahead of growth, more research needed for offseason applications.
	by restricting direct application of nutrients to established minimum setbacks (e.g., sinkholes, wells, gullies, surface inlets, or rapidly permeable soil areas)	Strong support, but mainly based intuitively from other studies. More research needed for pastures and haylands.
	address the amount of nutrients lost to erosion, runoff, drainage, and irrigation	Strong support that this is critical, but need more soils and sites, perhaps models.
	applications be based on current soil (within 5 yr) and tissue test results according to land grant university guidance	Moderate support, current soil tests do not report P or N indices.

TABLE ES.4. continued.

Purposes of the practice standard	Criteria for assessing achievement of the purpose	Support by the literature
Properly utilize manure or organic by-products as a plant nutrient source.	by reducing animal stress and death from toxic or poisonous plants	Moderate support, but not a major problem in humid areas.
	by improving and maintaining plant health and productivity	Strong support, except on roles of organic by-products.
	by basing management on target levels of forage utilization or stubble height as a tool to help ensure goals are met	Moderate support showing principles; little on specific management practices.
	by locating of feeding, watering, and handling facilities to improve animal distribution	Strong support that would benefit from quantitative models to better define.
Minimize agricultural nonpoint source pollution of surface and ground water resources.	by improving or maintaining riparian and watershed function	Moderate support, research needed on more soils and sites.
	by minimizing deposition or flow of animal wastes into water bodies	Strong support, but would benefit from models.
	by minimizing animal effects on stream bank stability	Strong support.
	by providing adequate litter, ground cover and plant density to maintain or improve infiltration capacity of the vegetation	Strong support in concept, but responses need to be quantified for a range of soils and sites.
	by providing ground cover and plant density to maintain or improve filtering capacity of the vegetation	Strong support, but responses need to be quantified for a range of species and mixtures.
	by minimizing concentrated livestock areas, trailing, and trampling to reduce soil compaction, excess runoff, and erosion	Strong support and a range of practices to minimize soil damage, but few to restore soil condition.
Protect air quality by reducing nitrogen emissions (ammonia and NOx compounds) and formation of atmospheric particulates.	by reducing accelerated soil erosion	Strong support, would benefit from use of models.
	by minimizing concentrated livestock areas to enhance nutrient distribution and improve ground cover	Strong support, but needs to be integrated with plants and their growth habits.
	by improving carbon sequestration in biomass and soils	Strong support, would benefit from use of models to quantify relationships.
	by application of soil nutrients according to soil test to improve or maintain plant vigor	Strong support for most monocultures, need more research on mixtures.
Maintain or improve physical, chemical, and biological condition of the soil.	by applying and managing nutrients in a manner that maintains or improves the physical, chemical, and biological condition of the soil	Strong support intuitively based on annual crops, but needs verification using long-term perennials.
	by minimizing the use of nutrient sources with high salt content unless provisions are made to leach salts below the crop root zone	Strong support, but it does not appear to be a problem unless excess rates applied.
	by not applying nutrients when the potential for soil compaction and rutting is high	No support, research needed because perennials can become compacted, but are not tilled.

> "Many studies were conducted for only 2 or 3 yr, which is insufficient for ecological adjustment to achieve a near steady state"

SYNOPSIS AND PERSPECTIVES CHAPTER 6

Following the focused assessment on the conservation standards, a general cross-cutting overview was developed that also included a futuristic perspective.

General Findings

- Nearly all studies were conducted on pastures or field plots on good soils with little consideration of topographic features or potential to transfer the response and environmental data to the landscape or watershed level.
- Many studies were conducted for only 2 or 3 yr, which is insufficient for ecological adjustment to achieve a near steady state for conditions being evaluated.
- Specific growth characteristics of most pasture and hayland species are known, but field responses were not always consistent with expectations, whether plant types were harvested mechanically or by grazing.
- Cost effectiveness of implementing a conservation standard was rarely considered in terms of returns to the land owner or values of ecosystem benefits for the landowner and public.
- No research was found that evaluated the production and ecosystem costs that would accrue if the practice was not implemented.
- In many cases the literature showed that a certain management scheme would improve economic productivity, yet the practice may not deliver desired ecosystem services.

- Very rarely was management designed to provide cost of environmental or ecosystem services relative to income from production of forage or animal product.
- When research is minimal or not available, implementation of a practice depends largely on experience and knowledge of local conditions from agency personnel.
- Little research assesses practices that reduce risk of failure; such research is needed to calculate costs during practice implementation.
- Authors sought research on emerging and future ecosystem interests; usually new methods were suggested to get more or better information to quantify the responses.
- The standards are updated about every 5 yr, but new technologies, especially analytical methods, and increased public interest in ecosystem outputs change more rapidly.
- Future research should be longer term and more comprehensive; however, this will exacerbate the time lag from perceived need to having the correct data to address the need.
- Ecosystem services need to be explicit in future standards to provide more focus.
- Most practices are considered long term and would benefit from monitoring the success on a periodic basis and providing assistance on using adaptive management to correct shortcomings.
- The agency will benefit from public education and widespread success stories.

"Models will help in planning conservation practices and determining variables to monitor while the practice is operational."

Implications: Evaluation teams assessed a single practice standard in a professional manner. There was good science support for most purposes and criteria, especially on factors affecting production. Unfortunately, because of a lack of credible methodologies and priority for determining value of services, the research over the past few decades used to develop production practices was rarely coupled with quantifiable measures or comparisons with economic or social values of the conservation practices or ecosystem services. The teams also could not evaluate expected or desired durations of effective functioning after the practice was implemented. Some newer publications addressed the more comprehensive issues.

Future criteria for practice standards for multiple purposes should explain expected outcomes more quantitatively, as well as provide estimates of the lifetime of the practice assuming adaptive management. Monitoring of practices to ensure they are working, and then using adaptive management to assist the landowner correct and extend the life of the practice will help maintain credibility and increase cost effectiveness to demonstrate fiscal responsibility. Is it more cost and outcome effective to have one practice that lasts 20 yr or to have two sites of the same practice that each last 10 yr? Models will help in planning conservation practices and determining variables to monitor while the practice is operational. The model could also guide adaptive management toward the most cost effective way to restore or maintain the practice.

There are many facets involved in the analyses of a practice and the outcomes are not always consistent through the life of a practice. For example, ecosystem risks during establishment may be very high for a species that has relatively low risk when established. Therefore, using forage plantings for a longer time in a rotation or managing to extend the life of a quality pasture reduces the amount of reseeding occurring each year to establish new stands. And one management approach for riparian areas may favor water quality over certain wildlife species, whereas another approach may favor wildlife over water quality. Keeping a pasture shorter may favor some ground nesting species, but have increased runoff and effects on water quality and fish in a nearby stream. Models may help in understanding the interactions and give guidance to trade offs and optimizing the solution.

Overall, it is imperative to understand expanding public goals and expectations from agriculture, beyond food, to management of natural resources in a sustainable way. As personal incomes increase, public expectations will continue to expand from having sufficient food to having it produced in a way that first preserves the environment and then provides other ecosystem services, especially for social issues and wildlife. Each step usually leads to higher food costs that are recognized and accepted. Already there are major issues emerging as agricultural and public priorities including pending climate change, water quantity and quality issues, biofuel issues, energy needs for food supplies, and values of environmental and ecosystem services. It is not known how much the public will pay for these.

With modern access to electronic information sources, improved media coverage of issues, and social media, both the public and agricultural community will usually be aware of emerging issues and likely will develop strong opinions before sufficient research has been conducted. The U.S. citizenry is already moving rapidly along this continuum; the challenge will be to stay ahead of the movement, because it will take even more years to develop the research base and recommendations. Intermediate term solutions will depend on educated and talented agency personnel who can provide credible science based recommendations until more specific data are assembled and evaluated. Success stories abound and should be used in public educational programs as USDA NRCS adopts and implements the new foundations for conservation standards.