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FEATURE

Pastureland Conservation Effects Assessment Project: Status and expected outcomes

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The Conservation Effects Assessment Project (CEAP) is a multiagency scientific effort to quantify environmental outcomes of conservation practices applied to private agricultural lands. The program is anticipated to help shape future conservation policies, programs, and practices. The integrated landscape approach will focus on enhanced ecological resilience and sustainable agricultural production, both of which are essential to maintaining livelihoods and meeting global food needs (Nowak and Schnepf 2010).

Principal components of CEAP include (1) detailed syntheses of scientific conservation literature; (2) a national assessment of conservation effects on ecosystem services; and (3) detailed investigations of conservation practices at various scales, including paddock, landscape, and watershed levels. The CEAP effort on grazing lands began in rangeland in 2006 (Weltz et al. 2008) with a synthesis of the scientific literature on key rangeland conservation practices (Briske forthcoming).

A CEAP effort on pastureland, primarily in the eastern and central United States, began in 2008. A literature synthesis documenting the science behind key conservation practices (Nelson forthcoming) revealed that scientific support exists for most conservation practices on pastureland, but critical knowledge, data, and technology gaps remain, including the following:

- Comprehensive assessments of effects of grazing management on a broad suite of environmental response variables, including soil, water, air, wildlife, plant, and livestock.
- Long-term research to monitor changes in biodiversity of pasture and hayland.
- Better understanding of landscape ecology and wildlife responses to pasture management.
- Effects of grazing animals on nutrient cycling and distribution across a landscape.
- Soil erosion data from pastures needed to calibrate runoff and erosion models and develop new models.
- Data on cost-effectiveness of best management practices.
- Models to integrate and extend site-specific information to landscape- and watershed-scale assessments of the ecosystem services provided by pastureland.

The synthesis pointed out that environmental studies on pastureland are often short-term (2 to 4 years), whereas the processes of interest may take decades to equilibrate and conducted at a paddock scale without regard to landscape position or location within a watershed. Other important needs include tools for assessing the risk and probability of success of a particular conservation practice in a particular place and time, robust monitoring and assessment tools for pastureland, appropriate process-based and biogeochemical models, and research methodologies that address ecosystem services across a broad range of disciplines.

In this paper, we discuss resource and conservation concerns on pastureland in the United States, describe recent CEAP-related research addressing these concerns, and outline the need for new tools and technologies for conservation management of pastureland.

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RESOURCE AND CONSERVATION CONCERNS ON PASTURELAND

There are 48.5 Mha of pastureland in the United States (figure 1) (USDA NRCS 2007). The conservation status of pastureland is not precisely known and is minimally discussed in the national Resource Conservation Act assessment (USDA NRCS 2011a). Better information is needed for development of appropriate policies and management decision-making related to US pastureland.

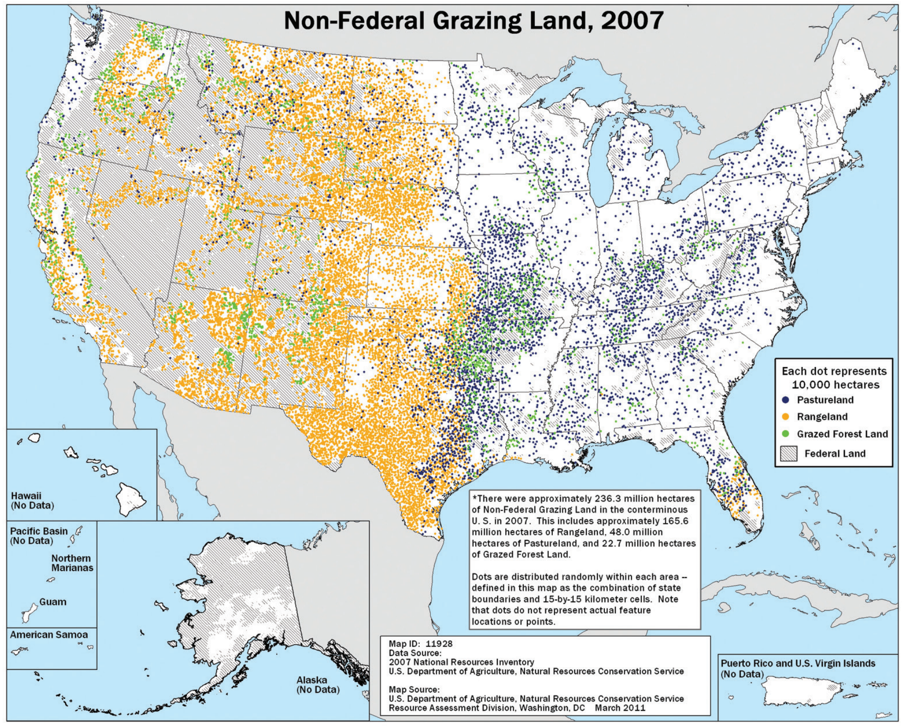
Soil and water resource conservation is critical because pastures are often small and frequently relegated to land unsuitable for more profitable field or horticultural crops. Pasture status depends on climate, prior land use, landscape position, soil type, and management inputs. In the eastern United States, large areas of grassland are rare, as many small land holdings segregate agricultural land from forest and are interspersed with growing urban areas.

Many pastures are managed with minimal attention to achieve full production potential. Continuous stocking with limited or no fertilizer input is the most common management on pasturelands, often without regard to grazing intensity, sward productivity, or subsequent effects on soil, water, and air quality. Stocking rate, grazing method, seasonal utilization, and fertilization timing, source, and rate could all be improved to increase productivity and to capture greater value from the potential ecosystem services of pastureland. Key ecosystem services include sequestering soil carbon (C); mitigating nutrient runoff; recharging ground and surface waters; maintaining above- and below-ground biodiversity, wildlife habitat, and recreation; and providing scenic landscapes.

Without adequate information about system-level, long-term environmental and economic risks of management practices, a singular focus on production and economics can result in decreased forage quality and quantity and increased erosion and nutrient loading off farm. Despite progress made in understanding how implementing conservation practices on cropland translates into environmental outcomes, similar data are meager or nonexistent for pasture and hayland (Nelson forthcoming). A research network is being assembled to develop such knowledge across a range of key US pasture ecosystems.

Figure 1

Area and distribution of nonfederal grazing land in the United States (USDA NRCS 2007).



Chesapeake Bay Watershed. The Chesapeake Bay watershed, home to 17 million people, drains the District of Columbia and all or portions of six eastern states into North America's largest estuary. Excess nutrient and sediment loadings from the watershed produce a dead zone that typically covers 15%-20% of the Bay. As urban and suburban land uses expand, well-managed agricultural land becomes increasingly vital for mitigating pollutant loadings to the Bay. The Chesapeake Bay watershed is 18.5% pasture and hayland (32,800 km^2); perennial grassland such as this filters rainwater and overland flow, maintains open space, and provides wildlife habitat.

Livestock producers in the northeastern and mid-Atlantic United States rely heavily on forages, pastures, and grazing management to reduce production costs and remain competitive. Recent efforts to develop total maximum daily loads for phosphorus (P) within the Chesapeake Bay watershed highlight grazing and pasture management as agricultural best management practices (BMPs) to reduce P loads (USDA NRCS 2010a).

Mississippi Atchafalaya River Basin. Pasture management is also critical in the Mississippi Atchafalaya River Basin (MARB), which drains 41% of the contiguous United States and contributes to a recurring 17,300 km^2 hypoxic zone in the Gulf of Mexico (USEPA 2011). The Mississippi River Basin Healthy Watersheds Initiative (MRBI), initiated to address pollutant loading related to agriculture, comprises 13 states surrounding the Mississippi River and includes numerous CEAP and MRBI Focus Area watersheds (USDA NRCS 2011b). Approved conservation practices for the MRBI include prescribed grazing, nutrient management, pasture and hayland planting, forage harvest management, fencing to control access to streams, and well-designed water facilities and walkways.

The MARB includes significant portions of the Great Plains, a region with a pronounced precipitation gradient from subhumid in the east to semiarid in the west and harsh hot to frigid temperature regimes. The region is characterized by mixed land uses with significant components of pastureland, cropland, and rangeland (prairie) across the landscape and within individual farms. Conservation challenges associated with mixed land use include landscape fragmentation (affecting wildlife habitat), degraded soils and pasture vegetation on abandoned cropland, managing grazing animals on cropland (vegetative winter wheat [*Triticum aestivum*], stubble of summer crops), and brush encroachment into prairies (e.g., Eastern red cedar [*Juniperus virginiana* L.]). Traditional field-by-field approaches to conservation planning frequently neglect habitat fragmentation. Research, extension, and conservation planning have largely focused on single enterprise systems. This approach does not help landowners compare options for investing across enterprises on the farm or plan for multiple economic and ecological goals and does not easily support evaluation of grazing animal impacts on annual cropland.

RESEARCH IN SUPPORT OF PASTURELAND CONSERVATION EFFECTS ASSESSMENT PROJECT

Pasture Scale. Grazing intensity is the key variable controlling many livestock and environmental responses on pastureland (Sollenberger et al. forthcoming). Research by USDA Agricultural Research Service (ARS) and land grant universities has supported CEAP objectives by addressing environmental outcomes of grazing management. With its partners, USDA ARS has quantified effects of stocking rate, grazing method, fertilizer management, and winter feeding practices on water and soil quality (Owens et al. 1994; Owens and Shipitalo 2009, 2011). Soil organic C and total nitrogen (N) accumulation are affected by forage utilization regime (Franzluebbers and Stuedemann 2010). Nutrient stratification occurs horizontally within a paddock due to animal behavior and also occurs vertically in soil due to surface accumulation of plant residues and manure (Franzluebbers et al. 2000). Intensity and spatial distribution of soil nutrients in livestock concentration areas varies with management type

(Franzluebbers and Stuedemann 2010), and the relationship of high soil nutrient gradients with vegetation cover and surface runoff can determine surface-water nutrient contamination risks (Sanderson et al. 2010).

USDA ARS and collaborating researchers seek to (1) understand multiple interactive effects of grazing management alternatives on productivity; profitability; and soil, water, air, plant, and animal responses; (2) understand the role of soil, landscape position, land use history, and climate on the potential of pastureland to sequester soil organic C, mitigate greenhouse gas (GHG) emissions, and develop resilient agroecosystems; and (3) quantify changes in soil organic C, nutrient balances, and water cycling across a diversity of conditions expected from improved pasture management.

Watershed Scale. USDA ARS and Penn State University (jointly funded by the National Institute of Food and Agriculture, USDA ARS, and USDA Natural Resources Conservation Service [NRCS]) investigated watershed-level effects of agricultural land use and BMP placement in Spring Creek watershed in central Pennsylvania. Fencing, cattle crossings, and streambank stabilization were applied to all streamside pastures in one subwatershed of Spring Creek in 1991and1992. A second subwatershed was largely untreated, and a third primarily forested subwatershed was used as a nonagricultural control. Pre- and post-treatment monitoring of water quality from 2001 to 2003 and again from 2007 to 2008 demonstrated a decrease in sediment and increase in trout populations in the treated subwatershed, but there was no change in nutrient concentrations (Carline and Walsh 2007; Brooks et al. 2011).

Spatial placement of BMPs was also investigated in the Spring Creek watershed. On-farm sampling and aerial photography were used to map livestock concentration areas, barnyards, buffer strips, and other land use types and BMPs. The land use maps were overlaid with detailed elevation maps to identify water flow pathways and possible nutrient movements or filtering. This information will be combined with long-term data on water quality in the watershed to help understand the environmental role of agricultural land use placement.

Cropland CEAP research in southwestern Oklahoma at the Fort Cobb Reservoir and Little Washita River watersheds has been expanded to address conservation issues related to grazing lands. In particular, hydrologic effects of encroaching Eastern Red Cedar into native prairie will be evaluated, focusing on hydrologic implications of plant interception of precipitation and seasonal shifts in water use. Studies on sediment sources (upland vs. channel, cropland vs. grazing land, gullies), fate and transport of eroded sediments, and BMPs for high-impact source areas are being initiated. New climatic approaches will attempt to better capture the spatio-temporal correlation of weather parameters across the landscape and represent recent climate variability and trends. Paddock-scale research is being expanded to address catchment-scale processes in mixed-enterprise crop-forage-energy-livestock systems and to identify management systems that enhance environmental services, productivity, and profitability. Additionally, studies on native prairie pastures are addressing management-intensive grazing versus continuous stocking, quantifying effects on vegetation, soil C, and soil physical properties.

Pastureland use in the Southern Piedmont extending from North Carolina to eastern Alabama is closely aligned with poultry production. Nutrient application with poultry litter has become a water quality concern when applied indiscriminately without concern for landscape position (Franklin et al. 2007). Future research by the USDA ARS at Watkinsville, Georgia, will address the critical role of poultry litter application timing, landscape features (e.g., sensitive riparian zones), and landscape nutrient balances to assess conservation in pastures. Key unexplored management issues include grazing method and stocking rate effects on residual herbage mass, surface soil organic matter and potential soil C sequestration, infiltration, and overland flow of water and nutrients (Franzluebbers 2010). Upper Oconee River Watershed in Georgia demonstrates how a well-documented history of land use change can help discern broad land use patterns on stream water quality (Fisher et al. 2000). Such changes in land use are essential to know, given the intense interactions among agricultural, urban, peri-urban, and extensive forested land uses.

TOOLS AND TECHNOLOGIES NEEDED FOR CONSERVATION MANAGEMENT

Pastureland Monitoring. The Pasture Condition Score (PCS), defined as "the status of the plant community and the soil in a pasture in relation to its highest possible condition under ideal management," was developed as a monitoring and management tool for pastureland (Cosgrove et al. 2001). There are critical dynamic conceptual ecological differences regarding the PCS and methods used to monitor rangeland health. The PCS emphasizes production and is not based on ecological sites or reference states. In contrast, rangeland health monitoring methods compare hydrologic function, soil and surface stability, and biotic integrity indicators to a standard reference condition (Pellant et al. 2005; Sanderson et al. 2009). There is a need to bring more quantitative and ecological rigor to the PCS system to bridge the gap between rangeland and pastureland so a more unified approach to assessing and monitoring grazing lands on a national scale can be achieved.

Forage Suitability Groups. USDA NRCS has developed Forage Suitability Groups (FSGs) within the context of Major Land Resource Areas to classify soil map units by their potentials and limitations for forage production (USDA NRCS 2003). Areas within the same group are expected to support the same species at comparable productivity levels and require similar conservation management. Delineation of FSGs is primarily based on expert knowledge and includes soil properties, climatic features, and physiography, as well as field trial data and other available information. FSG reports can be used as management guides and in conservation planning. These reports also provide production estimates, growth curves, soil limitations, and management interpretations. USDA NRCS is now using quantitative methods, cluster analysis, and ordination to identify key soil variables and FSGs.

Unlike the Ecological Site Descriptions (ESDs) used in rangelands, FSGs cannot be based on the presence of a characteristic plant community because pasture communities are composed primarily of introduced species and maintained by management. Despite that limitation, ongoing USDA ARS research is working to create a quantitative ecological basis for delineating FSGs or similar groupings. Such a scientifically-valid classification will form the basis for regional and national simulation modeling of pastureland ecology and environmental impacts. New research at El Reno, Oklahoma, and Mandan, North Dakota, will address extending FSGs and ESDs into prairie and other Great Plains land uses.

Pastureland National Resource Inventory and Assessment. NRCS has used resource inventories for more than 65 years to assess natural resources on nonfederal lands (USDA NRCS 2001). On-site National Resource Inventory (NRI) data provides information about land condition and related natural resources at several scales. Recent reports on rangeland highlighted issues such as rangeland health, invasive nonnative plant species, bare ground and intercanopy gaps (related to wind and water erosion and invasive plant establishment), and soil surface aggregate stability (Herrick et al. 2010; USDA NRCS 2010b).

USDA NRCS and ARS began a five-state pastureland NRI pilot project in 2007. In 2008, the pastureland NRI on-site study went "real time" with 13 states and expanded to 25 states in 2011. Previous NRI surveys included rangeland, pastureland, and forestland, but the data were mostly qualitative (Spaeth et al. 2003). The need for a more quantitative approach to the NRI to fulfill agency directives led to a new rangeland on-site NRI study in 2003, which continues today (Spaeth et al. 2005). Subsequently, the pastureland NRI approach was patterned after rangeland on-site study protocols with modifications, as needed, for pastureland (table 1). Once full-scale national collection of NRI data has been completed, an unparalleled description of the area and condition of US pasturelands will be presented.

Table 1

National Resource Inventory on-site field protocols for grazing lands by survey type.

Protocol name	Pastureland	Rangeland
Point locations and plot transect layout	X	X
Data gatherers	X	X
Ownership	X	X
Land cover/use	X	X
Forage suitability group/ecological site	X	X
Line point Transects for cover composition	X	X
Line intercept transects: canopy gaps	X	X
Soil stability test	OPT	X
Plant height	X	X
Dry weight rank	OPT	OPT
Production (species composition by weight)	NA	X
Standing biomass	X	NA
Plant census (replaces noxious/invasive)	X	X
Resource concerns	X	X
Conservation practices	X	X
Disturbance indicators	X	X
Rangeland health	NA	X
Pasture condition	X	NA
Sagebrush shape	NA	X

Notes: X = protocol is required. OPT = protocol is optional. NA = protocol is not applicable.

Simulation Modeling. The ALMANAC model has been extensively used to simulate crops (Kiniry and Bockholt 1998; Yun Xie et al. 2001) and warm season grasses (Kiniry et al. 2005; 2007). ALMANAC is the designated plant growth model for the western rangeland CEAP and may be useful for assessing conservation practices on pasturelands. The model simulates plant species and community influence on and response to fluctuating availabilities of water and nutrients.

A version of ALMANAC with preferential grazing is currently being evaluated with western grazing land data and with eastern pastureland grazing. Future refinement of the model is planned as model evaluation results are reported. New approaches to climatology that better reflect recent climate; multiyear persistent patterns; and extreme events such as drought, flood, heat waves, and shifts in frost-free probability are planned, as is linking to watershed models and validating the model for mixed land use regions.

The Integrated Farm System Model (IFSM) is a process-based model that simulates the full production system of beef, dairy, or crop farms over multiple weather years (Rotz et al. 2011). IFSM has been applied internationally to evaluate economic viability and environmental sustainability of management practices at the field and farm level (Rotz et al. 2002; Sanderson et al. 2006). For example, IFSM studies have demonstrated that precision management of feeding supplements and forage can bring small northeastern dairy farms into P balance, reduce off-farm P losses, and increase farmer net returns (Ghebremichael et al. 2007). However, while IFSM simulates pastures with both warm- and cool-season forages (Corson et al. 2007a, 2007b), future research needs include representing species diversity within a pasture and implementing preferential grazing.

SUMMARY

The economic and environmental value of pastureland can be realized through sustainable land management and animal production practices that support livelihoods and provide multiple ecosystem services. To fully realize multiple ecosystem benefits of soil C sequestration, GHG mitigation, nutrient cycling, and water conservation, pasturelands must be valued as a land use equivalent to other agricultural land uses (Steiner and Franzluebbers 2009).

CEAP facilitates the development of a focused national network of USDA ARS and land grant university research locations in partnership with USDA NRCS to address conservation issues on pastureland. Meeting CEAP research objectives will provide quantitative understanding of the environmental outcomes of conservation practices on pastureland. This strong scientific basis will facilitate the development of comprehensive erosion control, nutrient management, and conservation planning technologies, which will in turn reduce environmental impacts from pastureland and provide a foundation for future work.

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