Pasture monitoring at a farm scale with the USDA NRCS pasture condition score system

M.A. Sanderson, S.C. Goslee, J. Gonet, and R. Stout

Abstract: The Pasture Condition Score (PCS) system, developed by the USDA Natural Resources Conservation Service, is a monitoring and assessment tool for pastureland enrolled in conservation programs. Ten indicators of vegetation and soil status are rated on a 1 to 5 scale and are summed to give an aggregate score, which is interpreted for management recommendations. Information is lacking, however, on how PCS results vary within and among environments and farms. We applied the PCS on two farms in Pennsylvania (one dairy, one beef), two dairy farms in New York, and an organic dairy in Maryland. All pastures (25 to 63 per farm) on each farm were evaluated according to PCS methodology in spring, summer, and autumn of 2004, 2005, and 2006. Aggregate PCS scores ranged from 30 to 40 (indicating some improvements were needed to pasture management) and were relatively stable within management recommendation categories across seasons in 2004 and 2006. The PCS scores in 2005, however, plummeted (below 25 to 30—indicating major management changes to prevent degradation) on the Pennsylvania and Maryland farms because of drought. Pastures used for heifers and dry cows or as wintering areas often had lower scores than other pastures. Typically, these pastures were on less productive soils, steep slopes, and were stocked intensively. There was much overlap among individual score categories for some indicators, which suggests that fewer but broader score categories (e.g., low, medium, high) would simplify the system for farmers. The monitoring workload could be reduced by assessing representative subsets of pastures managed similarly or in similar landscape positions instead of all pastures on a farm.

Key words: grazing management—livestock—pasture assessment

About 62% or 30 million ha (74 million ac) of pastureland in the United States require some type of conservation treatment, such as prescribed grazing management, nutrient management, or pasture and hayland planting (USDA NRCS 2003, 2004). Recent developments in grassland-based livestock production systems have created a need for new methods of assessing and monitoring pastures. For example, assessment and monitoring tools are needed in forage budgeting, stocking rate or stocking density decisions, nutrient management plans, and meeting regulatory requirements of governmental programs (e.g., the Conservation Stewardship Program, Federal Register 2005).

Methods to assess and monitor rangeland health have been developed and implemented in the Western United States (Pyke et al. 2002). Development of methodology for pastureland, however, has lagged. Early versions of tools for pastureland monitoring were adapted from tools for rangeland use (Cropper 2004), despite critical differences in several attributes between pasture and rangeland. Rangelands are concentrated in the drier western United States and are managed as native ecosystems with few or no inputs. Pastureland vegetation consists mostly of introduced species adapted to higher rainfall or irrigated conditions and typically receive management and agronomic inputs such as seed, fertilizer, and pesticides. Thus, some criteria and indicators used in rangeland monitoring may not be appropriate for pastureland, and different criteria, indicators, and approaches may be required.

The Pasture Condition Score (PCS) system was developed as a monitoring and management tool on grazing lands (Cosgrove et al. 2001). In this system, pasture condition is defined as “the status of the plant community and the soil in a pasture in relation to its highest possible condition under ideal management.” Ten indicators (proportion of desirable plants in the sward dry matter, plant cover, plant diversity, plant residue, plant vigor, proportion of legume in the sward dry matter, uniformity of use, livestock concentration areas, soil compaction, and soil erosion) (table 1) of pastureland status are rated on a 1 to 5 scale and are summed to give an aggregate score (table 2), which is evaluated along with causative factors explaining reasons for low condition scores. The PCS has been implemented for USDA Natural Resources Conservation Service (NRCS) conservation programs, such as the Conservation Security Program (Federal Register 2005), which is currently called the Conservation Stewardship Program.

The PCS methodology recommends that pastures be scored yearly to track trends or changes in pastures. It also recommends “…it is often wise to score a pasture at different, key times during the year before deciding to make changes in management” (Cosgrove et al. 2001). Previously, we reported survey results on pasture condition scores of selected pastures on farms across the northeast United States (Sanderson et al. 2005). In this study, our objective was to determine how pasture condition scores varied within farms and determine the variation in pasture condition scores within and among grazing seasons. This information will be useful in developing efficient assessment and monitoring systems for farm advisors and farmers.

Materials and Methods
We contacted extension service and NRCS advisors in Pennsylvania, Maryland, and New York to identify potential farms for this study. These three states account for nearly half of the pastureland area in the 13 northeastern states (USDA NRCS 2003). Our criteria for farm selection included the following:

1. Pasture should contribute substantially to the farm system.
Table 1
Descriptions of the 10 indicators in the pasture condition score system (Cosgrove et al. 2001; Cropper 2004).

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description and purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of desirable plants</td>
<td>Pasture composition of plants that livestock will readily graze</td>
</tr>
<tr>
<td>Plant cover</td>
<td>Live stems and green leaf cover of all desirable and intermediate species; critical measure of hydrologic condition</td>
</tr>
<tr>
<td>Plant diversity</td>
<td>Number and proportion of forage grass and legume species</td>
</tr>
<tr>
<td>Plant residue</td>
<td>Amount of standing dead and litter ground cover; critical to nutrient cycling</td>
</tr>
<tr>
<td>Plant vigor</td>
<td>Visible signs of nutrient, drought, or pest stress</td>
</tr>
<tr>
<td>Proportion of legumes</td>
<td>As a proportion of the sward dry matter; legumes supply nitrogen and have high nutritive value</td>
</tr>
<tr>
<td>Uniformity of use</td>
<td>Estimates of areas rejected by grazing animals and areas that have been overgrazed</td>
</tr>
<tr>
<td>Livestock concentration areas</td>
<td>The number, size, and proximity to water channels significantly effects on surface and ground water</td>
</tr>
<tr>
<td>Soil compaction</td>
<td>Estimates of animal treading resulting in soil compaction by visual estimates of soil roughness and probing with a wire</td>
</tr>
<tr>
<td>Soil erosion</td>
<td>Visual estimates of degree of sheet, rill, wind, gully, streambank, and shoreline erosion</td>
</tr>
</tbody>
</table>

Table 2
Explanation of pasture condition score categories (from Cosgrove et al. 2001).

<table>
<thead>
<tr>
<th>Individual indicator score</th>
<th>Aggregate score</th>
<th>Interpretation and management recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>45 to 50</td>
<td>No changes in management needed at this time</td>
</tr>
<tr>
<td>4</td>
<td>35 to 45*</td>
<td>Minor changes would enhance, do most beneficial first</td>
</tr>
<tr>
<td>3</td>
<td>25 to 35</td>
<td>Improvements benefit productivity and/or environment</td>
</tr>
<tr>
<td>2</td>
<td>15 to 25</td>
<td>Needs immediate management changes, high return likely</td>
</tr>
<tr>
<td>1</td>
<td>10 to 15</td>
<td>Major effort required in time, management, and expense</td>
</tr>
</tbody>
</table>

* To be eligible for enrollment in certain USDA Natural Resources Conservation Service programs (e.g., the Conservation Security Program) pastureland must score 35 or higher (Federal Register 2005).

2. The farms should be dairy or beef, the predominant animal agricultural enterprises in the northeastern United States.

3. The farmer would be willing to share farm records and management information on a confidential basis.

After meeting and consulting with county extension agents, NRCS technical advisors, and candidate farmers, we chose five farms (based on the three criteria listed above) for the study (table 3). Two farms were in Pennsylvania (PA1 and PA2, beef and dairy, respectively), two were in New York (NY1 and NY2, both dairies), and one was in Maryland (MD1, organic dairy).

We visited each farm in spring (April or May), summer (July), and autumn (September or October) of 2004, 2005, and 2006, to collect vegetation, soils, PCS score, and farm management data. We established a permanent transect for monitoring vegetation and soil properties in nearly all pastures on each farm with a few exceptions. Some transects were added, moved, or abandoned because of changes in farm management. There were 10 to 30 0.25 m² (2.7 ft²) quadrats (depending on pasture size) on the line transects. The quadrats were spaced on a zigzag pattern alternating to the left, right, or center of the line transect. The same start and end points were used for the transects at each sampling, but we did not relocate the quadrats exactly. Within each quadrat, plant canopy cover was visually estimated for each species along with ground cover of litter and amount of bare ground, according to an eight-point cover-class scale (0% to 1%, 1% to 5%, 5% to 10%, 10% to 25%, 25% to 50%, 50% to 75%, 75% to 95%, and 95% to 100%). This method mainly estimates the dominant plant species and was not meant as an exhaustive survey.

All pastures on each farm were evaluated according to the published methodology for the PCS system (tables 1 and 2) (Cosgrove et al. 2001) on each date. The same person rated all pastures, with the exception of one farm in summer of 2004. Each pasture was walked in a structured way with at least two passes in a zigzag pattern while noting several observations during each pass to aid in estimating scores for the individual indicators. Each indicator was estimated visually.

Table 3

<table>
<thead>
<tr>
<th>Farm</th>
<th>County and state</th>
<th>Pastures (ha)</th>
<th>Number of pastures monitored</th>
<th>Operation type</th>
<th>Dominant soil types</th>
<th>Physiographic province</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD1</td>
<td>Frederick, Maryland</td>
<td>85</td>
<td>55 to 63</td>
<td>Organic seasonal dairy</td>
<td>Farquier and Myersville silt loams</td>
<td>Piedmont</td>
</tr>
<tr>
<td>NY1</td>
<td>Delaware, New York</td>
<td>43</td>
<td>16 to 20</td>
<td>Pasture-based dairy</td>
<td>Willowemoc channery silt loam and Halcott rocky soil</td>
<td>Allegheny plateau</td>
</tr>
<tr>
<td>NY2</td>
<td>Delaware, New York</td>
<td>46</td>
<td>14 to 18</td>
<td>Pasture-based dairy</td>
<td>Willowemoc and Lewbeach channery silt loams</td>
<td>Allegheny plateau</td>
</tr>
<tr>
<td>PA1</td>
<td>Dauphin, Pennsylvania</td>
<td>101</td>
<td>18 to 30</td>
<td>Beef cow-calf farm</td>
<td>Lansdale loam and silt loam</td>
<td>Piedmont</td>
</tr>
<tr>
<td>PA2</td>
<td>Northumberland, Pennsylvania</td>
<td>81</td>
<td>20 to 27</td>
<td>Pasture-based dairy</td>
<td>Weikert shaly silt loam</td>
<td>Ridge and valley</td>
</tr>
</tbody>
</table>
obtained from the nearest recording station. Weather data for each farm was
randomly collected from the nearest recording station. 

winter pasture management; and (10) animal
field preparation); (8) age of the pastures; (9) 
numbering or conserved forage (hay, bal 
tomatoes); (4) fertilizer or manure amounts
periods on pastures; (3) approximate stocking 
numbers and types of grazing animals (e.g., 
forage species used, seeding rates, applications; (5) frequency and timing 
of clipping or conserved forage (hay, bal 
psi), (4) 1.4 to 1.7 MPa (200 to 250 psi), (5) 
psi), (2) 0.7 to 1.0 MPa (100 to 150 psi), (3) 
MPa (0 to 100 psi), (2) 0.7 to 1.0 MPa (100 
to 150 psi), (3) 1.0 to 1.4 MPa (150 to 200 
MPa (0.08 in) screen, and analyzed at the Penn 
waterers, feeders) were avoided. The soil 
and obvious animal concentration areas (e.g., 
zigzag pattern. Fence lines, visible dung piles, 
and obvious animal concentration areas (e.g., 
zigzag pattern. Fence lines, visible dung piles, 
and obvious animal concentration areas (e.g.,

A cone penetrometer (Dickey-John model with a 1.9 cm [0.75 in] tip) was used 
to measure soil resistance as an estimate of 
soil compaction (Penn State University 2002; ASABE 2006). Soil resistance to 
penetration is a sensitive indicator of the effects of grazing on soil strength (Chanasyk and Naeth 1995). 
Five to 30 measurements were taken perpen 
Silt texture (%)

We gathered several pieces of information (if available) from the farmers: (1) the 
numbers and types of grazing animals (e.g., 
patients, heifers, dry cows, etc.); (2) the 
frequency, length, and timing of grazing 
periods on pastures; (3) approximate stocking 
densities; (4) fertilizer or manure amounts 
and applications; (5) frequency and timing 
of clipping or conserved forage (hay, bal 
age, silage) harvest; (6) amount and types of 
supplemental feed used on pastures or fed in 
the barn; (7) field management for new seed 
ings (e.g., forage species used, seeding rates, 
field preparation); (8) age of the pastures; (9) 
winter pasture management; and (10) animal 
production. Weather data for each farm was 
obtained from the nearest recording station.

The PCS score data were examined to 
check the assumption of normality, and 
slight skewness was detected in plots of 
residuals. Transformations did not resolve 
the small degree of skewness; thus untrans 
formed data were analyzed. A linear, mixed 
models procedure (SAS 2003) was used to 
analyze the data. Farms and environments 
(nine environments, combinations of years 
and seasons) were considered fixed effects, 
and pastures within farms were considered 
random effects. Means were separated with 
the PDIFF procedure in Statistical Analysis 
Systems with a Bonferroni adjustment. 
Transect data on bare ground, forage species 
cover, legume cover, and soil resistance were 
compared against the associated indicator 
ratings with the Spearman rank (r). Box plots 
were used to examine PCS score distributions 
among and within farms and years.

Results and Discussion

Aggregate Scores—Yearly and Seasonal Variation. The mixed model analysis indi 
cated significant effects of environment (year 
and season), farms, and an interaction among 
farms and environments for aggregate PCS 
scores. Average PCS scores, along with out 
comes of mean comparisons, are in table 5. 
Because our primary interests were the range 
of variation in scores and explanations for 
the variation, we also present box plots of the 
scores by farm and season to display score 
distributions (figure 1).

In 2004, PCS scores for farms MD1, NY2, 
and PA2 remained relatively stable or increased 
slightly from spring to autumn (table 5, fig 
ure 1). The majority of PCS scores for MD1 
were between 35 and 45 (category of “only 
minor changes to management needed”) 
table 5). Scores decreased for NY1 in sum 
er, and scores for PA1 decreased in autumn. 
To be eligible for certain USDA NRCS con 
servation programs (e.g., the Conservation 
Security Program), pastures must score 35 or 
better (Federal Register 2005).

The PCS scores in 2005 decreased dra 
atically from spring to autumn for farms 
MD1, PA1, and PA2 (table 5) (figure 1) 
because of hot and dry weather that affected 
a large area of the mid-Atlantic region dur 
ing mid to late summer. Scores for these 
farms were in or near the category where 
 immediate changes to pasture management 
were necessary to prevent further degrada 
tion (scores between 15 and 25). Rainfall in 
September was 0.7 cm (0.3 in) at MD1 
compared with the long-term average of

| Table 4
| Soil nutrient levels and soil texture in the 0 to 15 cm soil layer on each farm in spring 2006. |
|----------------------------------|---|---|---|---|---|
|                                | MD1 | NY1 | NY2 | PA1 | PA2 |
| pH                              |     |     |     |     |     |
| Average                         | 6.8 | 5.7 | 6.0 | 6.5 | 5.8 |
| Range                           | 6.4 to 7.3 | 5.0 to 6.6 | 5.2 to 6.5 | 6.1 to 7.1 | 5.1 to 6.8 |
| SD                              | 0.2 | 0.5 | 0.3 | 0.3 | 0.4 |
| Organic matter (%)              |     |     |     |     |     |
| Average                         | 4.1 | 5.9 | 6.8 | 2.2 | 4.1 |
| Range                           | 2.8 to 5.3 | 3.6 to 8.6 | 5.9 to 9.6 | 1.6 to 3.1 | 2.7 to 5.9 |
| SD                              | 0.6 | 1.1 | 0.8 | 0.4 | 0.9 |
| Phosphorus (mg kg⁻¹)            |     |     |     |     |     |
| Average                         | 13 to 199 | 13 to 86 | 13 to 302 | 37 to 382 | 27 to 332 |
| Range                           | 33 | 18 | 80 | 37 | 27 |
| SD                              | 0.6 | 0.5 | 0.7 | 0.4 | 0.8 |
| Potassium (mg kg⁻¹)             |     |     |     |     |     |
| Average                         | 221 | 128 | 190 | 221 | 251 |
| Range                           | 72 to 453 | 65 to 209 | 65 to 534 | 103 to 375 | 74 to 806 |
| SD                              | 87 | 41 | 111 | 64 | 139 |
| Soil texture (%)                |     |     |     |     |     |
| Sand                            | 25.6 | 34.6 | 46.4 | 39.0 | 36.5 |
| Silt                            | 43.9 | 40.7 | 36.1 | 35.0 | 39.0 |
| Clay                            | 30.5 | 24.7 | 17.4 | 22.8 | 24.5 |

Notes: PA1, PA2, NY1, NY2, and MD1 represent study sites (see table 3). 
SD = standard deviation.
August and September rainfall was only 34% of the long-term average at PA1 and was 57% at PA2. The PCS scores for NY1 and NY2 did not change as much as other farms during 2005, primarily because rainfall was above the long-term average and summer temperatures were relatively moderate in Delaware County, New York, during 2005. In 2006, the patterns and categories of PCS scores were stable among farms, except for farm PA2, which had a large decrease in PCS during the summer (table 5) (figure 1).

In most instances the reduction in PCS scores because of environmental stress in summer and autumn was temporary and did not signal a long-term decline in pasture condition. Scores typically rebounded to prestress levels within a few months or by the spring of the next year (table 5) (figure 1). For example, PCS scores for farm MD1 bordered on the second-lowest category (15 to 25, category indicating “immediate changes needed to management to prevent degradation”) (table 2) in the autumn of 2005; however, by the spring of 2006, the PCS scores had returned to the highest category and remained in that range for the rest of the year. Thus, most pastures had a large capacity to recover from environmental stresses.

The strong effect of weather on PCS scores suggests the need for multiple assessments during the grazing season. Basing management decisions on a single evaluation during the grazing season could give misleading results. The “Guide to Pasture Condition Scoring” suggests rating pastures at several critical management periods, including the beginning and end of the grazing season and during times of plant stress (Cosgrove 2001). Our data strongly supports these recommendations.

**Aggregate Scores—Within Farm Variation.** The dairy farms generally had a similar structure of pastureland use and management. Farmers grouped pastures into those for the milking herd, heifer pastures, and dry cow pastures. Some pastures were set aside for hay or balage harvest in spring and then were grazed in summer (labeled hay/graze in figure 2). There were also one or two pastures designated as sacrifice areas for winter feeding or holding areas during wet weather. The beef farm (PA1) was structured differently. One set of pastures was used as a wintering area for the beef cow–calf herd and then was grazed as needed during the remainder of the year. A set of older, unimproved permanent pastures along the stream bisecting the farm was used for steers and heifers and sometimes for the main herd. The remaining pastures were grazed in rotation with spring- and fall-calving cows herds.

Pasture management and landscape features had a large effect on PCS scores. Pastures used for heifers and dry cows or for wintering cattle frequently had lower PCS scores than other pastures (figure 2). Typically, livestock on these pastures were stocked at higher densities, and grazing periods were longer than on other pastures. On some farms, these pastures were on less productive soils and steep slopes, which may have affected scores.

Pastures on farm MD1, an organic dairy, were relatively uniform with gentle slopes (3% to 8%) and had all been established at about the same time in the 1990s. The uniformity in landscape and management of this farm probably contributed to the uniformity of PCS scores during the three years of monitoring (figures 1 and 2). Pastures grazed by heifers had a lower mean and wider range in scores than other pastures.

On the NY1 dairy farm, PCS scores reflected grazing management and landscape effects. The pastures used for hay and grazing were on lower lying areas (3% to 8% slopes) of the farm, and PCS scores remained above 35 (figure 2). Most of the pastures grazed by milking herd 1 occurred on relatively steep slopes (15% to 35%), but more than 75% of the scores were above 35 during the year. In contrast, the pastures grazed by milking herd 2 were on a very steep hillside (10% to 70% slopes) that had been cleared of trees in 1997 and seeded to a “conservation mix” of grasses and legumes. Soil pH and P were low (5.2 and 17 mg kg\(^{-1}\), respectively), brush was prevalent, and forage was not well utilized by the cattle. The dry cows and heifers were kept on pastures with shallow, low-fertility soil and abundant brush. As a result, the PCS scores for these pastures rarely exceeded 35. At both the NY1 and NY2 farms, the pastures set aside for hay in spring and used for grazing later had high PCS scores. The sacrifice pasture on NY2 had very low scores because of compacted, bare soil.

At the PA2 dairy, pastures grazed by heifers were on steep slopes (15% to 25%) and were continuously stocked, which resulted in frequent overgrazing. Bare ground and significant erosion were frequently noted in the pastures and resulted in low PCS scores (figure 2). Dry cow pastures were also on steep slopes (15% to 25%). These site characteristics probably limited PCS scores.

Pasture condition scores on the PA1 beef farm varied according to current and previous management. Pastures that had been in long-term hay production before conversion to pasture maintained high PCS scores in a narrow range (figure 2). The lowest scores occurred in the pastures used for wintering cattle and on a set of pastures that had repeated seedling failures and an eroded stream channel (labeled “Field 17” in figure 2). The wintering pasture and Field 17 had much bare ground and abundant weedy species, which reduced scores. Field 17 also suffered from erosion and soil degradation from livestock concentration along a small intermittent stream. The stream was fenced to exclude cattle in 2005, and PCS scores improved (data not shown).

Scores or ratings in the PCS system are not evaluated against a standard reference condition or site. Rather, scores are to be assigned to a pasture “…in relation to its highest possible condition under ideal management” (Cosgrove et al. 2001). Thus, it is assumed
that management changes (e.g., changes in stocking density; fertilizing; reseeding pastures) alone can improve PCS scores, regardless of landscape or site characteristics. This is in contrast to the methodology used for assessing indicators of rangeland health, in which indicators are evaluated based on their degree of departure from an ecological reference area or ecological site description (Pyke et al. 2002). Although the PCS scores on farms we monitored changed dramatically in response to weather and to management, it is clear that some pastures had inherent site characteristics (e.g., rocky, excessively drained soils; very steep slopes) that would limit or
Figure 2
Variation in pasture condition scores within five farms in the northeastern United States. Pastures were grouped by primary management or use. Data are all scores across spring, summer, and autumn for three years on each farm. Boxes show the distribution of values from the 25th and 75th percentiles, whiskers indicate the 10th and 90th percentiles, and the lines inside the boxes indicate the median values. Individual data points indicate outliers. Dashed horizontal lines indicate cutoff values for management recommendation categories.

Notes: PA1, PA2, NY1, NY2, and MD1 represent study sites (see table 3).
constrain attempts to improve PCS through management. In these instances, evaluating indicators against an ecological or site-type reference condition may be useful. A starting point for this effort could be the use of forage suitability groups (Cropper 2003).

**Individual Indicator Scores.** To better understand the changes in composite PCS scores, we examined the distributions of scores for the 10 individual indicators (figure 3). The indicators for legume content and forage diversity scored lowest on all farms in all years. About 70% of legume indicator scores were in category 1. An indicator score of 1 means that the legume content was 10% or less of the sward dry matter, and an indicator value of 2 means that the legume component was 11% to 19% of the sward dry matter. Legume canopy cover estimated in the quadrats on pasture transects was 20% on farm MD1, and less than 10% on other farms (table 6). White clover was the most abundant legume. Our previous surveys of PCS on northeastern farms also showed that the legume and forage diversity indicators scored lowest (Sanderson et al. 2005). The low proportion of legumes in pastures on the farms is consistent with other research in the northeast United States. Legumes accounted for about 15% of sward dry matter (based on hand separations of herbage) in pastures on 32 farms in Pennsylvania, New York, and Vermont (Byers and Barker 2000; Byers et al. 2000). White clover (Trifolium repens L.) was the most abundant legume in those studies. Legume dry matter proportions of 35% to 40% are considered optimum for sustainable herbage yields and forage quality of mixed-species pastures (Thomas 1992).

The legume component of pastures can be affected by soil pH and P along with grazing management. The average soil pH on PA2, NY1, and NY2 was below 6.0, lower than recommended for most cool-season legumes (Snyder and Leep 2007) (table 4). Thus, soil pH may have limited legume persistence on these farms. Soil P was at or above agronomic sufficiency levels on all farms (table 4) and probably did not limit legume persistence. From discussions with the farmers and visual observation, we noted that farmers often struggled with managing the rapid spring growth of forage in pastures. This led to accumulation of tall, over-mature forage, which may have shaded legumes and reduced their persistence and contribution to sward dry matter (Höglin and Frankow-Lindberg 1998).

Multiplying legume canopy cover by 0.7 estimates legume content as a percentage of the sward dry matter in pastures of the northeastern United States (based on comparisons of visual estimates of legume canopy cover with hand-separated samples \( n = 99, r^2 = 0.78, \text{ root mean square error} = 16.4 \) (M.A. Sanderson unpublished data). There was good agreement among the visual estimates of legume content (percentage of sward dry
matter) in the sward and corresponding PCS scores for the indicator (figure 4) (Spearman \( r = 0.57, p < 0.001 \)). The average value for visual estimates fell within the prescribed PCS indicator ranges with the exception of the 25th and 75th percentiles. Whiskers indicate the 10th and 90th percentiles, solid lines indicate the median values, and dashed lines indicate the mean. Individual data points indicate outliers. Area between the dashed horizontal lines indicates the range that corresponds to the PCS score for percent legume (figure 4) (Spearman \( r = 0.56, p < 0.001 \)). There was poor agreement, however, within score categories and a large degree of overlap among categories. The distribution of scores for the plant diversity indicator fell mainly among scores of 1 and 2 (figure 3), which according to the scoring criteria, indicated that only a few forage species dominated in pastures. The plant diversity indicator is based mainly on the number of “well represented” (20% of

### Table 6

Canopy cover of the top ten plant species in pastures on five farms in the northeastern United States. Data are averaged for all pastures on the farms over three years and three sampling times per year. Use of bold indicates legume species.

<table>
<thead>
<tr>
<th>MD1 species</th>
<th>Cover (%)</th>
<th>NY1 species</th>
<th>Cover (%)</th>
<th>NY2 species</th>
<th>Cover (%)</th>
<th>PA1 species</th>
<th>Cover (%)</th>
<th>PA2 species</th>
<th>Cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tall fescue</td>
<td>34</td>
<td>Kentucky bluegrass</td>
<td>27</td>
<td>Kentucky bluegrass</td>
<td>27</td>
<td>Tall fescue</td>
<td>26</td>
<td>Orchardgrass</td>
<td>19</td>
</tr>
<tr>
<td>White clover</td>
<td>17</td>
<td>Dandelion</td>
<td>10</td>
<td>Orchardgrass</td>
<td>14</td>
<td>Kentucky bluegrass</td>
<td>18</td>
<td>Tall fescue</td>
<td>15</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>16</td>
<td>White clover</td>
<td>8</td>
<td>Dandelion</td>
<td>14</td>
<td>Orchardgrass</td>
<td>17</td>
<td>Kentucky bluegrass</td>
<td>7</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>12</td>
<td>Orchardgrass</td>
<td>7</td>
<td>White clover</td>
<td>9</td>
<td>White clover</td>
<td>5</td>
<td>Perennial ryegrass</td>
<td>7</td>
</tr>
<tr>
<td>Dandelion</td>
<td>4</td>
<td>Germander speedwell</td>
<td>7</td>
<td>Tall fescue</td>
<td>7</td>
<td>Perennial ryegrass</td>
<td>3</td>
<td>White clover</td>
<td>6</td>
</tr>
<tr>
<td>Common plantain</td>
<td>3</td>
<td>Tall fescue</td>
<td>6</td>
<td>Timothy</td>
<td>5</td>
<td>Smooth crabgrass</td>
<td>3</td>
<td>Dandelion</td>
<td>5</td>
</tr>
<tr>
<td>Red clover</td>
<td>3</td>
<td>Timothy</td>
<td>5</td>
<td>Quackgrass</td>
<td>5</td>
<td>Bentgrass</td>
<td>2</td>
<td>Quackgrass</td>
<td>3</td>
</tr>
<tr>
<td>English plantain</td>
<td>1</td>
<td>Quackgrass</td>
<td>3</td>
<td>Germander speedwell</td>
<td>4</td>
<td>Timothy</td>
<td>2</td>
<td>Chicory</td>
<td>2</td>
</tr>
<tr>
<td>Common chickweed</td>
<td>1</td>
<td>Reed canarygrass</td>
<td>2</td>
<td>English plantain</td>
<td>2</td>
<td>Northern crabgrass</td>
<td>1</td>
<td>Lambsquarters</td>
<td>2</td>
</tr>
<tr>
<td>Perennial ryegrass</td>
<td>1</td>
<td>Redtop</td>
<td>2</td>
<td>Common plantain</td>
<td>2</td>
<td>Common chickweed</td>
<td>1</td>
<td>Alfalfa</td>
<td>2</td>
</tr>
</tbody>
</table>

Notes: PA1, PA2, NY1, NY2, and MD1 represent study sites (see table 3).
desirable species) and 5 (desirable species > 80% of the plant community).

Visual estimates of plant canopy cover (100 minus percentage bare ground) were positively correlated with the individual PCS scores for the indicator (figure 6) (Spearman $r = 0.45, p < 0.001$). There was very poor agreement, however, within score categories and no separation in distribution of scores among categories. Visual estimates of vegetation cover can be highly variable compared with quantitative methods, such as point-intercept or grid-point sampling (Godínez-Alvarez et al. 2009). Other research has shown that variation in visual estimates of ground or canopy cover was least at the extremes and greatest between 20% and 80% (Murphy and Lodge 2002). Plant canopy cover contributes to site stability and resistance to surface water runoff. Critical values of ground cover are around 70% to 80% cover (Butler et al. 2006). Below these levels, bare soil areas begin to merge, which increases the potential for surface runoff and erosion. The amount of bare ground also indicates the effect of grazing on vegetation (Pueyo et al. 2006).

All pastures had greater soil resistance than areas that did not receive animal traffic. More than 70% of the soil compaction indicator scores fell in categories 3 and 4 (figure 3). Field measurements of soil resistance were positively correlated with the indicator score (figure 7) (Spearman $r = 0.44, p < 0.01$). The mean values of soil resistance in pastures seemed to be best related to the PSC indicator scores in categories 3, 4, and 5 in spring and autumn. There was a large overlap, however, among the distributions of penetrometer data in all score categories. There was very poor agreement in score categories 1 and 2, which had the fewest observations.

Soil compaction indicator scores were lower in the summer than in spring or fall (figure 7). Lower rainfall leading to dry soil in the summer probably caused the increase in soil resistance (we did not adjust penetrometer readings for soil moisture). Dry soils generally have greater resistance to penetration than wet soils (Chanasyk and Naeth 1995). A soil resistance measure of 2.1 MPa (300 psi) or greater is considered restrictive to root growth (Taylor and Burnett 1964). Soil resistance readings were at or near this value on some pastures in summer and autumn. The low compaction scores and associated
high soil resistance readings that occurred in the dry summer and autumn of 2004 and 2005 (data not shown) changed in response to removal of livestock, precipitation, and soil freeze-thaw action during the winter and returned nearer to baseline levels in the spring. Seasonal changes in soil bulk density and resistance to penetration were closely related to the soil water status of grasslands in Canada (Chanasyk and Naeth 1995). Natural recovery of soils from treading damage by livestock often is limited to the surface 15 cm (6 in) of soil (Drewry 2006). Heavily affected soils may take a long time (months to years) to recover.

The PCS system is mainly intended for agency personnel use. Modifying the system for rapid on-farm use would require simplifying and broadening the rating categories for some indicators, such as plant or ground cover and legume proportion among others (Murphy and Lodge 2002). For example, in a “pasture health kit” developed in Australia (McCormick and Lodge 2001), seven indicators of pasture status (ground cover, soil surface resistance, proportion of productive pasture plants, proportion of green herbage, and suitability for animal production) are estimated according to broad categories of low, medium, and high. The categories for the ground cover indicator are <40% (low), 40% to 70% (medium), and >70% (high). For proportion of productive pasture species (roughly equivalent to the “desirable plants” indicator in PCS) the ranges are <45%, 45% to 60%, and >60%. For legume proportion, the ranges are <10%, 10% to 30%, and >40%. Similarly, visual soil assessment methodology for New Zealand hill country pastures rates soil and plant indicators according to three broad classes (Shepherd et al. 2000).

Our data suggest that some indicators in the PCS system could be modified with fewer but broader categories to simplify its use (e.g., the Vermont PCS version [USDA NRCS 2009]).

Other approaches to evaluating pastures have used herbage yield and nutritive value indicators along with plant and soil status indicators. Proposed indicators for intensively managed grasslands in Germany include legume content of the sward, dry matter yield potential, crude protein and energy concentration in the herbage, soil productivity class, and weed abundance (Treyse et al. 2008). Dry matter yield potential was based on soil productivity class, and nutritive value
estimates were based on estimates of legume and weed in the sward. Quantitative indices based on the indicators were useful in diagnosing differences between conventional and organic farms regarding production potential and management status.

Summary and Conclusions
We demonstrated that pasture condition scores vary among and within grazing seasons mainly in response to weather. Our data suggest that assessing pasture condition at the start of the grazing season, during stressful growing conditions, and near the end of the season would provide timely information for making pasture management decisions. Pasture condition scores also vary widely within farms, primarily because of management differences among pastures used for different classes of livestock. Grouping pastures managed and used for different classes of cattle (e.g., heifer, dry cow, or holding pastures) and monitoring representative subplots, may reduce the monitoring workload. Some pastures had inherent site characteristics that would limit efforts to improve PCS through management. In these instances, evaluating indicators against an ecological or site-type reference condition may be more useful than striving for “ideal” conditions.

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