doi:10.2489/jswc.64.6.423

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

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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 that "…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.

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Table 1
Descriptions of the 10 indicators in the pasture condition score system (Cosgrove et al. 2001; Cropper 2004).

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

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

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

* 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 m^2 (2.7 ft^2) 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
Characteristics of the five farms monitored during 2004, 2005, and 2006.

Farm	County and state	Pastures (ha)	Number of pastures monitored	Operation type	Dominant soil types	Physiographic province
MD1	Frederick, Maryland	85	55 to 63	Organic seasonal dairy	Farquier and Myersville silt loams	Piedmont
NY1	Delaware, New York	43	16 to 20	Pasture-based dairy	Willowemoc channery silt loam and Halcott rocky soil	Allegheny plateau
NY2	Delaware, New York	46	14 to 18	Pasture-based dairy	Willowemoc and Lewbeach channery silt loams	Allegheny plateau
PA1	Dauphin, Pennsylvania	101	18 to 30	Beef cow-calf farm	Lansdale loam and silt loam	Piedmont
PA2	Northumberland, Pennsylvania	81	20 to 27	Pasture-based dairy	Weikert shaly silt loam	Ridge and valley

according to the scoring criteria in the PCS system.

In spring 2006, we collected one composite soil sample of 15 to 20 cores to a 0 to 15 cm (0 to 6 in) depth from each pasture on the five farms (Hedges and Kirkland 1994). The individual cores were taken with a 2.54 cm (1 in) diameter steel soil probe on a zigzag pattern. Fence lines, visible dung piles, and obvious animal concentration areas (e.g., waterers, feeders) were avoided. The soil samples were air-dried, sieved to pass a 2 mm (0.08 in) screen, and analyzed at the Penn State Agriculture Analytical Laboratory for organic matter, pH, phosphorus (P) (Mehlich III extractant), potassium (K), (table 4) magnesium (Mg), and calcium (Ca) (Sims et al. 1995).

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 perpendicular to the soil surface to a 15 cm (6 in) depth on the same transects used for vegetation assessment in each pasture. In addition, at least 36 measurements were taken in areas that received no animal traffic. The penetrometer was pushed manually into the soil at about 30 mm s^{-1} (1.2 in sec^{-1}). Maximum readings on the cone penetrometer dial were recorded on a scale of 1 to 6: (1) 0 to 0.7 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 psi), (4) 1.4 to 1.7 MPa (200 to 250 psi), (5) 1.7 to 2.1 MPa (250 to 300 psi), and (6) >2.1 MPa (>300 psi).

We gathered several pieces of information (if available) from the farmers: (1) the numbers and types of grazing animals (e.g., milking cows, 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, balage, silage) harvest; (6) amount and types of supplemental feed used on pastures or fed in the barn; (7) field management for new seedings (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.

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	46	33	82	212	101
Range	13 to 199	13 to 86	13 to 302	37 to 382	27 to 332
SD	33	18	80	37	27
	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.

The PCS score data were examined to check the assumption for normality, and slight skewness was detected in plots of residuals. Transformations did not resolve the small degree of skewness; thus untransformed 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 indicated significant effects of environment (year and season), farms, and an interaction among farms and environments for aggregate PCS scores. Average PCS scores, along with outcomes 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, figure 1). The majority of PCS scores for MD1 were between 35 and 45 (category of "only minor changes to management needed") (table 2). Scores decreased for NY1 in summer, and scores for PA1 decreased in autumn. To be eligible for certain USDA NRCS conservation programs (e.g., the Conservation Security Program), pastures must score 35 or better (Federal Register 2005).

The PCS scores in 2005 decreased dramatically 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 during 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 degradation (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 5
Pasture condition scores averaged within farms during spring, summer, and autumn of three years.

	2004			2005			2006		
Farm	Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn
MD1	37	38a*	41a	38a	37a	25c	36	37a	37a
NY1	35	29b	31b	36ab	31ab	34a	34	33ab	33ab
NY2	33	33ab	36ab	34ab	33ab	33ab	34	33ab	37ab
PA1	34	35b	31b	34ab	31ab	26bc	34	33a	33ab
PA2	35	33ab	35ab	33b	30b	24c	34	25b	30b

* Values followed by different letters differ at $p < 0.05$ as determined by PDIFF in Statistical Analysis Systems with a Bonferroni correction.

9.7 cm (3.8 in). 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 cow 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.

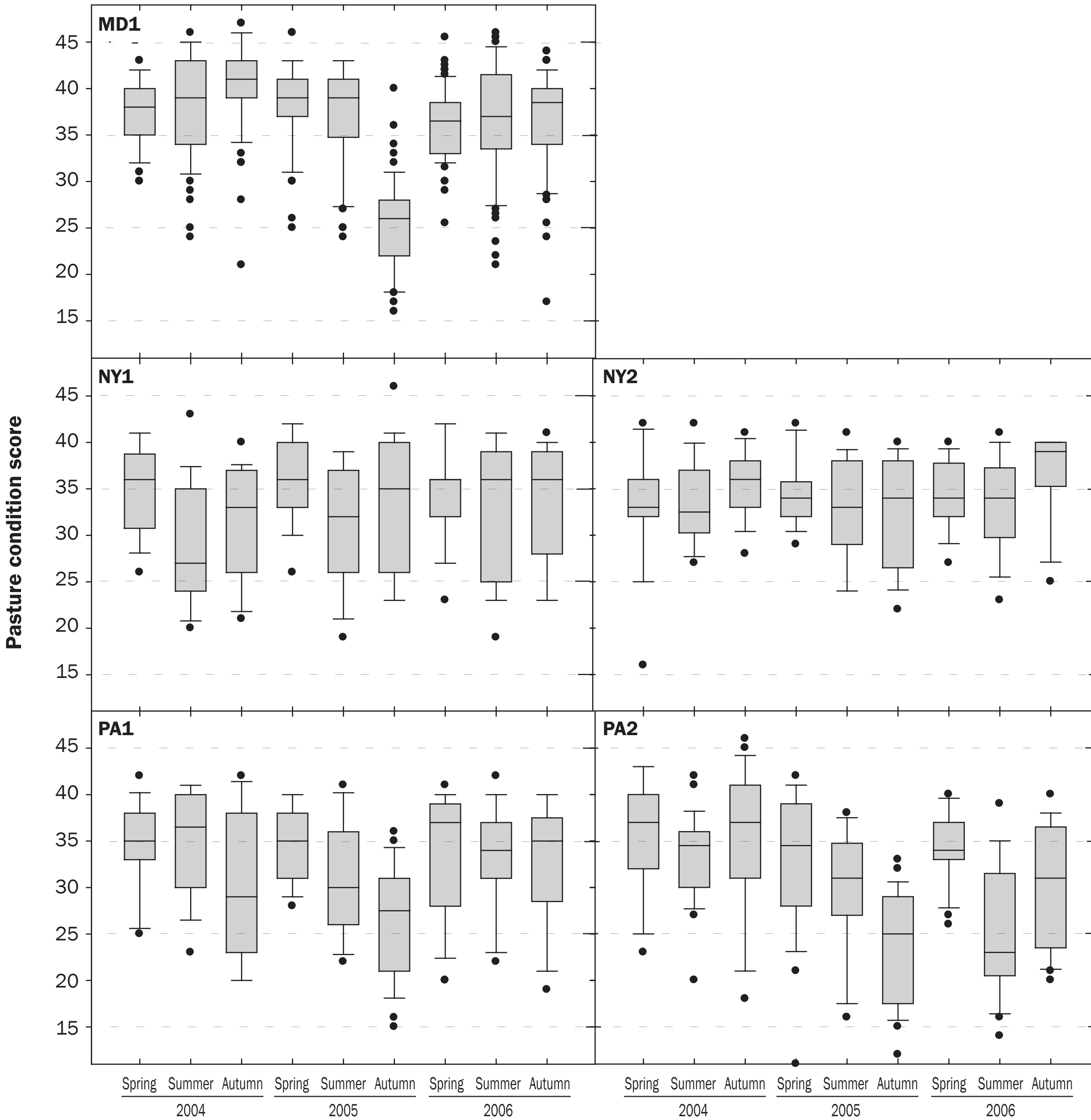
On the NY1 dairy farm, PCS scores reflected grazing management and landscape effects. The pastures used for hay and grazing were on lower lying areas (3% to 8% slopes) of the farm, and PCS scores remained above 35 (figure 2). Most of the pastures grazed by milking herd 1 occurred on relatively steep 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 seeding 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

Figure 1
Pasture condition scores on five farms in the northeastern United States during spring, summer, and autumn of 2004, 2005, and 2006. Boxes show the distribution of values from the 25th and 75th percentiles, whiskers indicate the 10th and 90th percentiles, and the line inside the boxes indicates the median value. Individual data points indicate outliers. Dashed horizontal lines indicate cutoff values for management recommendation categories.

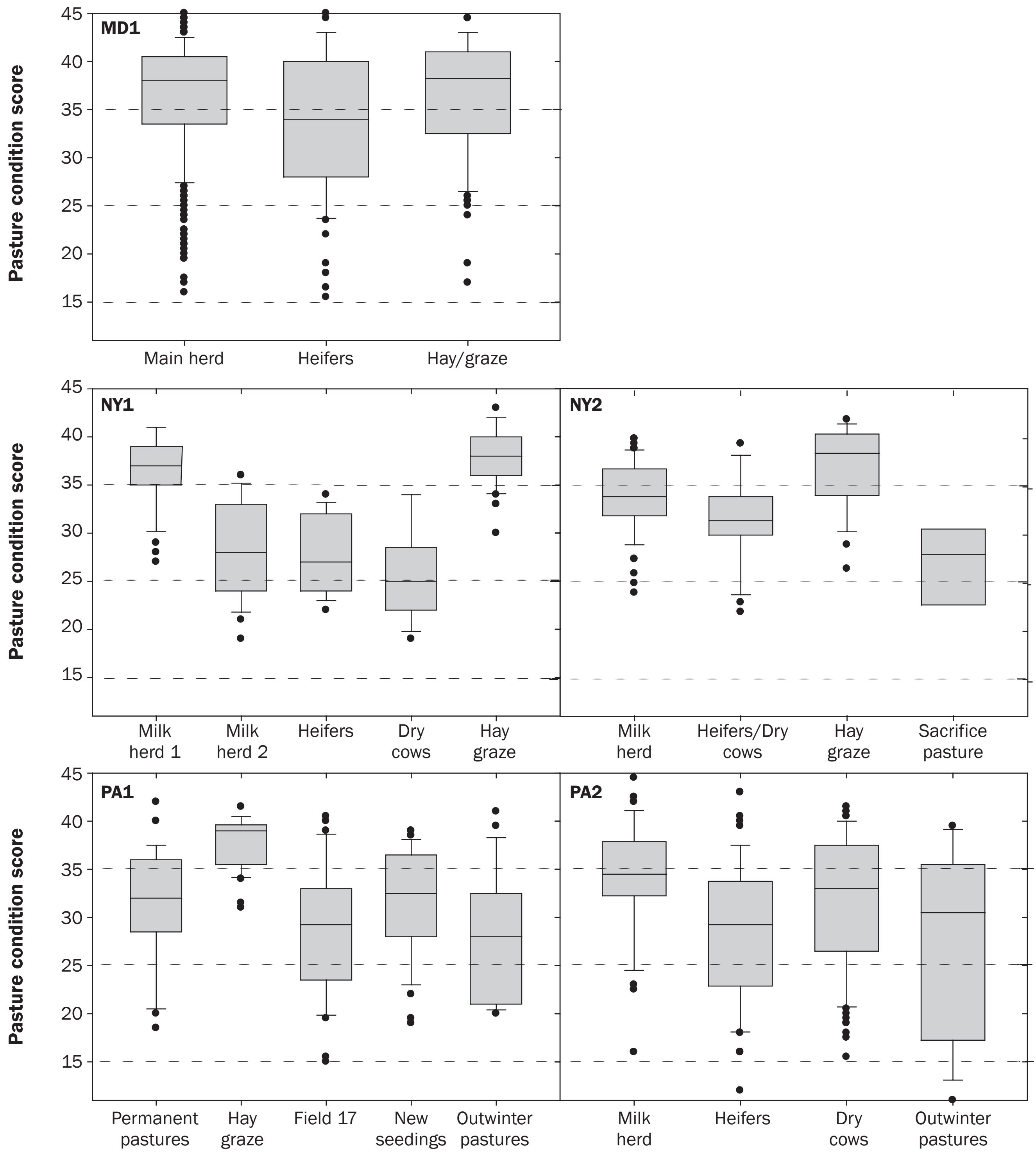


Notes: PA1, PA2, NY1, NY2, and MD1 represent study sites (see table 3).

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.



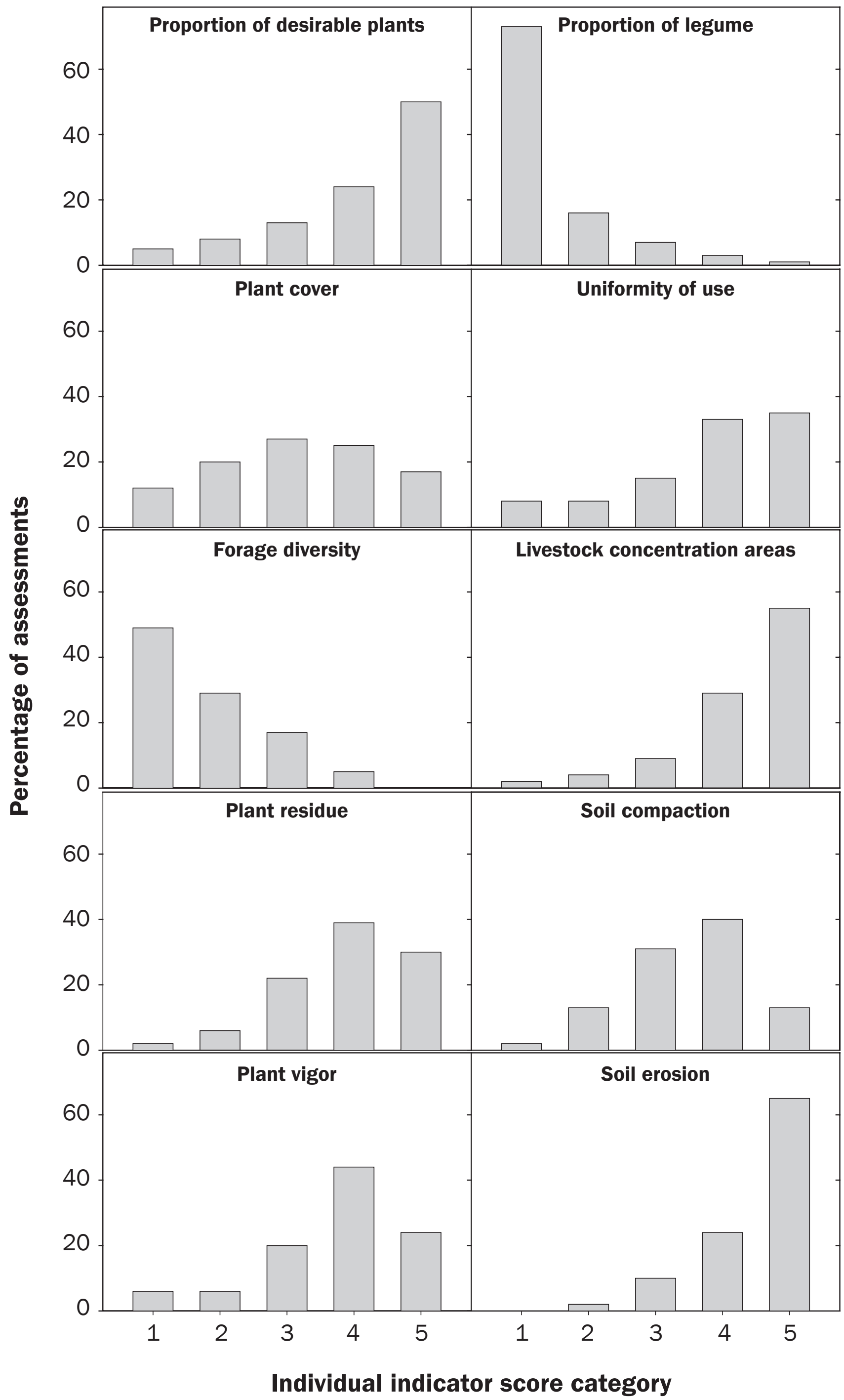
Notes: PA1, PA2, NY1, NY2, and MD1 represent study sites (see table 3).

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 (Höglind and Frankow-Lindberg 1998).

Figure 3
Distributions of individual indicator scores. Data are for all farms, years, and seasons (n = 1,252).



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, 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

Table 6

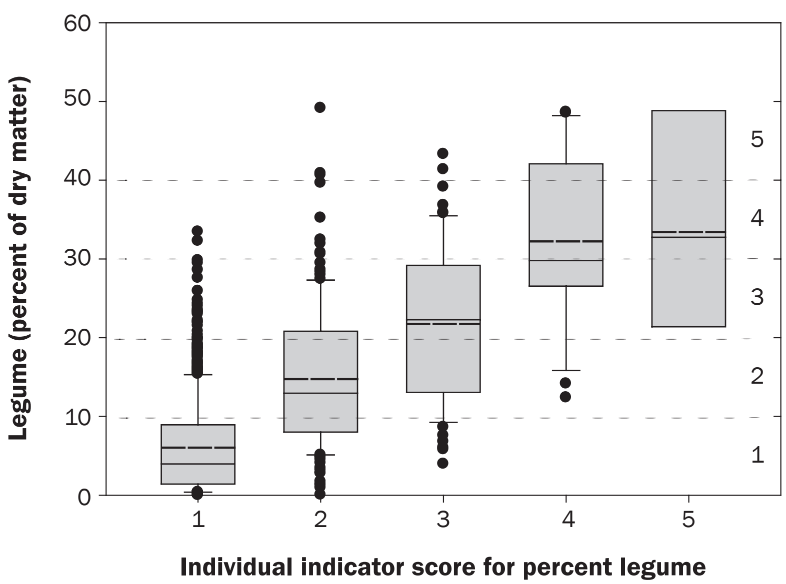
Canopy cover of the top ten plant species in pastures on five farms in the northeastern United States. Data are averaged for all pastures on the farms over three years and three sampling times per year. Use of bold indicates legume species.

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

Notes: PA1, PA2, NY1, NY2, and MD1 represent study sites (see table 3).

Figure 4

Relationship between visual estimates of legume proportion in the sward (*y*-axis) and indicator scores for percent legume (*x*-axis). Boxes show the distribution of values from the 25th and 75th percentiles, whiskers indicate the 10th and 90th percentiles, solid lines inside the boxes 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 indicator values of 1 to 5 in the pasture condition score methodology. Data are for all years, seasons, and farms.



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 score category 5, which had very few observations. There was a small overlap between the 75th percentile for score category 1 and the 25th percentile of the other categories; however, the remaining categories had significant overlap.

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 sward dry matter) grasses and legumes in the sward. Data on the canopy cover of the 10 most abundant plant species on each farm indicated that only two to four plant species accounted for more than 10% canopy cover (table 6). The most abundant species were Kentucky bluegrass (*Poa pratensis* L.), orchardgrass (*Dactylis glomerata* L.), and tall fescue (*Lolium arundinaceum* S.J. Darbyshire). Grasses accounted for 51% (PA2) to 72% (PA1) of the canopy cover. The low legume content of most pastures also contributed to low plant diversity scores. In a study on the degree of plant diversity in northeastern pastures, total plant species richness of northeastern grazing lands ranged from 16 to 49 species per 1,000 m^2 (0.25 ac) with an average of 32 species per 1,000 m^2 (0.25 ac) (Tracy and Sanderson 2000). Pastures in that survey typically supported one or two dominant and subordinate species with the remainder of the species pool accounted for by transient, weedy species. White clover, bluegrass, and orchardgrass were the most abundant species.

Visual estimates of percentage forage species cover (used as an estimate of "desirable plants") were positively correlated with the PCS score for the desirable plants indicator (figure 5) (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 in category 5 was nearly separated from the remaining categories at the 25th and 75th percentiles. About 70% of the indicator scores fell in categories 4 and 5 (figure 3). The best agreement between forage cover and desirable plant indicator score seemed to be in categories 4 (60% of the plant community as 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

Figure 5
Relationship between visual estimates of forage plant cover (percent relative cover) and indicator scores for desirable plants. Boxes show the distribution of values from the 25th and 75th percentiles, whiskers indicate the 10th and 90th percentiles, solid lines inside the boxes 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 indicator values of 1 to 5 in the pasture condition score methodology. Data are for all years, seasons, and farms.

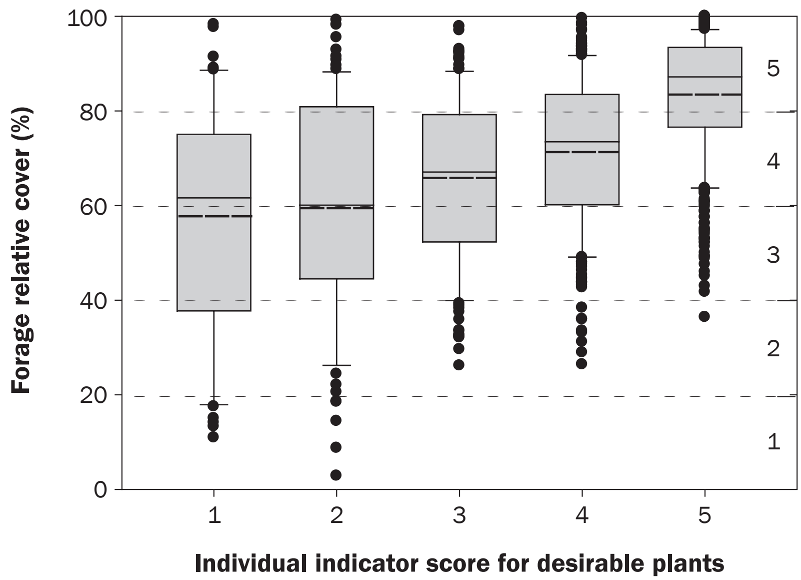


Figure 6
Relationship between visual estimates of total plant canopy cover (percent relative cover) and indicator scores for total plant cover. Boxes show the distribution of values from the 25th and 75th percentiles, whiskers indicate the 10th and 90th percentiles, solid lines inside the boxes indicate the median values, and dashed lines indicates the means. Individual data points indicate outliers. Area between the dashed horizontal lines indicates the range that corresponds to the indicator values of 1 to 5 in the pasture condition score methodology. Data are for all years, seasons, and farms.

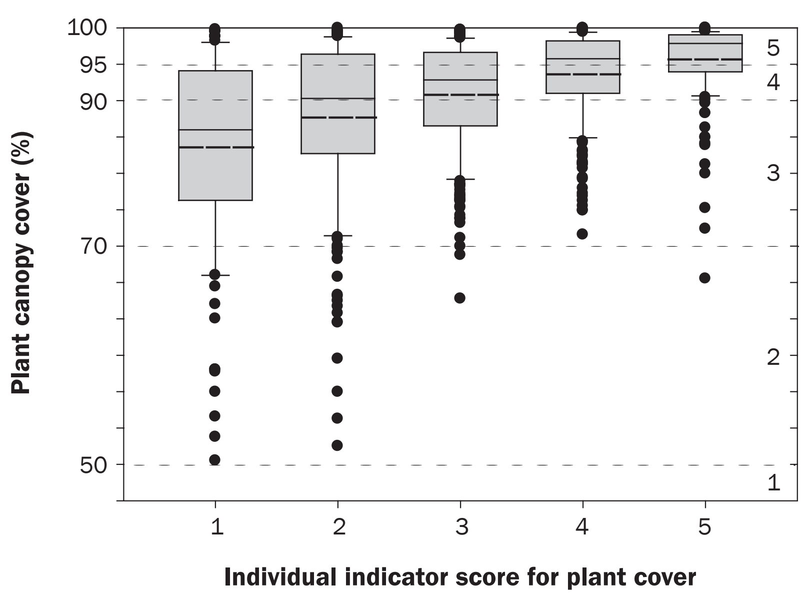
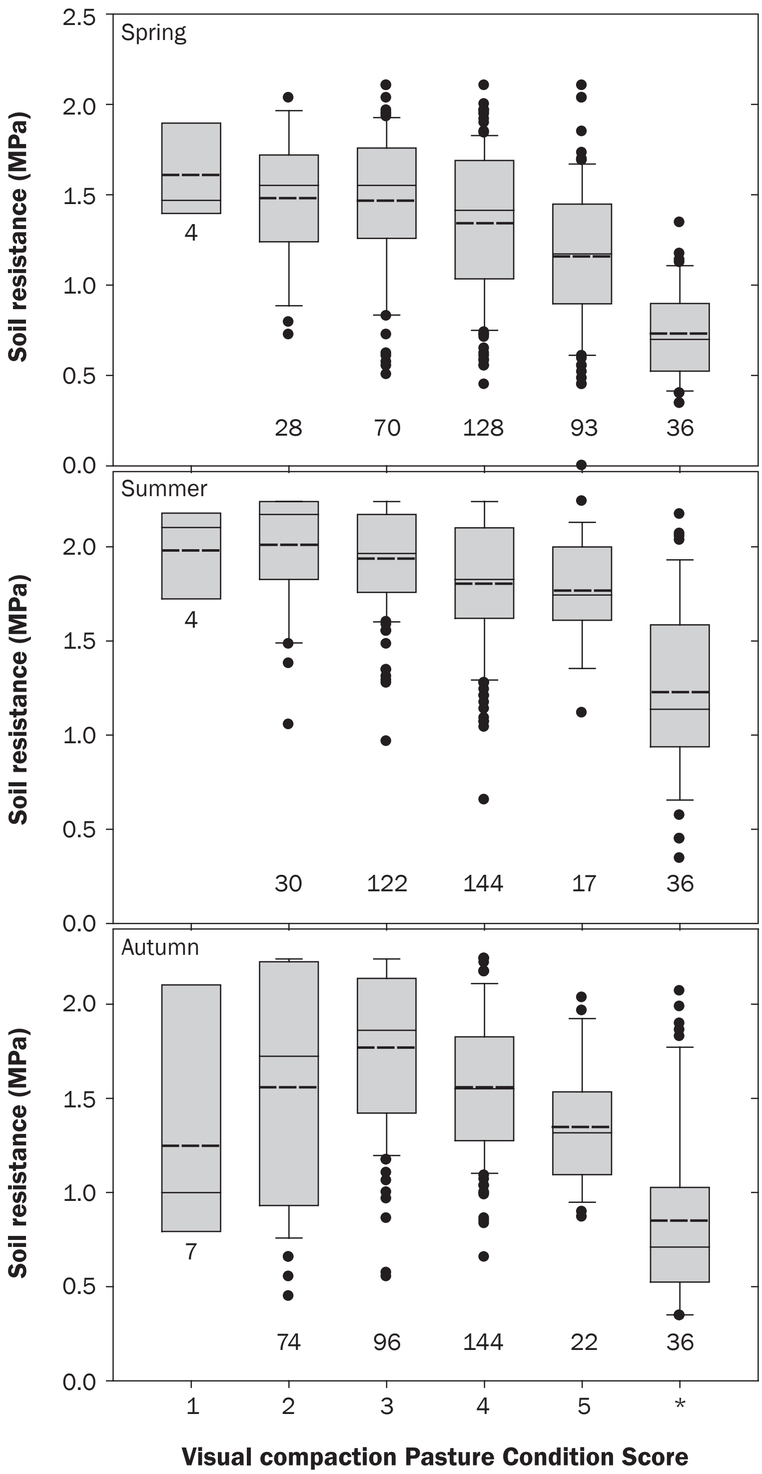


Figure 7

Relationship between soil resistance measured by cone penetrometer and indicator scores for soil compaction in spring, summer, and autumn. Boxes show the distribution of values from the 25th and 75th percentiles, whiskers indicate the 10th and 90th percentiles, solid lines inside the boxes indicate the median values, and dashed lines indicate the means. Individual data points indicate outliers. Data are averaged for farms and years. The number of observations in each category are indicated at each box plot. The * on the *x*-axis indicates penetrometer values from areas that received no animal traffic (e.g., under or just outside of fences).



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 indictors 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 subsets, 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.

Acknowledgements

We thank the farmers who allowed us to come on their farms to conduct this research. Their hospitality and interest is much appreciated. This work was supported by funds from a Conservation Effects Assessment Project (CEAP) jointly funded by the USDA Natural Resources Conservation Service and the USDA Agricultural Research Service. We also thank John Phillips, statistician for the USDA Agricultural Research Service North Atlantic Area, Wyndmoor, Pennsylvania for guidance and assistance with the mixed model analyses of the data; and Jeff Herrick, USDA Agricultural Research Service, Las Cruces, New Mexico, for providing helpful critical comments on an earlier version of this manuscript.

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