



Integrated Upland Vegetation and Soils Monitoring for Chaco Culture National Historical Park

2009 Summary Report, revised

Natural Resource Data Series NPS/SCPN/NRDS—2011/202



ON THE COVER

Sandy Loam ecological site at Chaco Culture National Historical Park
Photograph by Jim DeCoster

Integrated Upland Vegetation and Soils Monitoring for Chaco Culture National Historical Park

2009 Summary Report, revised

Natural Resource Data Series NPS/SCPN/NRDS—2011/202

James K. DeCoster
Megan C. Swan

National Park Service
Southern Colorado Plateau Network
Northern Arizona University
P.O. Box 5765
Flagstaff, AZ 86011-5765

October 2011

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and are applicable to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for timely release of basic data sets and data summaries. Care has been taken to ensure accuracy of raw data values, for which a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

Funding for the SCPN upland field crew was provided to Northern Arizona University by the National Park Service through Colorado Plateau CESU Agreement H1200040002 (Tasks NAU-285/289).

This report is available from the Southern Colorado Plateau Network website (<http://science.nature.nps.gov/im/units/scpn/>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>).

The corresponding author and project manager for this project is Jim DeCoster (jim_decoaster@nps.gov). Megan Swan is the botanist and crew leader for the project. Other contributions were made by the SCPN staff. The 2009 field crew consisted of Teresa DeKoker, Lara Dickson, Hillary Hudson, and Steve Till.

Please cite this publication as:

DeCoster, J. K., and M. C. Swan. 2011. Integrated upland vegetation and soils monitoring for Chaco Culture National Historical Park: 2009 summary report, revised. Natural Resource Data Series NPS/SCPN/NRDS—2011/202. National Park Service, Fort Collins, Colorado.

Introduction and background

The National Park Service Inventory and Monitoring (I&M) Program was designed to determine the status and monitor the conditions of park natural resources, providing park managers with a strong scientific foundation that informs resource management decisions. The Southern Colorado Plateau Network (SCPN) is monitoring vegetation and soils as overall indicators of upland ecosystem integrity (Thomas et al. 2006).

SCPN and park staff selected the Sandy Loam ecological site for long-term monitoring of upland vegetation and soils at Chaco Culture National Historical Park (CHCU). An ecological site is a landscape division with characteristic soils, hydrology, plant communities, and disturbance regimes and responses, and its classification is based on soil survey data (Butler et al. 2003). The Sandy Loam ecological site comprises a large area of the upland grassland systems at CHCU, and it faces numerous threats, including soil erosion, climate change, and invasion by nonnative species.

In 2007 the Integrated Upland Monitoring program of SCPN began monitoring upland sites at CHCU with the installation of 10 plots in the Sandy Loam ecological site. We have sampled the quadrats and gap intercept transects annually for three years to determine the range of temporal variability for key metrics. In this report, we document monitoring activities in the 2009 field season and compare these data with the data collected in 2007 and 2008.

Methods

Sampling frame

We derived the sampling frame from the map of the Sandy Loam ecological site, which was developed by the US Natural Resources Conservation Service (See Appendix A of DeCoster et al., in review). The sampling frame is the area from which we randomly select our sites, and hence the area to which statistical inferences can be made. To create the sampling frame, we modified the map of the ecological site using Geographical Information Systems (GIS) by removing areas within 100 m of roads or exceeding 20% slope.

We generated a set of spatially distributed sampling points using the Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). Park staff reviewed the sampling points and had the opportunity to reject those points that landed too close to archaeological sites and other sensitive resources. Before establishing a plot, the Integrated Upland crew conducted an ecological site assessment for each sampling point and rejected sites that did not fall within the ecological site, had a slope greater than 20%, were inaccessible, or contained a major disturbance. They rejected four points: two points were in proximity to archaeological sites, one was in proximity to a powerline and associated road, and one point fell in an inaccessible area in the park.

Field methods

In 2009, the SCPN Upland Monitoring crew sampled the same 10 plots that were established at CHCU in 2007. The plots were 0.50 ha in size, measuring 71 × 71 m. Shrub and herbaceous data and soil data were collected on three 50 m transects, spaced 25 m apart, within each plot. In 2007 the crew collected data from the plots in the latter part of October; in 2008 and 2009 they collected data in early October. Field methodology is provided in detail in the SCPN Integrated Upland Protocol (DeCoster et al. in review).

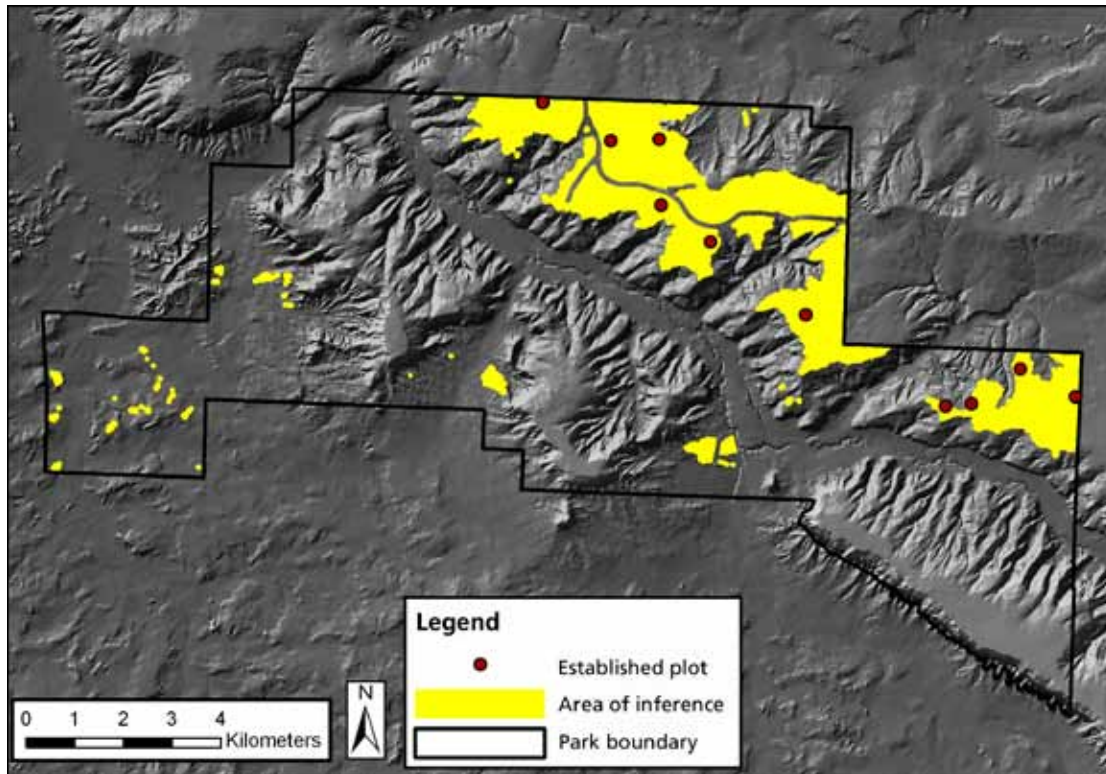


Figure 1. Sampling frame of Sandy Loam ecological site with the 10 plots established in 2007

Shrub and herbaceous vegetation

The crew sampled shrub and herbaceous vegetation within five sets of nested quadrats at 10 m intervals along each transect. The largest quadrat size was 10 m² (2 × 5 m), with four smaller quadrats nested inside (0.01 m², 0.1 m², 1 m², 5 m²). For each nested sub-quadrat we recorded the presence of individual vascular species. For each 10 m² quadrat we estimated percent cover for herbaceous and shrub species and recorded it as one of 12 cover classes (e.g. 2%–5%, 5%–10%, etc.). We also estimated the percent cover for functional groups (e.g. perennial grasses, forbs, shrubs) in the 10 m² quadrats and recorded the cover class for each.

Overstory trees and saplings

There were no trees in any of the plots.

Soil stability and hydrologic function

To measure the amount of bare soil, the crew recorded the length of basal gaps (the space between plant bases) along each transect. Percent cover of soil surface features was estimated in the 1 m² quadrats in conjunction with shrub and herbaceous data and recorded in one of 12 cover classes. A soil aggregate stability test was conducted in 2007, using 18 soil samples collected along the transects. This procedure was not repeated in 2008 or 2009.

Data summary

The sample unit for summary and analysis is the plot; hence, we summarized data at the level of the plot. In order to calculate summary statistics for the ecological site, means and standard deviations were calculated from the plot means.

For herbaceous and shrub vegetation, cover was calculated for each species from the cover class midpoints, e.g. using 7.5% for cover class 5%–10%. The mean cover was calculated for each plot, and the mean and standard deviation (SD) were calculated for the ecological site from the plot means. Species frequency was calculated for quadrats (mean percentage of quadrats per plot where the species occurs) and for plots (percentage of plots where the species occurs). Mean cover and SD of functional groups and surface features were calculated in a similar fashion.

We calculated four diversity measures for herbaceous and shrub species (Magurran 1988), first for all species and then for native species only.

(1) Species richness (S) is the number of species at a given spatial scale, and it was calculated at the level of the plot and at the level of the ecological site.

(2) The Shannon Diversity Index (H') provides a measure of species diversity that takes into account the relative abundance of each species:

$$- \sum_{i=1}^n p_i \ln p_i$$

where p_i is the abundance of each species.

(3) Species evenness (E) is a measure of the degree to which all species are equal in abundance:

$$H' / \ln(S)$$

(4) Beta diversity (β_w) is a measure of within-ecological site heterogeneity:

$$S_e / (S_p - 1)$$

where S_e is the total number of species found in the ecological site, and S_p is the mean number of species found per plot.

We made five calculations for the basal gaps data: median basal gap size, percentage of transects comprised by gaps and plant bases, percentage of transects comprised by each size class, and total number of gaps. Mean and SD were calculated for each metric.

Results

Shrub and herbaceous vegetation

Perennial grasses dominated the vegetation of the Sandy Loam ecological site at CHCU (table 1 and fig. 2), with less cover of shrubs, forbs, and cacti/succulents. Over the three years of sampling, the average cover of total live vegetation ranged between 15.87% and 22.19%, while perennial grasses ranged from 13.08% to 16.51%. Most functional groups had the greatest cover in 2007 and decreased over the three years, but the changes between the second and third year were not as great as the changes between the first two years. Annual grasses and forbs showed the largest changes: annual grasses showed a 90% decrease over the first two years, and forbs showed a 49% decrease. Standing dead herbaceous cover was highest in 2007 with 8.22% and lowest in 2008 with 2.20%. Standing dead woody cover ranged from 1.26% to 1.80% over the years.

Dominant grasses included *Bouteloua gracilis* (blue grama), *Pleuraphis jamesii* (James' galleta), and

Table 1. Mean foliar cover of functional groups for 2007, 2008, and 2009

Functional groups	Foliar cover (%)					
	2007		2008		2009	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
Total live foliar cover	22.19	(3.82)	17.30	(3.12)	15.97	2.39
Perennial grasses, graminoids	16.51	(5.65)	13.13	(4.22)	13.08	3.77
Annual grasses	0.10	(0.10)	0.01	(0.01)	<0.01	0.01
Forbs	0.78	(0.43)	0.40	(0.35)	0.20	0.19
Shrubs	4.31	(2.15)	3.00	(1.41)	2.27	1.54
Cacti, succulents	0.11	(0.12)	0.08	(0.10)	0.10	0.13
Standing dead herbaceous	8.22	(2.47)	2.20	(0.48)	5.55	2.91
Standing dead woody	1.55	(0.59)	1.26	(0.61)	1.80	0.61

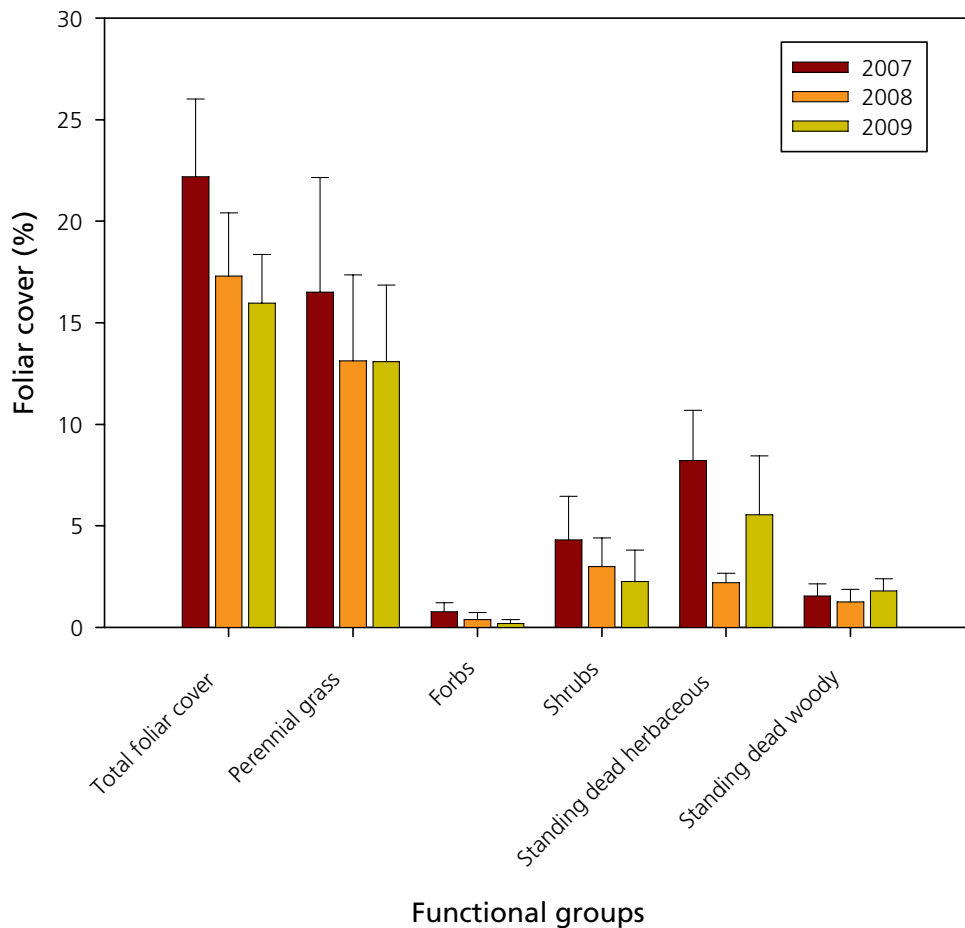


Figure 2. Mean cover of all functional groups (excluding annual grass) at the Sandy Loam ecological site in 2007, 2008, and 2009. Error bars represent one standard deviation.

Sporobolus cryptandrus (sand dropseed); dominant shrubs included *Gutierrezia sarothrae* (broom snakeweed) and *Chrysothamnus Greenei* (Greene's rabbitbrush); and dominant forbs included *Sphaeralcea coccinea* (scarlet globemallow) and *Plantago patagonica* (woolly plantain). Cover of individual species differed among the three years, but most of these changes were quite small, especially considering the large standard deviations (table 2 and fig. 3). Many species followed the pattern of the functional groups, showing their greatest cover in 2007. *Gutierrezia sarothrae*, *Sphaeralcea coccinea*, *Sporobolus cryptandrus*, and *Sporobolus airoides* (alkali sacaton) showed moderate variation in foliar cover.

Quadrat and plot frequencies did not change substantially between years, except for those species that showed large changes in cover. A number of species were not present in the plots in all three years. Some species were present in only one of the years and are referred to here as unique species. Others were present in two of the three years. In 2007 there were four unique species; in 2008 there were nine; and in 2009 there were five. Appendix A lists all species, along with common names, families, mean foliar covers, and plot frequencies by year.

We found two nonnative species in the plots in low abundance: *Bromus tectorum* (cheatgrass) and *Salsola tragus* (prickly Russian thistle). Both showed relatively large decreases in cover in 2008 and had approximately the same cover in 2009 as in 2007. For *Bromus tectorum*, both the quadrat and

Table 2. Foliar cover and frequency of the fifteen most abundant vascular species and all nonnative species in 2007, 2008, and 2009

Species	2007				2008				2009			
	Mean cover (%)	SD	Quad freq	Plot freq	Mean cover (%)	SD	Quad freq	Plot freq	Mean cover (%)	SD	Quad freq	Plot freq
<i>Bouteloua gracilis</i>	6.939	3.945	84.00	100	5.741	3.847	85.33	100	5.941	4.228	83.33	100
<i>Pleuraphis jamesii</i>	4.679	2.476	85.33	100	4.437	3.195	87.33	100	4.209	2.422	84.00	100
<i>Gutierrezia sarothrae</i>	2.084	1.682	82.00	100	0.864	0.607	76.00	100	0.350	0.424	48.67	90
<i>Sporobolus cryptandrus</i>	1.405	2.262	44.67	60	0.349	0.767	28.67	40	1.405	2.797	42.00	70
<i>Achnatherum hymenoides</i>	0.946	1.091	65.33	100	0.565	0.618	63.33	100	0.589	0.819	66.00	100
<i>Chrysothamnus Greenei</i>	0.697	0.774	33.33	80	0.774	0.949	38.00	90	0.627	0.754	32.67	80
<i>Atriplex canescens</i>	0.670	0.408	40.67	100	0.661	0.523	42.67	100	0.436	0.246	40.67	100
<i>Sporobolus airoides</i>	0.609	0.887	38.00	60	0.745	0.686	60.67	90	0.251	0.297	34.00	50
<i>Elymus elymoides</i>	0.396	0.673	35.33	100	0.207	0.215	38.00	100	0.192	0.110	46.67	100
<i>Krascheninnikovia lanata</i>	0.387	0.548	19.33	70	0.330	0.448	20.00	80	0.276	0.350	20.00	70
<i>Sphaeralcea coccinea</i>	0.256	0.183	67.33	100	0.232	0.146	81.33	100	0.114	0.119	48.67	100
<i>Artemisia filifolia</i>	0.219	0.539	4.00	20	0.141	0.363	6.00	40	0.168	0.498	4.00	20
<i>Artemisia frigida</i>	0.183	0.301	22.00	50	0.064	0.133	17.33	50	0.061	0.169	10.00	30
<i>Plantago patagonica</i>	0.139	0.091	84.67	100	0.001	0.002	1.33	10	0.001	0.001	1.33	20
<i>Artemisia bigelovii</i>	0.112	0.302	3.33	30	0.107	0.303	3.33	30	0.112	0.302	3.33	30
<i>Bromus tectorum</i> ^a	0.032	0.059	14.00	60	0.002	0.007	1.33	10	0.002	0.006	1.33	20
<i>Salsola tragus</i> ^a	0.018	0.050	9.33	20	0.007	0.017	4.67	20	0.001	0.001	1.33	20

Note: Species are arranged in descending order by their 2007 cover.

^a Nonnative species.

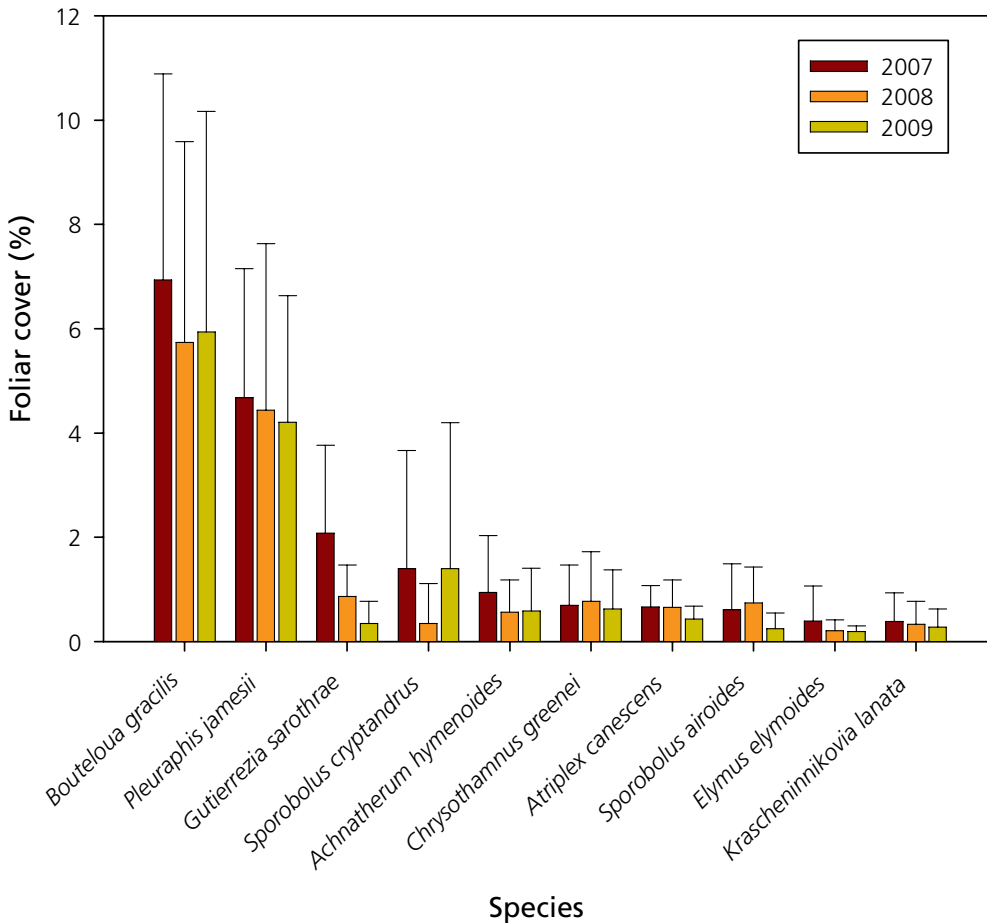


Figure 3. Mean foliar cover of the ten most abundant shrub and herbaceous species in 2007, 2008, and 2009. Error bars represent one standard deviation.

plot frequencies showed large decreases. *Salsola tragus* was found in two plots in all three years and showed decreases in both cover and quadrat frequency each map.

On the scale of the plot, the diversity indices decreased over the three years. Mean species richness went from 20.4 to 16.8 species per plot (table 3). Shannon diversity (which takes into account relative species abundance, and generally ranges between 1.5 and 3.5) decreased from 1.827 and 1.545, and evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) decreased from 0.608 and 0.549 (Margalef 1972). On the scale of the ecological site, both species richness and beta diversity reached their highest level in 2008. Species richness ranged between 36 and 45 species, and beta diversity (a measure of within site heterogeneity, generally ranging between 1 and 5) ranged between 2.113 and 2.528 (McClune and Grace 2002). When these indices were recalculated using only native species, they did not change substantially.

Soil stability and hydrologic function

The crew monitored the amount of exposed soil in two ways: cover estimates of soil surface features in quadrats and measurements of basal gaps along transects. These measurements were undertaken in all three years. As expected, most changes in the surface features were relatively small (table 4 and fig. 4). Four features, however, showed moderate variation among years: live plant base, dead herbaceous base, undifferentiated crust, and bare soil (table 4 and fig. 4). While the number of basal gaps

Table 3. Species diversity metrics for all species and for native species only

	2007		2008		2009	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
All species						
Plot						
Plot richness	20.4	(2.6)	18.8	(4.7)	16.8	(3.3)
Shannon diversity	1.827	(0.319)	1.687	(0.370)	1.545	(0.380)
Evenness	0.608	(0.105)	0.580	(0.117)	0.549	(0.121)
Ecological site						
Ecological site richness	41		45		36	
Beta diversity	2.113		2.528		2.278	
Native species						
Plot						
Plot richness	19.6	(2.6)	18.5	(4.5)	16.4	(3.0)
Shannon diversity	1.815	(0.312)	1.684	(0.366)	1.543	(0.379)
Evenness	0.613	(0.109)	0.582	(0.119)	0.553	(0.125)
Ecological site						
Ecological site richness	39		43		34	
Beta diversity	2.097		2.457		2.208	

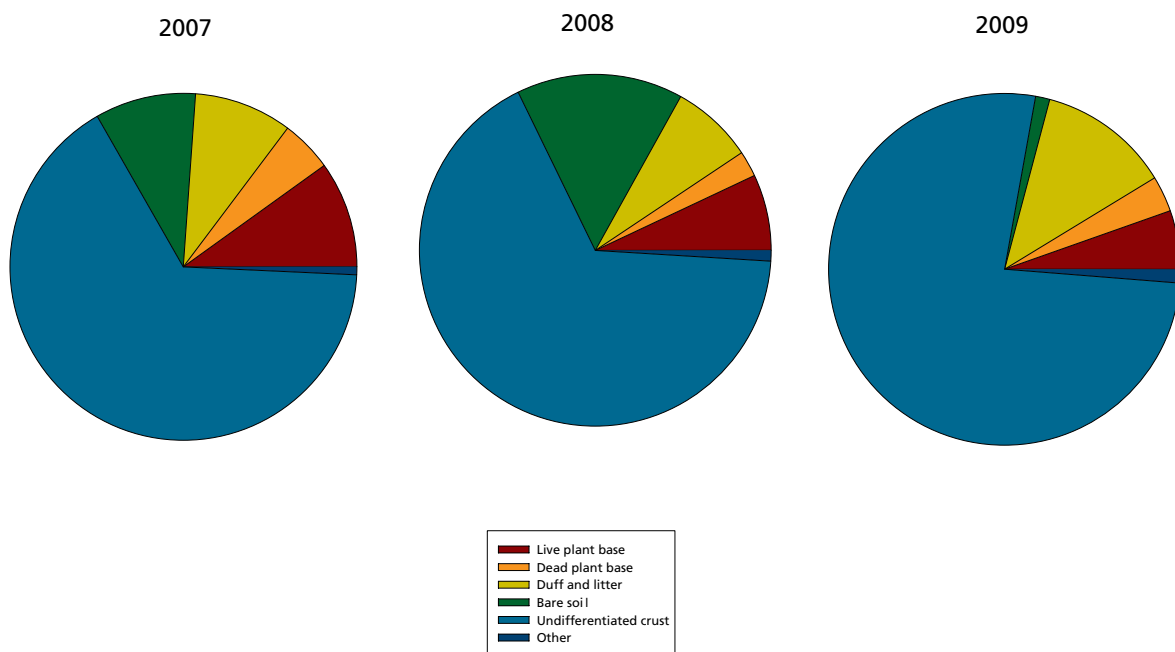
**Figure 4.** Mean cover of soil surface features in 2007, 2008, and 2009

Table 4. Cover of soil surface features in 2007, 2008, and 2009

Surface feature	2007		2008		2009	
	Mean (%)	(SD)	Mean (%)	(SD)	Mean (%)	(SD)
Live plant base	9.87	2.71	6.95	1.32	5.45	1.41
Dead woody base	0.49	0.28	0.46	0.34	0.28	0.16
Dead herbaceous base	4.31	1.69	1.90	0.57	3.04	1.15
Bare soil	9.35	6.31	15.24	15.58	1.33	1.02
Duff and litter	9.09	3.03	7.52	3.24	12.26	5.67
Undifferentiated crust	65.62	13.22	66.49	16.59	77.31	8.75
Moss	0.08	0.25	0.05	0.11	0.07	0.23
Lichen	0.00	0.00	<0.01	<0.01	0.00	0.00
Cyanobacteria	0.01	0.02	0.05	0.16	0.01	0.04
Fine gravel (0.2–2 cm)	0.40	0.59	0.50	0.93	0.64	1.19
Coarse gravel (2–7.5 cm)	0.20	0.35	0.27	0.52	0.42	1.04
Cobble (7.5–25 cm)	0.04	0.08	0.03	0.09	0.03	0.07
Stone, bedrock (>25 cm)	0.03	0.09	0.08	0.260	0.08	0.26
Woody debris	0.00	0	0.01	0.03	0.00	0.00

Note: The surface feature components do not add up to 100% because the calculations were made from cover class midpoints, and the estimations have observer error.

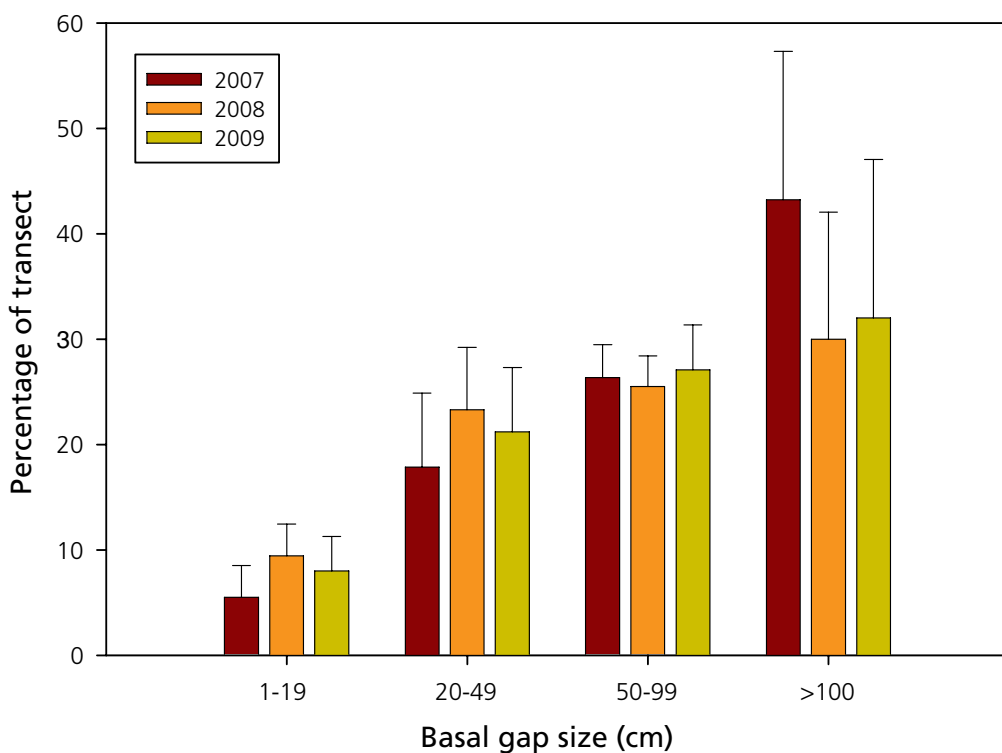


Figure 5. Percentage of transect in different gap sizes in 2007, 2008, and 2009. Error bars represent one standard deviation.

Table 5. Number of basal gaps, median gap size, and percentage of transect in different gap size classes in 2007, 2008, and 2009

Metric	2007		2008		2009	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
Number of gaps	259.7	(74.2)	340.9	(64.3)	312.2	(75.3)
Median gap size (cm)	38.4	(10.5)	24.4	(4.4)	28.7	(8.5)
Percent of transect in gaps 0–9 cm	5.5	(3.0)	9.4	(3.0)	8.0	(3.3)
Percent of transect in gaps 20–49 cm	17.9	(7.0)	23.3	(5.94)	21.2	(6.1)
Percent of transect in gaps 50–99 cm	26.4	(3.1)	25.5	(2.9)	27.1	(4.3)
Percent of transect in gaps ≥100 cm	43.2	(14.1)	30.0	(12.0)	32.0	(15.0)
Percent of transect in gaps	93.0	(2.4)	88.2	(3.3)	88.4	(3.2)
Percent of transect in plant bases	7.0	(2.4)	11.8	(3.3)	11.6	(3.3)

and the mean basal gap size showed large among-year variation, the percentage of transect occupied by the different basal gap sizes did not change substantially with the exception of gaps >100 cm (table 5 and fig. 5).

Discussion

The data presented here indicate some annual variation in the vegetation and surface features on the Sandy Loam ecological site among the years 2007, 2008, and 2009. Most functional groups and species had the highest cover values in 2007. Forbs and annual grass species changed the most over the years. The plot species diversity indices decreased each year, while the ecological site species diversity indices were highest in 2008.

The variation that did occur is, in part, attributable to variation in precipitation. 2007 had above average precipitation in most of the summer and fall months, while 2008 and 2009 had below average precipitation for most summer and fall months (with the exception of July 2008) (fig. 6). The timing and the amount of precipitation differentially influences germination, growth, and flowering of species. Annual species (e.g. *Plantago patagonica*) and perennial forbs (e.g. *Sphaeralcea coccinea*) seem to be the most influenced by these climatic variations. The two nonnative species, *Bromus tectorum* and *Salsola tragus*, were annuals and followed the trend of lower cover in the drier years. The large standing dead herbaceous cover in 2007 was likely the result of sampling later in the year after the first frost when it was difficult to distinguish the current years dead herbaceous cover from previous years’.

Cover of soil surface features, particularly live plant base, dead herbaceous base, undifferentiated crust and bare soil, varied among years. The variations in the live and dead plant base cover may have been the result of perennial grass mortality associated with dry conditions. The variation in undifferentiated crust and bare soil may be attributable to how soil surface features appear in wet conditions versus dry conditions. When the ground surface is wet, undifferentiated crust becomes more difficult to distinguish from bare soil. In addition, physical crust is formed by raindrop impact and decreases with increasing time since the last rainfall. As a result of a wet October in 2007, some of the plots were sampled after precipitation events, which may have made it difficult for the crew to estimate the cover of soil surface features.

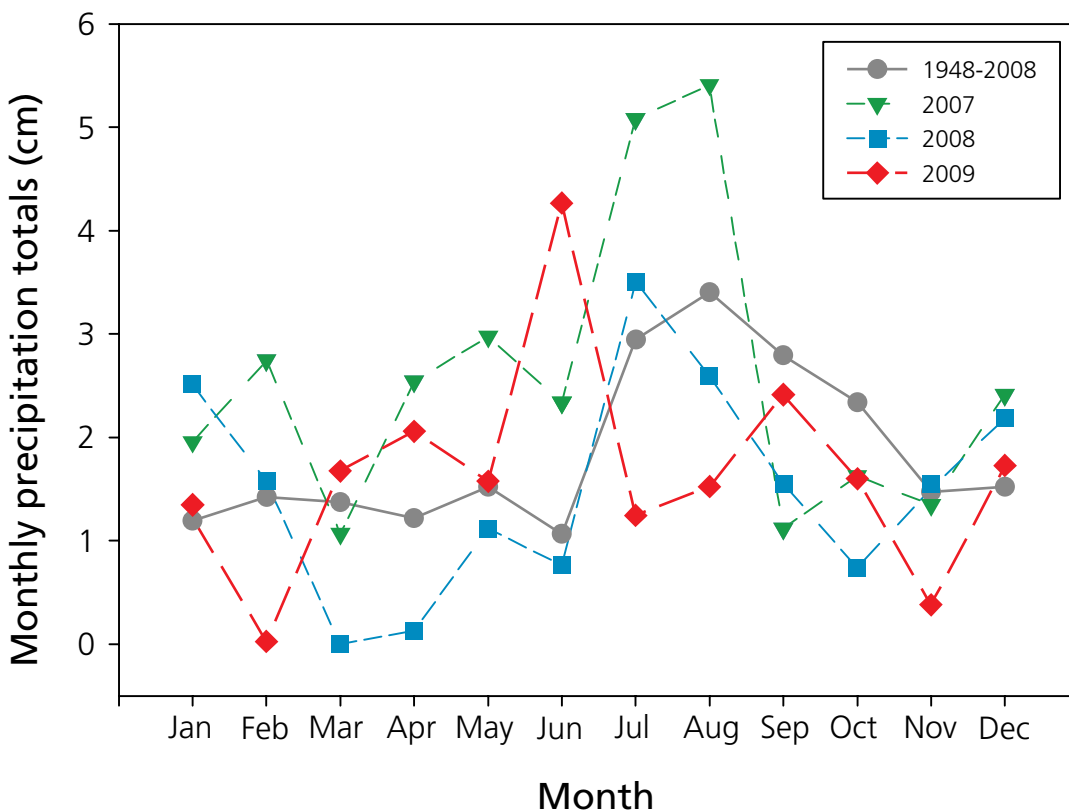


Figure 6. Total monthly precipitation for 2007, 2008, and 2009 with the mean monthly totals for 1948 through 2009 (WRCC 2010)

We stress that the differences noted between years are not indicative of any trend, since trends cannot be determined with only three years of sampling, nor should they be interpreted as being ecologically significant. The decrease in foliar cover of functional groups and species over the three year period is likely the result of variation in precipitation. Some variation in the data is also due to sampling error. Cover estimation may vary among individuals (and crews), species may be mis-identified, slight differences between observers in applying sampling methods may go unnoticed, and the locations of transects and quadrats vary slightly from year to year. We strive to minimize these errors by ensuring that transect lines are as straight as possible, quadrats are placed correctly, and field crews are thoroughly trained on methods and species identification and remain calibrated on cover estimation.

We plan to conduct power analysis using the three years of data, which will help determine the total number of plots necessary to detect change in the key metrics. A temporal sampling design will then be implemented, with the installation of additional plots in subsequent years. Each year's data will be compared to the previously collected data to analyze changes through time in vegetation composition and structure and in soil stability and hydrologic function. Trend analyses will be conducted once sufficient data have been collected.

Literature cited

- Butler, L. D., J. B. Cooper, R. H. Johnson, A. J. Norman, G. L. Peacock, P. L. Shaver, and K. E. Spaeth. 2003. National range and pasture handbook. United States Department of Agriculture, National Resources Conservation Service, Grazing Lands Technology Institute, Fort Worth, TX.
- DeCoster, J. K., C. L. Lauver, M. E. Miller, J. R. Norris, A. E. C. Snyder, M. C. Swan, L. P. Thomas, and D. L. Witwiski. Integrated upland monitoring protocol for the Southern Colorado Plateau Network. Natural Resource Technical Report, National Park Service, Fort Collins, CO, in review.
- Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, NJ.
- Margalef, R. 1972. Homage to Evelyn Hutchinson, or why there is an upper limit to diversity. *Transactions of the Connecticut Academy of Arts and Sciences* 44: 211–35.
- McCune, B. and J. B. Grace. 2002. Analysis of ecological communities. MJM Software Design.
- Stevens, D. L. and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99: 262–278.
- Thomas, L. P., M. N. Hendrie (editor), C. L. Lauver, S. A. Monroe, N. J. Tancreto, S. L. Garman, and M. E. Miller. 2006. Vital signs monitoring plan for the Southern Colorado Plateau Network. Natural Resource Report NPS/SCPN/NRR-2006/002. National Park Service, Fort Collins, CO.
- Western Regional Climate Center (WRCC). 2010. Monthly total precipitation for Chaco Canyon National Historic Park, NM. WRCC, Reno, NV. Available at <http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?nm1647> (accessed 12 May 2010).

Appendix A

Complete species list with mean foliar cover and frequency for herbaceous and shrub species in 2007, 2008, and 2009. Annual *Chamaesyce* spp. that were not identifiable to species in the field are placed in one of two groups based on leaf morphology.

Species	Common name	Family	2007			2008			2009		
			Foliar cover (%)	Plot frequency (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Plot frequency (%)
<i>Achnatherum hymenoides</i>	Indian ricegrass	Poaceae	0.946	100	100	0.565	100	100	0.589	100	100
<i>Aristida purpurea</i>	Fendler's threeawn	Poaceae	0.101	50	50	0.076	70	70	0.083	50	50
<i>Artemisia bigelovii</i>	Bigelow sage	Asteraceae	0.112	30	30	0.107	30	30	0.112	30	30
<i>Artemisia filifolia</i>	sand sagebrush	Asteraceae	0.219	20	20	0.141	40	40	0.168	20	20
<i>Artemisia frigida</i>	fringed sagebrush	Asteraceae	0.183	50	50	0.064	50	50	0.061	30	30
<i>Astragalus</i> sp.	milkvetch	Fabaceae	0.002	40	40	0.001	10	10	0	0	0
<i>Atriplex canescens</i>	fourwing saltbush	Chenopodiaceae	0.670	100	100	0.661	100	100	0.436	100	100
<i>Bouteloua gracilis</i>	blue grama	Poaceae	6.939	100	100	5.741	100	100	5.941	100	100
<i>Bromus tectorum</i> ^a	cheatgrass	Poaceae	0.032	60	60	0.002	10	10	0.002	20	20
<i>Chaetopappa ericoides</i>	rose heath	Asteraceae	0.055	70	70	0.028	80	80	0.024	80	80
<i>Chamaesyce</i> spp. Group A	annual sandmats	Euphorbiaceae	0.004	30	30	0.002	20	20	0.003	20	20
<i>Chamaesyce</i> spp. Group B	annual sandmats	Euphorbiaceae	0	0	0	0.003	10	10	0	0	0
<i>Chenopodium</i> spp.	goosefoot	Chenopodiaceae	0	0	0	0	0	0	0.006	50	50
<i>Chenopodium fremontii</i>	Fremont's goosefoot	Chenopodiaceae	0	0	0	<0.001	10	10	0	0	0
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	Chenopodiaceae	0.045	50	50	0.013	40	40	<0.001	10	10
<i>Chrysothamnus Greenei</i>	Greene's rabbitbrush	Asteraceae	0.697	80	80	0.774	90	90	0.627	80	80
<i>Comandra umbellata</i>	bastard toadflax	Santalaceae	0	0	0	0	0	0	<0.001	10	10
<i>Cryptantha</i> sp.	cryptantha	Boraginaceae	0	0	0	0	0	0	0.005	40	40
<i>Echinocereus triglochidiatus</i>	kingcup cactus	Cactaceae	0.005	10	10	0.006	30	30	0.005	10	10
<i>Elymus elymoides</i>	squirreltail	Poaceae	0.396	100	100	0.207	100	100	0.192	100	100
<i>Ericameria nauseosa</i>	rubber rabbitbrush	Asteraceae	0.080	20	20	0.083	20	20	0.052	20	20
<i>Erigeron</i> sp.	fleabane	Asteraceae	0	0	0	0	0	0	0.001	10	10
<i>Eriogonum cernuum</i>	nodding buckwheat	Polygonaceae	0.004	10	10	0.038	10	10	0.016	10	10
<i>Evolvulus nuttallianus</i>	shaggy dwarf morning-glory	Convolvulaceae	<0.001	10	10	0	0	0	0	0	0

Appendix A continued

Species	Common name	Family	2007		2008		2009	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Asteraceae	2.084	100	0.864	100	0.350	90
<i>Hesperostipa comata</i>	needle and thread	Poaceae	0.066	70	0.041	80	0.061	60
<i>Hymenopappus filifolius</i>	fineleaf hymenopappus	Asteraceae	<0.001	10	<0.001	10	0	0
<i>Krascheninnikovia lanata</i>	winterfat	Chenopodiaceae	0.387	70	0.330	80	0.276	70
<i>Lappula occidentalis</i>	flatspine stickseed	Boraginaceae	0	0	0	0	0.006	30
<i>Lycium pallidum</i>	pale desert-thorn	Solanaceae	0.028	10	0.019	20	0	0
<i>Machaeranthera canescens</i>	hoary tansyaster	Asteraceae	0.008	30	<0.001	10	0	0
<i>Monroa squarrosa</i>	false buffalograss	Poaceae	0.003	20	0.003	10	0	0
<i>Muhlenbergia torreyi</i>	ring muhly	Poaceae	0.066	50	0.035	50	0.035	40
<i>Oenothera</i> sp.	evening primrose	Onagraceae	0	0	0.001	30	0	0
<i>Opuntia polyacantha</i>	El Paso pricklypear	Cactaceae	0.106	90	0.084	100	0.112	90
<i>Opuntia whipplei</i>	Whipple's cholla	Cactaceae	0	0	<0.001	10	0	0
<i>Phacelia</i> sp.	scorpionweed	Hydrophyllaceae	0.056	40	0.001	20	<0.001	10
<i>Plantago patagonica</i>	woolly plantain	Plantaginaceae	0.139	100	0.001	10	0.001	20
<i>Pleuraphis jamesii</i>	James' galleta	Poaceae	4.679	100	4.437	100	4.209	100
<i>Rumex</i> sp.	dock	Polygonaceae	0	0	0.001	10	0.002	10
<i>Salsola tragus</i> ^a	prickly Russian thistle	Chenopodiaceae	0.018	20	0.007	20	0.001	20
<i>Sanvitalia abertii</i>	Albert's creeping zinnia	Asteraceae	0	0	0.001	10	0	0
<i>Sarcobatus vermiculatus</i>	greasewood	Chenopodiaceae	0	0	0	0	0.050	10
<i>Schkuhria multiflora</i>	many-flower false threadleaf	Asteraceae	0.008	30	0	0	0	0
<i>Solanum jamesii</i>	wild potato	Solanaceae	0	0	0.007	10	0	0
<i>Sphaeralcea</i> spp.	globemallow	Malvaceae	0.014	10	0	0	0.014	20
<i>Sphaeralcea coccinea</i>	scarlet globemallow	Malvaceae	0.256	100	0.232	100	0.114	100
<i>Sphaeralcea incana</i>	soft globemallow	Malvaceae	0	0	0.009	10	0	0
<i>Sporobolus airoides</i>	alkali sacaton	Poaceae	0.609	60	0.745	90	0.251	50
<i>Sporobolus contractus</i>	spike dropseed	Poaceae	0	0	0.002	10	0	0

Appendix A continued

Species	Common name	Family	2007		2008		2009	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Sporobolus cryptandrus</i>	sand dropseed	Poaceae	1.405	60	0.349	40	1.405	70
<i>Stephanomeria pauciflora</i>	brownplume wirelettuce	Asteraceae	<0.001	10	0	0	0	0
<i>Verbesina encelioides</i>	golden crownbeard	Asteraceae	0	0	<0.001	10	0	0
<i>Vulpia octoflora</i>	sixweeks fescue	Poaceae	0.076	100	0	0	0	0
Unknown 10032008-1			0	0	<0.001	10	0	0
Unknown 10032008-3			0	0	<0.001	10	0	0
Unknown 10202007-2			0.002	10	0	0	0	0
Unknown 10202007-4			0.001	10	0.	0	0	0
Unknown 10202007-5			<0.001	10	0	0	0	0

^a Nonnative species.