



Integrated Upland Vegetation and Soils Monitoring for Wupatki National Monument

2012–2014 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2016/1039



ON THE COVER
Plot in Loamy Upland ecological site at Wupatki National Monument
Photography by: SCPN

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1 Introduction

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 scientific foundation for making decisions and working with other agencies and the public to protect park ecosystems. The Southern Colorado Plateau Network (SCPN) is monitoring vegetation and soils as overall indicators of upland ecosystem integrity (Thomas et al. 2006).

In 2006, SCPN and park staff selected the Limy Upland and Sandstone Upland ecological sites for long-term monitoring of upland vegetation and soils at Wupatki National Monument (WUPA). An ecological site is a landscape division with characteristic soils, hydrology, plant communities, and disturbance regimes and responses. Its classification is based on soil survey data (Butler et al. 2003). These two ecological sites comprise a large area of the upland ecosystems at WUPA. They face numerous threats, including climate change and invasion by nonnative species. Between 2007 and 2010 we established and sampled 30 plots in the Limy Upland ecological site and 30 plots in the Sandstone Upland ecological site. In 2012 we implemented a panel design by resampling 20 of these plots in the Limy Upland ecological site.

In 2012, however, the U.S. Natural Resources Conservation Service (NRCS) began fieldwork for an updated soil map for WUPA, and new soil names and descriptions were approved in 2013. As a result, significant changes were made to the classification of ecological sites. After reviewing the new classification and following discussion with both NRCS and park staff, we revised our sampling frames to reflect the updated soil map and ecological site designations. Many established plots were decommissioned as they did not meet the criteria of the new classification, and new plots were established to align our sampling frames with the new classification. Plots formerly in the Limy Upland ecological site have been placed in the Volcanic Upland ecological site if they fit the criteria, or have been decommissioned. Similarly, plots that had been in the Sandstone Upland ecological site have been placed in the Loamy Upland ecological site, or have been decommissioned.

In 2012, we sampled 17 plots in what had been the Limy Upland ecological site, and in 2013 we sampled 21 plots in what had been the Sandstone Upland ecological site. In 2014 we sampled 19 plots in the newly developed sampling frame within the Volcanic Upland ecological site. In this report, we document monitoring activities during the 2012, 2013 and in the 2014 field seasons as we transitioned into our new panel design and our new sampling frame. We report these data in the context of the data collected between 2007 and 2010 in the first year of sampling for plots that were later incorporated into our panel design.

2 Methods

2.1 Sampling frame

We derived our original base sampling frames for the Limy Upland ecological site (Figure 1) and Sandstone Upland ecological site (Figure 2) from SSURGO soil maps, which were developed by the NRCS (see Appendix A of DeCoster et al. 2012). The sampling frame is the area from which we randomly select our sites, and hence the area to which statistical inferences can be made.

In making final adjustments to our sampling frames, we modified maps of the ecological site using Geographical Information System (GIS) technology to remove areas

- outside of the target ecological site (i.e., roads, development)
- at risk for erosion as a result of sampling (slopes $\geq 20\%$)

We generated a set of spatially distributed sampling points using the Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2004) for each sampling frame. Park staff visited the sampling points and rejected those points that landed too close to archeological sites and other sensitive resources. The integrated upland crew visited the first series of GRTS points and conducted an ecological site assessment, rejecting sites

that deviated substantially from the ecological site description, had a slope greater than 20%, or contained a major disturbance. In both the Limy Upland and Sandstone Upland ecological sites, we established and sampled 10 plots in 2007 and resampled them in 2008, 2009, and 2011. In 2010 we established and sampled in 20 additional plots. We resampled 20 of these plots in the Limy Upland ecological site in 2012, and in the Sandstone Upland ecological site in 2013.

NRCS revisions to the ecological sites at WUPA made it necessary to further modify our sampling frames following fieldwork in 2012. The Limy Upland ecological site was greatly expanded and renamed as the Volcanic Uplands ecological site. We have revised our sampling frame by using the soil map units of the new ecological site that largely overlapped with the old sampling frame. The Sandstone Upland ecological site was also revised, resulting in a large part of our sampling frame becoming the Loamy Upland ecological site. For both ecological sites, these revisions removed a few areas from the old sampling frame in some areas and expanded it into other areas. We created a new set of GRTS points for the new areas to identify new potential plots. Our current (revised) panel design places the plots in the old and new areas, such that the number of plots in each area is proportional to their respective areas. A number of plots in each site were decommissioned as they fell outside the area of the new sampling frames. Figures 1 and 2 show the modified sampling frames in the new ecological sites, with the plots that make up the panels for the revised panel design.

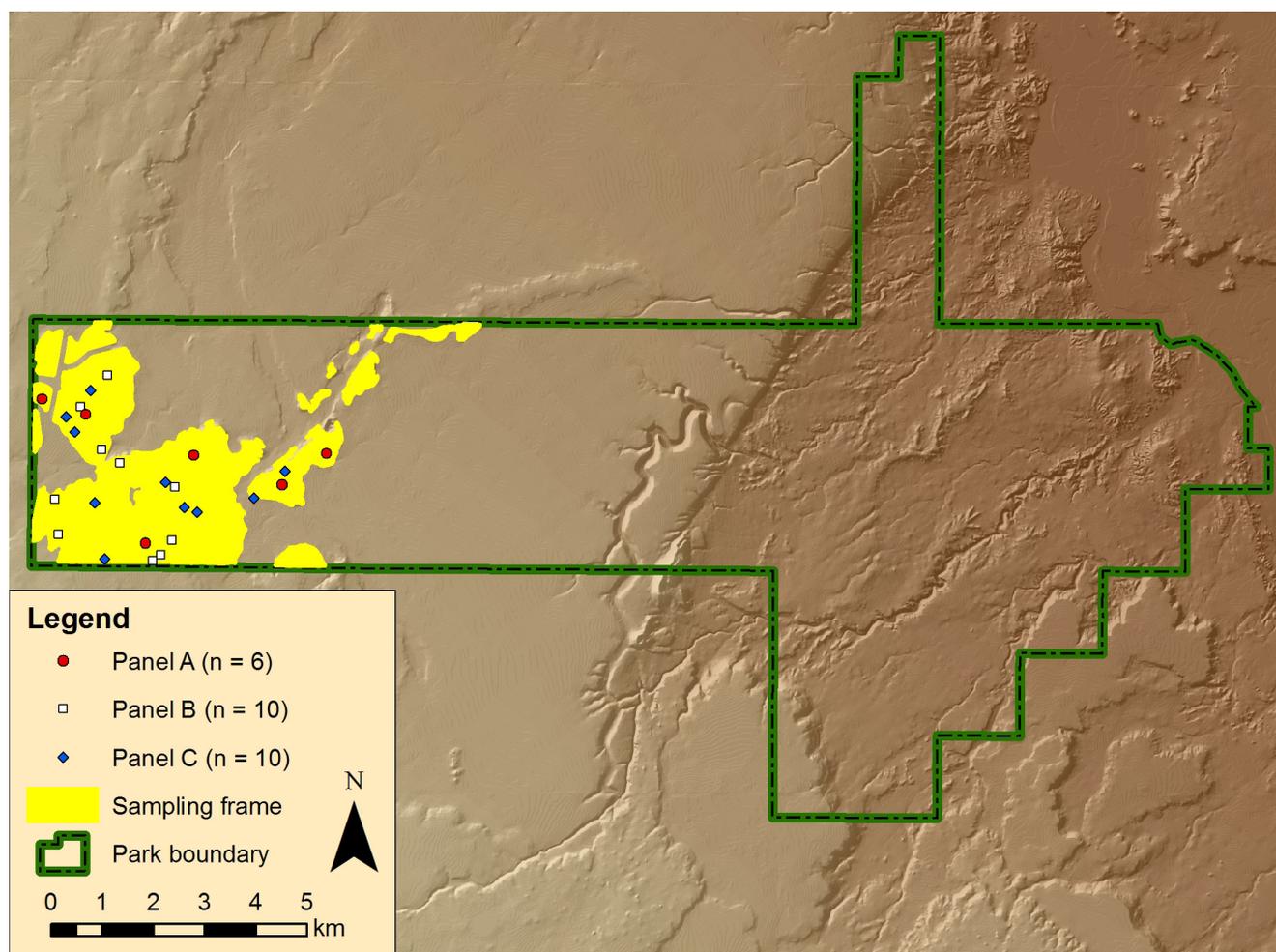


Figure 1. New sampling frame of the Volcanic Upland ecological site (formerly Limy Upland) at Wupatki NM. Plots are shown by panel.

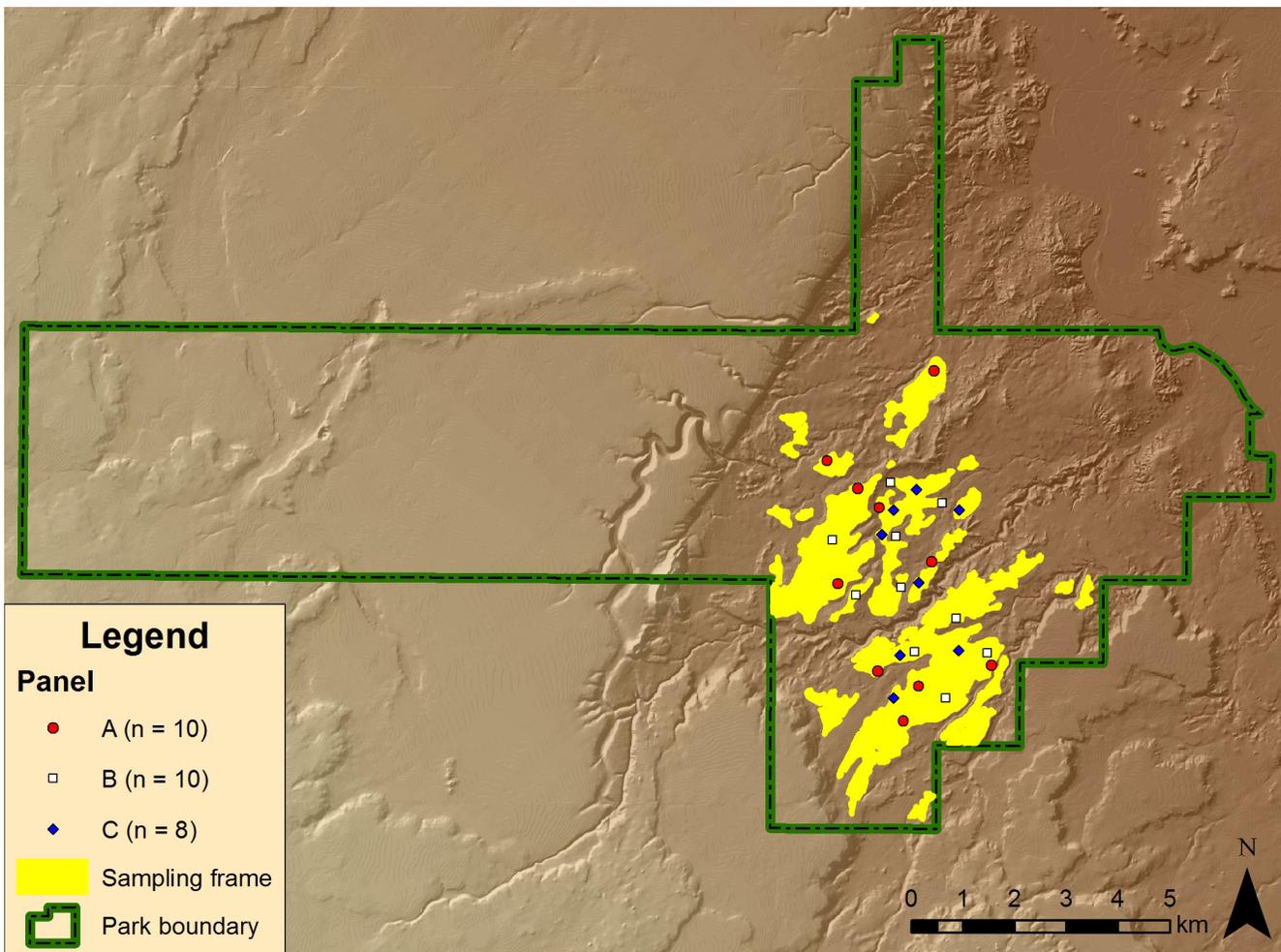


Figure 2. New sampling frame of the Loamy Upland ecological site (formerly Sandstone Upland) at Wupatki NM. Plots are shown by panel.

2.2 Field methods

SCPN’s integrated upland monitoring plots are 0.50 ha in size (measuring 71 × 71 m) and consist of 3 parallel 50 m transects spaced 25 m apart. We collected data for shrub and herbaceous species cover and frequency, functional group cover, and soil surface feature cover on all 3 transects within each plot. Detailed field methodology is provided in the SCPN integrated upland monitoring protocol (DeCoster et al. 2012). Plots were sampled in late August and early September of each year.

2.2.1 Shrub and herbaceous vegetation

We sampled shrub and herbaceous vegetation within 5 sets of nested quadrats at 10 m intervals along each transect. The largest quadrat size was 10 m² (2 × 5 m), with 4 smaller quadrats nested inside (0.01 m², 0.1 m², 1 m², 5 m²). We recorded the presence of every herbaceous and shrub species within each nested sub-quadrat. We estimated the percent cover of each species in the 10 m² quadrat and assigned them to 1 of 12 cover classes (e.g., 2% to <5%, 5% to <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.

2.2.2 Soils

We estimated the percent cover of soil surface features in the 1 m² quadrats along transects, and recorded cover in one of 12 cover classes.

2.2.3 Trees

Scattered individuals of *Juniperus monosperma* (oneseed juniper) are found in areas of both ecological sites. During the first sampling of each plot, we measured diameter at root crown of each overstory tree using diameter at root crown in a 50 x 50 m plot, and each sapling in a 25 x 25 m subplot. Trees were not remeasured in 2012 and 2013, so we will not present these initial tree data in this report.

2.3 Panel design and implementation

A rotating panel design is a sampling strategy sometimes used when estimates are produced regularly over time. Under such a design, equally sized sets of plots, or ‘panels’, are brought in and out of the sample through time in some specified pattern. This approach seeks to reduce monitoring costs by optimizing the balance between two desirable but competing monitoring qualities—frequent enough sampling to detect temporal change and a sample size large enough to capture the spatial heterogeneity of the target ecosystem. The overlap of panel sampling allows for an estimate of change for every pair of years included in the sample; this is termed a “temporally connected” sampling design and provides greater power to detect trends through time.

SCPN developed and implemented a rotating panel design for integrated upland monitoring in 2012 for both ecological sites in WUPA. The 30 monitoring plots within each ecological site are partitioned into 3 panels (n=10), with 2 of the 3 panels sampled every other year (Table 1). To maintain spatial balance, plots were assigned to panels according to their GRTS numbers; i.e. the plots with the 10 lowest GRTS numbers were assigned to Panel A; the second consecutive set of GRTS numbers were assigned to Panel B, etc.

In 2012, in the Volcanic Upland ecological site (formerly Limy Upland), we began the implementation of our panel design by resampling 20 plots representing panels A and B. However, following revision of the sampling frame in 2013, we replaced 11 of the existing 30 plots with 11 plots in the new areas of the sampling frame. This resulted in the decommissioning of plots and a reorganizing of the remaining plots within each panel. As a result, panel representation changed following the 2012 sampling event. In 2014, we established additional plots to replace those that had been decommissioned (Figure 3).

In 2013, we began the implementation of our panel design in the Loamy Upland ecological site (formerly Sandstone Upland) by resampling 19 plots representing panels A&B. We also installed and sampled 2 plots in panel C to complete that panel (data not presented here). Figure 3 shows the revised panel designs for the sampling frames of both ecological sites as implemented in 2013 and 2014.

2.4 Initial sampling: 2007–2010

Because we are implementing upland monitoring across 15 ecological sites in 10 parks, plot establishment for upland vegetation and soils monitoring in SCPN parks has occurred over several years. We began our monitoring in both ecological sites at WUPA by establishing and sampling 10 plots in 2007, which we resampled in 2008, 2009 and 2011 to understand the annual variation in key metrics (Figure 3). In 2010 we established and sampled an additional 20 plots in each ecological site. Following sampling frame revisions, we decommissioned many plots in each ecological site. We emphasize that data presented from the establishment period were collected over the course of 4 years and therefore do not represent a single sampling event. The full benefit of the panel design will not be realized until we have collected data through several cycles of the design.

2.5 Data summary

We first summarized data at the level of the plot, which is the sample unit, and then calculated the mean and standard deviation for most metrics from the plot means for each panel and time period (initial sampling year, 2012 and 2014). Three metrics—plot frequency, site richness and beta diversity—were calculated across all plots and were therefore not calculated by averaging plot values.

For the Volcanic Upland ecological site, we present data from panels A&B in 2012 and panels B&C in 2014, along with data from the initial sampling of all 3 panels (2007–2010) for context. For the Loamy Upland ecological site, we present data from panels A&B in 2013, along with data from the initial sampling of all 3 panels. We only

Table 1. Panel design for resampling monitoring plots in the Volcanic Upland and Loamy Upland ecological sites at Wupatki NM. Each panel comprises 10 plots for a total of 30 plots across 3 panels for each ecological site. A “-” indicates that no resampling was conducted for that panel during that year.

Panel	Year											
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Volcanic Upland ecological site												
A	10	-	-	-	10	-	10	-	-	-	10	-
B	10	-	10	-	-	-	10	-	10	-	-	-
C	-	-	10	-	10	-	-	-	10	-	10	-
Total	20	0	20	0	20	0	20	0	20	0	20	0
Loamy Upland ecological site												
A	-	10	-	-	-	10	-	10	-	-	-	10
B	-	10	-	10	-	-	-	10	-	10	-	-
C	-	-	-	10	-	10	-	-	-	10	-	10
Total	0	20	0	20	0	20	0	20	0	20	0	20

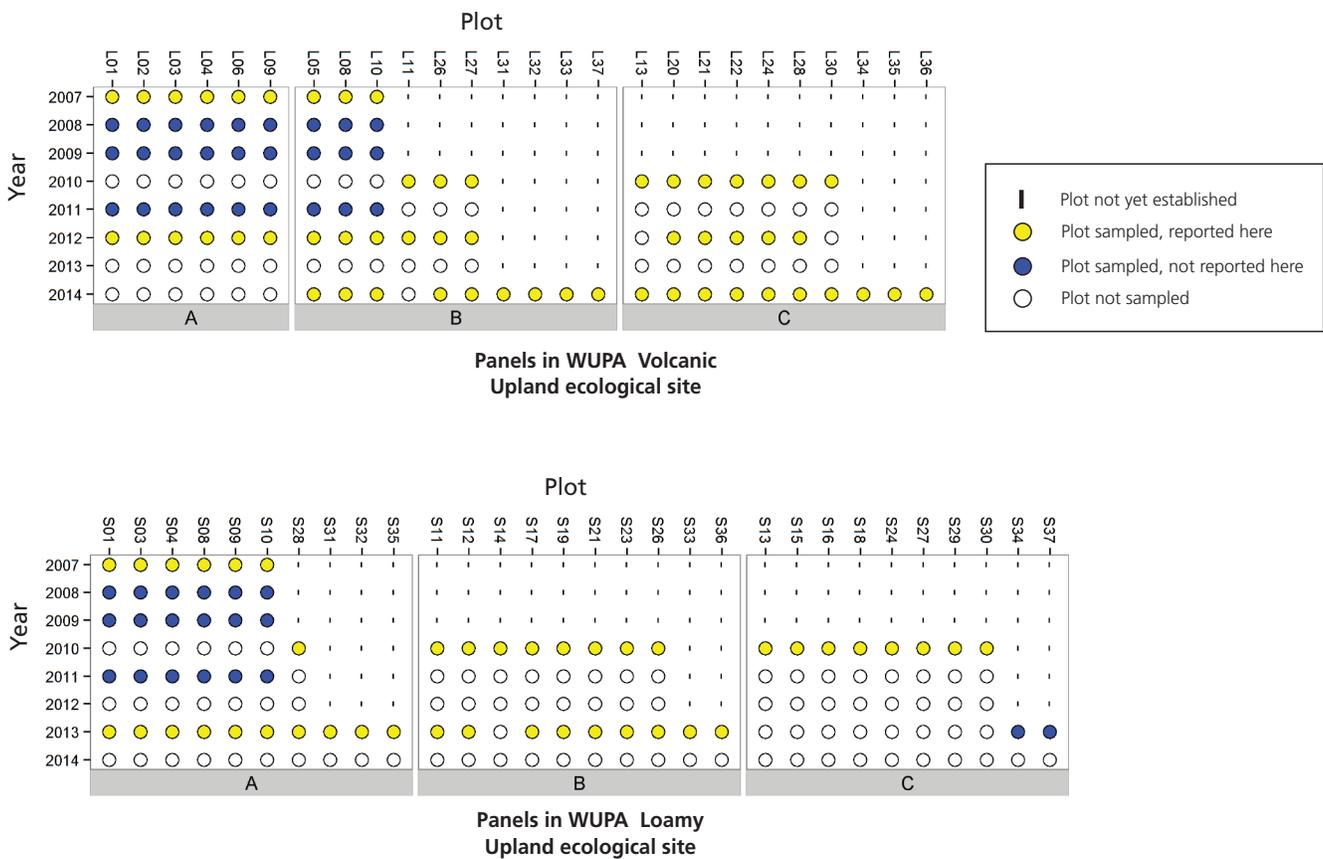


Figure 3. Sampling year and panel assignment for plots used in the panel design for integrated upland vegetation and soils monitoring at Wupatki NM, 2007-2014. First year of sampling is the year the plot was established. One plot in panel B of the Loamy Upland ecological site was missed in 2013, and one plot in panel B of the Volcanic Upland ecological site was missed in 2014; both are represented as unsampled plots in this figure.

present data from plots that have been retained through the sampling frame revision. For plots that had been sampled multiple times between 2007 and 2010, we only used data from the first time they were sampled. Due to the decommissioning of plots and the rearrangement of panels in both ecological sites, only a subset of the initial

plots are included in the data for the initial sampling period.

2.5.1 *Shrub and herbaceous species, functional groups and soil surface features*

For herbaceous and shrub vegetation, percent foliar cover was estimated for each species from the cover class midpoints, e.g., 7.5% for cover class 5%–10%. Mean percent foliar cover was calculated for each plot and year, and then the mean and standard deviation were calculated for each panel and time period. Mean cover and standard deviation of functional groups and soil surface features were calculated in a similar fashion.

For each panel and time period, we calculated species frequency for quadrats (mean percentage of 10 m² quadrats per plot in which the species occurs) and for plots (percentage of plots in which the species occurs). We summarized species foliar cover and plot frequency, and functional group foliar cover for both panels combined for 2012 and 2014 for the Volcanic Upland, and for 2013 for the Loamy Upland.

2.5.2 *Species diversity*

We calculated four diversity measures (Magurran 1988) for herbaceous and shrub species for each panel and time period— first for all species and then for native species only.

- (1) Species richness (S) is the number of species at a given spatial scale. This was calculated at both the level of the plot and at the level of the site (i.e. all plots within the panel).
- (2) The Shannon Diversity Index (H') provides a measure of species diversity that takes into account the relative abundance of each species and generally falls between 1.5 and 3.5:

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

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, and ranges between 0 and 1:

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

- (4) Beta diversity (β) is a measure of within-site heterogeneity and generally ranges between 1 and 5:

$$\beta = S_e / (S_p - 1)$$

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

We calculated plot richness, Shannon diversity, and evenness for each plot and year, and the mean and standard deviation were then calculated for the panel and time period. Site richness and beta diversity, which are not based on plot means, were calculated for each panel and time period.

3 Results

3.1 Volcanic Upland ecological site

3.1.1 Shrub and herbaceous vegetation

We examined foliar cover of functional groups, foliar cover and frequency of species, and species diversity, presenting the 2012 and 2014 data in the context of the data collected during the first year of sampling.

3.1.1.1 Functional group cover

Foliar cover of functional groups indicates broad patterns in shrub and herbaceous vegetation. Perennial grasses are dominant cover in the Volcanic Upland ecological site. In 2012, the mean total live foliar cover of all plots in panels A&B was 17.32% and the mean foliar cover of perennial grasses was 12.12% (Figure 4). Mean foliar cover of forbs was 5.43%. Shrubs and cacti/succulents were both less than 1%. There was no annual grass cover in the plots. Standard deviations were generally large across all functional groups, indicating large among-plot variability.

In 2014, the mean total live foliar cover of all plots in panels B&C was 19.17% and the mean foliar cover of perennial grass was 18.94% (Figure 4). Mean foliar covers of forbs, shrubs and cacti/succulents were all less than 1%. There was no annual grass cover in the plots. Standard deviations were generally large across all functional groups, indicating large among-plot variability.

Figure 5 presents the mean foliar cover of each functional group by panel for 2014, 2012 and the initial sampling period (2007–2010). Appendix A summarizes functional group cover data by sampling period and panel.

3.1.1.2. Species foliar cover and frequency

Examination of foliar cover and frequency of individual species allows for more thorough understanding of the structure and dynamics of the vegetation. In 2012, for both panels A&B combined, perennial grass species had the greatest mean foliar cover (Figure 6). These included *Hilaria jamesii* (James' galleta), *Bouteloua eriopoda*

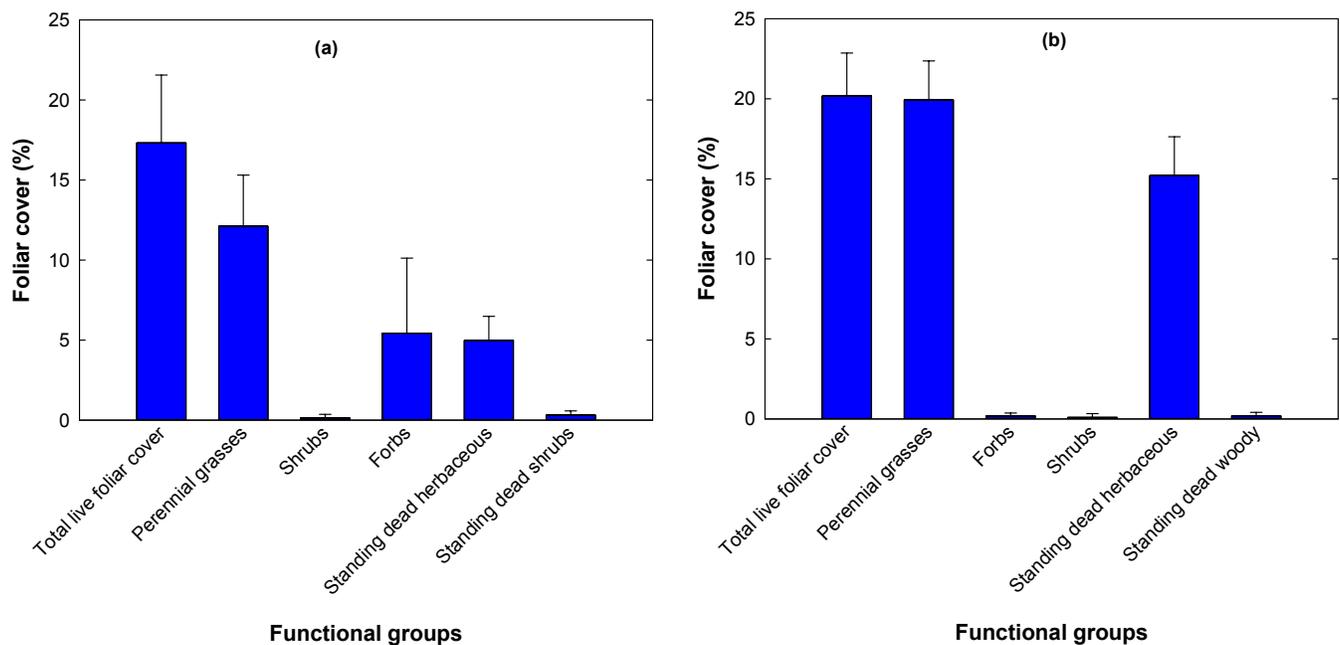


Figure 4. Mean percent foliar cover of functional groups for (a) panels A&B (n=12) in 2012, and (b) for panels B&C (n=19) in 2014 (b) in the Volcanic Upland ecological site at Wupatki NM. Error bars represent 1 standard deviation. Cacti/succulents are not included because of low cover; annual grasses did not occur in the plots.

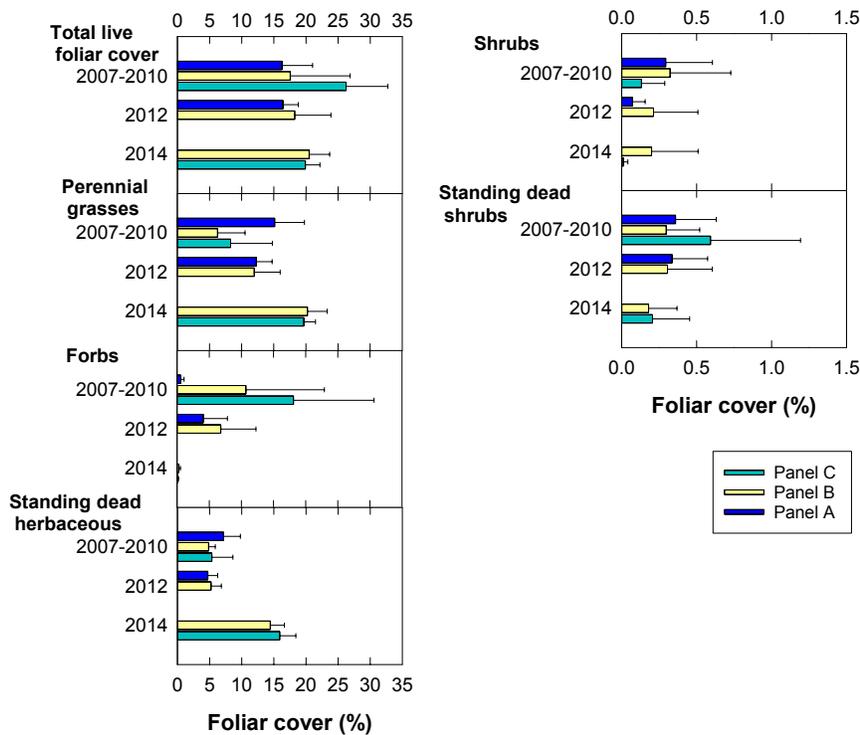


Figure 5. Mean percent foliar cover of functional groups, by panel, for 2012, 2014, and for the initial sampling year for all plots (2007–2010) in the Volcanic Upland ecological site at Wupatki NM. Error bars represent 1 standard deviation. Note the scales are different on the 2 columns. For panels A&B in 2007–2010 and 2012, n=6; for panel C in 2007–2010, n=7; for panel B in 2014, n=9; for panel C in 2014, n=10.

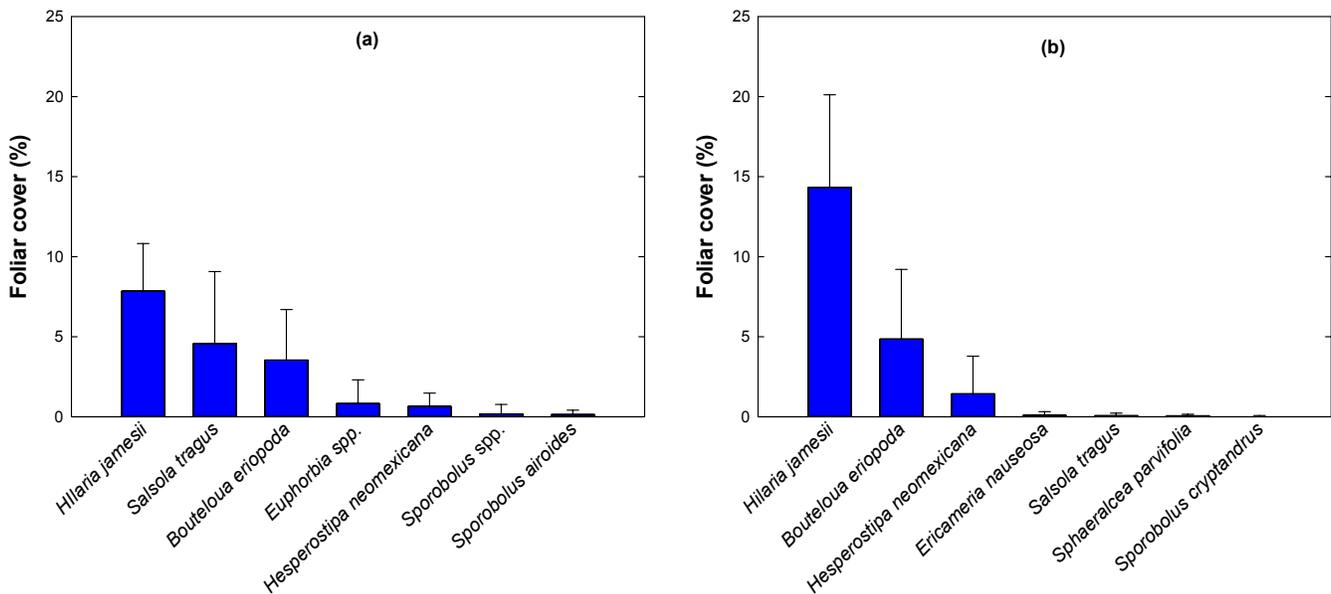


Figure 6. Mean percent foliar cover of the 7 most abundant shrub and herbaceous species for all 12 plots in panels A&B in 2012 (a) and for all 19 plots in panels B&C in 2014 (b) in the Volcanic Upland ecological site at Wupatki NM. Error bars represent 1 standard deviation.

(black grama) *Hesperostipa neomexicana* (New Mexico needlegrass), *Sporobolus* spp.(dropseed) and *Sporobolus airoides* (alkali sacaton). The most abundant forbs were the non-native *Salsola tragus* (prickly Russian thistle) and *Euphorbia* spp. (sandmat).

In 2014, for both panels B&C combined, perennial grass species again had the greatest mean foliar cover (Figure 6). These included *Hilaria jamesii*, *Bouteloua eriopoda* and *Hesperostipa neomexicana*. The most abundant forbs were *Sphaeralcea parvifolia* (globemallow) and the nonnative *Salsola tragus*. *Ericameria nauseosa* (rubber

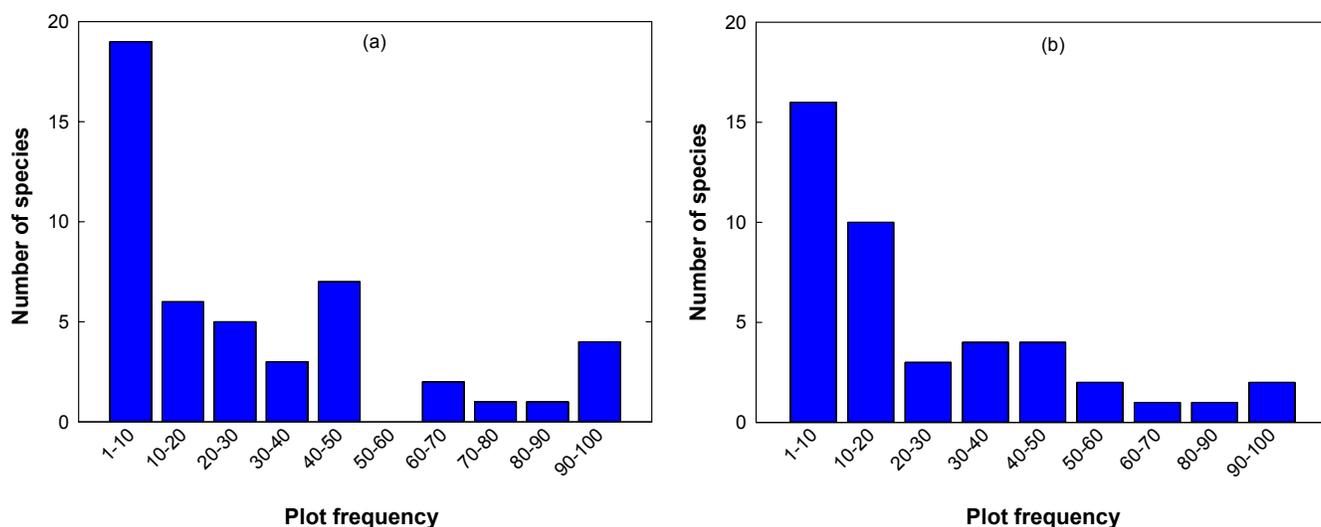


Figure 7. Number of species in each plot frequency class for (a) all 12 plots in panels A&B in 2012 and (b) for all 19 plots in panels B&C in 2014 in the Volcanic Upland ecological site at WUPA. Plot frequency classes differ between the graphs because of the different sample sizes.

rabbitbrush) was the most abundant shrub.

The number of species in each plot frequency class provides another means to understand the community composition of the vegetation. Most plant communities are dominated by a small number of species, with the majority of the species having low abundances, which translates into few species having high plot frequencies, and the majority of species having low plot frequencies. The Volcanic Upland ecological site at WUPA follows this pattern. In 2014, half of the species occurred in 10% of the plots or less (Figure 7). Only 5% (2) of the species occurred in all of the plots.

Figure 8 and Table 2 present mean foliar cover of the most abundant species for all panels in the 3 sampling periods. Figure 9 presents quadrat frequency of the most abundant species for all panels in the 3 sampling periods. Appendix B lists all species that occurred in the ecological site, their common names, and mean foliar cover and plot frequencies for each panel and sampling period.

A number of native species that did not occur in the original plots in the initial sampling frame were encountered in 2012. These included *Ipomoea costellata* (crestrub morning-glory), *Oenothera suffrutescens* (scarlet beebalm), *Psilostrophe sparsiflora* (greenstem paperflower), and *Tetradlea coulteri* (Coulter's wrinklefruit). See Appendix B for a complete list of species found in plots in the Volcanic Upland.

In 2014 a number of species were encountered in the plots for the first time. These included *Camissonia gouldii* (Diamond Valley suncup), *Chloracantha spinosa* (spiny chloracantha) and *Pemmeranthus parviflorus* (sunbright),

Four nonnative species were found in the plots (Table 2) in 2012. *Salsola tragus* occurred in all the plots and was the forb species with the greatest mean foliar cover—2.963% and 6.171% in panels A and B, respectively. The other 3 species, *Mollugo cerviana* (threadstem carpetweed), *Portulaca oleracea* (little hogweed) and *Kochia scoparia* (Mexican burning bush) were sparse, with low mean foliar covers and low quadrat frequencies.

Only two nonnative species were found in the plots in 2014. *Salsola tragus* was the forb species with the greatest mean foliar cover in 2014, although its cover was less than it was both in 2012 and in the initial sampling period. Its mean foliar cover was 0.103% and 0.041% , and its plot frequency was 88.9% and 40% in panels B and C respectively. *Mollugo cerviana* (thread-stem carpet-weed) occurred in trace amounts in panel B.

3.1.1.3 Species diversity

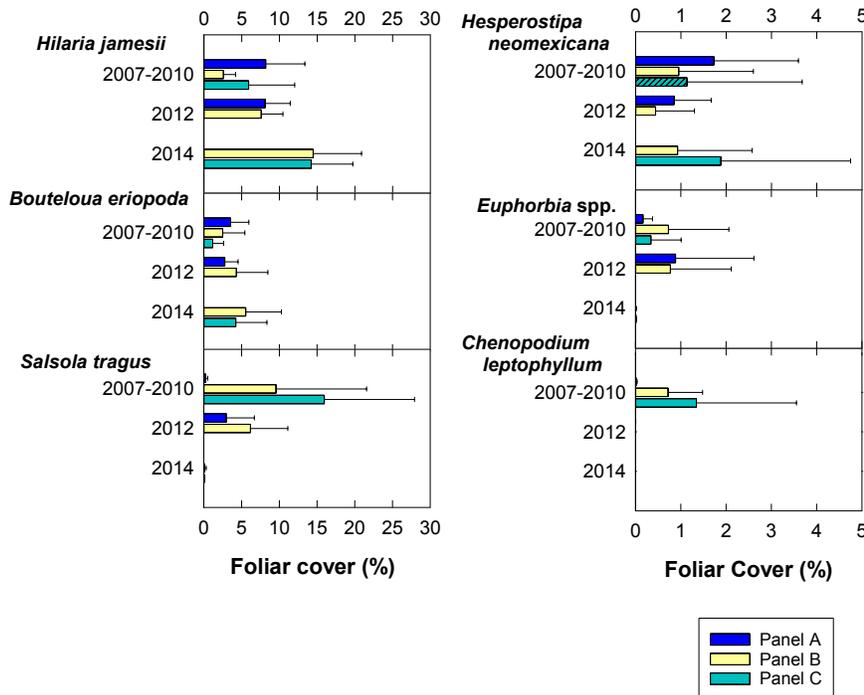


Figure 8. Mean percent foliar cover of the most abundant shrub and herbaceous species, by panel, for 2012 and 2014, and for the initial sampling year (2007–2010) in the Volcanic Upland ecological site at Wupatki NM. Includes species with a mean foliar cover > 0.75% in at least one of the panels. Note scales are different for each column. Error bars represent 1 standard deviation. For panels A&B in 2007–2010 and 2012, n=6; for panel C in 2007–2010, n=7; for panel B in 2014, n=9; for panel C in 2014, n=10.

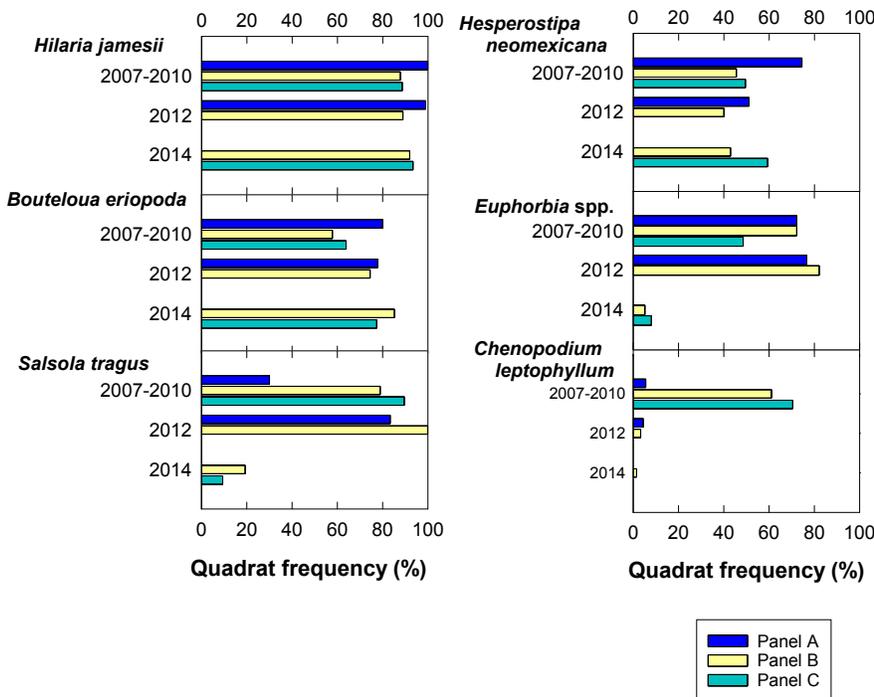


Figure 9. Mean quadrat frequency of shrub and herbaceous species with foliar cover > 0.75%, by panel, for 2012 and 2014, and for the initial sampling year (2007–2010) in the Volcanic Upland ecological site at Wupatki NM. For panels A&B in 2007–2010 and 2012, n=6; for panel C in 2007–2010, n=7; for panel B in 2014, n=9; for panel C in 2014, n=10.

The species diversity indices indicate low diversity on the scale of the plot and moderately low diversity on the scale of the site (Table 3 and Figure 10). In 2012, on the scale of the plot mean plot richness was 14.8 and 15.0 for panels A&B, respectively. Shannon diversity values (which takes the relative abundance of each species into account and generally ranges between 1.5 and 3.5) were 1.20 and 1.14 for panels A&B, respectively. Evenness values (the degree to which all species are of equal abundance, ranging between 0 and 1) were 0.45 and 0.43 for panels A&B. On the scale of the panel, 2012 richness values were 36 and 32 species. For panels A&B combined in 2012, there were a total of 45 species. Beta diversity values were 2.60 and 2.29. When we calculated the metrics using only native species, Shannon diversity, evenness and beta diversity all showed decreases.

For 2014, the species diversity indices indicate low diversity on the scale of the plot and moderately low

Table 2. Foliar cover and plot frequency of shrub and herbaceous species in the Volcanic Upland ecological site at Wupatki NM for 2012 and 2014, and for the initial sampling year for all plots (2007–2010). “Abundant species” includes only species with a mean foliar cover >0.1% in any of the panels. All nonnative species occurring in panels are included. Species are arranged in descending order based on their mean foliar cover in 2014 for both panels combined.

Abundant species	Initial sampling year between 2007 and 2010						2012				2014			
	Panel A, n=6		Panel B, n=6		Panel C, n=7		Panel A, n=6		Panel B, n=6		Panel B, n=9		Panel C, n=10	
	Mean cover (%)	Plot frequency (%)	Mean cover (%)	Plot frequency (%)	Mean cover (%)	Plot frequency (%)	Mean cover (%)	Plot frequency (%)	Mean cover (%)	Plot frequency (%)	Mean cover (%)	Plot frequency (%)	Mean cover (%)	Plot frequency (%)
<i>Hilaria jamesii</i>	8.173	100.0	2.570	100.0	5.923	100.0	8.097	100.0	7.589	100	14.469	100.0	14.216	100.0
<i>Bouteloua eriopoda</i>	3.554	100.0	2.494	100.0	1.184	100.0	2.771	100.0	4.308	100	5.547	100.0	4.230	100.0
<i>Hesperostipa neomexicana</i>	1.727	83.3	0.953	66.7	1.134	100.0	0.852	83.3	0.443	83.3	0.928	77.8	1.881	90.0
<i>Ericameria nauseosa</i>	0.355	100.0	0.356	83.3	0.136	71.4	0.06	50.0	0.204	83.3	0.179	66.7	0.010	40.0
<i>Salsola tragus</i>	0.230	66.7	9.566	100.0	15.958	100.0	2.963	100.0	6.176	100	0.103	88.9	0.041	40.0
<i>Sphaeralcea</i> spp.	0.123	83.3	0.042	83.3	0.004	57.1	0.011	50.0	0.073	83.3	<0.001	11.1	0.015	20.0
<i>Euphorbia</i> spp.	0.167	100.0	0.727	100.0	0.340	85.7	0.886	100.0	0.77	100	0.006	33.3	0.009	50.0
<i>Sporobolus airoides</i>	0.056	33.3	<0.001	16.7	0	0	0.606	50.0	0.024	16.7	0	0	0.010	10.0
<i>Chenopodium leptophyllum</i>	0.011	33.3	0.721	83.3	1.346	100.0	0.002	33.3	0.002	33.3	0.001	11.1	0	0
<i>Sporobolus</i> spp.	0.108	16.7	0	0	0	0	0	0	0	0	0	0	0	0
Nonnative species														
<i>Salsola tragus</i>	0.230	66.7	9.566	100.0	15.958	100.0	2.963	100.0	6.176	100.0	0.103	88.9	0.041	40.0
<i>Mollugo cerviana</i>	0	0	0	0	0	0	0.007	16.7	0	0	<0.001	11.1	0	0
<i>Portulaca oleracea</i>	0	0	0	0	0	0	0.002	16.7	0.005	33.3	0	0	0	0
<i>Kochia scoparia</i>	0	0	0.004	33.3	0.012	28.6	0.001	16.7	0.002	33.3	0	0	0	0

Table 3. Species diversity metrics for all species and for native species only, by panel, in the Volcanic Upland ecological site at Wupatki NM for 2012 and 2014, and for the initial sampling year for all plots (2007–2010). SD = standard deviation. Note: richness and diversity values from the initial sampling period (2007–2011) were calculated using slightly different species groupings than were used for the 2012 and 2014 sampling periods. Therefore, reported values from the initial period are not directly comparable to the later values. This discrepancy will be resolved in future reports.

	Initial sampling year between 2007 and 2010						2012				2014			
	Panel A, n=6		Panel B, n=6		Panel C, n=7		Panel A, n=6		Panel B, n=6		Panel B, n=9		Panel C, n=10	
All species	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Plot richness	11.7	1.0	13.3	2.5	11.0	2.9	14.8	3.1	15.0	3.7	12.2	3.5	9.0	3.5
Shannon diversity	1.05	0.35	1.02	0.50	0.82	0.32	1.20	0.25	1.14	0.28	0.72	0.22	0.66	0.29
Evenness	0.43	0.14	0.40	0.20	0.35	0.13	0.45	0.10	0.43	0.11	0.29	0.09	0.32	0.13
Native species														
Plot richness	11.0	0.9	12.0	2.4	9.7	2.6	13.3	2.6	13.3	3.3	11.2	3.4	8.6	3.3
Shannon diversity	0.99	0.33	1.18	0.29	0.94	0.24	1.06	0.20	0.86	0.34	0.69	0.22	0.65	0.29
Evenness	0.42	0.14	0.48	0.12	0.42	0.10	0.41	0.08	0.34	0.13	0.30	0.10	0.32	0.13
	Initial sampling year between 2007 and 2010						2012				2014			
All species	Panel A, n=6		Panel B, n=6		Panel C, n=7		Panel A, n=6		Panel B, n=6		Panel B, n=9		Panel C, n=10	
Panel richness	26		32		26		36		32		37		27	
Beta diversity	2.44		2.60		2.60		2.60		2.29		3.30		3.38	
Native species														
Panel richness	25		30		24		32		29		35		26	
Beta diversity	2.50		2.73		2.75		2.60		2.35		3.42		3.42	

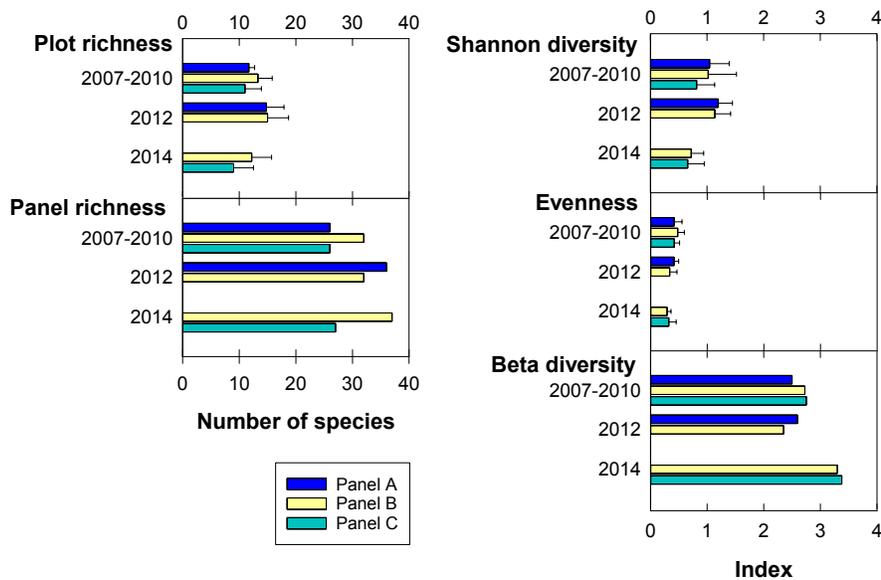


Figure 10. Diversity indices for all species, by panel, for 2012 and 2014, and for the initial sampling year for all plots (2007–2010) in the Volcanic Upland ecological site in Wupatki NM. For panels A and B in 2007–2010 and 2012, n=6; for panel C in 2007–2010, n=7; for panel B in 2014, n=9; for panel C in 2014, n=10.

diversity on the scale of the site (Table 3 and Figure 10). Mean plot richness was 12.2 and 9.0 for panels B&C, respectively. Shannon diversity values were 0.72 and 0.66 for panels B&C, respectively. Evenness values were 0.29 and 0.32. By panel, 2014 richness values were 37 and 27 species. For panels B & C combined in 2014, there were a total of 43 species. Beta diversity values were 3.30 and 3.38. For 2014, when we calculated the metrics using only native species, most metrics showed only small changes.

3.1.2 Soil surface features

We measured the amount of soil surface at risk for soil erosion using cover estimates of soil surface features in the quadrats. Fine gravel (cinders) was the dominant soil feature (Figure 11). We summarize the remaining categories here but not all are individually distinguished or displayed in Figure 11. These include bare soil and undifferentiated crust; live plant base and dead woody base; and litter and dead woody debris. Data values are available in Appendix C. In 2012 the mean cover of fine gravel was 79.9% and 72.3% for panels A&B. The mean cover of coarse gravel combined was 7.6% and 11.7%. All other features had mean cover values less than 5%. No cyanobacteria, lichen, or moss were recorded.

In 2014 the mean cover of fine gravel was 79.9% and 79.7% for panels B&C, respectively. The mean cover of cobble and stone combined was 4.7% and 6.3%. All other features had mean cover values of less than 5%. No cyanobacteria, lichen and moss were present in the panels.

3.2 Loamy Upland Ecological Site

3.2.1 Shrub and herbaceous vegetation

We examined foliar cover of functional groups, foliar cover and frequency of species, and species diversity, presenting the data from 2013 in the context of data from the initial sampling period.

3.2.1.1 Functional group cover

Examination of functional groups indicates broad patterns in shrub and herbaceous vegetation. Perennial grasses, shrubs and forbs co-dominated the Loamy Upland ecological site in 2013. The mean total live foliar cover of all plots in both panels was 14.44%, and the mean foliar cover of perennial grasses, shrubs and forbs ranged between 4.49% and 5.39% (Figure 12). Cacti/succulents and annual grasses were minor components with mean foliar cover of <0.01%. Standard deviations were moderately large across all functional groups, indicating moderately large among-plot variability.

Figure 13 presents the mean foliar cover of each functional group by panel for both 2013 and the initial sampling period (2007–2010). Appendix D summarizes functional group cover data by sampling period and panel.

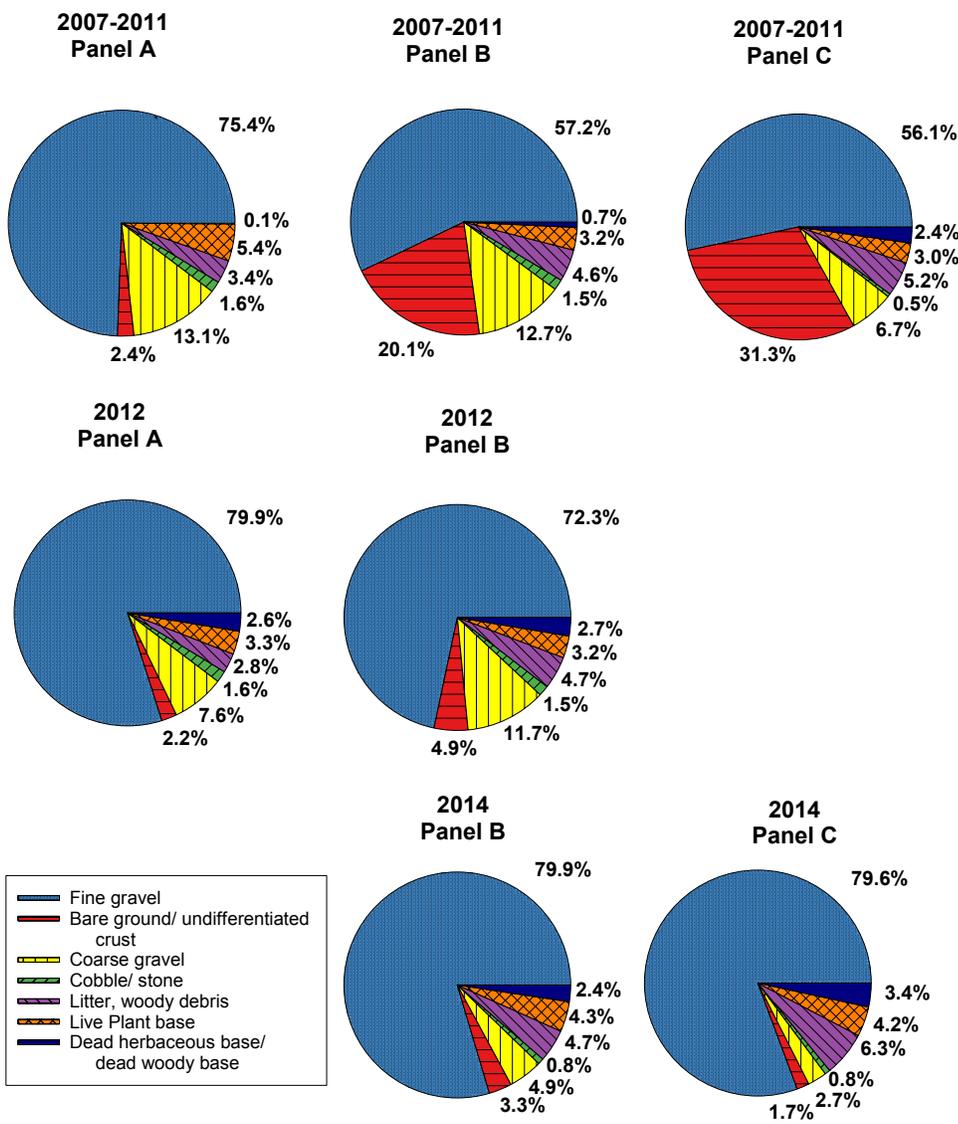


Figure 11. Mean percent cover of soil surface features by panel for 2012 and 2014, and for the initial sampling year for all plots (2007–2010) in the Volcanic Upland ecological site at Wupatki NM. Plot data are grouped by panel and time period. For panels A and B in 2007–2010 and 2012, n=6; for panel C in 2007–2010, n=7; for panel B in 2014, n=9; for panel C in 2014, n=10.

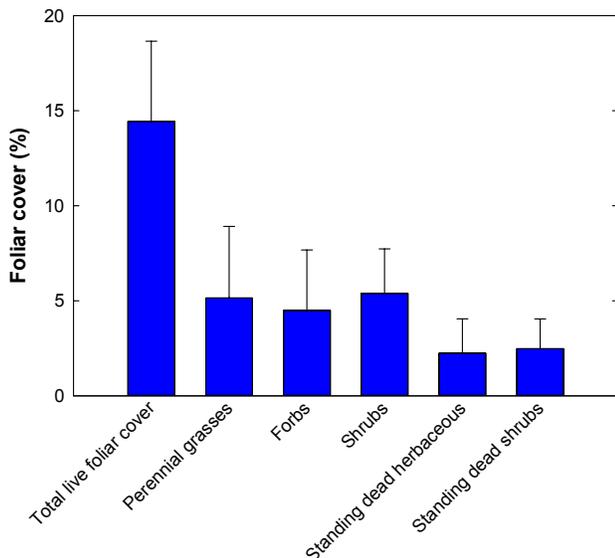


Figure 12. Mean percent foliar cover of functional groups for panels A&B combined (n=19) for 2013 in the Loamy Upland ecological site at WUPA. Cacti/succulents and annual grasses are not shown due to low foliar cover. Error bars represent 1 standard deviation.

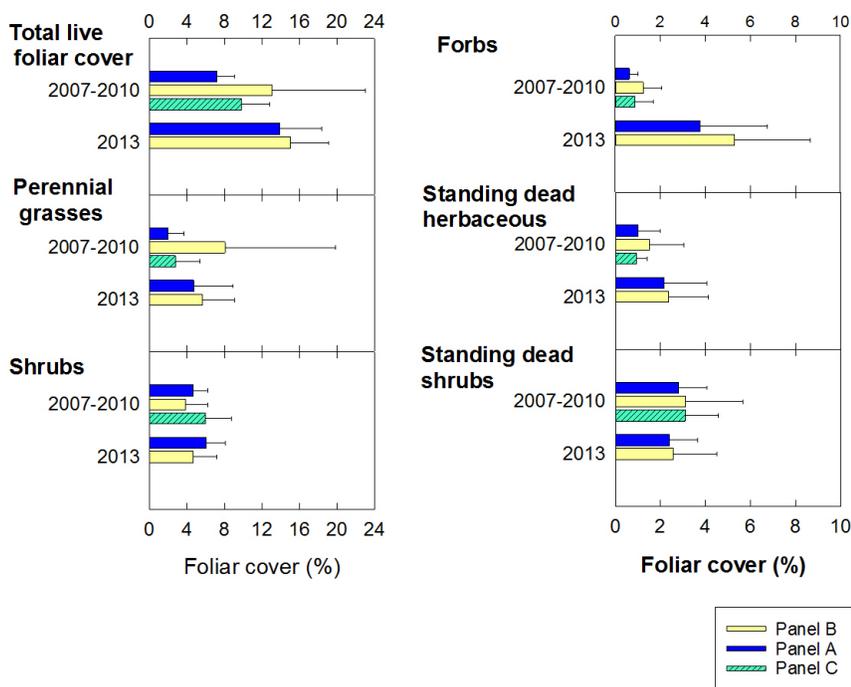


Figure 13. Mean percent foliar cover of functional groups, by panel, for 2013, and for the initial sampling year (2007–2010) in the Loamy Upland ecological site at Wupatki NM. Error bars represent 1 standard deviation. Note the scales are different on the 2 columns. For panel A in 2007–2011, $n=7$; for panel B and C in 2007–2010, $n=8$; for panel A in 2013, $n=10$; for panel B in 2013, $n=9$.

3.2.1.2 Species foliar cover and frequency

Amount of foliar cover and frequency of individual species provides a more thorough understanding of the structure and dynamics of the vegetation. In 2013, for panels A& B combined, the species with the greatest mean foliar cover were annual forbs in the *Euphorbia* genus (sandmat, formerly *Chamaesyce*), followed by the perennial grass *Hilaria jamesii* (Figure 14). Other abundant abundant perennial grasses included *Muhlenbergia porteri* (bush muhly), *Bouteloua eriopoda* and *Sporobolus airoides*. There were numerous abundant shrubs including *Ephedra torreyana* (Torrey’s jointfir), *Artemisia filifolia* (sand sage), *Fallugia paradoxa* (Apache plume), *Atriplex canescens* (fourwing saltbush), *Ericameria nauseosa* (rubber rabbitbrush) and *Gutierrezia sarothrae* (broom snakeweed). Members of the *Sphaeralcea* genus. (globemallow) were the second most abundant forbs after *Salsola tragus*.

The distribution the plot frequencies of the number of species in each plot frequency class provides another means to understand the community composition of the vegetation. Most plant communities are dominated by a small number of species, with the majority of the species having low abundances, which translates into few species having high plot frequencies, and the majority of species having low plot frequencies. This is true of the Loamy Upland ecological site at WUPA. For the 19 plots sampled in 2013, half of the species occurred in 20% of the plots or less (Figure 15). Thirteen species occurred in only 1 plot. Only one species occurred in all of the plots.

Figure 16 and Table 4 present mean foliar cover of the most abundant species for the 2 sampling periods by panel. Figure 17 and Table 4 present quadrat frequency of the most abundant species for the 2 sampling periods by panel. Appendix E lists all species that occurred in the ecological site, along with their common names, and mean foliar cover and plot frequencies for each panel and sampling period.

A number of native species were encountered for the first time in the restructured Loamy Upland sampling frame plots. These included *Aristida havardii* (Havard’s threeawn), *Bouteloua barbata* (sixweeks grama), *Descurainia pinnata* (western tansyaster), *Eriogonum deflexum* (flatcrown buckwheat), *Munroa squarrosa* (false buffalograss), *Sanvitalia abertii* (Abert’s creeping zinnia) and *Senna baubinioides* (twinleaf senna).

There were 3 nonnative species found in the plots. *Solanum elaeagnifolium* (silverleaf nightshade), *Salsola tragus* and *Mollugo cerviana* (Table 4). All were moderately sparse, with low mean foliar covers and low quadrat frequencies.

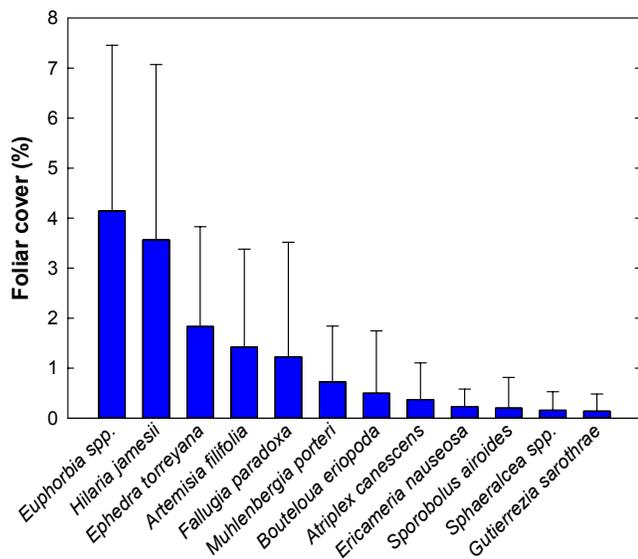


Figure 14. Mean percent foliar cover of the 12 most abundant shrub and herbaceous species for all 19 plots in panels A and B in the Loamy Upland ecological site at Wupatki NM in 2013. Error bars represent 1 standard deviation.

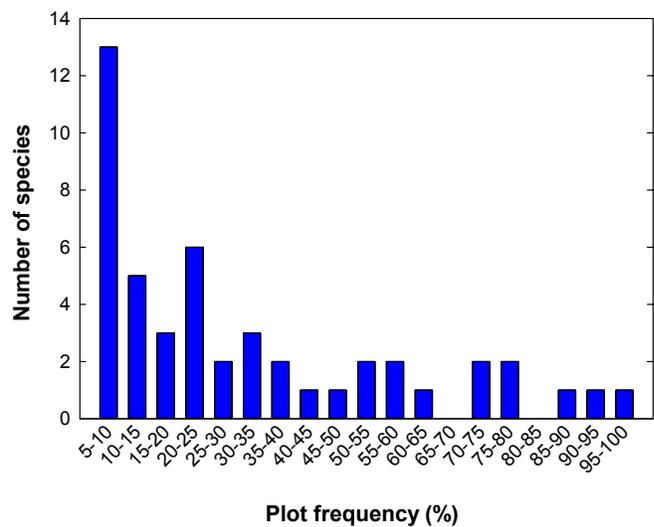


Figure 15. Number of species in each plot frequency class for all 19 plots in panels A&B in the Loamy Upland ecological site at Wupatki NM in 2013.

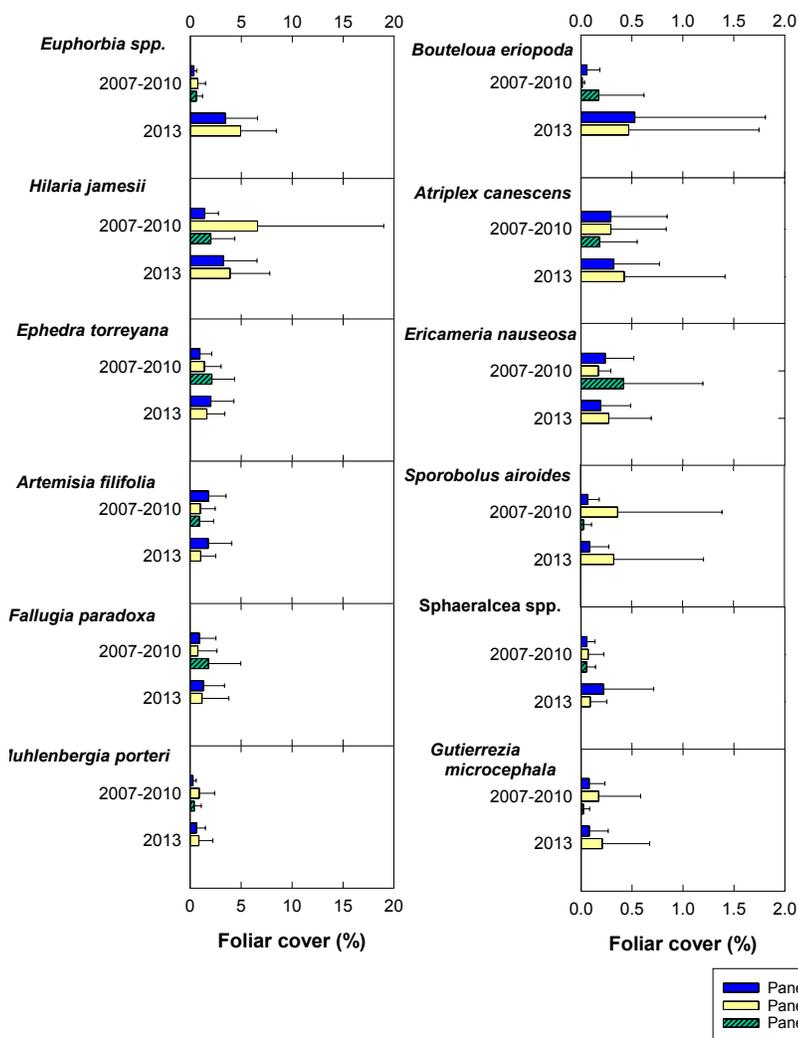


Figure 16. Mean percent foliar cover of the most abundant shrub and herbaceous species, by panel, for 2013, and for the initial sampling year (2007–2010) in the Loamy Upland ecological site at Wupatki NM. Includes species with a foliar cover >0.13% in at least one panel. Note that scales are different for each column. Error bars represent 1 standard deviation. For panel A in 2007–2011, n=7; for panel B and C in 2007–2010, n = 8; for panel A in 2013, n = 10; for panel B in 2013, n=9.

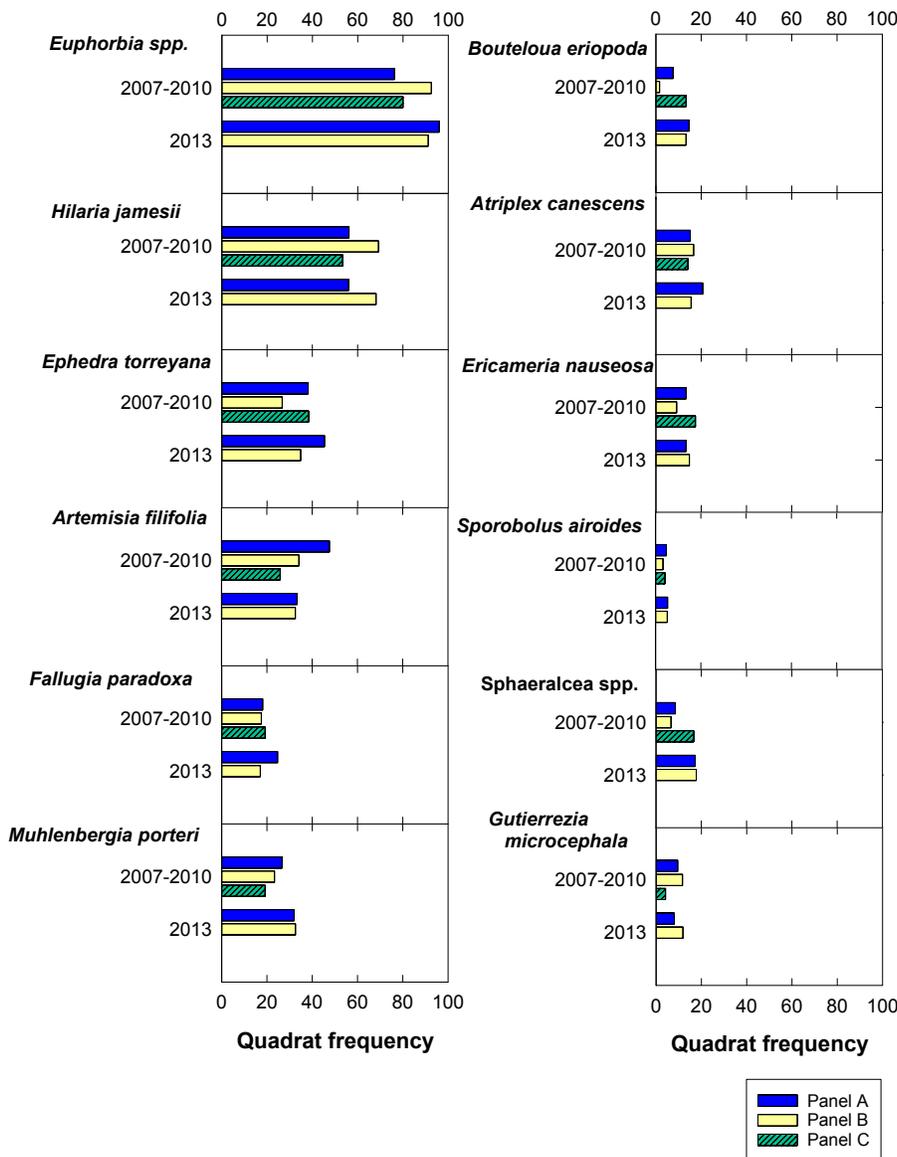


Figure 17. Mean quadrat frequency of shrub and herbaceous species with foliar cover >0.13%, by panel, for 2013, and for the initial sampling year (2007–2010) in the Loamy Upland ecological site at Wupatki NM. For panel A in 2007–2011, n=7; for panel B and C in 2007–2010, n = 8; for panel A in 2013, n = 10; for panel B in 2013, n=9.

3.2.1.3 Species diversity

For 2013, the species diversity indices indicate low diversity on the scale of the plot, and moderately low diversity on the scale of the site (Table 5 and Figure 18). Mean plot richness was 15.0 and 14.6 for panels A&B, respectively. Shannon diversity values were 1.52 and 1.44. Evenness values were 0.56 and 0.54. On the scale of the panel, richness values were 40 species for both panels. For panels A&B combined in 2013, there were a total of 49 species. When we calculated the metrics using only native species, they showed small changes.

3.2.2 Soil surface features.

We measured the amount of soil surface at risk for soil erosion using cover estimates of soil surface features in quadrats. Fine gravel (cinders) was the dominant soil feature with mean covers of 76.4% and 78.0% for panels A&B, respectively in 2013 (Figure 19). We summarize the remaining categories here but not all are individually distinguished or displayed in Figure 19. Data values are available in Appendix F. In 2013, the mean cover of litter was 8.0% for panel A and 6.8% for panel B. The mean covers of bare ground/undifferentiated crust were 6.6% in panel A and 4.7% in panel B. All other features had cover values less than 3%. No differentiated biological crusts (cyanobacteria, lichen and moss) were recorded. Note that for plots sampled in 2010, fine-textured cinders were interpreted as bare soil. Bare soil values for plots in panels B&C of the original sampling are much higher than other panels due to this error.

Table 4. Foliar cover and plot frequency of shrub and herbaceous species in the Loamy Upland ecological site at Wupatki NM for 2013, and for the initial sampling year for all plots (2007–2010). “Abundant species” includes only species with a mean foliar cover >0.1% in any of the panels. All nonnative species occurring in panels are included. Species are arranged in descending order based on their mean foliar cover in 2013 for both panels combined.

Abundant species	Initial sampling year between 2007 and 2010						2013			
	Panel A, n=7		Panel B, n=8		Panel C, n=8		Panel A, n=10		Panel B, n=9	
	Mean cover (%)	Plot frequency (%)	Mean cover (%)	Plot frequency (%)	Mean cover (%)	Plot frequency (%)	Mean cover (%)	Plot frequency (%)	Mean cover (%)	Plot frequency (%)
<i>Euphorbia spp.</i>	0.352	100.0	0.729	100.0	0.579	87.5	3.442	100.0	4.928	100.0
<i>Hilaria jamesii</i>	1.428	85.7	6.598	100.0	2.025	75.0	3.262	80.0	3.903	100.0
<i>Ephedra torreyana</i>	0.948	100.0	1.381	87.5	2.123	87.5	2.021	100.0	1.621	88.9
<i>Artemisia filifolia</i>	1.821	57.1	1.007	50.0	0.925	37.5	1.773	40.0	1.036	55.6
<i>Fallugia paradoxa</i>	0.904	42.9	0.758	62.5	1.790	37.5	1.291	60.0	1.155	66.7
<i>Muhlenbergia porteri</i>	0.281	85.7	0.885	50.0	0.390	50.0	0.611	80.0	0.852	66.7
<i>Bouteloua eriopoda</i>	0.059	28.6	0.013	25.0	0.175	37.5	0.529	30.0	0.469	33.3
<i>Atriplex canescens</i>	0.294	71.4	0.294	37.5	0.184	25.0	0.324	70.0	0.425	33.3
<i>Ericameria nauseosa</i>	0.238	85.7	0.172	75.0	0.420	37.5	0.195	80.0	0.273	77.8
<i>Sporobolus airoides</i>	0.068	28.6	0.363	12.5	0.028	12.5	0.090	40.0	0.325	22.2
<i>Sphaeralcea spp.</i>	0.058	42.9	0.070	37.5	0.055	37.5	0.221	50.0	0.091	55.6
<i>Gutierrezia microcephala</i>	0.079	28.6	0.172	25.0	0.022	12.5	0.081	40.0	0.207	33.3
<i>Ephedra viridis</i>	0.010	28.6	0.069	12.5	0.025	25.0	0.177	50.0	0.040	22.2
<i>Salsola tragus</i>	0.072	14.3	0.158	62.5	0.044	25.0	0.003	30.0	0.003	22.2
Nonnative species										
<i>Solanum elaeagnifolium</i>	0.059	14.3	0.071	25.0	0.003	12.5	0.051	20.0	0.056	11.1
<i>Salsola tragus</i>	0.072	14.3	0.158	62.5	0.044	25.0	0.003	30.0	0.003	22.2
<i>Mollugo cerviana</i>	0.033	14.3	0	0	0	0	0.001	20.0	0.001	11.1

Table 5. Species diversity metrics for all species and for native species only, by panel, in the Loamy Upland ecological site at Wupatki NM for 2013, and for the initial sampling year for all plots (2007–2010). SD = standard deviation. Note: richness and diversity values from the initial sampling period (2007–2011) were calculated using slightly different species groupings than were used for the 2012 and 2014 sampling periods. Therefore reported values from the initial period are not directly comparable to the later values. This discrepancy will be resolved in future reports.

	Initial sampling year between 2007 and 2010						2013			
	Panel A, n=7		Panel B, n=8		Panel C, n=8		Panel A, n=10		Panel B, n=9	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All species										
Plot richness	12.6	2.1	14.3	3.8	10.9	4.0	15.0	3.0	14.6	4.3
Shannon diversity	1.52	0.26	1.48	0.73	1.29	0.60	1.52	0.33	1.44	0.40
Evenness	0.60	0.08	0.55	0.24	0.53	0.20	0.56	0.11	0.54	0.14
Native species										
Plot richness	12.1	2.0	13.4	3.1	10.5	3.6	14.3	2.9	14.1	3.9
Shannon diversity	1.48	0.19	1.44	0.71	1.27	0.58	1.51	0.34	1.42	0.39
Evenness	0.60	0.07	0.54	0.24	0.53	0.20	0.57	0.11	0.54	0.13

	Initial sampling year between 2007 and 2010			2013	
	Panel A, n=7	Panel B, n=8	Panel C, n=8	Panel A, n=10	Panel B, n=9
All species					
Panel richness	28	39	35	40	40
Beta diversity	2.42	2.94	3.54	2.86	2.95
Native species					
Panel richness	25	37	33	37	37
Beta diversity	2.24	2.99	3.47	2.78	2.82

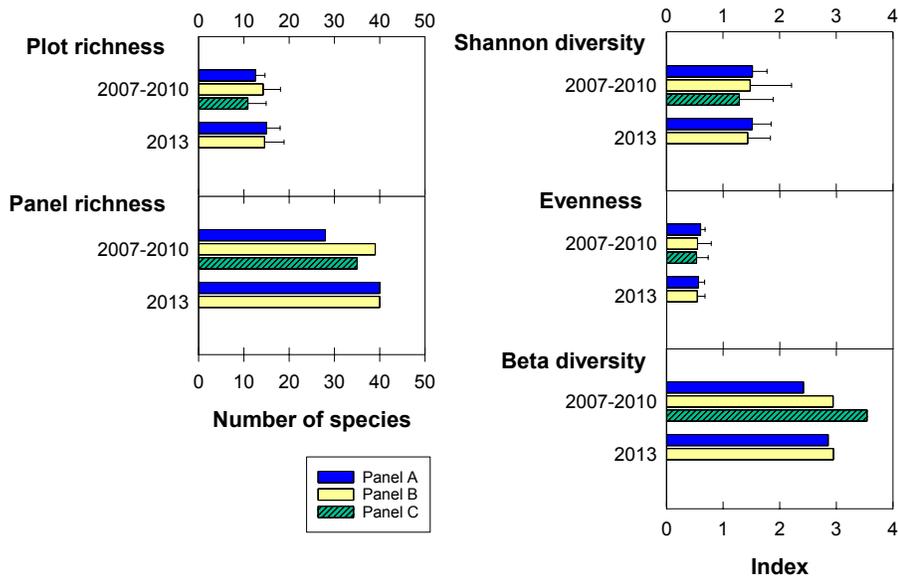


Figure 18. Diversity indices, by panel, for 2013, and for the initial sampling year (2007–2010) in the Loamy Upland ecological site in Wupatki NM. For panel A in 2007–2011, n=7; for panel B and C in 2007–2010, n = 8.; for panel A in 2013, n = 10; for panel B in 2013, n=9. Note: richness and diversity values from the initial sampling period (2007–2011) were calculated using slightly different species groupings than were used for the 2012 and 2014 sampling periods. Therefore reported values from the initial period are not directly comparable to the later values. This discrepancy will be resolved in future reports.

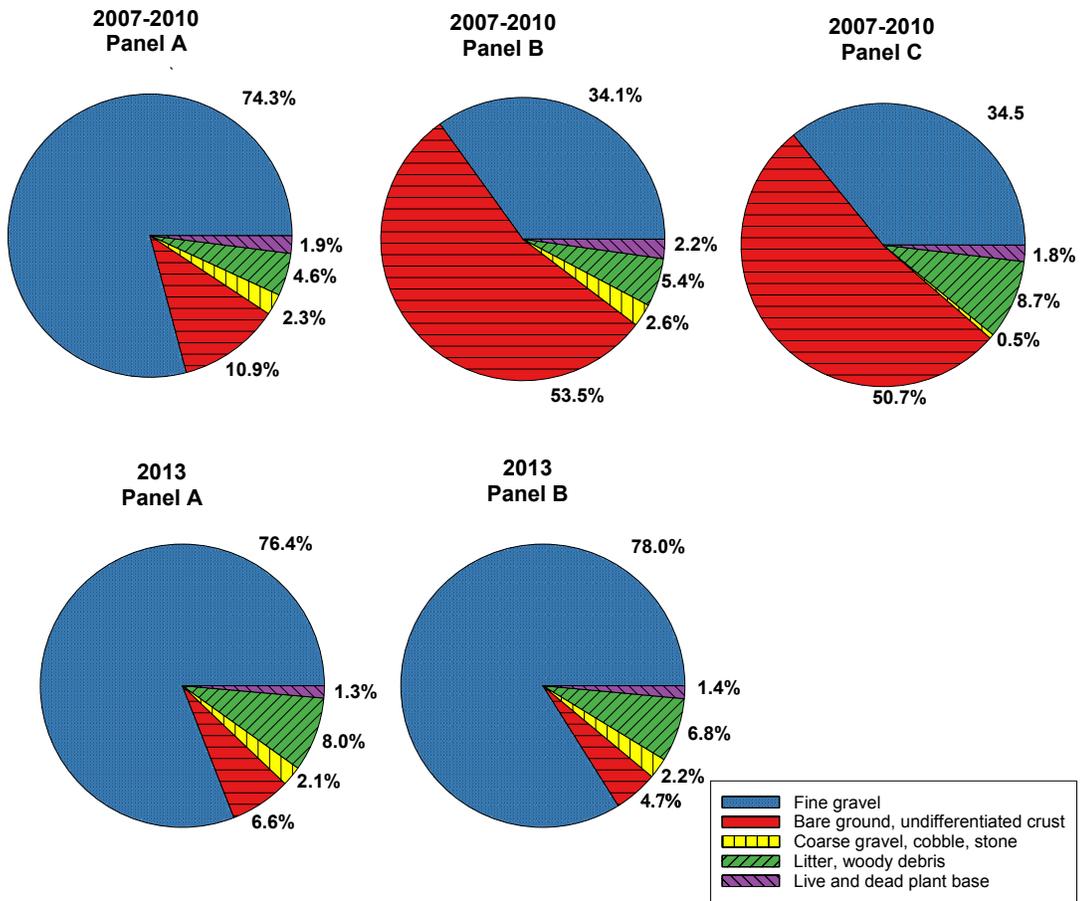


Figure 19. Mean percent cover of soil surface features, by panel, for 2013, and for the initial sampling year (2007–2010) in the Loamy Upland ecological site at Wupatki NM. The soil surface features do not add up to 100% because the calculations were made from cover class midpoints. For panel A in 2007–2011, n=7; for panel B and C in 2007–2010, n = 8; for panel A in 2013, n = 10; for panel B in 2013, n=9.

4 Discussion

The data summarized in this report represent the first panel-based sampling of vegetation and soils in the Volcanic Upland and Loamy Upland ecological sites at WUPA. The shrub and herbaceous data demonstrate that the Volcanic Upland ecological site is a grassland dominated by perennial grasses and annual forbs, and the Loamy Upland ecological site is a shrubland codominated by shrubs, perennial grasses and forbs. Four nonnative species occurred in the Volcanic Upland site: *Salsola tragus* was the forb with the highest mean foliar cover. The remaining three were sparse. Three nonnative species occurred in the Loamy Upland site, including *Salsola tragus*, all of which had low mean foliar cover and frequencies. Species diversity was low at the plot scale, and moderately low at the landscape scale. Soil erosion is not considered a threat to these ecosystems, given the layer of volcanic cinders on the soil surface.

While we present data across time periods, one must be careful in making comparisons and interpreting differences in just a few data points as signs of change. This is especially true for WUPA where the sampling frames were revised to conform to the new ecological site designations. Our resampling of 10 plots at these 2 sites between 2008 and 2009 (data not reported here) revealed moderate variation in species foliar cover and frequency from year to year that appeared to be at least partially the result of variation in precipitation over those years (DeCoster and Swan 2011). We found that herbaceous species—particularly annual grasses and forbs, but also perennial forbs—had lower foliar cover and frequencies in dry years compared to wet years. Annual variation in herbaceous species abundance suggests that data from multiple points in time are needed in order to identify meaningful vegetation trends. High variation in the data is also expected due to the reduced small sample sizes of 6 or 7 plots per panel.

According to our panel design, we will visit each ecological site at WUPA every other year, sampling 2 of the panels on each visit. By 2016 we will have the full cohort of 10 plots established in each panel, and will move forward following the sampling frame revision. After several years of collecting data using our panel design, variation among plots within a year will represent spatial variation, and the variation within a panel across sampling periods will represent temporal variation. As we accumulate more data we will be able to detect and eventually publish trends in the condition of vegetation and soils for the Volcanic Upland ecological site and the Loamy Upland site at WUPA.

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Appendix A: Foliar cover of functional groups in the Volcanic Upland ecological site at Wupatki National Monument, 2007–2014

Table A-1. Foliar cover of functional groups by panel in the Volcanic Upland ecological site at Wupatki NM for 2012 and 2014, and for the initial sampling year for all plots (2007–2010). The means for the live functional groups do not add up to the total live foliar cover because the calculations were made from cover class midpoints, components may overlap.

Foliar cover	Initial sampling year between 2007 and 2010						2012				2014			
	Panel A, n=6		Panel B, n=6		Panel C, n=7		Panel A, n=6		Panel B, n=6		Panel B, n=9		Panel C, n=10	
	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Total live foliar cover	16.26	4.76	17.54	9.34	26.24	6.50	16.40	2.40	18.25	5.63	20.49	3.20	19.90	2.26
Perennial grasses	15.13	4.65	6.25	4.28	8.29	6.49	12.28	2.47	11.96	4.03	20.23	3.08	19.67	1.81
Annual grasses	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forbs	0.56	0.53	10.70	12.21	18.09	12.55	4.06	3.76	6.79	5.48	0.25	0.26	0.12	0.10
Shrubs	0.29	0.31	0.32	0.40	0.13	0.16	0.07	0.09	0.21	0.30	0.20	0.31	0.01	0.03
Cacti/succulents	0.01	0.03	<0.01	<0.01	0.001	0.002	0.01	0.02	0.02	0.04	0.01	0.02	<0.01	0.01
Standing dead herbaceous	7.18	2.60	4.84	1.04	5.34	3.28	4.73	1.52	5.22	1.60	14.44	2.19	15.91	2.51
Standing dead shrubs	0.36	0.27	0.30	0.22	0.59	0.60	0.34	0.24	0.31	0.30	0.18	0.19	0.21	0.25

Appendix B: Plant species list for the Volcanic Upland ecological site at Wupatki National Monument, 2007-2014

Table B-1. Plant species list with mean foliar cover and plot frequency for each panel in the Volcanic Upland ecological site at Wupatki NM for 2012 and 2014, and for the initial sampling year for all plots (2007–2010).

Species	Common name	Initial sampling year between 2007 and 2010						2012				2014			
		Panel A, n=6		Panel B, n=6		Panel C, n=7		Panel A, n=6		Panel B, n=6		Panel B, n=9		Panel C, n=10	
		Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Achnatherum hymenoides</i>	Indian ricegrass	0	0	0.001	16.7	0	0	0	0	0.001	16.7	0.005	22.2	0	0
<i>Amaranthus</i> spp.	pigweed	0	0	0.006	33.3	0	0	0.003	33.3	0.056	66.7	0.004	11.1	0	0
<i>Aristida adscensionis</i>	sixweeks threeawn	0	0	0	0	0	0	0	0	0	0	<0.001	11.1	0	0
<i>Aristida havardii</i>	Havard's threeawn	0	0	0	0	0	0	0	0	0	0	0.027	22.2	0.003	20.0
<i>Aristida purpurea</i>	purple threeawn	0	0	0	0	0	0	0	0	0	0	0.031	55.6	0.004	20.0
<i>Aristida</i> spp.	threeawn	0.007	33.3	0.053	16.7	0	0	0.007	33.3	0.014	50.0	0	0	0	0
<i>Astragalus lentiginosus</i>	freckled milkvetch	0	0	0	0	0	0	0	0	0	0	0.006	44.4	0.004	50.0
<i>Astragalus</i> spp.	milkvetch	0	0	0.002	16.7	0.002	42.9	0.003	66.7	0.001	33.3	0.026	11.1	0	0
<i>Bouteloua curtipendula</i>	sideoats grama	0.039	16.7	0	0	0	0	0.008	16.7	0	0	0	0	0	0
<i>Bouteloua eriopoda</i>	black grama	3.554	100.0	2.494	100.0	1.184	100.0	2.771	100.0	4.308	100	5.547	100.0	4.230	100.0
<i>Bouteloua gracilis</i>	blue grama	0	0	0	0	0	0	0.009	33.3	0	0	<0.001	11.1	0.010	10.0
<i>Camissonia gouldii</i>	Diamond Valley suncup	0	0	0	0	0	0	0	0	0	0	0.002	11.1	0	0
<i>Chaetopappa ericoides</i>	rose heath	0.006	83.3	0.016	66.7	<0.001	14.3	0.007	66.7	0.009	83.3	0.002	55.6	0.005	20.0
<i>Chamaesaracha coronopus</i>	greenleaf five eyes	0	0	0.003	33.3	0.001	28.6	0	0	0.012	33.3	0	0	<0.001	10.0

a Nonnative species

Table B-1. (continued) Plant species list with mean foliar cover and plot frequency for each panel in the Volcanic Upland ecological site at Wupatki NM for 2012 and 2014, and for the initial sampling year for all plots (2007–2010).

Species	Common name	Initial sampling year between 2007 and 2010						2012				2014			
		Panel A, n=6		Panel B, n=6		Panel C, n=7		Panel A, n=6		Panel B, n=6		Panel B, n=9		Panel C, n=10	
		Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Chenopodium</i> spp.	goosefoot	0	0	0.001	16.7	0	0	0	0	0	0	0	0	0	0
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	0.011	33.3	0.721	83.3	1.346	100	0.002	33.3	0.002	33.3	0.001	11.1	0	0
<i>Chloracantha spinosa</i>	spiny chloracantha	0	0	0	0	0	0	0	0	0	0	0.006	11.1	0	0
<i>Chrysothamnus depressus</i>	longflower rabbitbrush	0	0	0.008	16.7	0	0	0	0	0	0	0	0	0	0
<i>Cryptantha cinerea</i>	James' cryptantha	0	0	0	0	0	0	0.001	16.7	0	0	0	0	0	0
<i>Cryptantha</i> spp.	cryptantha	0	0	0	0	0	0	0	0	0	0	<0.001	11.1	0	0
<i>Cylindropuntia whipplei</i>	Whipple's cholla	0.003	16.7	0.001	16.7	0.007	14.3	0.003	16.7	0.017	33.3	0.011	22.2	0.002	10.0
<i>Dieteria canescens</i>	hoary tansyaster	0	0	0.001	16.7	0.001	14.3	0.007	16.7	0.001	16.7	<0.001	11.1	0	0
<i>Elymus elymoides</i>	squirreltail	0	0	0	0	0	0	0.001	16.7	0.004	33.3	0.006	22.2	0	0
<i>Ericameria nauseosa</i>	rubber rabbitbrush	0.355	100	0.356	83.3	0.136	71.4	0.06	50	0.204	83.3	0.179	66.7	0.010	40.0
<i>Escobaria vivipara</i>	spiny star	0	0	0	0	<0.001	14.3	0	0	0	0	0	0	0	0
<i>Euphorbia exstipulata</i>	squareseed spurge	0.001	16.7	0.012	50	0.001	14.3	0.002	16.7	0.067	50	0	0	0	0
<i>Euphorbia fendleri</i>	Fendler's sandmat	0.002	16.7	0	0	<0.001	14.3	0	0	0	0	<0.001	11.1	0.001	10.0
<i>Euphorbia</i> spp.	annual sandmat	0.167	100	0.727	100	0.34	85.7	0.886	100.0	0.77	100.0	0.006	33.3	0.009	50.0
<i>Evolvulus nuttallianus</i>	shaggy dwarf morning-glory	0.013	50	0.005	33.3	0.003	42.9	0.02	66.7	0.004	33.3	0.003	11.1	0.006	50.0
<i>Glandularia gooddingii</i>	southwestern mock vervain	0.012	16.7	0	0	0	0	0.001	16.7	0	0	0.003	33.3	0.003	40.0
<i>Gutierrezia microcephala</i>	threadleaf snakeweed	0	0	0.004	33.3	0	0	0	0	0.001	16.7	0.002	11.1	0	0
<i>Hesperostipa neomexicana</i>	New Mexico needlegrass	1.727	83.3	0.953	66.7	1.134	100.0	0.852	83.3	0.443	83.3	0.928	77.8	1.881	90.0
<i>Hilaria jamesii</i>	James' galleta	8.173	100.0	2.57	100	5.923	100.0	8.097	100.0	7.589	100.0	14.469	100.0	14.216	100.0

a Nonnative species

Table B-1. (continued) Plant species list with mean foliar cover and plot frequency for each panel in the Volcanic Upland ecological site at Wupatki NM for 2012 and 2014, and for the initial sampling year for all plots (2007–2010).

Species	Common name	Initial sampling year between 2007 and 2010						2012				2014			
		Panel A, n=6		Panel B, n=6		Panel C, n=7		Panel A, n=6		Panel B, n=6		Panel B, n=9		Panel C, n=10	
		Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Hoffmannseggia drepanocarpa</i>	sicklepod holdback	0.003	16.7	0.002	16.7	<0.001	14.3	0	0	0.005	16.7	0	0	<0.001	10.0
<i>Ipomoea costellata</i>	crestrub morning-glory	0	0	0	0	0	0	0.01	16.7	0	0	0	0	0	0
<i>Kallstroemia californica</i>	California caltrop	0	0	0.001	16.7	0	0	0	0	0.004	16.7	0	0	0	0
<i>Kochia scoparia</i> ^a	Mexican burningbush	0	0	0.004	33.3	0.012	28.6	0.001	16.7	0.002	33.3	0	0	0	0
<i>Krascheninnikovia lanata</i>	winterfat	0.008	16.7	0	0	0	0	0.003	16.7	0	0	0	0	0	0
<i>Lycium andersonii</i>	water jacket	0	0	0	0	0	0	0.008	16.7	0	0	0	0	0	0
<i>Mentzelia albicaulis</i>	whitestem blazingstar	0	0	0	0	<0.001	14.3	0	0	0	0	0	0	0	0
<i>Mentzelia multiflora</i>	Adonis blazingstar	0	0	0.002	16.7	0.01	42.9	0	0	0	0	0	0	0	0
<i>Mollugo cerviana</i>	threadstem carpetweed	0	0	0	0	0	0	0.007	16.7	0	0	<0.001	11.1	0	0
<i>Oenothera suffrutescens</i>	scarlet beebalm	0	0	0	0	0	0	0	0	0.004	33.3	0.007	44.4	0	0
<i>Opuntia spp.</i>	prickly pear	0.008	16.7	0	0	<0.001	14.3	0.011	50.0	0	0	0	0	0.002	20.0
<i>Phemeranthus parviflorus</i>	sunbright	0	0	0	0	0	0	0	0	0	0	<0.001	11.1	0	0
<i>Polanisia dodecandra</i>	redwhisker clammyweed	0	0	0.001	16.7	0	0	0	0	0.007	16.7	0	0	0	0
<i>Pomaria jamesii</i>	James' holdback	0.004	33.3	0.001	16.7	0.006	14.3	0.01	33.3	0	0	0	0	0.004	20.0
<i>Portulaca oleracea</i> ^a	little hogweed	0	0	0	0	0	0	0.002	16.7	0.005	33.3	0	0	0	0
<i>Portulaca pilosa</i>	kiss me quick	0	0	0	0	0	0	0.001	16.7	0	0	0	0	0	0
<i>Psilostrophe sparsiflora</i>	greenstem paperflower	0	0	0	0	0	0	0.001	16.7	0	0	0	0	0	0

^a Nonnative species

Table B-1. (continued) Plant species list with mean foliar cover and plot frequency for each panel in the Volcanic Upland ecological site at Wupatki NM for 2012 and 2014, and for the initial sampling year for all plots (2007–2010).

Species	Common name	Initial sampling year between 2007 and 2010						2012				2014			
		Panel A, n=6		Panel B, n=6		Panel C, n=7		Panel A, n=6		Panel B, n=6		Panel B, n=9		Panel C, n=10	
		Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Salsola tragus</i> ^a	prickly Russian thistle	0.23	66.7	9.566	100.0	15.958	100.0	2.963	100.0	6.176	100.0	0.103	88.9	0.041	40.0
<i>Senecio flaccidus</i>	threadleaf ragwort	0.012	33.3	0.007	33.3	0	0	0	0	0	0	0	0	0	0
<i>Sphaeralcea hastulata</i>	spear globemallow	0	0	0	0	0	0	0	0	0	0	0.016	33.3	0	0
<i>Sphaeralcea parvifolia</i>	small-leaf globemallow	0	0	0	0	0	0	0	0	0	0	0.075	66.7	0.045	50.0
<i>Sphaeralcea</i> spp.	globemallow	0.123	83.3	0.042	83.3	0.004	57.1	0.123	83.3	0.111	100	<0.001	11.1	0.015	20.0
<i>Sporobolus airoides</i>	alkali sacaton	0.056	33.3	<0.001	16.7	0	0	0.261	50	0.024	16.7	0	0	0.010	10.0
<i>Sporobolus contractus</i>	spike dropseed	0	0	0	0	0	0	0	0	0	0	0.002	11.1	0.005	10.0
<i>Sporobolus cryptandrus</i>	sand dropseed	0.001	16.7	0	0	0.009	14.3	0	0	0.001	16.7	0.022	33.3	0.017	10.0
<i>Sporobolus</i> spp.	dropseed	0.108	16.7	0	0	0	0	0.344	16.7	0	0	0	0	0	0
<i>Stephanomeria pauciflora</i>	brownplume wirelettuce	0	0	0.001	16.7	0.002	28.6	0.001	33.3	0.005	66.7	0.006	55.6	0.002	40.0
<i>Stephanomeria</i> spp.	wirelettuce	0.001	16.7	0.004	50	0	0	0.001	16.7	0.001	16.7	<0.001	11.1	0	0
<i>Tetradlea coulteri</i>	Coulter's wrinklefruit	0	0	0	0	0	0	0	0	0.001	16.7	0	0	0	0
<i>Tragia ramosa</i>	branched noseburn	0	0	0	0	0	0	0	0	0	0	0	0	0.003	10.0
<i>Zinnia grandiflora</i>	Rocky Mountain zinnia	0.012	50.0	0.001	16.7	0.026	14.3	0.006	50.0	0.007	33.3	0.021	55.6	0.014	40.0

a Nonnative species

Appendix C. Cover of soil surface features in the Volcanic Upland ecological site at Wupatki National Monument, 2007–2014

Table C-1. Cover of soil surface features by panel in the Volcanic Upland ecological site at Wupatki NM for 2012 and 2014, and for the initial sampling year for all plots (2007–2010). The soil surface features do not add up to 100% as the calculations were made from cover class midpoints. Standard deviation = SD.

Soil surface feature	Initial sampling year between 2007 and 2010						2012				2014			
	Panel A, n=6		Panel B, n=6		Panel C, n=7		Panel A, n=6		Panel B, n=6		Panel B, n=9		Panel C, n=10	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Live plant base	5.36	1.71	3.23	1.77	3.02	1.56	3.33	1.25	3.19	1.26	4.33	1.04	4.22	1.04
Dead woody base	0.02	0.03	0.02	0.02	0.10	0.15	0.01	0.01	0.03	0.03	0.02	0.03	0.07	0.07
Dead herbaceous base	0.10	0.24	0.73	0.88	2.31	1.02	2.60	0.76	2.63	1.15	2.37	0.82	3.29	1.21
Bare soil	1.12	0.62	16.44	19.24	28.07	20.30	2.19	1.95	4.85	3.02	0.47	0.40	0.24	0.21
Litter	3.39	1.12	4.62	3.05	5.01	1.42	2.79	1.08	4.73	1.29	4.71	1.80	5.71	2.68
Undifferentiated crust	1.23	1.75	3.67	3.84	3.26	2.58	0	0	0	0	2.83	2.31	1.49	2.08
Moss	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lichen	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyanobacteria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fine gravel (0.2 to <2 cm)	75.39	11.92	57.17	22.26	56.08	19.24	79.92	7.97	72.33	18.64	79.91	10.64	79.60	5.25
Coarse gravel (2.0 to <7.5 cm)	13.14	12.65	12.73	17.99	6.71	6.14	7.58	7.21	11.66	17.60	4.94	8.19	2.71	2.15
Cobble (7.5 to < 25 cm)	0.81	0.54	1.43	2.59	0.25	0.23	0.87	0.62	1.18	1.48	0.60	0.60	0.54	0.53
Stone, bedrock (≥25 cm)	0.78	0.90	0.10	0.20	0.24	0.44	0.78	0.84	0.32	0.49	0.24	0.43	0.22	0.32
Woody debris	0	0	0	0	0.17	0.46	0	0	<0.01	0.01	0.01	0.02	0.60	1.86

Appendix D. Foliar cover of functional groups in the Loamy Upland ecological site at Wupatki National Monument, 2007–2013

Table D-1. Foliar cover of functional groups by panel in the Loamy Upland ecological site at Wupatki NM for 2013, and for the initial sampling year for all plots (2007–2010). The means for the live functional groups do not add up to the total live foliar cover because the calculations were made from cover class midpoints, components may overlap. SD= standard deviation.

Foliar cover type	Initial sampling year between 2007 and 2010						2013			
	Panel A, n=7		Panel B, n=8		Panel C, n=8		Panel A, n=10		Panel B, n=9	
	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Total live foliar cover	7.18	1.85	13.03	9.96	9.80	3.04	13.91	4.49	15.02	4.09
Perennial grasses	2.01	1.66	8.07	11.81	2.76	2.60	4.71	4.18	5.63	3.44
Annual grasses	0	0	0	0	0	0	0	0	<0.01	0.01
Forbs	0.62	0.39	1.24	0.84	0.88	0.79	3.77	2.97	5.28	3.40
Shrubs	4.68	1.50	3.88	2.31	5.97	2.77	6.02	2.08	4.69	2.54
Cacti/succulents	0	0	0.01	0.03	0	0	0	0	0.01	0.02
Standing dead herbaceous	1.00	0.98	1.52	1.52	0.91	0.50	2.15	1.91	2.35	1.79
Standing dead shrubs	2.81	1.25	3.13	2.53	3.11	1.48	2.40	1.26	2.57	1.93

Appendix E. Plant species list for the Loamy Upland ecological site at Wupatki National Monument, 2007–2013

Table E-1. Plant species list with mean foliar cover and plot frequency for each panel in the Loamy Upland ecological site at Wupatki NM for 2013, and for the initial sampling year for all plots (2007–2010).

Species	Common name	Initial sampling year between 2007 and 2010						2013			
		Panel A, n=7		Panel B, n=8		Panel C, n=8		Panel A, n=10		Panel B, n=9	
		Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Achnatherum hymenoides</i>	Indian ricegrass	0.057	71.4	0.050	37.5	0.008	37.5	0.027	60.0	0.020	55.6
<i>Ambrosia acanthicarpa</i>	flatspine burr ragweed	0.075	14.3	0	0	0.015	12.5	0	0	0	0
<i>Amsonia spp.</i>	bluestar	0	0	0	0	0.063	12.5	0	0	0	0
<i>Aristida havardii</i>	Havard's threeawn	0	0	0	0	0	0	0.019	30.0	0.014	33.3
<i>Aristida purpurea</i>	Fendler's threeawn	0.004	14.3	0.030	37.5	0.003	12.5	0.003	20.0	0.005	33.3
<i>Artemisia filifolia</i>	sand sagebrush	1.821	57.1	1.007	50.0	0.925	37.5	1.773	40.0	1.036	55.6
<i>Astragalus spp.</i>	milkvetch	0.002	14.3	0.003	12.5	0.006	37.5	0.001	10.0	0.008	11.1
<i>Atriplex canescens</i>	fourwing saltbush	0.294	71.4	0.294	37.5	0.184	25.0	0.324	70.0	0.425	33.3
<i>Atriplex confertifolia</i>	shadscale saltbush	0	0	0	0	0.296	12.5	0	0	0	0
<i>Bouteloua barbata</i>	sixweeks grama	0	0	0	0	0	0	0.001	20.0	0.003	22.2
<i>Bouteloua eriopoda</i>	black grama	0.059	28.6	0.013	25.0	0.175	37.5	0.529	30.0	0.469	33.3
<i>Brickellia oblongifolia</i>	Mohave brickellbush	0.003	14.3	0	0	0	0	<0.001	10.0	0	0
<i>Chaetopappa ericoides</i>	rose heath	0.001	28.6	0.002	12.5	0	0	0.012	30.0	0.002	11.1
<i>Chamaesaracha coronopus</i>	greenleaf five eyes	0	0	0.003	12.5	0.008	12.5	0	0	0.005	22.2
<i>Cylindropuntia whipplei</i>	Whipple's cholla	0	0	0	0	<0.001	12.5	0	0	0	0
<i>Dasyochloa pulchella</i>	low woollygrass	0.013	28.6	0.008	50.0	0.012	25.0	0.032	50.0	0.027	33.3
<i>Descurainia pinnata</i>	western tansyaster	0	0	0	0	0	0	0.005	10.0	0	0
<i>Elymus elymoides</i>	squirreltail	0	0	0.003	12.5	0	0	0.002	20.0	0.003	22.2
<i>Ephedra torreyana</i>	Torrey's jointfir	0.948	100.0	1.381	87.5	2.123	87.5	2.021	100.0	1.621	88.9

Table E-1. (continued) Plant species list with mean foliar cover and plot frequency for each panel in the Loamy Upland ecological site at Wupatki NM for 2013, and for the initial sampling year for all plots (2007–2010).

Species	Common name	Initial sampling year between 2007 and 2010						2013			
		Panel A, n=7		Panel B, n=8		Panel C, n=8		Panel A, n=10		Panel B, n=9	
		Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Ephedra viridis</i>	mormon tea	0.010	28.6	0.069	12.5	0.025	25.0	0.177	50.0	0.040	22.2
<i>Ericameria nauseosa</i>	rubber rabbitbrush	0.238	85.7	0.172	75.0	0.420	37.5	0.195	80.0	0.273	77.8
<i>Eriogonum cernuum</i>	nodding buckwheat	0	0	0.048	25.0	0	0	0	0	0.009	11.1
<i>Eriogonum corymbosum</i>	crispleaf buckwheat	0.008	28.6	0.063	12.5	0.035	12.5	0.050	10.0	0	0
<i>Eriogonum deflexum</i>	flatcrown buckwheat	0	0	0	0	0	0	0	0	<0.001	11.1
<i>Eriogonum leptocladon</i>	sand buckwheat	0.021	14.3	0	0	0	0	0.026	30.0	0	0
<i>Euphorbia exstipulata</i>	squareseed spurge	0	0	0	0	0.001	12.5	0.024	10.0	0	0
<i>Euphorbia fendleri</i>	Fendler's sandmat	0.002	42.9	0.016	50.0	0.020	50.0	0.013	70.0	0.030	77.8
<i>Euphorbia spp.</i>	sandmat	0.352	100.0	0.729	100.0	0.579	87.5	3.442	100.0	4.928	100.0
<i>Fallugia paradoxa</i>	Apache plume	0.904	42.9	0.758	62.5	1.790	37.5	1.291	60.0	1.155	66.7
<i>Forestiera pubescens</i>	stretchberry	0	0	<0.001	12.5	0	0	0	0	0	0
<i>Gutierrezia microcephala</i>	broom snakeweed	0.079	28.6	0.172	25.0	0.022	12.5	0.081	40.0	0.207	33.3
<i>Hesperostipa neomexicana</i>	New Mexico needlegrass	0	0	<0.001	12.5	<0.001	12.5	0.005	10.0	0.036	33.3
<i>Hilaria jamesii</i>	James' galleta	1.428	85.7	6.598	100.0	2.025	75.0	3.262	80.0	3.903	100.0
<i>Hopia obtusa</i>	vine mesquite	0	0	0.029	12.5	0	0	0	0	0.006	11.1
<i>Lycium andersonii</i>	water jacket	0	0	0	0	0	0	0	0	0.002	11.1
<i>Mentzelia albicaulis</i>	whitestem blazingstar	0	0	0.078	100.0	0.002	37.5	0	0	0	0
<i>Mentzelia spp.</i>	blazingstar	0	0	0.002	12.5	0	0	0	0	<0.001	11.1
<i>Mollugo cerviana</i>	threadstem carpetweed	0.033	14.3	0	0	0	0	0.001	20.0	0.001	11.1
<i>Muhlenbergia porteri</i>	bush muhly	0.281	85.7	0.885	50.0	0.390	50.0	0.611	80.0	0.852	66.7
<i>Munroa squarrosa</i>	false buffalograss	0	0	0	0	0	0	<0.001	10.0	0.001	11.1

Table E-1. (continued) Plant species list with mean foliar cover and plot frequency for each panel in the Loamy Upland ecological site at Wupatki NM for 2013, and for the initial sampling year for all plots (2007–2010).

Species	Common name	Initial sampling year between 2007 and 2010						2013			
		Panel A, n=7		Panel B, n=8		Panel C, n=8		Panel A, n=10		Panel B, n=9	
		Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Opuntia</i> spp.	prickly pear	0	0	0.010	12.5	0	0	0	0	0	0
<i>Phacelia</i> spp.	phacelia	0	0	0.001	12.5	0	0	0.005	30.0	0.001	11.1
<i>Physalis hederifolia</i>	ivyleaf groundcherry	0	0	0.001	12.5	0	0	0	0	0	0
<i>Psilostrophe sparsiflora</i>	greenstem paperflower	0	0	0.032	12.5	0.003	12.5	<0.001	10.0	0.002	11.1
<i>Salsola tragus</i>	prickly Russian thistle	0.072	14.3	0.158	62.5	0.044	25.0	0.003	30.0	0.003	22.2
<i>Sanvitalia abertii</i>	Abert's creeping zinnia	0	0	0	0	0	0	<0.001	10.0	0	0
<i>Senna bauhinoides</i>	twinleaf senna	0	0	0	0	0	0	<0.001	10.0	0	0
<i>Solanum elaeagnifolium</i> ^a	silverleaf nightshade	0.059	14.3	0.071	25.0	0.003	12.5	0.051	20.0	0.056	11.1
<i>Sphaeralcea</i> spp.	globemallow	0.058	42.9	0.070	37.5	0.055	37.5	0.221	50.0	0.091	55.6
<i>Sporobolus airoides</i>	alkali sacaton	0.068	28.6	0.363	12.5	0.028	12.5	0.090	40.0	0.325	22.2
<i>Stanleya pinnata</i>	desert prince's plume	0	0	0.020	12.5	0.048	25.0	0	0	0.037	22.2
<i>Stephanomeria</i> spp.	wirelettuce	0.019	100.0	0.044	62.5	0.038	50.0	0.020	80.0	0.037	77.8
<i>Tetradlea coulteri</i>	Coulter's wrinklefruit	0.063	57.1	0.037	62.5	0.028	37.5	0.118	50.0	0.035	66.7
<i>Tiquilia nuttallii</i>	Nuttall's crinklemat	0	0	0.014	37.5	0.058	37.5	0.002	10.0	0	0
<i>Yucca angustissima</i>	narrowleaf yucca	0	0	0	0	0	0	0	0	<0.001	11.1
<i>Zinnia grandiflora</i>	Rocky Mountain zinnia	0	0	0.100	25.0	0.005	25.0	0.010	10.0	0.125	33.3

^a Nonnative species

Appendix F. Cover of soil surface features in the Loamy Upland ecological site at Wupatki National Monument, 2007–2013

Table F-1. Cover of soil surface features by panel in the Loamy Upland ecological site at Wupatki NM for 2013, and for the initial sampling year for all plots (2007–2010). The soil surface features do not add up to 100% as the calculations were made from cover class midpoints. Standard deviation = SD

Soil surface feature	Initial sampling year between 2007 and 2010						2013			
	Panel A, n=7		Panel B, n=8		Panel C, n=8		Panel A, n=10		Panel B, n=9	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Live plant base	1.39	0.80	1.53	1.18	0.97	0.89	0.66	0.52	0.66	0.53
Dead woody base	0.31	0.25	0.24	0.24	0.40	0.19	0.24	0.13	0.17	0.08
Dead herbaceous base	0.18	0.25	0.39	0.29	0.42	0.38	0.42	0.44	0.53	0.53
Bare soil	7.98	16.99	49.96	28.78	45.73	38.20	5.30	9.69	3.38	7.16
Litter	4.49	2.05	5.02	4.10	8.58	5.69	7.40	3.27	6.75	2.97
Undifferentiated crust	2.92	3.13	3.52	4.10	4.92	10.97	1.25	1.49	1.28	1.93
Moss	0	0	0	0	0	0	0	0	0	0
Lichen	0	0	0	0	0	0	0	0	0	0
Cyanobacteria	0	0	0	0	0	0	0	0	0	0
Fine gravel (0.2 to <2 cm)	74.32	18.81	34.11	27.82	34.46	36.67	76.40	6.43	78.00	7.47
Coarse gravel (2.0 to <7.5 cm)	1.99	3.22	1.86	1.53	0.42	0.36	1.81	2.10	1.44	1.76
Cobble (7.5 to < 25 cm)	0.20	0.29	0.66	1.14	0.06	0.09	0.27	0.37	0.67	1.01
Stone, bedrock (≥25 cm)	0.09	0.19	0.03	0.08	0	0	0.06	0.16	0.08	0.12
Woody debris	0.09	0.21	0.37	1.00	0.11	0.11	0.62	1.87	0.01	0.02

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