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Effects of topography on the relationship between soil conditions and the vigor of *Andropogon gerardii* and *Sorghastrum nutans*

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Abstract

An understanding of topography is important to prairie management and ecological science. Spatial variability of resources impacts the success of plants in micro-environments. We studied the vigor of Big Bluestem and Indian Grass and the soil conditions on three hills in CERA prairies. Our results indicated increased vigor of Indian Grass with decreased elevation, as we hypothesized. The general absence of any relationship between elevation with soil conditions and plant vigor could have been a result of differences between the two plants, infrequent burnings, and irregularities. However, our results may also point toward the inherent complexity of resource variability in an ecosystem.

Introduction

Studying the spatial variability of energy and nutrients in an ecosystem contributes to an understanding of complex ecological processes. The availability of light, water, and soil nutrients is influenced by topography. Previous studies of topographic variability in tallgrass prairie have studied physiological interactions along a resource gradient (Schimel et al. 1991) and the relationship between soil water availability and primary productivity (Knapp et al. 1993).

Creating a management program for restoring or reconstructing a prairie requires a detailed understanding of topographic factors influencing plant growth. Hilltops and slopes tend to have less organic matter and moisture than valleys and flat areas because water carries these nutrients downhill (Mlot 1990). Varying soil moisture and organic content in turn affect plant growth and vigor (Barnes 1986).

We compared plant vigor with soil moisture and organic content along three hills at CERA (in Big Basin, Wilson, and Dam Prairies) to ascertain the effects of elevation and slope on plant growth. For plant vigor we measured height, stem width, and density. For soil characteristics we measured percent soil moisture and soil organic content (%LOI). We chose *Andropogon gerardii* (Big Bluestem) and *Sorghastrum nutans* (Indian Grass) as the focus of our study. Both species are warm-season grasses that are dominant in many tallgrass prairies (Reichman 1987, Knapp et al. 1993); they are also two of the most abundant grass species at CERA. We hypothesized that *A. gerardii* and *S. nutans* would exhibit greater height, stem width, and density at lower elevations because of increased moisture and organic matter availability.

Materials and Methods

We collected data from one southern-sloping hill at each of Big Basin, Wilson, and Dam Prairies at CERA. Wilson and Dam Prairies were restored between 1969 and 1975. Big Basin Prairie was restored in 1987. They were seeded with four prairie grasses (Kaw Big Bluestem, Oto Indian Grass, Blackwell Switch Grass, and Blaze Little Bluestem) and have not been recently burned or enriched with forbs. In this study, each hill study site will be referred to by the proper name of its respective prairie. On each hill, we set up six parallel (east-west) 30-meter transects perpendicular to the slope, with 15 meters between each transect (see Figure 1). We collected two different types of data: plant characteristics and soil conditions. The plant characteristics included the height, stem width, and density of *A. gerardii* and *S. nutans.* Soil conditions included soil moisture and soil organic content.

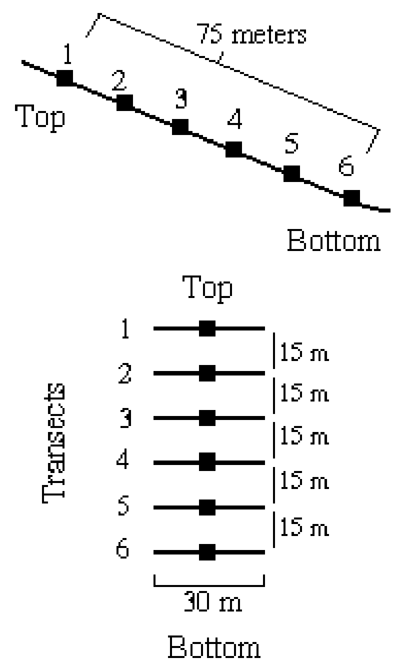
Plant Characteristics

We took five random 0.25 m^2 samples along each transect and measured the height (cm) and stem width (mm) of the tallest Big Bluestem and Indian Grass plant in each sample. We also counted the number of individuals in each sample in order to determine density. We measured plants at Big Basin on 23 October, at Wilson on 25 October, and at Dam on 30 October 2000.

Soil Conditions

On 8 November 2000, we measured soil moisture (% water content) with an electronic probe at four random points along each of the 18 transects. Three soil samples per transect were collected on 13 November. The samples were dried and on 19 November we determined the soil organic content by measuring loss on ignition. After

Figure 1: diagram of transect lay-out on south-sloping hills at CERA



measuring the dry mass, samples were placed in a muffle furnace at 400°C for one hour. Then we removed and re-massed the samples. The difference between the two masses divided by the original mass is the percent loss on ignition.

Statistical Analysis

We analyzed the changes in width, height, and density of Big Bluestem and Indian Grass along the slope of each hill using regression in order to compare elevation and plant vigor. We also used regression to determine whether there was a significant relationship between the soil characteristics and elevation, and the soil characteristics and plant vigor.

Results

Plant Vigor and Elevation

At Dam, Wilson, and Big Basin Prairies, the density of Indian Grass tended to increase as elevation declined. Changes in density (Fig. 2) were significant at Dam ($F_{1,4}$ = 25.77; P = 0.007) and nearly significant at Big Basin ($F_{1,4}$ = 4.96; P = 0.09). Height (Fig. 3) was significantly negatively correlated with elevation at Big Basin ($F_{1,4}$ = 7.94; P = 0.048) and Dam ($F_{1,4}$ = 11.19; P = 0.029). Width (Fig. 4) was significantly correlated at only Dam ($F_{1,4}$ = 24.48; P = 0.008). Mean width increased among the three lower transects at Big Basin, and the greatest value on the hill was along the lowest transect.

There was no significant relationship between measures of the vigor of *A. gerardii* – height, width, and density – and changes in elevation at Big Basin, Wilson, or Dam. At Dam, none of the 5 samples along transects two and four included any specimens of Big Bluestem. Height (Fig. 5) and width (Fig. 6) were lowest along transect three and greater at the top and bottom of the hill. On the other two hills, there were no observable patterns in mean height and width in relation to the elevation. However, density (Fig. 7) tended to decrease from the top of the hill (to transect 4 for Big Basin; to transect 3 for Wilson) and then peaked and decreased again to the bottom of each hill.

Plant Vigor and Soil Conditions

Neither soil moisture (Fig. 8) nor soil organic content (Fig. 9) were significantly related to changes in elevation., but at Big Basin there was a nearly significant correlation between moisture and elevation ($F_{1,4}$= 5.52; P = 0.079).

We found a marginally significant correlation between Indian Grass density and soil moisture at Big Basin ($F_{1,4}$ = 6.57 ; P = 0.06). Other measures of Indian Grass vigor did not correspond to changes in soil moisture. At Dam, soil organic content appeared to be related to Indian Grass height ($F_{1,4}$ = 69.93; P = 0.001) and width ($F_{1,4}$ = 15.53; P = 0.017). Although soil organic content was not significantly related to density of Big Bluestem, it did significantly correlate

Figure 2. Mean density (with standard error bars) of S. nutans at Big Bas (23/10/00), and Dam (25/10/00).

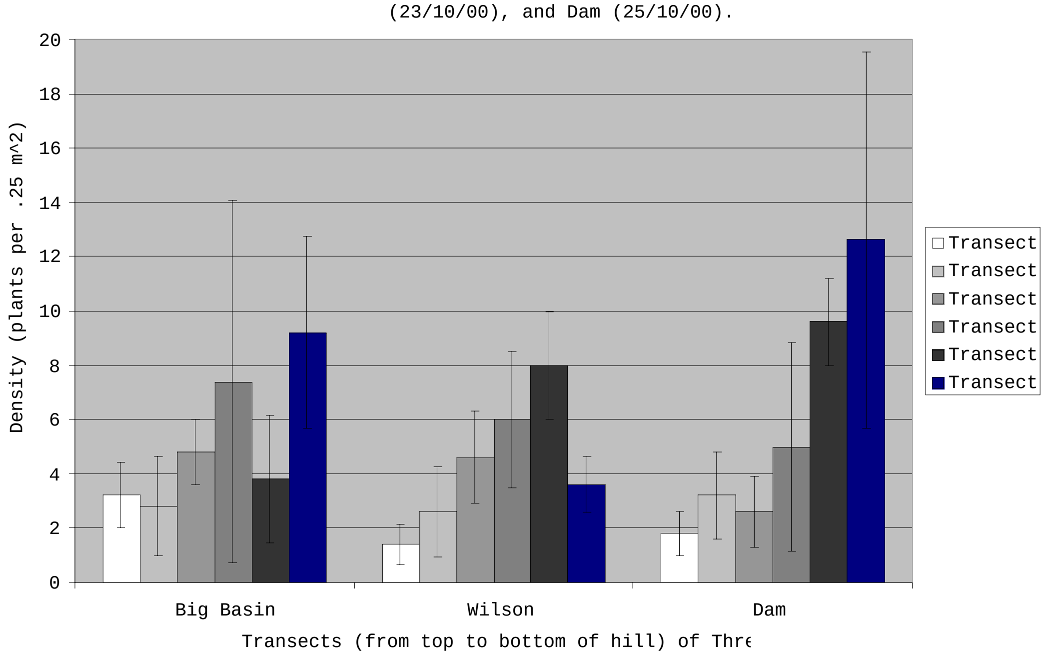
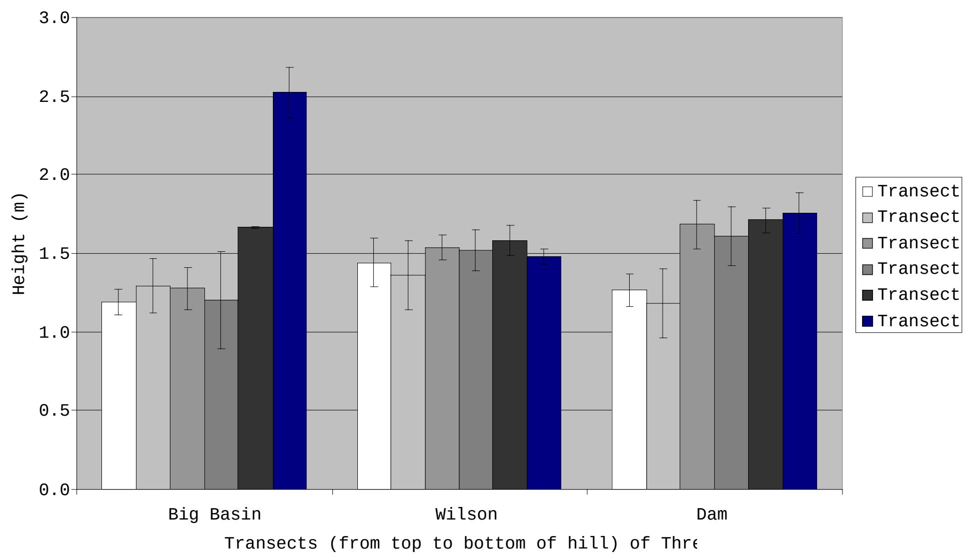


Figure 3. Mean height (with standard errSr batrs)saof Big Basin (23/10/00),
(23/10/00), and Dam (25/10/00).



with Big Bluestem height at Dam ($F_{1,2}$ = 26.36; P = 0.036). The mean width of Big Bluestem at Dam and Wilson was marginally significantly related to soil moisture [($F_{1,2}$ = 9.82 ; P = 0.089), ($F_{1,2}$ = 5.08 ; P = 0.087)].

Discussion

Plant Vigor and Elevation

Our data on *S. nutans* largely corresponded with our hypothesis that height, stem width, and density would increase as elevation decreased (Figs. 2, 3, 4). We made this hypothesis because as water flows downhill it creates erosion, carrying moisture and soil from higher to lower areas. This would lead to greater moisture and nutrient availability in low flat regions as compared to higher sloped regions (Mlot 1990). Increasing soil moisture and organic content would in turn lead to greater plant growth (Schimel et al. 1991).

Unlike the results for *S. nutans*, our data on *A. gerardii* did not support our hypothesis that height, stem width, and density would increase from the top to the bottom of a hill (Figs. 5, 6, 7). One possible explanation could be the different photosynthetic processes of C3 and C4 plants. Because *A. gerardii* is a C4 grass, it tends to dominate well-drained areas where it has a competitive advantage over C3 plants with less efficient photosynthetic processes. However, in areas with greater moisture availability, high efficiency is not necessary. In these areas, *A. gerardii* may actually be at a disadvantage to C3 plants, which have less expensive photosynthetic methods. This could account for the greater success of *A. gerardii* at the top as compared to the bottom of our hills (Reichman 1987, Knapp et al. 1993).

However, both *S. nutans* and *A. gerardii* are C4 grasses so we were expecting them to have similar growth patterns. Our results may be different for *S. nutans* and *A. gerardii* because they are adapted to grow in slightly different environments. Bowen (1999) found that *S. nutans* grows well in areas with intermediate moisture availability while Barnes (1986) found that *A. gerardii* grows better in drier areas.

Our data may also have been affected by irregularities at our study sites.

Figure 4. Mean width (with standard error bars) of S. nutans at Big Basin (23/10/00), (23/10/00), and Dam (25/10/00).

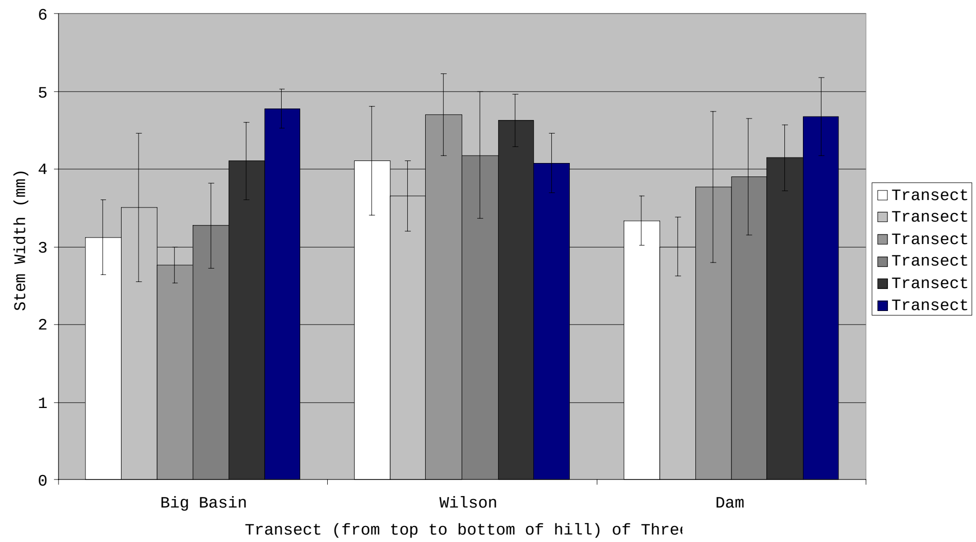
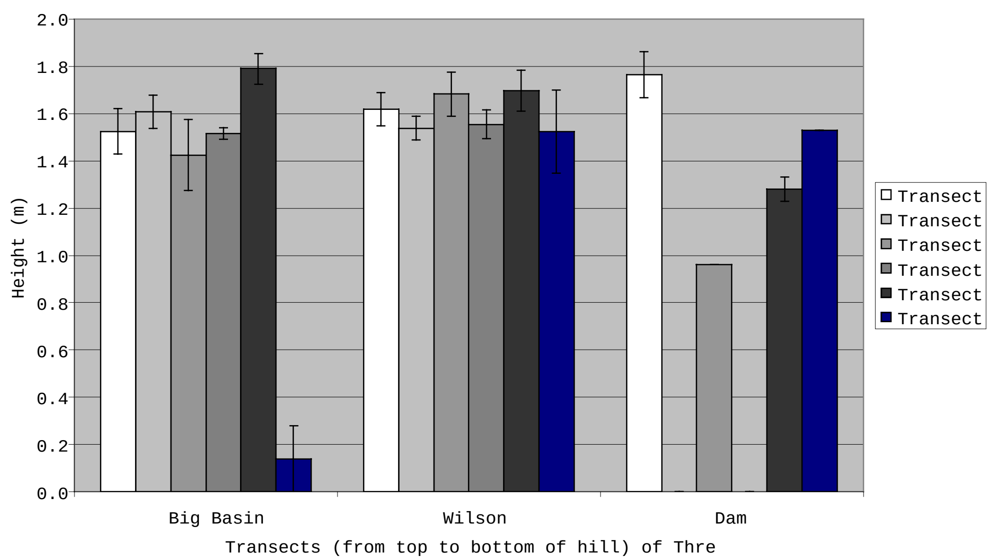


Figure 5. Mean height (with standard errA. gerardii of A. gerardii at Big Bas (23/10/00), and Dam (25/10/00).

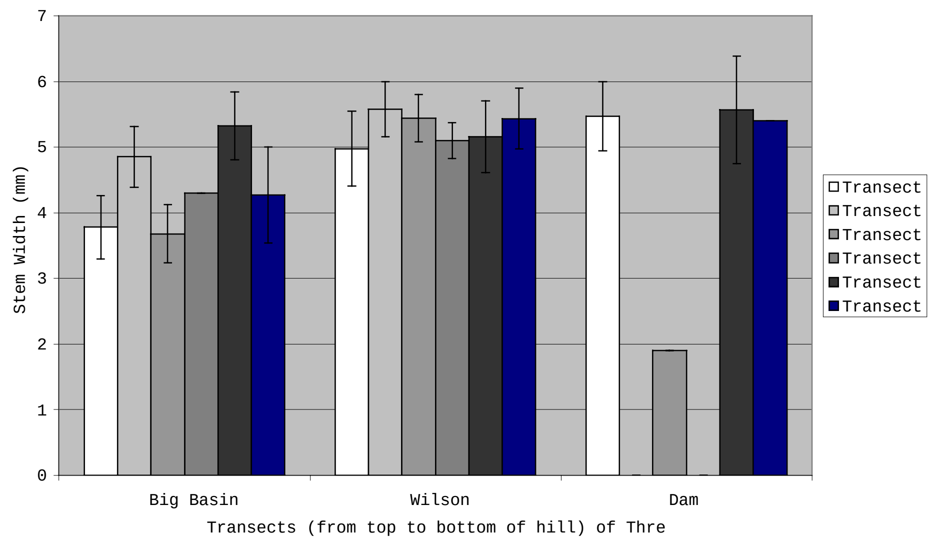


For example, a large tree had fallen along much of our fourth transect at Big Basin, and the immediate area was covered with a short grass unlike the surrounding tallgrass prairie vegetation. At both Wilson and Dam Prairies, there were large stands of sunflower plants. The short grasses and the sunflower plants dominated these areas and may have left few resources available for other plants, possibly resulting in lower densities of *A. gerardii* and *S. nutans* along these transects (transect 4 at Big Basin, 3 and 6 at Wilson, and 1-4 at Dam).

Soil Conditions and Elevation

With the exception of soil moisture at Big Basin Prairie, our soil moisture and soil organic content data did not correspond with our hypothesis that water and nutrient availability would increase as elevation decreased (Figs. 8 and 9). These results may be due to the fact that Big Basin, Dam, and Wilson Prairies

Figure 6. Mean width (with standard err A. gerardii of A. gerardii at Big Bas
(23/10/00), and Dam (25/10/00).



have been burned only 1 to 3 times in the past 30 years. In an experiment that also studied topographic variation in plant vigor and soil conditions, Knapp et al. (1993) found that the accumulation of litter in unburned prairies resulted in little sunlight reaching the soil, regardless of location in uplands or lowlands. This in turn led to more limited trends in soil moisture along elevation gradients.

The areas surrounding our study sites may also have affected our soil moisture data; the bottom of both Big Basin and Dam Prairies were relatively protected. Trees were growing in the valleys below Big Basin and Dam Prairies, and there was a large bank on the western side of Dam Prairie. The bank and trees may have sheltered these areas from rainfall and led to lower than expected percent water content in the soil.

Plant Vigor and Soil Conditions

Our regression statistics suggested that there were few significant relationships between either soil moisture or soil organic content and measures of plant vigor. Infrequent burning and the subsequent accumulation of litter at our study sites may have contributed to the limited correlation between soil conditions and plant vigor. Knapp et al. (1993) found that infrequent burning limits the relationship between soil moisture and net primary productivity.

Overall, our research did not support our hypothesis that plant vigor would increase as elevation decreased due to greater soil moisture and nutrient availability. Several factors could explain why our results did not conform to our hypothesis, including differences between *A. gerardii* and *S. nutans* habitat requirements and resource usage, irregularities at our study sites, and the accumulation of litter due to infrequent burning. The Knapp et al. (1993) study experimentally assessed the impact of different burn regimes on these issues of topography, soil, and plants. Future research could help explain the other factors by exploring the differences between *A. gerardii* and *S. nutans* in relation to the topographic variability of resources such as light, air moisture, and soil nitrogen content. In addition, further studies would benefit from utilizing various scales of topographic change, either greater or smaller than the 15-meter distance between transects used in our study.

Although we did not find any definitive effects of topography and soil conditions on plant growth, understanding the interactions of these different factors is important to both ecology and prairie restoration. Our hypothesis may have been misguided in seeking a simple relationship among topography, soil conditions, and plant vigor. The term “irregularities” merely describes the natural variation in topographic features. No slope is geometrically even, and resources will never be homogeneously distributed. The complex web of pattern and process varies spatially across every ecosystem. Management programs must take into account the effects of varied topography and soil conditions if they are to successfully create diverse, vigorous prairie plant communities.

Acknowledgements

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Figure 7. Mean density (with standard err A. gerardii of A. gerardii at Big Ba
(23.10/00), and Dam (25/10/00).

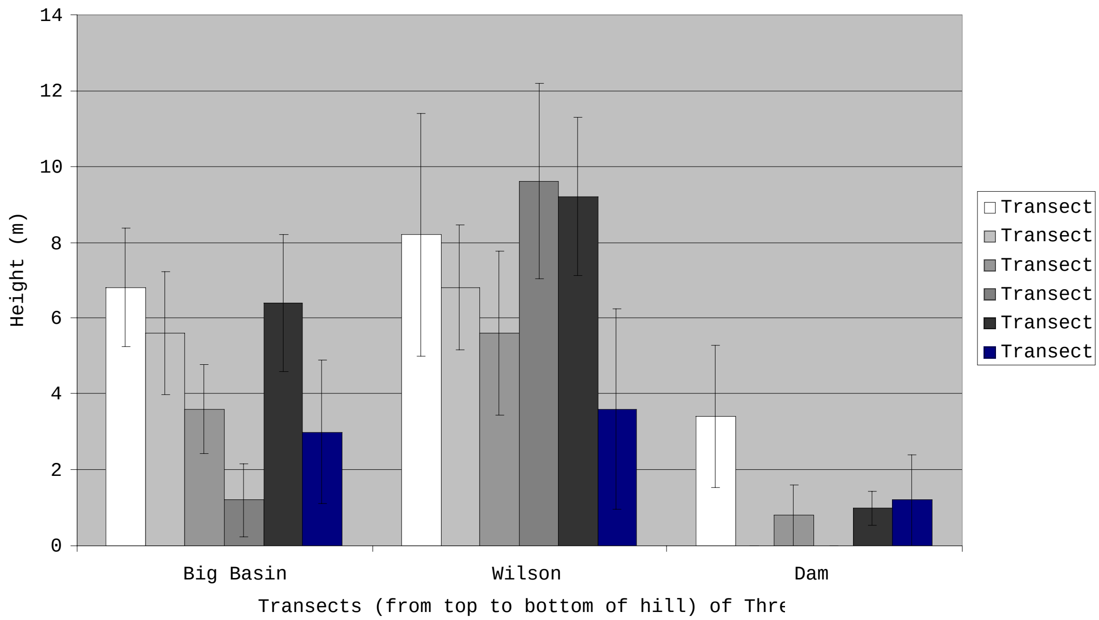

Figure 8. Mean % Soil Moisture (with standard error bars) at Big Basi
(11/8/00).

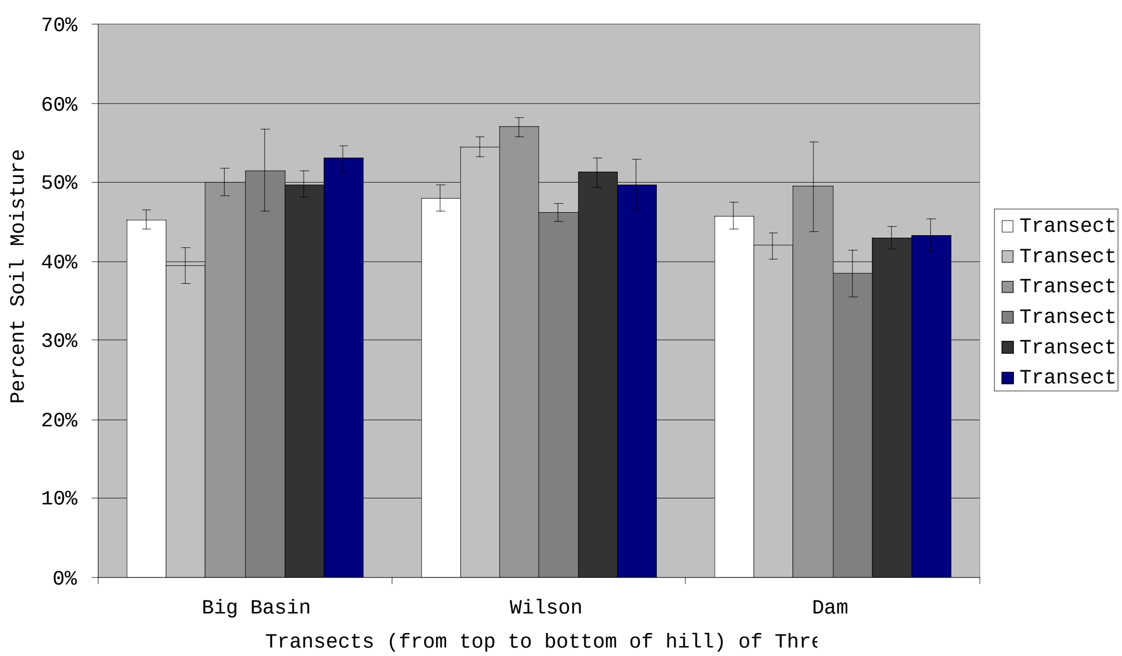

Figure 9. Mean soil organic content (with standard error bars) at Big Basin, Wils