Effect of Grazing Treatment on Soil Moisture in Semiarid Rangelands

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ABSTRACT

The rangelands of southeastern Idaho are important from both an ecological and economic perspective. Consequently, assessing and monitoring rangeland health is also important. Soil moisture is a key rangeland health parameter as it is the principal limiting factor in semi-arid ecosystems. While numerous factors may affect soil moisture, this paper focuses upon the effect of grazing on soil moisture using three treatments within the same soil association. The treatments, simulated holistic planned grazing (SHPG), rest rotation (RESTROT), and total rest (TREST) were treated with 36, 6, and 0 animal days per hectare respectively. Soil moisture was measured with 36 pseudo-randomly placed Decagon ECH_2O (EC-10) capacitance sensors during the years 2006, 2007 and 2008. Statistical analyses revealed differences in percent volumetric water content (%VWC) among all treatments in each year save for the comparison between the RESTROT and TREST pastures. In all cases, the SHPG pasture had the highest %VWC and within pasture comparisons indicated very little difference across each individual pasture. Mixed procedure models in SAS indicate strong environmental and treatment effects as explanatory variables for the observed difference in %VWC. Results of vegetation transect analysis indicated no difference in percent shrub cover for the two production treatments (SHPG and RESTROT), but a difference in the amount of litter present in later years of this study. It was concluded that management decisions (grazing and rest) can have substantial influence upon soil moisture and that even within production systems, soil moisture can vary substantially as a result of animal impact and the duration of grazing within a growing season.

KEYWORDS: grazing, volumetric water content, VWC, EC-10, capacitance sensors

INTRODUCTION

Southeastern Idaho is a region where the high-desert plains of the Snake River exist alongside mountain ranges. The economy of this semi-arid region is varied, but geographically dominated by farming and ranching industries. Ecologically, the sagebrush-steppe rangelands of southeastern Idaho provide important habitat for Greater sage-grouse (*Centrocercus urophasianus*) and other sagebrush-obligate species (Fischer et al. 1993). Urbanization, ranching, farming, fire prevention efforts, and invasions of non-indigenous plant species have impacted the vegetation in this area (Whisenant 1990) and for these reasons the rangelands of southeastern Idaho are particularly appealing for researchers examining the effects of drought, global climate change, and desertification on rangeland ecosystems and rangeland health.

The term rangeland health describes an important concept, but is fraught with varying definitions and connotations (National Research Council 1994, Savory 1999, Williams and Kepner 2002, O'Brien et al. 2003, Pellant et al. 2005). However, one commonality exists amongst these definitions, the importance of ground cover for proper hydrologic function (O'Brien et al. 2003). While hydrologic function has been defined as the ability of rangelands to capture, store, and release water (Pellant et al. 2000), it is difficult to accurately measure and monitor the inputs and outputs in the field. Instead, several indicators have been developed to characterize hydrologic function with percent bare ground exposure and soil moisture being some of the most commonly applied and accepted indicators (Booth and Tueller 2003, Taylor 1986). Indeed, Thomas and Squires (1991) argue that soil moisture is the principal determinant of productivity and the primary driver of rangeland condition in semi-arid ecosystems.

Soil moisture is an important environmental indicator of both the soil-water balance and of a soil's ability to regulate the hydrologic cycle. Soil water content (expressed as either percent water by weight, percent water by volume, or cm of water per cm of soil) can range from 0.05 g/g (5.0%) in xeric regions to 0.50 g/g (50%) or above (Werner 2002, GLOBE 2005) in more mesic areas. Various methodologies exist to measure soil moisture (electrical resistance blocks, tensiometers, gravimetric calculations, neutron probe, time domain reflectrometry, and capacitance probes) with some being more accurate and acceptable than others (Werner 2002). Regardless of the methodology used to estimate soil moisture, site specific calibration curves must be developed (GLOBE 2005).

The depth at which soil moisture instruments are placed is important if results are to be meaningful. For most rangeland applications, instruments should be located within the root zone of the site-specific plant community. It has been established that soil water content is dependent upon soil type, structure, porosity, and organic matter (Werner 2002). In addition, soil water content can be affected by changes in vegetation, runoff from adjacent roads, as well as other factors. The goal of this study was to determine if soil water content is also affected by land management decisions (e.g., grazing and rest) within semi-arid sagebrush steppe rangelands.

METHODS

Study area

Soil moisture data were collected at the O'Neal Ecological Reserve, an area of sagebrush-steppe rangelands in southeastern Idaho approximately 30 km southeast of Pocatello, Idaho (42° 42' 25"N 112°

13' 0" W), where many local-scale rangeland studies are being conducted (Figure 1). The O'Neal Ecological Reserve (http://www.isu.edu/departments/CERE/o'neil.htm) was donated to the Department of Biological Sciences at Idaho State University by Robin O'Neal. The O'Neal Ecological Reserve receives < 0.38 m of precipitation annually (primarily in the winter) and is relatively flat with an elevation of approximately 1400 m. The dominant plant species include big sagebrush (*Artemisia tridentata*) with various native and non-native grasses and forbs, including Indian ricegrass (*Oryzopsis hymenoides*) and needle-and-thread (*Stipa comata*). Soils in the O'Neal study area are homogeneous and of the McCarey series-McCarey variant soil association. These shallow, well-drained soils lie over basalt flows and were originally formed from weathered basalt, loess, and silty alluvium (USDA NRCS 1987).

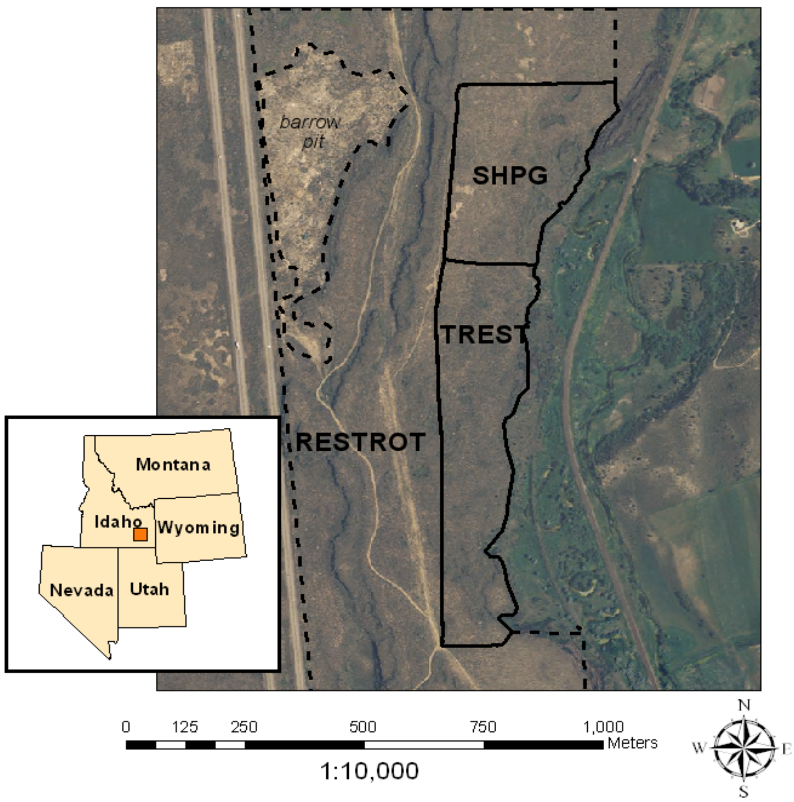

Figure 1. The O'Neal study area. The rest rotation pasture extends beyond this map to both the north and south. Note: no samples were taken from the barrow pit in the northwest corner of this map for any part of this study.

Field data

In 2005 and prior to any experimentation, the study area was sampled (n = 60) to establish pre-treatment vegetation cover conditions. In addition, hi-resolution (0.15 m) aerial imagery was acquired to provide a census of ground cover conditions that could be revisited in the future after fences were constructed and grazing treatments were implemented. Ocular estimates of percent cover were made for bare ground, litter, grass, shrub, and dominant weed. Cover was classified into one of nine classes {1) None, 2) 1-5%, 3) 6-15%, 4) 16-25%, 5) 26-35%, 6) 36-50%, 7) 51-75%, 8) 76-95%, and 9) > 95%} and all observations were made by viewing the vegetation perpendicular to the ground.

Treatment pastures were fenced in late summer 2005. In 2006, 2007, and 2008, the study area was sampled to monitor each treatment pasture. For each sample plot (n = 50 sample plots/pasture) two-10 m line transects were arranged perpendicular to each other and crossing at the 5 m mark of each line transect. Using the point-intercept method, observations were recorded every 0.2 m along each 10 m line, beginning at 0.10 m and ending at 9.8 m (n = 50 observations per line or 100 observations per plot). Percent shrub, grass, and litter cover were estimated in this fashion as was bare ground exposure. Beginning in 2007, forage biomass was measured using a plastic coated cable hoop 2.36 m in circumference (0.44 m^2). The hoop was randomly tossed into each of four quadrants (NW, NE, SE, and SW) centered over the sample point. All vegetation within the hoop that was considered forage for cattle, sheep, and wild ungulates was clipped and weighed (+/- 1g) using a Pesola scale tared to the weight of an ordinary paper bag. Grasses and forbs were weighed separately while woody species (i.e., sagebrush) were not clipped or included in the forage biomass measurements. The measurements were later used to arrive at an estimate of forage expressed in pounds per acre and kilograms per hectare (Sheley et al. 2003).

Instrumentation

Thirty-six Decagon ECH$_2$O (EC-10) capacitance sensors were installed across the O'Neal study area (Figure 2) in spring 2006 with 12 probes used in each of three treatment pastures (SHPG, RESTROT, and TREST). The EC-10 capacitance sensors (+/- 2% accuracy) used for this study were buried at a depth of 10cm. This depth was selected as it is within the root zone of the sagebrush-steppe plant community and at a depth where soil moisture responds rapidly to precipitation events and plant water use. More shallow placements were avoided as the sensors were more likely to be moved or damaged by livestock, rodents, and freeze/thaw cycles. Deeper placements were not possible in all sites across the study area due to underlying rock. The sensors were placed pseudo-randomly as true random placement was not possible because of numerous rock outcroppings and the concern that cattle would disturb or destroy the probes and data loggers if placed along existing trails or near water tanks. Nine data loggers were used (three per pasture) with four EC-10 capacitance sensors attached to each data logger. The EC-10 capacitance sensors were placed the maximum distance away from the data loggers as allowed by the data cables (approximately 18m).

In June 2006, six soil core samples (15.31 cm^3) were removed from the ground immediately adjacent to six EC-10 probes (approximately 15% of the probes were sampled, two from each treatment pasture). The soil was weighed (+/- 1 g) and stored in marked plastic bags for further analysis. The samples were then oven-dried and weighed again. Using these data, soil bulk density (g/cm^3), water volume (ml), and volumetric water content (VWC m^3 water/ m^3 soil) were determined. VWC (Y-axis) was regressed against raw probe output values (X-axis) to arrive at a line-of-best-fit and quadratic calibration function using third-order polynomial regression. The calibration equation (R^2 = 99.7) used for this study was:

$$Y = 4.86E\text{-}07x^2 + 6.22E\text{-}05x - 7.81E\text{-}02 \qquad \text{(Eq. 1)}$$

where Y = calibrated volumetric water content (m^3 / m^3)

x = raw output values from the EC-10 capacitance sensor

Percent volumetric water content was found by multiplying the calibrated VWC by 100. All soil moisture values given in this paper will be expressed as %VWC.

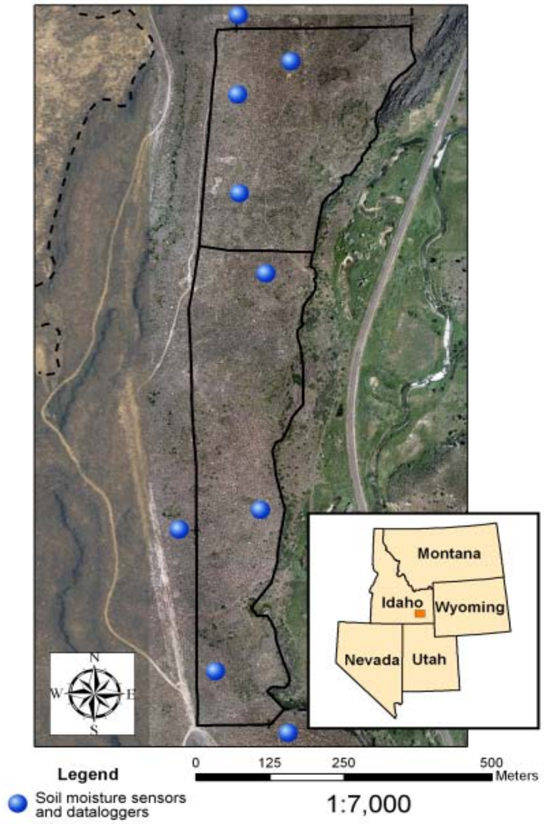

Figure 2. The location of the soil moisture sensors followed a star-like pattern around the dataloggers (shown as large dots on the map). Placement was pseudo-random and avoided both rock outcrops and existing cattle trails.

Soil moisture measurements were collected every six hours beginning 8 July 2006 and throughout the duration of this study (1 September 2008). All data were calibrated (using the equation above) and stored in an ArcSDE Geodatabase along with all spatial, temporal, and raw probe data. For the purposes of this study, soil moisture data were analyzed for the growing season only (i.e., through August 31^{st}).

Also present at the O'Neal Ecological Reserve was a Davis Vantage Pro2 Weather Station (http://www.davisnet.com). Since June 2006, the O'Neal weather station has measured and recorded temperature, humidity, barometric pressure, wind speed and direction, precipitation, solar radiation, and solar energy every two hours. In addition, the Vantage Pro2 weather sensor also calculates dew point, various heat indices, and evapotranspiration (ET_0). Evapotranspiration is calculated and recorded as hourly potential ET_0 (in mm) using measured and calculated variables (Jensen et al. 1990, Davis 2006). Due to the small size of the O'Neal Ecological Reserve uniformity of environmental conditions which may affect soil moisture was assumed.

Grazing

Prior to this experiment and the construction of additional fencing, the entire study area (1491 ha) was managed as a single unit under a rest-rotation grazing system. For over two decades cattle grazed at low density (approximately 300 head) for long periods of time (30 days). Late in 2005, the study area was divided into three treatment pastures. The first was a simulated holistic planned grazing (SHPG) pasture where cattle graze at high density (66 AU/ 11 ha) for a short period of time (6 days) during the first week of June each year (2006-2008). The second treatment was a rest-rotation (RESTROT) pasture where cattle graze at low density (300 AU/ 1467 ha) for long periods of time (30 days) during the month of May each year. By following this grazing schedule, both production pastures were grazed at as near the same time as was logistically possible. The third treatment was a total rest (TREST) pasture (13 ha) where no livestock grazing has occurred since June 2005.

Statistical analysis

Pre-treatment shrub, grass, and litter cover, and bare ground exposure were compared between pastures using ANOVA (i.e., SHPG was compared with RESTROT, SHPG was compared with TREST, and RESTROT was compared with TREST) to determine if a difference pre-existed, which could account for any observed differences in %VWC of the soils.

An inverse relationship was expected between soil moisture and percent cover when all other factors were constant (precipitation, soil association, etc) across the study area. This relationship suggests that the treatment pasture having the highest soil moisture should have the lowest percent cover of vegetation. To investigate this, ANOVA was used to compare shrub cover (primarily Wyoming big sagebrush [*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young]) between pastures using field data collected in 2007 and 2008. In addition, since litter acts as mulch and can affect the % VWC of soils, differences in percent litter within each treatment pasture were investigated using point-intercept transect data from 2007 and 2008. ANOVA was used for pair-wise comparison of treatments (i.e., SHPG and RESTROT, SHPG and TREST, RESTROT and TREST).

Differences in forage biomass were investigated to help understand any observed differences in %VWC of the soils. To accomplish this, forage biomass estimates (kg/ha) were compared between treatment pastures using ANOVA.

Daily average %VWC was calculated for each treatment pasture (n = 48 [12 probes were located in each pasture with four measurement made per day]). In addition, weekly average %VWC was calculated for each treatment replicate (three data loggers were located in each pasture and treated as replicates). Four spreadsheets were prepared, one for 2006 (8 July 2006 through 31 August 2006), another for 2007 (1 April 2007 through 31 August 2007), a third for 2008 (1 April 2008 through 31 August 2008), and a fourth for 2006-2008 together with data arranged in week, year, data logger, and mean %VWC columns). The former yearly spreadsheets contained mean %VWC arranged in columns representing the three treatment pastures (SHPG, RESTROT, and TREST). ANOVA were calculated comparing pairs of treatments individually (i.e., SHPG and RESTROT, SHPG and TREST, RESTROT and TREST) within each year. To better account for the interactive effects of treatment and the environment (weekly and annual differences in soil moisture due primarily to precipitation, and temperature) and to provide a more robust and conservative test, a mixed procedures model was applied using SAS software and 2007 and 2008 data (note: the data from 2006 was not used in this test as the same number of weeks were not sampled causing a lack of convergence error in the SAS procedure). The fixed effects calculations followed Prasad-Rao-Jeske-Kackar-Harville methodologies while the degrees of freedom calculation followed the Kenward-Roger method.

Spatial heterogeneity of the soil was investigated to determine the degree of variability that existed within the soils. To accomplish this, 2006 soil moisture data were used (these data would tend to show the least treatment effect) and each pasture was sub-sampled by selecting six EC-10 capacitance sensors (two diagonally juxtaposed sensors were selected from each data logger [with four sensors each]) and the daily mean %VWC was compared with the daily mean %VWC for the remaining six EC-10 capacitance sensors in the same treatment pasture. ANOVA was used to compare within pasture daily mean %VWC.

RESULTS AND DISCUSSION

Results of analyses comparing pre-treatment conditions within each pasture indicate no difference in ground cover pre-existed with the exception of shrub cover, which was found to be slightly higher in the TREST pasture than in the SHPG pasture (Table 1). No other differences were found in other cover classes or treatment pastures.

Table 1. Comparisons of pre-treatment (2005) land cover conditions and results of statistical analyses

			Median Cover Class	
Treatment	**Shrub**	**Grass**	**Litter**	**Bare Ground**
SHPG	1-5%[1]	1-5%	16-25%	36-50%
RESTROT	1-5%	1-5%	16-25%	36-50%
TREST	16-25%[1]	1-5%	6-15%	26-35%

[1] *indicates a statistical difference was found between these two areas (P < 0.001)*

The results of vegetation cover analyses during the experiment indicate no difference in percent cover of shrubs between the SHPG and RESTROT pastures ($P = 0.687$ and $P = 0.584$) in both 2007 and 2008 respectively, while a difference was found between the SHPG and TREST pasture ($P = 0.002$) in 2007. This difference was not seen in the 2008 sampling however ($P = 0.417$) and given the heterogeneity of semi-arid rangelands and the fact that specific sample points were not revisited each year it is noteworthy that the between pastures comparison (where within year environmental conditions were constant) revealed no difference in percent cover of shrubs in most cases.

The ANOVA tests comparing percent litter revealed statistically significant differences among all three treatments ($P < 0.001$) beginning in 2007 but no difference prior to this time. Pair-wise comparison showed significant differences between the SHPG and RESTROT pastures ($P < 0.001$) in both 2007 and 2008, as well as between the SHPG and TREST pastures in 2007. No difference in litter was found between the SHPG and TREST pastures in 2008 ($P = 0.07$) and no statistical difference was found between the TREST and RESTROT pastures ($P > 0.001$) at any time throughout this study.

These results suggest that total rest and rest-rotation (partial rest) treatments have similar effects on litter and that treatment has the ability to modify litter cover. Litter affects soil nutrients and soil structure as its decay adds nutrients to the soil, improves soil structure, and reduces soil erosion (Nagler et al. 2000). Soil temperature, a controlling factor for soil moisture as it affects evaporation, is also affected by the amount of litter (Davidson et al. 1998). Consequently, the changes observed in the SHPG treatment pasture appear to be the result of several interactive affects (high intensity short duration grazing, animal impact, and increased litter cover) producing a positive feedback cycle which may ultimately improve the condition and sustainability of rangelands (Redman 1978, Snyman 2002, Fynn 2008). Naeth et al. (1991a) reported that litter itself can hold water and thus affect the soil moisture. The authors imply that water holding capacity (WHC) depends on vegetation type which is influenced by grazing. Naeth et al. (1991b) have also studied grazing impacts on litter and soil organic matter with reference to grazing regimes of light to heavy intensities grazed early, late, and continuous throughout the growing season. They found more medium- and small-particle sized organic matter occurred in grazed treatments compared to un-grazed (i.e., total rest) pastures. Recently Neufeld (2008) evaluated how litter affects soil moisture. Through that study it was concluded that the relationship between litter and soil moisture is a complex one, dependent upon climate, landscape, soil properties and vegetation type.

Forage biomass comparisons indicate more above-ground grass biomass was found in the SHPG pasture ($\underline{x}$ = 58.6 kg/ha [S.E. = 3.2]) relative to that found in the RESTROT pasture ($\underline{x}$ = 39.5 kg/ha [S.E. = 3.8]) in 2007 ($P < 0.001$). This difference was not seen in 2008 ($P = 0.17$) although the mean above ground grass biomass was slightly higher in the SHPG pasture ($\underline{x}$ = 79.9 kg/ha [S.E. = 5.1]) than in the RESTROT pasture ($\underline{x}$ = 68.5 kg/ha [S.E. = 6.4]). The difference observed is most likely attributable to how livestock utilized the pastures, the time span between when the cattle were removed from the pastures and when the pastures were sampled, and differences in precipitation. From January 1^{st} to June 30^{th} 0.105 m of precipitation fell in 2007 whereas 0.097 m of precipitation fell over the same time period in 2008. Significant differences ($P < 0.001$) were also observed between the production pastures (SHPG and RESTROT) and the TREST pasture ($\underline{x}$ = 131.9 kg/ha [S.E. = 10.2] and $\underline{x}$ = 239.2 kg/ha [S.E. = 24.0] in 2007 and 2008, respectively) in both 2007 and 2008. This result may be somewhat misleading however as all pastures were sampled following grazing. Consequently the TREST pasture was expected to have higher above-ground grass biomass.

Analyses comparing daily %VWC among treatment pastures indicate significant difference ($P < 0.001$) when all treatments are compared at once. Pair-wise comparisons indicate statistically significant differences between the SHPG and RESTROT pastures in 2006, 2007, and 2008 ($P < 0.001$) and between the SHPG and TREST pastures in 2006, 2007, and 2008 ($P < 0.001$). No difference in %VWC was found between the RESTROT and TREST pastures in either 2006 ($P = 0.161$) or 2007 ($P = 0.749$) although differences were found in 2008 ($P < 0.001$) (Table 2).

Table 2. Mean %VWC comparisons by treatment

	$\bar{x}$ %VWC		
Treatment	**2006**	**2007**	**2008**
SHPG	23.3	44.1	45.8
RESTROT	19.7	34.8	34.7
TREST	19.2	31.9	29.8

Within pasture comparisons indicate very little difference existed in %VWC across each individual pasture. The SHPG pasture revealed the greatest heterogeneity ($P < 0.025$) while both the RESTROT and TREST pastures showed no detectable difference ($P = 0.15$ and $P = 0.12$ respectively). It is difficult to know if the difference observed within the SHPG pasture is due to an *a priori* difference in soils or an early observable effect of treatment. While it is impossible to know, it is most likely a combined effect of both treatment and soil heterogeneity.

Results from the mixed procedures model and type three test of fixed effects indicate the observed differences in %VWC at the O'Neal study area were principally due to weekly effects ($F = 91.87$ $P < 0.0001$) (e.g., early season %VWC differs from late season %VWC suggesting a purely environmental influence) followed by the year x pasture interaction ($F = 20.03$ $P < 0.0001$). This secondary effect indicates that while %VWC differs annually, it is differentially variable by pasture, suggesting both an environmental and treatment influence. The third significant explanatory effect was the week x year interaction ($F = 6.29$ $P < 0.0001$) while the final significant effect was attributable to the pasture variable alone ($F = 4.89$ $P = 0.05$). This latter effect indicates that the treatment applied within each pasture accounts for some significant portion of the total variability seen in %VWC at this study area and coupled with the year x pasture interaction, suggests that treatment has the ability to make substantial changes to rangeland soils.

The response of %VWC (Daily % VWC) to precipitation events was investigated using data collected in 2007 to better understand the hydrologic cycling dynamics within the study area and within each pasture (Figure 3). As expected, soil moisture content at 10 cm increased rapidly after precipitation events and declined at equivalent rates. During the summer months, the rate of soil water decline was much greater than autumn rates. Furthermore, while absolute %VWC is highest in the SHPG pasture (Table 2) the trend followed in all pastures is nearly identical.

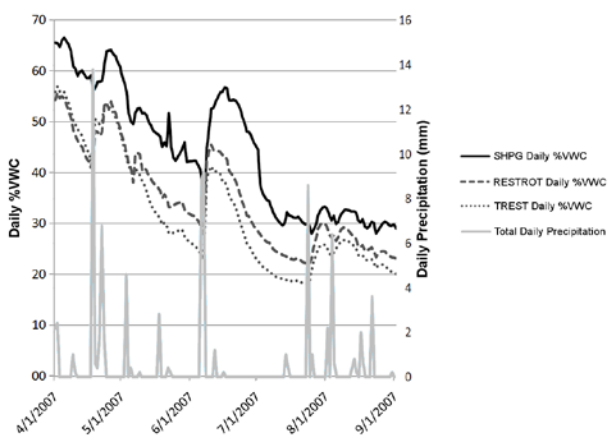

Figure 3. Soil moisture response in each treatment pasture relative to rainfall events during the summer of 2007 illustrates a rapid increase in response to precipitation followed by a decline at nearly equivalent rates.

Assessment of error and bias

The accuracy of the Decagon ECH_2O (EC-10) capacitance sensors was +/- 2%. Conservatively applying known instrumentation error indicates that if mean %VWC was within 4% for any two treatment pastures then the real difference between those treatments may be questionable even if they were found to be statistically different. This condition occurred only in 2006 (Table 2). All other comparisons do not satisfy the error condition tolerance of +/- 4% and are considered valid.

A potential bias of this study is related to the pseudo-random positioning of the Decagon ECH_2O (EC-10) capacitance sensors. Ideally, the sensors would have been placed in an absolutely random fashion, however this was not possible for two reasons: 1) the McCarey series-McCarey variant soil association found throughout the study area is typified by having very shallow bedrock (approximately 0.25 m) which precludes a true random placement of sampling probes and requires *in situ* placement adjustments, 2) the study area is actively grazed by cattle and placement of sampling probes could not be located close to trails or water sources as the increased presence of cattle would increase the probability of the probes, their buried wire connections and above ground data loggers would be damaged or destroyed. To minimize potential damage and avoid rock outcroppings we chose to use a pseudo-random location strategy where true random locations were first generated using Hawth's tools (within ESRI's ArcGIS) and final placement was decided during installation based upon field conditions and the considerations noted above. In all cases, final placement of the sensors was made as close to the randomly generated location as possible.

Another potential bias in this study and one the authors have tried to accommodate for is the uneven sampling duration. The Decagon ECH_2O (EC-10) capacitance sensors became operational on 8 July 2006 and continued in operation throughout this study. As a result, the 2006 growing season records do not include measurements made prior to July 8. This shortcoming was corrected in 2007 and 2008 as records from April 1 through August 31 were available and used in this study. For this reason, empirical comparisons of %VWC between 2006 and latter years were limited.

A potential error in this study relates to the frequency of daily soil moisture observations (4/day) and averaging. It is likely that soil moisture varies diurnally but if soil moisture levels varied disproportionately across the three treatment pastures an error could have been introduced. Such phenomena are unlikely however, as the soil association is homogeneous across all three treatment pastures. Daily soil moisture fluctuations were expected to be uniform and any slight error due to averaging was consistent across all treatments.

This study was part of a larger study focusing upon the use of remote sensing satellite imagery to detect changes in vegetation land cover. To augment understanding of detected changes, soil moisture sensors were deployed in 2006 concurrent with commencement of experimental grazing and satellite imagery acquisition. Soil type was the same (McCarey series-McCarey variant soil association [NRCS 1987]) across all experimental pastures and pre-treatment vegetation cover data (2005) showed little overall difference in shrub, grass, litter, or bare ground exposure, soil moisture was assumed to be similar prior to treatment. However, to draw a final conclusion regarding the effect of treatment on soil %VWC, pre-treatment conditions should be known, not assumed. While this study presents interesting trends and observations one cannot conclusively state that a given treatment tends to encourage higher soil moisture rates relative to another treatment. Observations made during this experiment are encouraging and illustrate that treatment is a statistically important effect. Furthermore the trend of continued divergence in %VWC among the treatments is interesting and appears promising (Figure 4). Future research should be directed toward answering this question using a larger replicated study with at least one year of pre-treatment data collection.

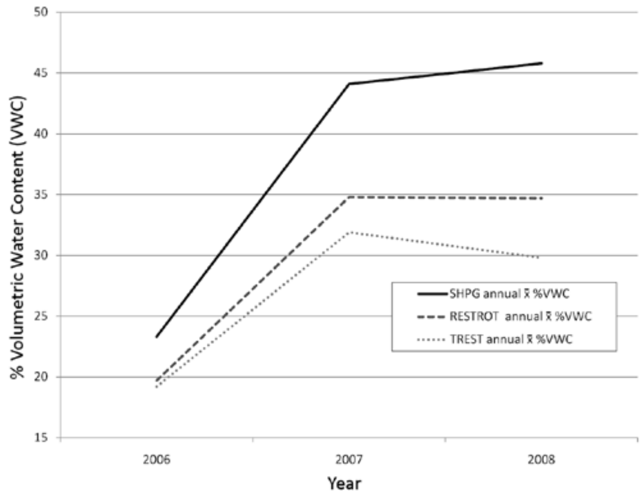

Figure 4. Mean annual %VWC within each treatment pasture. Note: 2006 data appear substantially lower than shown in subsequent years but this is believed to be a function of duration of sampling rather than real differences. In addition, note the continued increase in mean %VWC within the SHPG pasture and the decline in mean %VWC in the TREST pasture. These changes are most likely due to actual treatment differences.

Management Implications

Water absorption and retention capacity of soils depends upon soil type (e.g, sand, silt, and clay), porosity, and organic matter or colloidal content (Singer and Munns 1987, Werner 2002), vegetation cover, and numerous other factors. The effect of treatment on soil moisture is not well recognized although some studies have documented the effect of grazing on carbon dynamics (Haferkamp and Macneil 2004) or evaluated the effect of grazing on various physical properties of soil (Wheeler et al. 2002).

This study demonstrates that season-long mean soil moisture (expressed as %VWC) can vary significantly even within areas with the same vegetation cover and soil type (McCarey series-McCarey variant soil association) and presumably the same soil porosity and organic matter content. The latter may not be entirely true however and was not analyzed as part of this study. Indeed the difference in treatment may have altered the porosity and organic matter of the soils within each treatment pasture, thereby offering one explanation of how these soils were able to retain more water throughout the growing season (Naeth et al. 1991b). In addition, the increase in litter as a result of the treatment has the ability to increase the soil's ability to retain water by both adding organic matter through decomposition and by acting as mulch which shades the soil from direct solar contact and also cools the soil which reduces loss of moisture through evaporation. These interactive effects may ultimately lead to changes in plant community composition if the differences in soil characteristics (moisture and temperature) create a microenvironment that favors certain plant species.

CONCLUSIONS

While soil type and shrub cover were effectively the same across the study area, mean % VWC was found to differ. Pair-wise comparisons indicate that mean % VWC for the SHPG treatment pasture was significantly higher than that found in the RESTROT or TREST treatment pastures while mixed procedures modeling in SAS revealed a strong environmental as well as treatment effect. Animal impact and the duration of grazing (i.e., spatio-temporal effects) may be responsible for some of these differences. Interrelated with animal impact, increased litter cover in the SHPG pasture may play a role in the observed soil moisture differences. Although the relationship between litter and soil moisture is complex, the current literature (Naeth et al. 1991a; Neufeld 2008) suggests that litter can affect soil moisture and soil organic matter. Holistic planned grazing appears to offer a management alternative with beneficial results measured on this landscape. In light of these encouraging results, additional studies are warranted relative to the merits of holistic planned grazing and the ability of treatment to favorably modify landscapes.

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