Chapter

Soil Moisture Regime and Mound Position Effects on Soil Water and Vegetation in a Native Tallgrass Prairie in the Mid-Southern United States of America

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Abstract

Prairie mounds are unique soil surface features that will become increasingly scarce as native tallgrass prairies are continually lost. This study aimed to evaluate (i) whether the soil moisture regime (SMR), mound position, and soil depth affect soil volumetric water content (VWC) and (ii) whether the SMR and mound position affect vegetation over time. Soil VWC was measured continuously from April 2017 to June 2018, and vegetation was sampled in June and August 2017 and in May and August 2018. Maximum VWC for selected rainfall events was ~ 2.5 times greater at 10 cm in the aquic inter-mound than the udic mound position at 30 cm. Soil dry-down rates were four times greater in the udic soil at 10 cm than the aquic soil at 30 cm. Aboveground plant biomass was numerically largest (8489 kg ha^{-1}) at the aquic summit in August 2018 and smallest (1280 kg ha^{-1}) at the aquic inter-mound in May 2018. Results clearly demonstrate the effects that prairie mound topography and differing SMRs have on soil water dynamics and prairie vegetation and suggest that management efforts need to account for mound topography and SMR in order to be most successful.

Keywords: Ozark Highlands, Arkansas, udic, aquic, prairie mounds

1. Introduction

Before the onset of European agriculture, 1.62×10^8 ha of prairie covered the vast area of land from Canada to Mexico and from the Rocky Mountains to western Indiana, known as the Great Plains [1, 2]. Tallgrass prairies once encompassed 6.0×10^7 ha from Canada and Minnesota south to Texas and were the dominant presettlement vegetation type in the eastern third of the Great Plains [2, 3]. Since 1830, tallgrass prairie loss in the United States is estimated between 82 and 99%, exceeding the loss of any other major ecosystem in North America [2]. Due to the substantial prairie loss, tallgrass prairies are now considered to be North America's most endangered ecosystem [3]. Factors including conversion to farmland, introduction of

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non-native forage crops, woody plant encroachment, overgrazing, and urban expansion have contributed to the reduction of tallgrass prairies in North America [2, 4].

Tallgrass prairies are the most mesic prairie variety, and as a result, multiple resources, including soil moisture, may control net primary productivity (NPP) in this ecosystem [5]. Evidence of differing soil moisture dynamics in mounded and inter-mound soil have been described in various field studies [6–8]. Research has generally concluded that inter-mound soils are wetter, often possessing greater water contents, than mounded soil profiles [6–8]. Water content measurements conducted by Ross et al. [8] on a silt loam surface in northwestern Minnesota indicated that mounded soils contained lower water contents at respective depths than the inter-mound soil. Profile descriptions of mounded and inter-mound soils have noted that redoximorphic (redox) concentrations and depletions occur at shallower depths in inter-mound soils, further substantiating that inter-mound soils are wetter than mounded soil [6, 9]. Common depletions were identified in the surface horizon of an inter-mound profile, whereas depletions were absent in the corresponding mounded profile in the top 85 cm in the Arkansas River Valley within the Ouachita physiographic province [9]. Crayfish (*Cambarus* spp.) chimneys are commonly reported in inter-mound soils, but are rarely present in mounded soils, which again suggests that inter-mounds contain more moisture than mounded soils [7, 9]. Additionally, studies have indicated that water is retained longer in inter-mound profiles than in mounded soils [7]. Water is likely retained in the inter-mound for longer periods of time because mounded positions have greater permeability and internal drainage and lower clay contents than inter-mound soils, which increases water movement through the mounded soil profile [7].

The differing water dynamics between mounded and inter-mound soil profiles described in previous studies would likely lead to differences in biomass production and differing plant communities between the mound positions. Studies have characterized herbage production on mounds compared with inter-mounds, differences in vegetation composition (i.e., grass or forb dominated), as well as similarities between plant composition of mounds and inter-mounds [8, 10–12]. Studies conducted by Allgood and Gray [10] on a silt loam surface in eastern Oklahoma and McGinnies [12] on a silt loam soil in Colorado analyzed herbage production of mounds compared with inter-mound mound positions and concluded that mounds generally produce more biomass than inter-mounds. A study conducted by McGinnies [12] in Colorado on a silt loam mounded soil and a loam inter-mound soil noted that the air-dry herbage yields were 94, 180, 323, 358, and 542% greater on seeded mounds than on seeded inter-mounds for intermediate wheatgrass (*Thinopyrum intermedium*), crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.], smooth brome (*Bromus inermis* Leyss.), Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski], and big bluegrass (*Poa secunda* J. Presl), respectively.

Studies analyzing whether grasses or forbs were more abundant on mounded positions have yielded mixed results [8, 10]. Scientists have hypothesized that mounds containing pocket gophers (*Geomys bursarius*) will tend to be dominated by grasses, as pocket gophers primarily feed on forb species [10, 13]. Additionally, mound size may determine whether grasses or forbs are the dominant form of vegetation [8]. At the Waubon Prairie in northwestern Minnesota on a silt loam surface, small mounds were generally dominated by grasses, whereas medium-sized mounds were forb-dominant and large mounds were comprised mostly of shrubs [8]. Additionally, vegetation differences between mounds and the surrounding prairie occur because mounded soils exhibit increased biological soil disturbance compared with inter-mound soils [11]. As soil is continually disturbed, vegetation succession occurs, which promotes the abundance of pioneer forb species and other disturbance-tolerant plants [8, 11].

Studies determining whether plant species richness was greater on mound or inter-mound mound positions have also provided mixed results. Brotherson [11] concluded that the species richness on the mound was only slightly larger than the species richness of the corresponding inter-mound in Iowa, with 51 plant species identified on the mounds and 48 species identified in the inter-mound on soils with loam, clay loam, and silty clay loam soil textures [11, 14]. Of the 51 plant species present on the mounds, 38 were also present in the adjacent prairie [11]. Conversely, Allgood and Gray [10] noted that 18 plant species were identified on inter-mound soils, whereas 13 plant species were identified on mounded soils on a silt loam soil in eastern Oklahoma. Of the 18 species located on inter-mound soils, 6 were also located on mounded soils [10]. Although the studies may disagree on whether species richness was greater in mound or inter-mound soils, both studies demonstrated that a degree of dissimilarity between plant species comprising mounds and inter-mounds exists. Scientists have hypothesized the reason for the dissimilarity between mounds and inter-mounds is due to the microtopographic variation of the mounds compared with inter-mound soils [11, 15].

Studies analyzing soil moisture with time and vegetation in tallgrass prairies within the Ozark Highlands are of interest as the Ozark Highlands occupies a topographic, climatic, and botanical transition zone from the grassland-dominated Great Plains to the west and northwest to the warm and wetter forest to the east and southeast [1, 16, 17]. The Ozark Highlands Major Land Resource Area (MLRA) 116A occupies portions of eastern Oklahoma, northwestern and north-central Arkansas, and southwestern to south-central Missouri and is approximately 85,720 km^2 [18]. The Ozark Highlands land cover distribution is characterized as approximately 54% forest, 33% grasslands, 5% cropland, 4% urban development, 3% water, and 1% other [19]. The forested region of the Ozark Highlands is inhabited by oak (*Quercus* spp.), hickory (*Carya* spp.), and shortleaf pine (*Pinus echinata* Mill.) [19]. Common grassland species present in the Ozark Highlands include fescue (*Festuca* L.), big bluestem (*Andropogon gerardii* V.), little bluestem [*Schizachyrium scoparium* (Michx.) Nash], indiangrass [*Sorghastrum nutans* (L.) Nash], and dropseeds (*Sporobolus* spp.) [19]. Corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] are agronomic crops typically grown in the Ozark Highlands.

Alfisols and Ultisols are the dominant soil orders present in the Ozark Highlands [20]. Limestone, dolomite, and occasionally sandstone are common parent materials in the region [20]. Argillic horizons have developed over time as physical and chemical weathering has caused the cherty limestone parent material to disintegrate into chert and clay [20]. Soils in the Ozark Highlands are shallow to very deep, moderately to excessively well-drained, and medium- to fine-textured [20].

Prairie mounds have been described as soils with special scientific value, but relatively little research has been conducted on undisturbed prairie mounds in native tallgrass prairies [21]. Most research of prairie mounds has occurred on the west coast [15, 22, 23], but few studies have been performed in the mid-southern region of the United States. Additionally, most prairie mound research has focused on determining valid hypotheses for mound formation, while various aspects of prairie mounds have been studied specifically in northwest Arkansas [24, 25], in northeast Arkansas [26], and in central and southern Arkansas [9, 27]. Though various studies have reported soil moisture differences between mound and inter-mound areas, none of the studies evaluated soil moisture dynamics over extended time periods and multiple seasons. In additional, potential vegetation differences in mounded ecosystems in Arkansas have not been researched. Therefore, the objective of this field study was twofold: (i) characterize soil volumetric water content (VWC) differences between landscape positions (i.e., mound summit and inter-mound) over time and among soil depths (i.e., 10, 20, 30, and 50 cm) in contrasting soil moisture regimes (SMR) (i.e., aquic and udic) and (ii) determine the effect of landscape position (i.e., mound and inter-mound), soil moisture regime (i.e., aquic and udic), and time on vegetative properties [i.e., total productivity, total diversity, species evenness, species richness, vegetation similarity, and grass abundance compared with other species abundance (i.e., sedges, rushes, and forbs)] in a native tallgrass prairie in the Ozark Highlands region of northwest Arkansas. It was hypothesized that numerous differences in soil moisture, vegetation, and soil morphology would exist with depth among the various mound positions across soil moisture regimes.

2. Materials and methods

2.1 Site description

Research for this field study began in April 2017 at the Chesney Prairie Natural Area, hereafter referred to as Chesney Prairie, located near Siloam Springs, Benton County, Arkansas (36°13′12″ N lat., 94°28′57″ W long., **Figure 1**). Chesney Prairie is part of the Ozark Highlands (MLRA 116A) [18].

The Chesney Prairie (**Figure 1**) is a tallgrass prairie that has been managed by the Arkansas Natural Heritage Commission (ANHC) since 2000 [28]. Chesney Prairie is a 33-ha remnant of prairie ecosystems that formerly encompassed over 30,000 ha of the Ozark Plateau and is one of the few prairie remnants on the Arkansas portion of the Springfield Plateau [29]. In addition, Chesney Prairie and the nearby Stump Prairie are the two remaining native prairie remnants of Lindsley's Prairie, which once encompassed approximately 6200 ha around present-day Siloam Springs, AR [30].

Chesney Prairie is a diverse prairie that supports over 450 plant species, including 290 native plant species and 18 rare plant species [29]. Big bluestem (*Andropogon gerardii* V.), little bluestem [*Schizachyrium scoparium* (Michx.) Nash], indiangrass [*Sorghastrum nutans* (L.) Nash], and switchgrass (*Panicum virgatum*) are typical prairie grasses present at Chesney Prairie [30]. Common forb species inhabiting Chesney Prairie include large flower tickseed (*Coreopsis grandiflora*), prairie

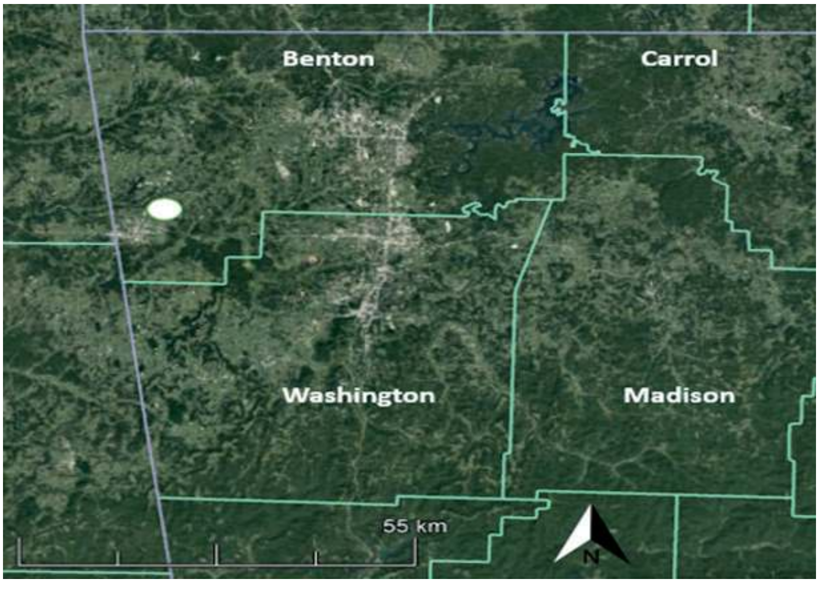

Figure 1.
Map depicting the approximate location of Chesney prairie (represented with oval) located in Benton County, Arkansas.

grayfeather (*Liatris pycnostachya*), and rattlesnake master (*Eryngium yuccifolium*). Periodic prescribed burns and invasive species eradication are management practices currently used to increase the native plant population [30]. Prescribed burning has occurred approximately every 3 years, with the last burn occurring in January 2017.

Chesney Prairie contains two soil series: Jay silt loam (fine-silty, mixed, active, thermic Oxyaquic Fragiudalf), which is in a udic soil moisture regime, and Taloka silt loam (fine, mixed, active, thermic Mollic Albaqualfs), which is in an aquic soil moisture regime [31, 32]. The macroscale slope is approximately 4%, and the land surface undulates some throughout the entire Chesney Prairie area. However, slopes are ≤2% within each soil mapping unit [1]. Numerous prairie mounds are present at Chesney Prairie, and the prairie is divided by Sager Creek, an ephemeral stream. The prairie mounds are ~20.9 m in diameter and ~0.7 m in height and are roughly circular.

The mean average air temperature throughout the region containing the Chesney Prairie over the past 30 years was 14.9°C, with an average January minimum of 2.9°C and an average July maximum of 26.1°C [33]. The mean annual precipitation over the past 30 years was 1203 mm, with approximately 64% of the rainfall occurring during the growing season from April to October [33].

2.2 Soil water content monitoring

To continuously monitor changes in soil VWC with depth over time, two prominent mounds were identified in both the Jay and Taloka soil series, and the distance from summit to summit was measured. The inter-mound position, defined as the midpoint between the mound summits, was marked. On 8 April 2017, at both the inter-mound positions between the two mound summits and at one of the adjacent mound summits in both soil series, a small trench was manually excavated after cutting and removing the top layer of sod. Water content reflectometers (model CS615, Campbell Scientific, Inc., Logan, UT) were installed horizontally at depths of 10, 20, 30, and 50 cm below the soil surface. The small trench was filled back in with soil from the appropriate natural horizon, and the intact piece of sod was placed back on top where it was removed from to maintain a minimally disturbed appearance (**Figure 2**). The water content reflectometer wires were shallowly buried and connected to a datalogger (model CR10X, Campbell Scientific, Inc.) to record data every 5 minutes and output mean volumetric soil water contents hourly. Approximately weekly, data were manually transferred to a storage module (model SM16M, Campbell Scientific, Inc.) using a keyboard display (model CR10KD, Campbell Scientific, Inc.) and transferred to a desktop computer. Volumetric soil water contents were measured and recorded through 30 June 2018.

To determine the effects of mound position (i.e., mound summit and inter-mound), depth below the soil surface (i.e., 10, 20, 30, and 50 cm), and soil moisture regime (i.e., aquic and udic) on soil volumetric water content dynamics, dry-down periods were determined for each major rainfall event between 1 June 2017 and 31 May 2018. Dry-down periods for each depth were identified as the linear phase between the maximum and minimum soil water content measured for each event before the next wetting event occurred. The maximum and minimum soil water contents for each depth were also recorded for each rainfall event for subsequent analyses. Water content maxima and the soil water content 2 days after the maximum was achieved were used to calculate the rate of dry-down for selected rainfall events.

2.3 Weather station

A micrometeorological weather station was erected on-site on 15 April 2017 in the Jay soil series area at Chesney Prairie to measure rainfall, air temperature, and

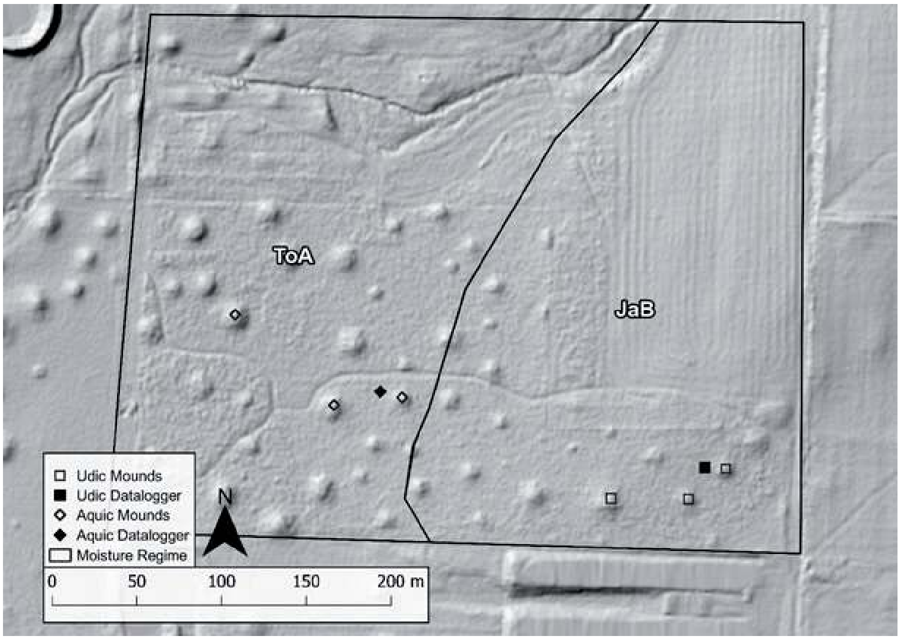

Figure 2.
Satellite imagery depicting the locations of the aquic and udic volumetric water content dataloggers and all mounds sampled within the aquic (i.e., ToA) and udic (i.e., JaB) soil moisture regimes at Chesney prairie. Data downloaded from Arkansas GIS Office [48].

relative humidity. The weather station contained a 25-cm-diameter tipping bucket rain gauge (model TR-525 M, Texas Electronics, Inc., Dallas, TX) and a combined air temperature/relative humidity sensor (model HMP50, Campbell Scientific, Inc., Logan, UT). Both sensors were connected to a datalogger (model CD10X, Campbell Scientific, Inc.), which recorded data every 2 minutes and output data summaries every hour. Approximately weekly, data were manually collected on a storage module (model SM16M, Campbell Scientific, Inc.) using a keyboard display (model CR10KD, Campbell Scientific, Inc.) and transferred to a desktop computer. Precipitation, air temperature, and relative humidity were measured and recorded through 30 June 2018.

2.4 Vegetation sampling and analysis

Vegetation samples were collected on 2–3 June and 17–18 August 2017 and 19 May and 16 August 2018 from mound summit and inter-mound positions in the Jay and Taloka soil series. At each position, all vegetation within a 0.25-m^2 metal frame was cut to approximately a height of 2 cm. Stem by stem, the cut vegetation was bagged separately as either a grass or other (i.e., a sedge, rush, shrub, etc.). In total, three vegetation samples were collected at mound summit and inter-mound positions in each soil series on each sample date. Vegetation samples were oven dried at 55°C for at least 5 days and weighed to determine dry matter by vegetation type (i.e., grasses or other).

Dry matter data in May 2018 were used to determine vegetation diversity using the Shannon-Wiener index [34]. Each plant species within the 0.25 m^2 metal frame was identified to determine the species richness for the site. The number of a given plant species was recorded and divided by the total number of plants observed to calculate the relative abundance for each species. The relative abundance of each plant species was used in the Shannon-Wiener equation to calculate the diversity index. The resulting diversity index and species richness were then used to calculate evenness. The Shannon-Wiener and evenness equations are outlined below:

$$H = -\sum_{i=1}^{n} (pi) \ln(pi) \tag{1}$$

where H is the Shannon-Wiener Index, s is the number of species, and pi is the proportion of total sample belonging to the i^{th} species, and

$$EH = H/\ln(s) \tag{2}$$

where EH is evenness, H is the Shannon-Wiener Index, and s is the number of species. Additionally, a Sorenson coefficient was calculated using Eq. (3) to determine the similarity of vegetation comprising the mounded and inter-mound positions within and across soil moisture regimes:

$$Ss = 2a/(2a + b + c) \tag{3}$$

where a is the number of species both locations have in common, b is the number of species present in only location one, and c is the number of species present in only location two.

2.5 Statistical analysis

Based on a completely random design, an analysis of variance (ANOVA) was conducted using PROC MIXED in SAS 9.4 to evaluate the effects of soil moisture regime (i.e., udic and aquic), mound position within soil moisture regime (i.e., mound summit and inter-mound within the aquic and udic soil moisture regimes), time (i.e., wet and dry season), depth (i.e., 10, 20, 30, and 50 cm) and their interaction on soil water content maxima and minima achieved, and the rate of dry-down during drying events. Multiple drying events isolated over time served as temporal replication for these analyses.

Based on a split-split plot, completely random experimental design, a three-factor ANOVA was conducted using PROC MIXED in SAS 9.4 to evaluate the effects of soil moisture regime (i.e., aquic and udic), mound position (i.e., mound summit and inter-mound), time (i.e., sample date), and their interactions on aboveground dry matter production. The whole-plot factor was soil moisture regime, the split-plot factor was mound position, and the split-split-factor was time. A four-factor ANOVA was conducted in SAS 9.4 to evaluate the effects of soil moisture regime (i.e., aquic and udic), mound position (i.e., mound summit and inter-mound), time (i.e., sampling date), biomass type (i.e., grasses or other species), and their interactions on total dry matter production. Lastly, a two-factor ANOVA was conducted in SAS 9.4 to determine the effects of soil moisture regime (i.e., aquic and udic), position (i.e., mound summit and inter-mound), and their interaction on Shannon-Wiener diversity and species richness and evenness. For all analyses, the least significant difference (LSD) was used to separate means at the 0.05 level.

3. Results and discussion

3.1 Water content dynamics

Soil water contents exhibited distinct trends with time at both mound positions (i.e., summit and inter-mound) within both soil moisture regimes (i.e., aquic and udic). Precipitation totaled 117.5 cm at the field site from 1 June 2017 to 31 May 2018 and was within 10% of the 30-year normal annual precipitation (120.3 cm) for the region, designating the current year as a typical/average year for the region encompassing the study site (**Figure 3**). In total, 112 independent precipitation events (i.e., periods of precipitation of any magnitude separated by half a day without precipitation) occurred from mid-April 2017 to 31 May 2018. Of the 112 precipitation events, 95 occurred during 1 June 2017 to 31 May 2018. Approximately 59% of the precipitation events within the study period caused a clear response (i.e., a response that could be easily differentiated from normal fluctuations in VWC) in the 10-cm sensor for each mound position within both soil moisture regimes, while only 14 of the 95 precipitation events caused a clear response in all 16 sensors (**Figures 4** and **5**).

Seasonal wet-up and dry-down trends resulting from precipitation patterns were evident at each mound position within both soil moisture regimes and were most pronounced at the aquic inter-mound (**Figures 4** and **5**). Seasonal dry-down periods began in early summer [approximately day of year (DOY) 170] with the subsequent wet-up period beginning in late fall (approximately DOY 300), continuing through spring (**Figures 4** and **5**). Noticeable wet-up and dry-down periods have been recorded in previous research by Briggs and Knapp [5], who observed seasonal dry-down periods beginning in late summer and wet-up periods occurring in spring and early summer at depths of 25 and 100 cm over an 11-year period at the Konza Prairie. Additionally, the annual soil volumetric water content (VWC) fluctuations in the current study roughly followed the four phases of annual soil moisture as described by Illston et al. [35]. In Oklahoma, the statewide soil fractional water index (FWI) entered a moist plateau phase from November to mid-March, a transitional drying phase from mid-March to mid-June, an enhanced drying phase from mid-June to late August, and ending with the recharge phase from late August to November [35]. In the current study, the moist plateau period occurred between mid-February and May (**Figures 4** and **5**). During the moist plateau phase, volumetric water contents were at their largest and were relatively consistent due to reduced evaporation and evapotranspiration from low sun angles and dormant vegetation [35]. The transitional drying phase, characterized by a gradual decrease in VWC from increased evapotranspiration from growing vegetation [35], occurred from June to early July, followed by the enhanced drying stage from early July to early October. During the enhanced drying stage, soil VWCs decline sharply to their seasonal low due to continued evapotranspiration and limited inputs of water from

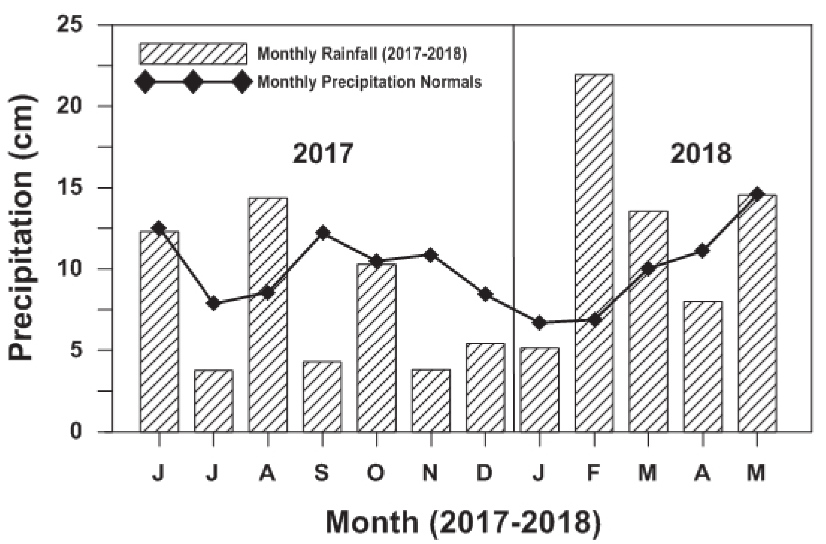

Figure 3.
Monthly precipitation recorded at the study site compared to the 30-year normal monthly precipitation for the region encompassing the study site from June 2017 to May 2018.

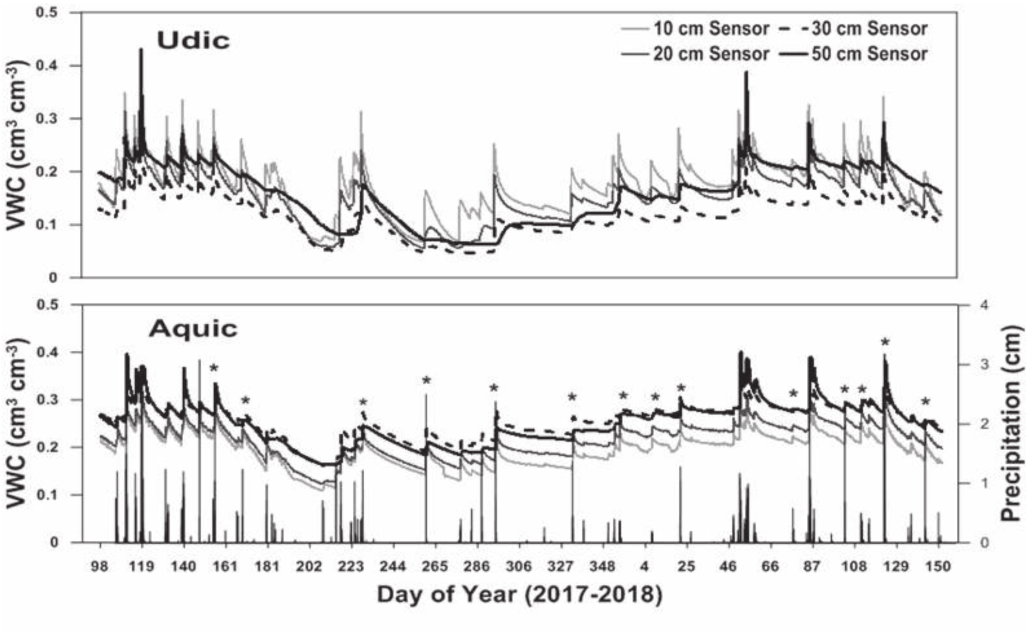

Figure 4.
Volumetric water content and precipitation over time with depth (10, 20, 30, and 50 cm) for the udic and aquic mound summit. Precipitation events denoted with an asterisk were used for statistical analysis.

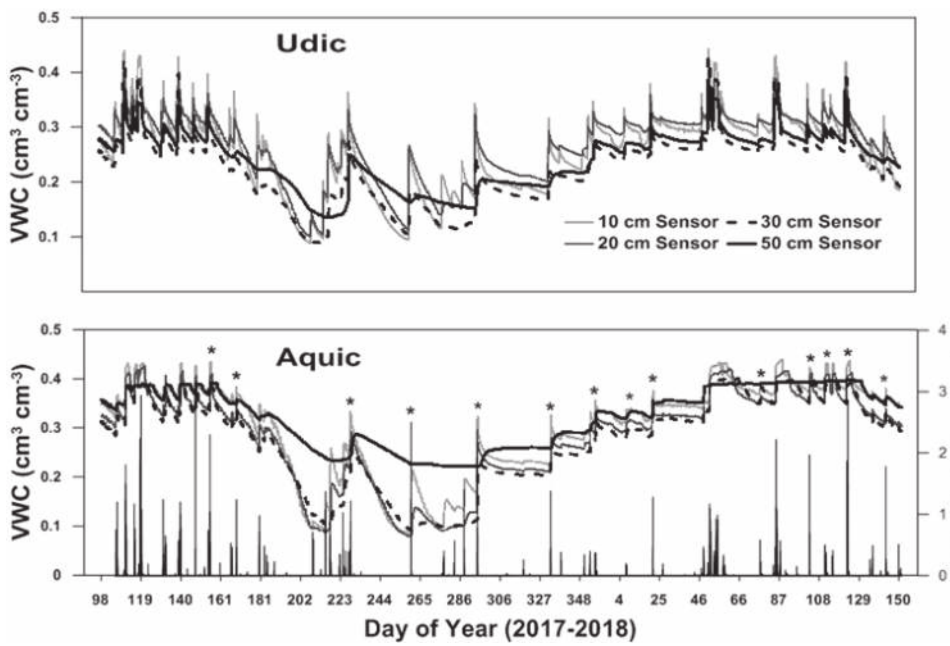

Figure 5.
Volumetric water content and precipitation over time with depth (10, 20, 30, and 50 cm) for the udic and aquic inter-mound. Precipitation events denoted with an asterisk were used for statistical analysis.

precipitation [35]. Lastly, the soil VWC gradually increased from early October to early February during the recharge phase, as a result of decreased evapotranspiration due to low sun angles and inputs of water from precipitation [35].

In general, the mound positions within the aquic soil had larger VWCs over time at respective depths than the corresponding mound position in the udic soil moisture regime (**Figures 4** and **5**). Additionally, the inter-mound positions generally contained larger VWCs at respective depths than the mound summit of the same soil moisture regime, as expected based on the soil morphological characteristics (**Figures 4** and **5**). The results of the study agree with observations [6, 7, 9] and measurements [8] of water content in mounded and inter-mound profiles from past research. In the Arkansas River Valley, in a silt loam surface, redox depletions were identified at the soil surface in inter-mound pedons, whereas depletions were not present in mounded soil profiles until a depth of 85 cm, indicating that inter-mound soils are generally wetter than mounded profiles [9]. Soil moisture was likely greater and retained longer in inter-mound soil profiles due to greater clay concentrations and lower saturated hydraulic conductivities typical of inter-mound soils than in mounded profiles [7, 36].

Volumetric water contents in the udic mound were generally largest at the 10-cm depth and lowest at the 30-cm depth, whereas VWCs were generally largest at either the 30- or 50-cm depths and smallest at the 10-cm depth in the aquic mound (**Figure 4**). Additionally, seasonal dry-down was more pronounced in the udic mound, in which VWCs at all depths fell below 0.1 $cm^3 cm^{-3}$, than the aquic mound, which recorded no VWCs lower than 0.1 $cm^3 cm^{-3}$ (**Figure 4**). Volumetric water contents in the udic inter-mound were generally largest at either the 10- or 20-cm depth and lowest at 30 cm, whereas VWCs were generally largest at the 10-cm depth during wet-up periods and at the 50-cm depth during periods of dry-down in the aquic inter-mound positions (**Figure 5**). As with the udic inter-mound, VWCs were generally lowest at 30 cm in the aquic inter-mound (**Figure 5**). The seasonal dry-down period was more pronounced in the aquic inter-mound than in the udic inter-mound, with exception of the 50-cm depth in the aquic inter-mound, which was not impacted by dry-down as dramatically as the 10-, 20-, and 30-cm depths (**Figure 5**).

The magnitude and frequency of response to precipitation events appeared to be larger for the surface sensors (i.e., 10 and 20 cm) than for the 30- and 50-cm sensors for each mound position (**Figures 4** and **5**). Additionally, the magnitude of response to a precipitation event was generally larger in the udic soil moisture regime than in the aquic soil moisture regime when similar mound positions were compared (**Figures 4** and **5**). Similar soil water content trends were noted in Briggs and Knapp [5], in which larger and more numerous maxima were observed over time in the 25-cm sensor than in the 100-cm sensor, indicating that soil near the surface was more influenced by wet-up and dry-down events than soil deeper in the profile. Surface soil layers likely exhibited larger decreases in VWC during dry-down events than subsurface layers due to losses of water through evapotranspiration and/or vertical drainage. Additionally, surface sensors likely responded to rainfall events more frequently than subsurface sensors due to redistribution of water in the soil profile. Most of the water that infiltrates into the soil surface from a precipitation event will likely percolate through the surface soil layers (i.e., 10 and 20 cm). However, the amount of water reaching the subsurface (i.e., 30 and 50 cm) soil layers may be diminished as water is extracted by plants, which would then require a larger precipitation event to occur before water contents at lower soil depths increase. In addition, subsurface soils may respond to fewer precipitation events because they are more influenced by additions of water from deeper in the soil profile (i.e., a seasonal high water table) as opposed to additions of water from the soil surface. The effect of a seasonal high water table on soil volumetric water content was clearly demonstrated at the 50-cm depth in the aquic inter-mound from approximately DOY 46 to 130 (**Figure 5**). From DOY 46 to 130, soil water contents in the 10-, 20-, and 30-cm depth fluctuated from multiple wet-up and dry-down events, whereas the 50-cm depth gradually increased with no distinct peaks, indicating that the 50-cm depth was more influenced by water moving upwards from deeper in the soil profile than from water moving downward from precipitation events.

3.2 Soil hydraulic properties

All soil hydraulic properties were affected by one or more or a combination of treatment factors evaluated (i.e., SMR, mound position within SMR, season, and/or soil depth). Maximum and minimum soil VWCs differed ($P < 0.05$) by depth within respective mound positions across SMRs (**Table 1**). Maximum soil VWC was numerically largest (0.39 cm^3 cm^{-3}) at the 10-cm depth in the aquic inter-mound and was significantly smallest (0.16 cm^3 cm^{-3}) at the 30-cm depth in the udic mound (**Figure 6**). Additionally, maximum soil VWCs were at least numerically greater in the aquic and udic inter-mound positions than in the corresponding mound summits at each depth (**Figure 6**). When respective mound positions were compared across SMRs, the maximum VWC was at least numerically greater in the aquic mound position than that of the udic mound position for a given depth, excluding the mound summit at the 10-cm depth (**Figure 6**).

The mean minimum soil VWC was numerically largest (0.29 cm^3 cm^{-3}) at the 50-cm depth in the aquic inter-mound and numerically smallest (0.11 cm^3 cm^{-3}) at the 30-cm depth in the udic mound (**Figure 6**). Additionally, the minimum soil VWC was at least numerically larger at respective depths at the inter-mound position than at the mound summit within the same SMR (**Figure 6**). When respective mound positions were compared across SMRs, the minimum VWC was at least numerically greater in the aquic than that of the udic mound position for a given depth (**Figure 6**).

Averaged over mound position within SMR and season, both maximum and minimum soil VWCs differed ($P < 0.05$) with depth across SMRs (**Table 1**). Mean maximum VWC was numerically largest (0.32 cm^3 cm^{-3}) at the 10-cm depth in the udic SMR and smallest (0.23 cm^3 cm^{-3}) in the udic SMR at the 30-cm depth. The maximum VWC was greater at each depth interval in the aquic than udic SMR, with exception of at the 10-cm depth, in which maximum VWC in the SMRs did

Source of variation	Max VWC	Min VWC	DDR
		P	
Soil moisture regime	0.001	0.003	0.016
Position within SMR [Pos(SMR)]	<0.001	0.005	0.714
Season (S)	0.959	0.062	0.355
Depth (D)	<0.001	0.001	<0.001
SMR × S	0.299	0.419	0.424
Pos × S(SMR)	0.667	0.310	0.852
SMR × D	<0.001	0.004	<0.001
SMR × D(Pos)	<0.001	0.001	0.122
S × D	0.003	0.561	0.014
SMR × S × D	0.765	0.142	0.850
Pos × S × D(SMR)	0.933	0.854	0.906

Table 1.
Summary of the combined effects of soil moisture regime (aquic and udic) position within soil moisture regime (summit or inter-mound within the aquic and udic soil moisture regime), season (wet and dry), and depth (10, 20, 30, and 50 cm) on soil maximum volumetric water content after a rainfall event (max VWC), minimum volumetric water content after a rainfall event (min VWC), dry-down rate (DDR), and lag time (LT) in a mounded native tallgrass prairie in the Ozark highlands region of Northwest Arkansas.

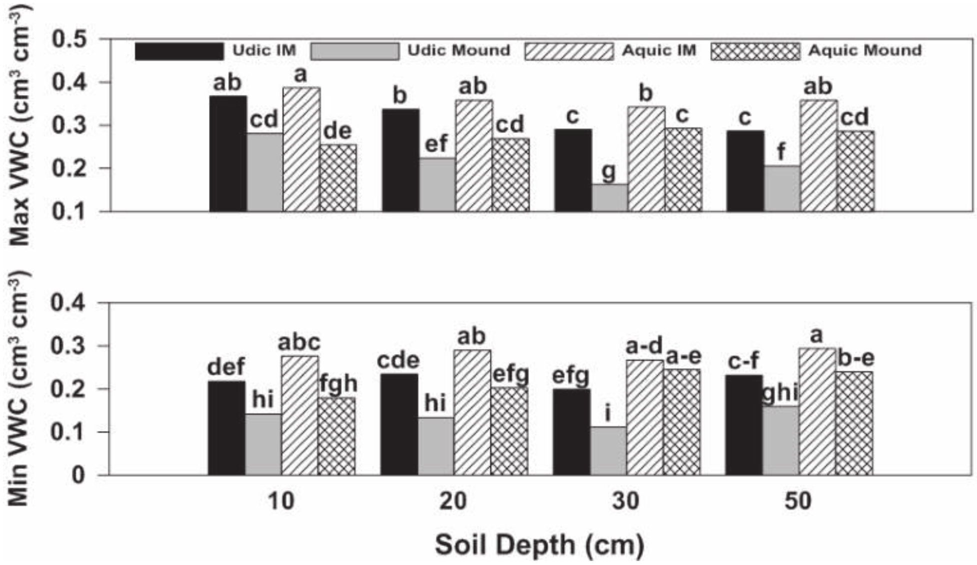

Figure 6.
The effects of soil depth averaged over mound position and soil moisture regime on maximum volumetric water content (Max VWC) and minimum volumetric water content (Min VWC) for selected precipitation events in aquic and udic soils in a mounded native tallgrass prairie in the Ozark highlands region of Northwest Arkansas. Means with different letters are significantly different at the 0.05 level.

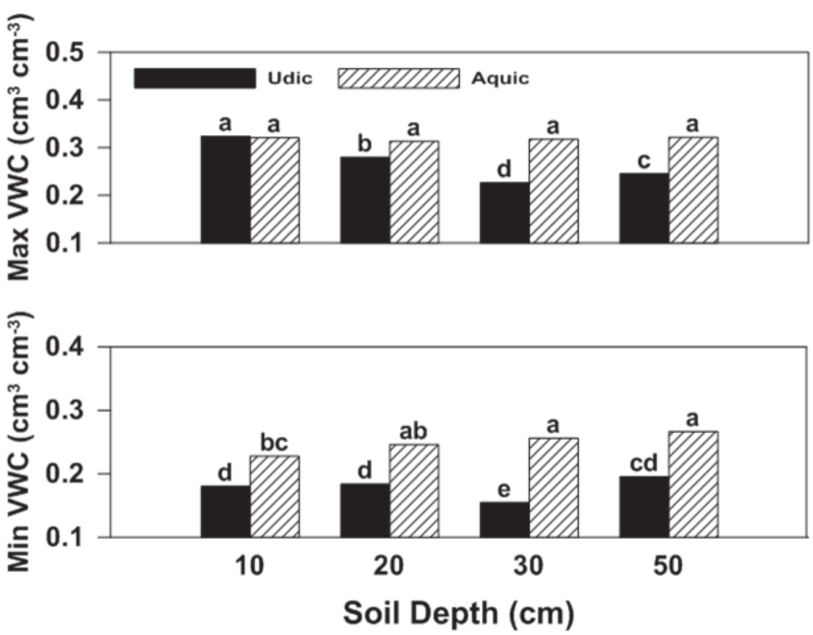

Figure 7.
Soil depth effects on maximum volumetric water content (max VWC) and minimum volumetric water content (Min VWC) for selected precipitation events in aquic and udic soils in a native tallgrass prairie containing prairie mounds in the Ozark highlands region of Northwest Arkansas. Means for a soil property with different letters are significantly different at the 0.05 level.

not vary. Minimum soil VWC was numerically largest (0.27 cm^3 cm^{-3}) at the 50-cm depth in the aquic and smallest (0.16 cm^3 cm^{-3}) at the 30-cm depth in the udic SMR (**Figure 7**). Compared across SMRs, the aquic soil contained a minimum VWC that was, on average, 1.4 times larger than that of the udic soil (**Figure 7**).

Averaged over mound position, SMR, and position within SMR, maximum VWC differed (P = 0.003) between seasons by depth (**Table 1**). Maximum soil VWC was largest (0.33 cm^3 cm^{-3}) during the dry season at 10 cm and numerically smallest (0.27 cm^3 cm^{-3}) during the dry season at 30 cm (**Figure 8**). When seasons were compared, maximum VWC was larger in the dry season than wet season at 10 cm, larger in the wet season than the dry season at 50 cm, and did not vary by season at depths of 20 and 30 cm (**Figure 8**). Additionally, averaged over SMR, depth, and season, maximum and minimum VWCs differed ($P < 0.05$) between mound positions within SMRs (**Table 1**). Maximum VWC was largest (0.36 cm^3 cm^{-3}) in the aquic inter-mound and smallest (0.22 cm^3 cm^{-3}) in the udic summit (**Figure 9**). The aquic soil contained larger maximum VWCs at each mound position (**Figure 9**). Similar to the maximum VWCs, minimum VWC was largest (0.28 cm^3 cm^{-3}) at the aquic inter-mound and smallest (0.14 cm^3 cm^{-3}) at the udic summit (**Figure 9**). The aquic SMR contained a larger minimum VWC than the udic soil when respective mound positions were compared (**Figure 9**).

The aquic soil likely had larger maximum and minimum VWCs than the udic soil based on characteristics of the two soil series. The internal drainage of the

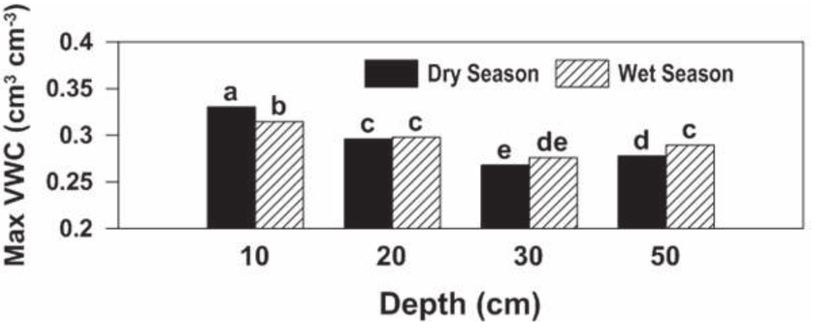

Figure 8.
Soil depth effects on maximum volumetric water content for selected precipitation events during the wet and dry season in a native tallgrass prairie containing prairie mounds in the Ozark highlands region of Northwest Arkansas. Means with different letters are significantly different at the 0.05 level.

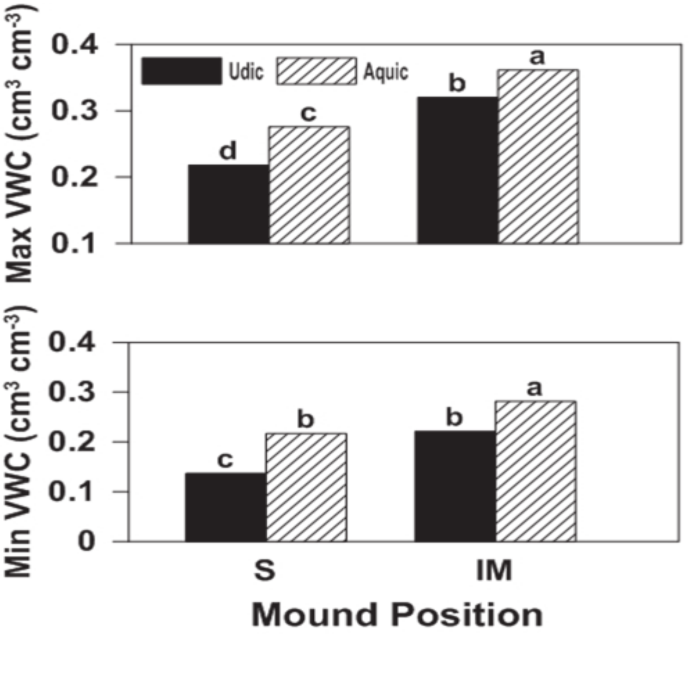

Figure 9.
Mound position within soil moisture regime effects on maximum volumetric water content (Max VWC) and minimum volumetric water contents (Min VWC) for selected precipitation events in native tallgrass prairie with prairie mounds in the Ozark highlands region of Northwest Arkansas. Means for a soil property with different letters are significantly different at the 0.05 level.

aquic SMR (i.e., Taloka soil series) is characterized as somewhat poorly drained, which would retain more water than the moderately well-drained Jay soil series (i.e., udic SMR). Similar trends in soil moisture were noted by Henninger et al. [37] in east-central Pennsylvania across six soil series [i.e., Klinesville (Lithic Dystrudepts), Calvin (Typic Dystrudepts), Leck Kill (Typic Hapludults), Hartleton (Typic Hapludults), Albrights (Aquic Fragiudalfs), and Alvira (Aeric Fragiaquults)]. The somewhat poorly drained Alvira soil maintained greater soil moisture levels than the moderately well- to well-drained soils for the duration of the study [37]. Differences in maximum and minimum VWCs between the mound summit and inter-mound mound positions likely resulted from differing clay concentrations, soil organic matter (SOM) contents, and estimated bulk densities. Inter-mound clay concentrations were at least numerically larger than that in the corresponding mound summit position at each 10-cm depth interval to a depth of 90 cm in both SMRs (**Table 2**). Increased clay concentrations would result in greater water-holding capacity, accounting for the greater maximum and minimum VWCs in inter-mound mound positions. Additionally, larger maximum and minimum VWCs in the inter-mound position may be attributed to greater SOM. Soil organic matter has the ability to absorb water and promote soil aggregation, both of which enhance soil water-holding capacity. According to Scott et al. [38], for every 1% of SOM, the soil can hold 154,340 liters of plant-available water per hectare to a depth of 1 m. In the current study, SOM contents were at least numerically larger

Soil property	Depth (cm)	Udic		Aquic	
		Summit	Inter-mound	Summit	Inter-mound
Clay (g g^{-1})	0–10	0.05 t†	0.06 st	0.07 rst	0.09 p-t
	10–20	0.06 st	0.07 rst	0.08 q-t	0.12 n-r
	20–30	0.06 st	0.11 o-s	0.10 p–t	0.17 k-n
	30–40	0.07 rst	0.18 j-m	0.09 p–t	0.20 h-k
	40–50	0.08 q-t	0.25 d-h	0.10 p–t	0.23 f-j
	50–60	0.09 p-t	0.27 b-f	0.11 o-s	0.26 c-g
	60–70	0.10 p–t	0.30 a-d	0.10 p–t	0.27 b-f
	70–80	0.12 n-r	0.33 a	0.13 m-q	0.31 abc
	80–90	0.13 m-q	0.30 a-d	0.14 l-p	0.32 ab
SOM (Mg ha^{-1})	0–10	50.3 cd	59.7 a	43.1 efg	57.1 ab
	10–20	38.2 g-l	47.7 de	37.2 i-m	39.0 g-k
	20–30	34.7 k-o	41.6 f-i	33.7 l-p	32.5 m-r
	30–40	35.4 j-n	36.6 i-m	33.6 l-p	28.3 q-x
	40–50	30.7 n-t	29.7 o-u	29.9 o-u	24.7 u-B
	50–60	28.3 q-x	25.5 t-A	27.5 r-x	23.3 x-C
	60–70	28.3 q-x	29.0 p-w	29.0 o-w	23.4 x-C
	70–80	23.3 x-C	28.3 q-x	23.8 w-B	20.2 BCD
	80–90	21.4 ABC	27.6 r-x	21.5 ABC	20.1 BCD

†*All means for a soil property followed by different letters are significantly different at the 0.05 level.*
Adapted from Durre et al. [36].

Table 2.
Summary of the combined effects of soil moisture regime (aquic and udic), mound position (summit and inter-mound), and soil depth (0–90-cm in 10-cm intervals) on soil clay concentrations and soil organic matter in a native tallgrass prairie with prairie mounds in the Ozark highlands region of Northwest Arkansas.

in inter-mounds to a depth of 20 and 40 cm for the aquic and udic soil, respectively, which would result in a larger water-holding capacity for the inter-mounds than for the mounds at those depths (**Table 2**). Soil bulk density was at least numerically larger at each depth interval in the mound summit, which would account for the lower maximum and minimum VWCs than in the inter-mound position (**Table 3**). Increased bulk densities result in a lower soil water-holding capacity due to decreased total porosity.

Averaged across mound position, SMR, and position within SMR, the rate of dry-down differed (P = 0.01) by season with depth (**Table 1**). The soil dry-down rate was greatest (0.029 $cm^3\ cm^{-3}\ day^{-1}$) during the dry season at 10 cm and numerically lowest (0.009 $cm^3\ cm^{-3}\ day^{-1}$) during the wet season at 30 cm (**Figure 10**). Dry-down rates were greater during the dry season than the wet season at 10 cm, but no seasonal differences occurred at the 20- or 30-cm depth (**Figure 10**). Averaged across mound position within SMR and season, soil dry-down rate differed (P < 0.01) with depth between SMRs (**Table 1**). Soil dry-down rates were largest (0.032 $cm^3\ cm^{-3}\ day^{-1}$) in the udic at 10 cm and numerically smallest (0.008 $cm^3\ cm^{-3}\ day^{-1}$) in the aquic SMR at 30 cm (**Figure 10**). Though soil dry-down rates were larger in the udic than the aquic SMR at 10 cm, no differences in dry-down rate between SMR were noted at the 20- and 30-cm depths (**Figure 10**).

Soil dry-down rates were likely larger during the dry season at 10 cm due to evapotranspiration. Water added to the soil during the dry season will likely be quickly removed by growing plants, which would increase the rate of soil dry-down.

Soil property	Depth (cm)	Summit	Inter-mound
BD ($g\ cm^{-3}$)	0–10	1.27 k†	1.14 m
	10–20	1.37 gh	1.30 jk
	20–30	1.40 efg	1.35 hi
	30–40	1.40 efg	1.37 gh
	40–50	1.43 cde	1.39 fg
	50–60	1.45 abc	1.39 fg
	60–70	1.44 bcd	1.38 fgh
	70–80	1.47 ab	1.38 fgh
	80–90	1.48 a	1.40 efg
K_{sat} ($mm\ hr.^{-1}$)	0–10	43.7 c	63.4 a
	10–20	31.1 def	32.5 de
	20–30	26.2 fgh	20.1 ijk
	30–40	25.0 ghi	12.2 l-q
	40–50	19.9 jk	7.0 p–t
	50–60	17.5 j-m	6.1 rst
	60–70	17.8 jkl	5.9 st
	70–80	13.3 l-o	4.6 t
	80–90	11.8 m-s	4.9 t

†*All means for a soil property followed by different letters are significantly different at the 0.05 level.*
Adapted from Durre et al. [36].

Table 3.
Summary of the combined effects of mound position (summit and inter-mound) and depth (0–90-cm in 10-cm intervals) on estimated bulk density (BD) and estimated saturated hydraulic conductivity (K_{sat}) in a native tallgrass prairie with prairie mounds in the Ozark highlands region of Northwest Arkansas.

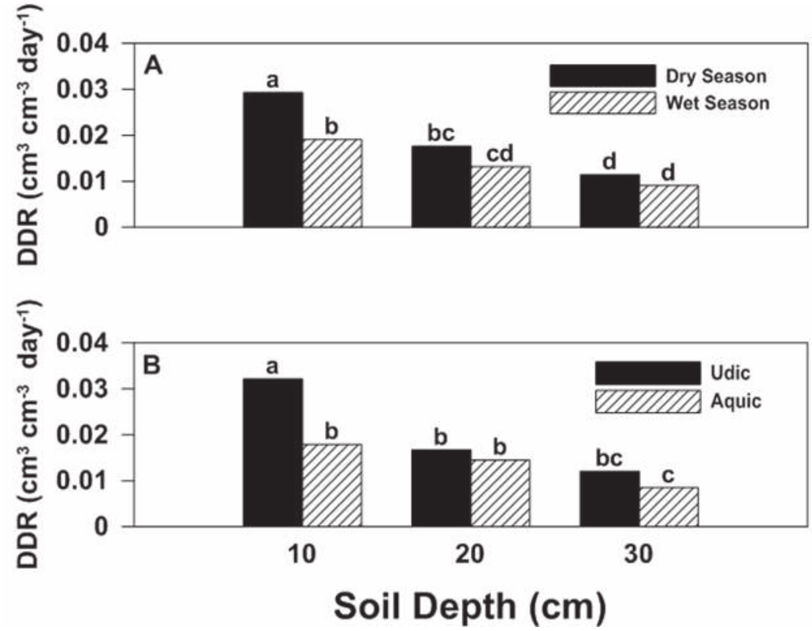

Figure 10.
Soil depth effects on dry-down rates of selected precipitation events during the (A) wet and dry season and in (B) udic and aquic soil moisture regimes in a native tallgrass prairie containing prairie mounds in the Ozark highlands region of Northwest Arkansas. Means with different letters are significantly different at the 0.05 level.

A study conducted by Henninger et al. [37] in east-central Pennsylvania noted that water entering the top 15 cm of soil during the summer months was quickly depleted by evapotranspiration resulting in annually low soil moisture contents in each soil series studied. As evapotranspiration decreased in September, the soil moisture contents increased indicating that dry-down rates were slowing with changing seasons [37]. Additionally, soil dry-down rates were likely at least numerically larger at 10 cm than at 30 cm due to decreased saturated hydraulic conductivities with depth (**Figure 10**, **Table 3**).

3.3 Vegetation differences

Three vegetative properties were affected by one or more or a combination of treatment factors evaluated (i.e., SMR, mound position, and sample date). Total dry matter (DM) differed (P = 0.04) between SMRs across mound position over time (**Table 4**). Total DM was numerically greatest (8489 kg ha^{-1}) at the aquic summit in August 2018 and numerically smallest (1280 kg ha^{-1}) at the aquic inter-mound in May 2018 (**Figure 11**). Total DM production was similar at corresponding mound positions between the aquic and udic soils for every treatment combination excluding the aquic and udic mound summits in June and August 2017, in which the udic mound summit produced more DM than the aquic summit (**Figure 11**). Additionally, the mound summit positions generally produced more biomass than the inter-mound positions in both soil moisture regimes (**Figure 11**). Total DM was at least numerically lowest for each respective mound position-SMR combination in May 2018 than all other sampling dates (**Figure 11**).

Averaged across mound position, total DM varied (P = 0.03) among SMR-biomass type combinations over time (**Table 5**). Total DM was numerically greatest (5027 kg ha^{-1}) in the aquic-grass combination in August 2018 and numerically least (814 kg ha^{-1}) in the aquic-grass combination in May 2018 (**Figure 11**). For the aquic SMR, grasses significantly outproduced other species on both end-of-season

Source of variation	Grass DM	Forb DM	Total DM	PG
		P		
Soil moisture regime	0.856	0.369	0.128	0.812
Position (P)	0.027	0.097	<0.001	0.951
Sampling date (SD)	<0.001	0.142	<0.001	0.065
SMR × P	0.837	0.156	0.096	0.275
SMR × SD	0.017	0.550	0.161	0.352
P × SD	0.537	0.878	0.071	0.976
SMR × P × SD	0.077	0.956	0.035	0.502

Table 4.
Summary of the combined effects of soil moisture regime (aquic and udic), position (mound summit or inter-mound), and sampling date (2 June 2017, 17 August 2017, 19 May 2018, and 16 August 2018) on grass dry matter (grass DM), forb dry matter (Forb DM), total dry matter (total DM), and percent grass (PG) in a mounded native tallgrass prairie in the Ozark highlands region of Northwest Arkansas.

samples, whereas no differences in DM occurred on either early season sample (**Figure 11**). For the udic soil, grasses outproduced other species in August 2017, with no differences occurring on June 2017 or during the 2018 season (**Figure 11**). Grasses outproducing other plant species is typical of tallgrass prairie ecosystems, as grasses generally account for most of the biomass production and forbs provide species richness and diversity [3, 39].

Averaged across mound position, grass DM differed (P = 0.02) between SMRs over time (**Table 4**). Grass DM was numerically largest (5027 kg ha^{-1}) among all treatment combinations in the aquic soil moisture regime in August 2018 and smallest (814 kg ha^{-1}) in May 2018 in both soil moisture regimes, which did not differ (**Figure 11**). Grass DM was similar between the aquic and udic soils at each sampling date excluding August 2018, in which the aquic soil produced more DM than the udic soil (**Figure 11**). Averaged across SMR and sample date, grass DM differed (P = 0.03) between mound positions, with the mound summit producing 3216 kg ha^{-1} than the 2331 kg ha^{-1} of grass DM in the inter-mound position.

Previous studies analyzing the effect of soil moisture on biomass production have indicated that soil moisture influences plant biomass production. Total above- and belowground biomass had a significant positive correlation with soil moisture content from 0 to 30 cm below the soil surface across 81 grassland ecosystems in the Loess Plateau, China [40]. Similarly, a correlation study conducted by Wu et al. [41] in the Qinghai-Tibetan Plateau, China, concluded that aboveground biomass significantly increased with increased soil moisture in the 0–10- (R^2 = 0.83) and 10–20-cm (R^2 = 0.79) depth intervals. Briggs and Knapp [5] analyzed the influence of soil moisture on biomass production in burned and unburned treatments at Konza Prairie and concluded that soil moisture did not affect grass or forb net primary productivity in long-term unburned watersheds. Conversely, soil moisture at depths <1 m were determined to significantly increase grass and total NPP at annually burned sites [5]. Although the aquic summit generally contained more water than the udic summit, the udic summit produced more total DM than the aquic summit during the 2017 season (**Figure 11**). Increased biomass production in the udic mound summit may have resulted from greater soil organic matter contents to a depth of 60 cm in the udic summit (**Table 2**). Additionally, the aquic and udic inter-mounds exhibited no difference in total DM production, indicating that soil moisture differences between the aquic and udic inter-mound did not affect the biomass production (**Figure 11**).

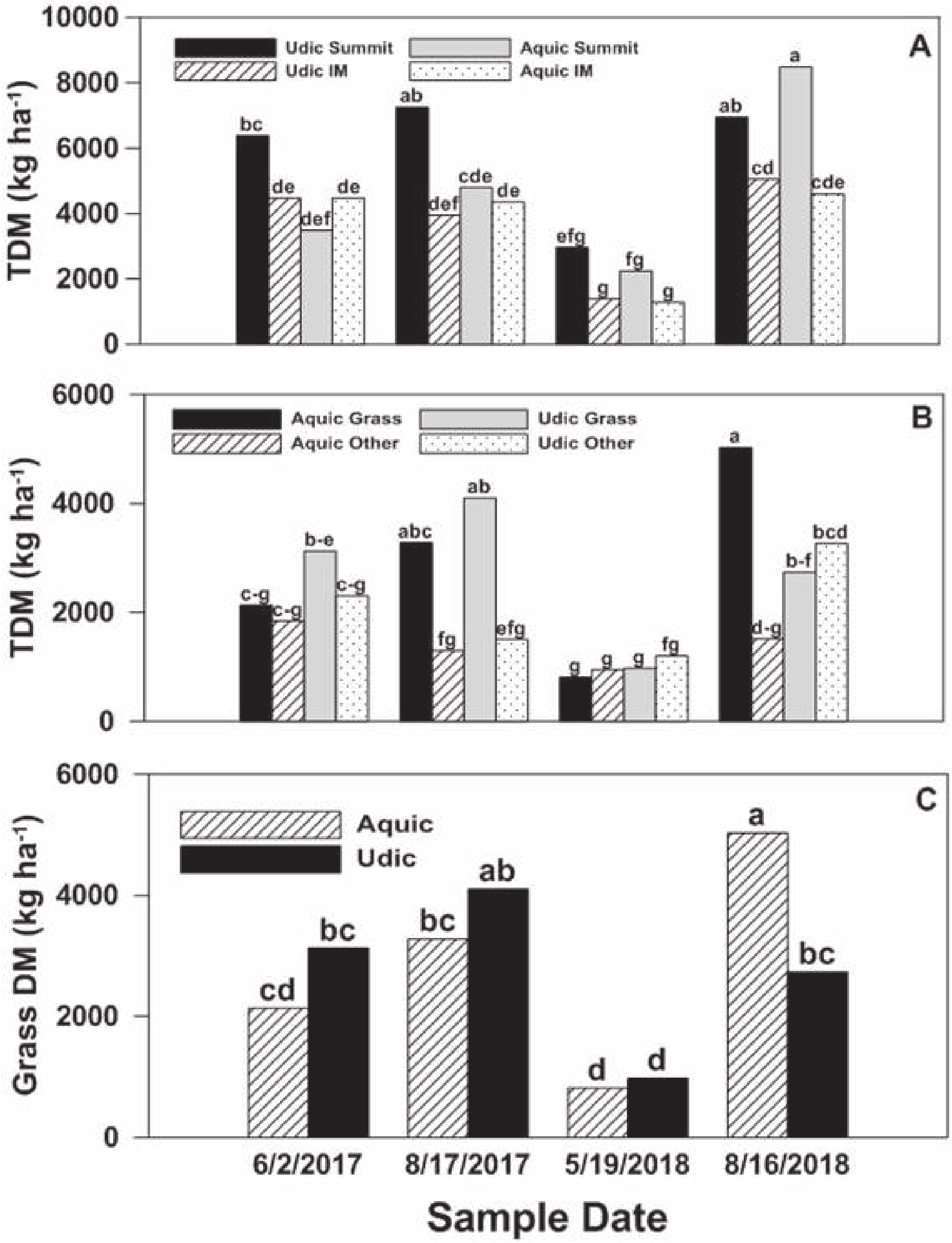

Figure 11.
Sampling date, mound position, and soil moisture regime effects on total dry matter (TDM) (A), sampling date, soil moisture regime, and biomass type effects on total dry matter (TDM) (B), and sampling date and soil moisture regime effects on grass dry matter (grass DM) in a native tallgrass prairie with prairie mounds in the Ozark highlands region of Northwest Arkansas (C).

The difference in DM production between the two early season samples (i.e., June 2017 and May 2018; **Figure 11**) likely resulted from the prescribed burn performed in January 2017. The prescribed burn eliminated dead plant material (i.e., necromass) from the ecosystem and provided the soil with more direct sunlight, which then stimulated plant growth for the 2017 season [42, 43]. The necromass from the increased-biomass-producing 2017 season then shaded the soil surface, slowing soil warming and reducing light availability to newly emerging plants, which would account for the lower total DM production in May 2018 [44].

Source of variation	TDM
	—*P*—
Soil moisture regime	0.128
Position (P)	0.011
Sampling date (SD)	<0.001
Biomass type (BT)	0.001
SMR × P	0.377
SMR × SD	0.689
P × SD	0.559
SMR × BT	0.232
P × BT	0.814
SD × BT	0.035
SMR × P × SD	0.457
SMR × P × BT	0.257
SMR × SD × BT	0.028
P × SD × BT	0.969
SMR × P × D × BT	0.341

Table 5.
Summary of the combined effects of soil moisture regime (aquic and udic), position (mound summit and inter-mound), sampling date (2 June 2017, 17 August 2017, 19 May 2018, and 16 August 2018), and biomass type (grass and other species) on total dry matter (TDM) in a mounded native tallgrass prairie in the Ozark Highlands region of northwest Arkansas.

The results of the study are supported by past research analyzing herbage production on mound and inter-mound mound positions [6, 12]. Mounded mound positions seeded with intermediate wheatgrass (*Thinopyrum intermedium*), crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.], smooth brome (*Bromus inermis* Leyss.), Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski], and big bluegrass (*Poa secunda* J. Presl) produced 94, 180, 323, 358, and 542% greater herbage yields for the respective plants than the inter-mound positions seeded with the same plants [12]. Additionally, similar to the results of this study, annual forage production on mounded soils in eastern Oklahoma was 4997 kg ha^{-1} compared with 3227 kg ha^{-1} produced by inter-mound soil [10]. Researchers have suggested that mounded soils likely produce larger quantities of biomass than inter-mound soils as a result of enhanced soil fertility and larger quantities of plant-available water present in mounded profiles due to a larger volume of soil in mounded profiles than in inter-mound profiles [12, 45]. According to McGinnies [12], mounded soils contained 66% more nitrogen than inter-mound positions, which would account for mounds producing larger quantities of biomass. At the current site, soil total nitrogen was unaffected by mound position [36]. Soil pH was similar between and across soil moisture regimes for mound summit and inter-mound positions, with exception of the udic mound and udic inter-mound, in which the inter-mound had a more alkaline pH [36]. The water contents in the current study may have been too large in the inter-mounds to promote optimal plant growth, which would explain why herbage production was generally at least numerically larger in the mound summits of both soil moisture regimes. Mound summits had deeper depths to redox features and saturated or near-saturated conditions than the corresponding inter-mound positions, which may have better promoted vegetative growth.

Vegetation comprising the udic mound was 30.7% similar to the vegetation present at the udic inter-mound position. When mound positions were compared across SMRs, the aquic and udic mound summits exhibited 42.8% similarity, whereas the aquic and udic inter-mounds were only 29.6% similar. Lastly, vegetation comprising the aquic mound was 41.3% similar to that of the aquic inter-mound position. The results of the study are supported by previous research analyzing mound summit and inter-mound vegetation [11]. Vegetational similarity between mounds and the adjacent non-mounded prairie area was reported as 35.2% at Kalsow Prairie in Iowa, which is within the range reported in the current study [11]. Scientists have hypothesized the reason for the dissimilarity between the mound positions is due to the microtopographic variation of the mounds compared to inter-mound soils [11, 15]. Del Moral and Deardorff [15] noted that hairy cat's ear (*Hypochaeris radicata* L.) only grew in micro-depressions located on mounds. Additionally, Del Moral and Deardorff [15] determined that plant species, such as racomitrium moss [*Racomitrium canescens* (Hedw.) Brid.], responded to changes in drainage and insolation on mounds, which directly influences soil moisture availability.

Total diversity, species richness, and species evenness were unaffected ($P > 0.05$) by any of the treatment factors (i.e., mound position and SMR) evaluated. Total plant diversity was numerically lowest (0.51) at a udic summit, numerically largest (2.10) at an aquic inter-mound and averaged 1.40 throughout the entire prairie area. Species richness was numerically lowest (5.0) among multiple mound positions, numerically largest (14) at a udic inter-mound, and averaged 7.8 across the entire prairie area. Species evenness was numerically smallest at a udic summit (0.32), numerically largest at an aquic summit (0.89), and averaged 0.70 across the entire prairie area. The plant diversity indices studied may have been influenced by the sampling date. Plants were sampled and identified at the beginning of the growing season, and plant DM during this period was at least numerically lower than on all other sample dates. Additionally, many plants had not yet flowered by this early sampling date. Due to reduced biomass production during the early season, plant diversity indices may have been best represented from plant samples collected during the late-season sample, although the current study still provides valuable insight on plant diversity and species richness and evenness.

Studies analyzing plant species diversity, richness, and evenness in mounded ecosystems are not numerous; however, the results of this study agree with past research comparing plant species richness between mound and inter-mound positions [10, 11, 46]. In eastern Oklahoma, no appreciable difference in species richness occurred between mounded and inter-mound positions, with 18 plants identified in the inter-mound and 13 species identified in the mounded position [10]. Similarly, 51 plant species were identified on mounded positions compared to 49 species in the adjacent prairie at Kalsow Prairie in Iowa [11].

Research has suggested that soil moisture influences plant diversity and species richness and evenness [40, 41]. Across 81 grassland sites in the Loess Plateau of northwestern China, Shannon-Wiener diversity and species richness were significantly and positively correlated with soil water storage in the top 30 cm of soil, while species evenness was correlated to water storage from the 0- to 20-cm depth [40]. Additionally, the Shannon-Wiener diversity, Margalef's index of species richness, and Whittaker's index of species evenness exhibited significant positive relationships with soil water content for seedlings, saplings, and adult tree species in a tropical, dry, deciduous forest in the Vindhyan Highlands, India [47]. Among the various plant growth stages (i.e., seedlings, saplings, and adults), soil water content accounted for 65–77% of the variability in plant diversity, 39–61% of the variability in species richness, and 60–68% of the variability in species evenness [47]. Contrary to the previous studies, despite plant aboveground biomass, vegetative cover, and plant height increasing with soil moisture, plant species richness exhibited an inverse relationship with soil water content in an alpine wetland in the Maqu Wetland Protection Area, China [41]. It was hypothesized that large quantities of soil moisture and species density in the alpine wetlands allowed dominant plant species to outcompete other species, resulting in lower plant species richness [40, 41]. The nonsignificant diversity indices in the current study may be a result of the early season sampling opposed to soil moisture differences, as past research has shown that plant diversity, species richness, and species evenness are directly or inversely related to soil moisture gradients [40, 41, 47].

4. Conclusions

This field study demonstrated that soil hydraulic and vegetative properties differed among soil moisture regime, site position, soil depth, time, and their treatment interactions. The results of this study support the hypothesis that maximum VWCs would increase with depth and be greater in the inter-mound than in the mound positions, whereas VWC minima would be the lowest near the soil surface and in mound positions than being deeper in the profile and in inter-mound positions, respectively. The results of this study support the hypothesis that soil maximum and minimum VWCs would be at least numerically larger in the aquic SMR for a given mound position than in the corresponding udic position. Results did not support the hypotheses that soil dry-down rates would be largest in the mound summits and decrease with depth. However, results partially supported the hypotheses that dry-down rates would be larger in the aquic than udic SMR and be larger during the wet than dry season.

The results of the study did not respectively support the hypotheses that (i) total vegetation diversity would be greatest in the inter-mound and in the udic SMR, (ii) species richness would be greatest at the inter-mound position in both SMRs, and (iii) species evenness would be greatest on the mound summit in both SMRs. Additionally, the hypothesis that total aboveground plant productivity would be greatest on the mound summit than on the inter-mound position on each sampling date and that grasses would be more abundant than other species at mound summit and inter-mound positions at each sampling date was however partially supported. Lastly, results did not support the hypothesis that total aboveground plant productivity would be greater in the aquic than udic SMR at each sampling date.

The study clearly demonstrated that soil volumetric water content and vegetative properties differed among mound positions and between SMRs within the top 50 cm of soil over time. Therefore, prairie management and restoration activities need to account for differing soil moisture regimes and mound topographies in order to be most successful. This study has provided detailed insight into water dynamics and vegetative properties in mounded tallgrass prairie ecosystems; however, additional research detailing soil water contents and vegetation in mounded ecosystems is needed as research on the topic is limited. Research should be continued at Chesney Prairie to monitor the effects of burning the prairie every 3 years on soil physical and chemical properties and vegetation in the mounded tallgrass prairie. Additionally, future research should be focused on identifying additional mounded, native tallgrass prairie fragments to sample across the United States to determine how physical and chemical properties of soil and vegetation in mounded ecosystems differ geographically.

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Conflict of interest

There are no conflicts of interest to declare.

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