Rock Movement on the Konza Prairie: Bison acting as Geomorphic Agents

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Abstract

There has always been a lack of knowledge about animals acting as geomorphic agents especially larger animals such as the American Bison. The purpose of this research was to amend that and add new knowledge to the database of information involving geomorphic agents. Our goal was to investigate if bison act as geomorphic agents by either forcibly pressing rock fragments down into the surface of a hillslope or kicking rocks when they make their way down, up, or across the hillslope. We tested our theory by creating two sets of transects where rocks were placed evenly along lines parallel to slope. From there, we monitored the rocks for four weeks, consistently checking on them to see if there had been any movement. Based on our data, we conclude that bison have a relatively large number of interactions with rocks on the Konza Prairie and do have a high likelihood of acting as geomorphic agents.

Introduction

Research concerning the once expansive tallgrass prairie ecosystem of the Great Plains has been the focus of recent scientific inquiry across several disciplines, including biology and geology, due to the diversity and adaptability of the ecosystem (Ranglack et al., 2017). At the center of North America exists one of the most diverse ecoregions, the Flint Hills of eastern

Kansas. This ecoregion contains an expansive array of native flora and fauna that have survived under the harshest prairie conditions. The Flint Hills were once home to millions of free ranging bison that helped shape and cultivate the prairie landscape (Meaghe, 1986). Our understanding of the impact these large herds of bison once had on the Flint Hills landscape is limited due to the lack of early documentation. Recently through extensive research, scientists have found that certain bison behaviors such as wallowing and large herd movement erode the topsoil of the prairie environment (Jung, 2017). Although we know that bison act as agents of geomorphic change due to these common herd behaviors, little research exists to determine how bison impact the movement of rock fragments on the surface of the soil. It is only assumed that bison play a role in the movement of rock with little research and literature to support this claim. Thus, our understanding of bison's impact towards the movement of rock fragments in general, is extremely limited as almost no research on the subject has been conducted.

Similar to other regions of the Great Plains, the Flint Hills contain relatively flat rock and rock fragments along the hillslopes, acting as an armor preventing further soil erosion (Hancock, 2007; Knapp and Oviatt, 1998; Smith, 1991). This rock and sediment can be seen throughout the Flint Hills after annual grassland burns are conducted, exposing the rock to natural elements and wildlife. With the free ranging bison located at the Konza Prairie in certain watersheds, we hypothesize that an interaction between the soil armor of large, relatively flat, rocks and the bison herd will occur. Due to the lack of research, we decided to look further into the correlation between bison movement and sediment movement across the grassland hillslopes containing loose rock. Our research is focused on a small portion inside the Flint Hills known as the Konza Prairie Biological Research Station or the Konza Prairie. The Konza Prairie is the site of our research due to the large amount of preserved prairie grasslands with very little impact from surrounding agriculture. Containing a small herd of bison, we may be able to find a preliminary connection between bison movement and sediment movement on hillslopes of the study area.

The Konza Prairie was studied to answer a two-part question developed by our research group involving the bison herds environmental role in the Flint Hills region as they traverse across the landscape. More specifically, do bison herds impact the downward movement of rock fragments on hillslopes? Following the main question of our research, a second question is addressed stating, if there is evidence of rock movement in correlation to an interaction with the bison, what is the magnitude of this movement?

Background

Natural History of Bison

Historically, bison have lived and called the Tallgrass Prairie home for millions of years. The earliest signs of bison seen in North America dates back 2.5 million years ago when the ancient ancestors of the modern bison migrated from Eurasia to North America. This period, known as the Pleistocene epoch or the Last Ice Age, began 2.5 million years ago and ended around 11,000 years ago. The largest mammal migration from Russia to Alaska occurred during this time due to land bridges or ice that connects large amounts of land normally separated by water. Following the migration of these animals across from Asia into North America, the largest ever known species of bison, referred to as *Pletobos*, evolved into the modern day North American bison (*Bison bison)* (Meagher, 1986). Along with the steppe bison and mountain bison, the North American bison (*Bison bison),* is one of the last species of bison still seen around the world today (Guthrie, 1970).

Once humans migrated into the Tallgrass Prairie, we can find historical cave paintings from the early Paleoindians detailing the presence of large herds of bison (Ritterbush, N.D). It is believed that during this time, bison frequented the Tallgrass Prairie due to the abundance of prairie grasses like big bluestem (*Andropogon geradii*) and little bluestem (*Schizachyrium scoparium*) as a favorited food source (Ritterbush, N.D.) Due to the abundance of these prairie grasses, it can be observed that bison stick to a defined grazing pattern often following the same paths leading to favorited sites for food, water, and breeding grounds (Schuler et al., 2006). This pattern, represented in Figure 1, shows the bison's preferred primary range and the max secondary range depending on the availability of natural resources during the late Pleistocene.

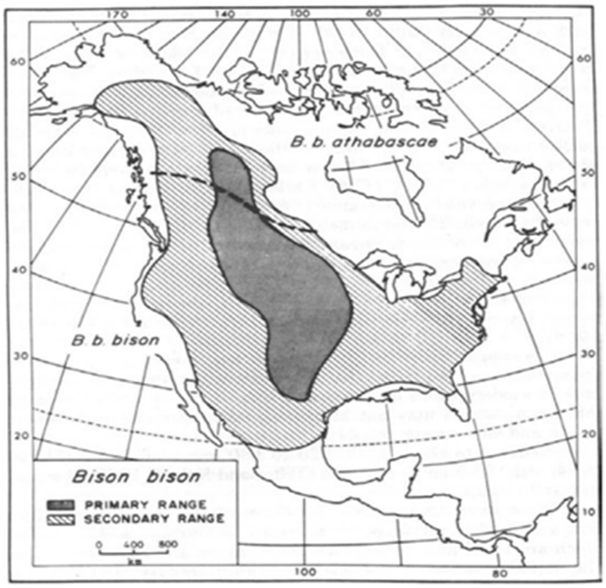

Figure 1- *Bison bison* historical range during the late Pleistocene with primary range in central North American grasslands extending out to maximum secondary ranges (Meagher, 1986). The darker gray color represents the primary range of the bison, and the striped area represents their secondary range.

Towards the end of the Pleistocene, we see a decline in large mammals across the entire world known as the megafaunal extinction. In the case of the bison, we see a dramatic loss in numbers throughout the Tallgrass Prairie during this time. Around 8,500 years ago, the number of bison located in the Tallgrass Prairie were on a steady incline, but due to unknown reasons, scientists have noticed a sudden decline of mammal species in the Tallgrass Prairie (Flores, 2017). Scientists believe that this decline could be due to several factors including a maxed-out land carrying capacity, loss of natural predators, changes in the ecosystem and later, the introduction of European immigrants (Flores, 2017). As we approach closer to the present we can see through the accounts of settlers and Native American tribes the large decline within the past three hundred years. From the first-hand accounts of the Comanche and Kaw Native American tribes, we can see that substantial portions of bison herds were still present but declining due to unknown reasons to the Native American people (Flores, 2020). Piecing together history through early settler's journals and native American accounts, we can see that man's westward expansion along with sport poaching only sped up the demise and eventual extinction of the Steppe and Mountain bison (Flores, 2020).

Small pockets of bison are still located in protected areas and private grasslands of what once was the Tallgrass Prairie. The herd located at the Konza Prairie Biological Research Station is one of these small groups of bison that are still seen and studied today as a keystone species of this landscape (Knapp et al., 1999). Current research on the Konza bison herd has resulted in the idea that the large concentration of bison throughout the Flint Hills once had a significant impact on the landscape and the environment (Ranglack et al., 2015). Research in Konza Prairie has shed light on behaviors that could potentially have an impact on the landscape of the Flint Hills (Knapp et al., 1999). Due to the lack of research on the role of bison in course sediment movement along hillslopes, the importance of understanding bison behavior is essential when considering their historical effects on the evolution of the landscape since the Pleistocene Epoch of the soil armor.

Bison Behavior

Bison play an extremely important role in the functionality of the Konza Prairie. Bison living in the Tallgrass Prairie increase habitat heterogeneity and alter ecosystem processes, such as energy flow and community dynamics and interactions, through their grazing and wallowing behaviors (Knapp et al., 1999). Wallowing is a behavior exhibited by many ungulates and is when an animal rolls around in the dirt or mud. Through research, it has been found that bison prefer to create wallows on slightly sloped areas and avoid extremely steep areas (Coppedge and Shaw, 2000). Wallows were almost always formed in spring or fall burned watersheds during this 1993 experiment and out of the 170 wallowing behaviors observed, 60% of them occurred on bare soil (Coppedge and Shaw, 2000). Through the examination of previous reports tracking bison wallowing patterns, we were able to use this information to best choose a field location to conduct our experiment. In addition to wallowing patterns, bison impact their landscape through their grazing patterns.

Bison are extensive grazers and do not use their landscape randomly (Vinton, et al., 1993). Watershed burn treatments impact bison grazing patterns and create 'ecological magnets' (Raynor, et al., 2015) in recently burned grasslands that draw ungulate grazers towards it because of the nutritious plant matter that grows after a burn. Seasonality also contributes to grazing preferences. From July-September, elevation was determined to be the strongest topographic driver of space utilization and less important from April-June (Raynor, et al., 2015). It was found that grasslands burned in spring were more universally used by bison, determined by selection or avoidance of certain watersheds. December annually burned watersheds were the most avoided areas compared to the other treatments. 2-year and 4-year spring burned watersheds were used more often during their burn year than the watersheds burned annually (Raynor, et al., 2017).

Understanding the factors that contribute to bison grazing preferences is important for understanding how the landscape can be altered by these native grazers. Conducting research on bison and their characteristics allows researchers in tallgrass prairies all over the world to properly manage the land.

Additionally, bison have specific plant preferences for grazing. Bison prefer to graze on the four main Kansas types of grass: big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), and Indian grass (*Sorghastrum nutans*) (Knapp et al., 1999). Bison tend to graze in grass-dominated patches and stay away from shrub and forb-dominated patches (Plumb and Dodd, 1993). A previously conducted study determined that the grass to forb ratio was found to be much higher in the more frequently burned watersheds compared to the unburned watersheds. This helps us understand why bison preferred grazing on recently burned watersheds. Seasonality contributes to plant growth along with the burn treatment of the selected watershed. Our experiment was conducted in the winter and spring months (January through May). This was another factor that we considered when choosing our experiment site because we wanted the area to be a preferred grazing site for the bison.

Bison Impacts on Grassland Ecosystems

Bison wallows are a common occurrence on the prairies and an estimated 130 million wallows were scattered across the entire North American Great Plains Pre-European settlement (McMillan, 1994). The wallows created by bison disrupt the properties of the soil and can disrupt the natural process of the ground. Typically, at the edge of a wallow there is greater vegetation production and a higher concentration of magnesium and sodium. Whereas carbon and nitrogen ratios are higher in the soil adjacent to the wallow, compared to inside the wallow (McMillan, 1994).

Different bison grazing strategies also affect the vegetation and soil makeup. Land which has been grazed has a significantly lower amount of biomass in the soil than ungrazed land (Walters and Martin, 2003). The movement of bison across the landscape does decrease the amount of vegetation on the topsoil and can dislodge soil from the ground. The frequency of bison grazing is an additional factor in the amount of eroded soil or vegetative patterns that the ground will experience. Adaptive multi-paddock grazing (AMP) is a grazing style where animals are rotated through different sections of land to graze while other sections regrow. Compared to light grazing and heavy grazing, the AMP style was found to have a significantly lower non-native plant species (Hillenbrand et al., 2019). The free range of bison on the Konza Prairie Biological Station mimics the AMP grazing patterns. While other animals graze over grass landscapes, one study concluded that bison contributed to the largest percentage of bare ground coverage compared to cattle grazing and areas left ungrazed (Grudzinski, et al., 2016). Bison have an impact on the coverage of the land they graze and because of their long history in the grasslands, it is important to understand any geomorphic affect bison have on the landscape.

Studies of rock movement with and without animal interaction

Studies of the movement of rocks down hillslopes have been happening since the late 1960s with “Rates of Surficial Rock Creep on Hillslopes in Western Colorado” published in 1967 by S.A. Schumm. Many other studies have since built off this research and we have gained a substantial amount of knowledge about how rocks move, how quickly they move, and what impact their movement has on the surrounding landscape (Ai, Wei et.al,2017; Persico et.al, 2005; DiBiase, 2017). Some of the most important information that has been gathered from these studies was that slope angle in relation to rock movement is not exponential. This is because of the many factors that also effect rock movement, the ranking of elements that influence sediment transport soil type having the most influence, then level of runoff, amount of rainfall, topography, and lastly, the type and amount of vegetation, and the effects different topography has on the movement of rocks down hillslopes (Schumm, 1967; Ai, Wei et.al, 2015; Hongwei et al. 2021). Eventually, the idea of animals acting as geomorphic agents was brought up by Govers and Poesen (1998). As geomorphologists, they wished to prove their theory that animals deserved more recognition as geomorphic agents (Govers and Poesen, 1998). The studies that were done based on this idea proved that the idea was indeed accurate, animals do have the ability to be a significant geomorphic agent and play a role in the shaping of the landscape (Govers and Poesen, 1998; Ungar, 2009). We based our experiment on those studies about rock movement in general and the impact that it has on the landscape as well as the studies of animals acting as the cause of that rock movement. While there has been research done about animals as geomorphic agents it is sparce and seemingly none has been done with an animal the size of a bison. The hope we have with this research is to be able to add to that knowledge base so that further understanding of animals as geomorphic agents can be had.

Geological and Geomorphological Background

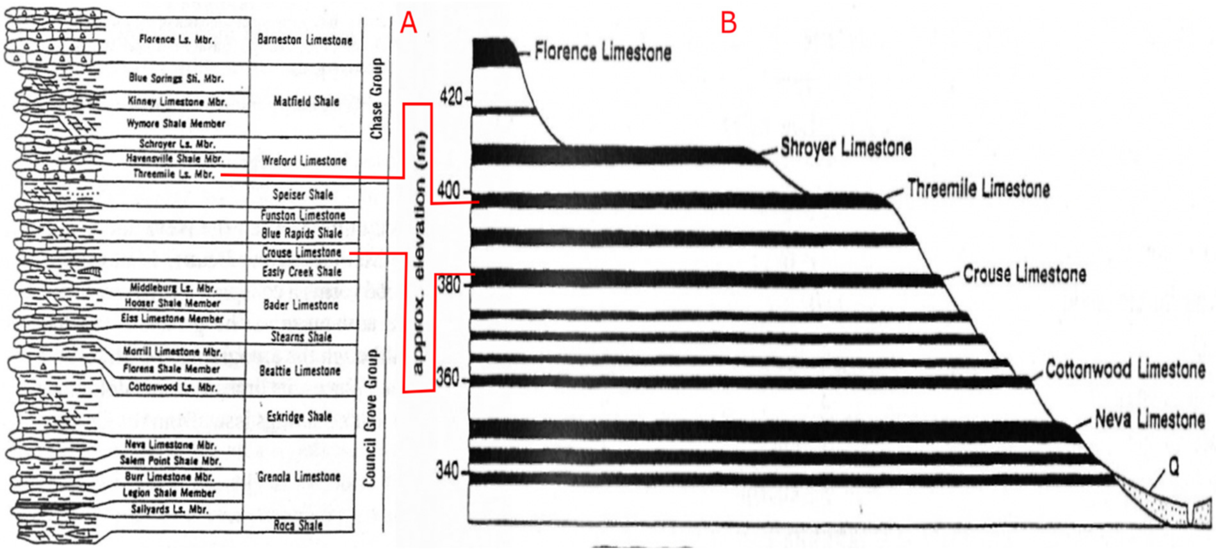

Figure 2: This figure depicts the stratigraphy of Konza and the associated bench and slope erosional patterns. On the left, A designates a not to scale stratigraphic column and breakdown of the beds found in Konza. B designates a sketch of Konza's geologic beds with their elevation as well as associated bench and cliff features. The black layers in B are limestone layers while the white layers are shale. The red lines between the two depictions equate the beds of the experiment site in the stratigraphic column to their location on the sketch. Retrieved and adapted from (Knapp and Oviatt, 1998)

The geology of the Konza Prairie consists of interbedded layers of shales and limestones with varying degrees of chert and bioclast composition. Two geological groups compose the strata in the area, the Council Grove and Chase groups. The eleven geological units that comprise the Council Grove group are as follows: Roca shale, Grenola limestone, Eskridge shale, Bealttie limestone, Stearns shale, Badar limestone, Easly Creek shale, Couse limestone, Blue Rapids shale, Funston Limestone, and Speiser shale. Additionally, the Grenola limestone, Bealttie limestone, and Badar limestones are divided into individual members. The Grenola limestone consists of Sallyards limestone, Legion shale, Burr limestone, Salem Point shale, and Neva limestone members. Beattie limestone unit consists of the Cottonwood limestones, Florena shale, and Morrill limestone member. Lastly, the Badar limestone is divided into the Eiss limestone, Hooser shale, and Middleburg limestone members. The Chase group consists of three units, the Wraford limestone, Matfield shale, and the Barneston limestone. The Wraford is further divided into the Threemile limestone, Havensville shale, and Schroyer limestone members. Similarly, the Matfield shale unit is divided into the Wymore shale, Kinney limestone, and Blue Springs shale members. Finally, the youngest member, the Florence limestone member of the Barneston limestone unit is the highest observable bed in the Konza Prairie at ~490m in elevation. Shale layers are overlain by soil and vegetation characteristic of Tallgrass Prairies. Erosion patterns in the Konza Prairie are dictated by this bedrock geology. Limestone contains beds, bench, and cliff features, whereas shale beds are eroded to form soil covered slopes (Moore, 1951). Springs can be found in some outcrops of the contacts between limestone and shale units, even at these contacts the shale is not readily visible. Shrub vegetation can be found in units with multiple joints because of the available water, this is best depicted in the Cottonwood limestone unit (Knapp and Oviatt, 1998).

Limestone and eroded limestone blocks are abundant, while there are few places where shale is exposed at the surface. The beds are generally flat, with some slight dipping and a system of joints; there are no faults or folds within the bedrock in this area (Knapp and Oviatt, 1998). Fluvial processes found in the Konza Prairie are lateral erosion and deposition. There is a total of 353 first order streams in low relief basins and 486 first order streams in high relief basins with stream orientations of the low relief areas in the Konza being most abundant between 320 and 30 degrees north, whereas in the high relief area, the most abundant orientations are 0 and 90 degrees north. Smith (1991) found that dominant geomorphic erosional processes in Konza are sapping, overland flow, lateral erosion and deposition, downcutting, damming of stream channels by logjams, in-channel deposition behind logjams, and pond deposition. These current processes are due to precipitation drainage and its interaction with the soil.

Due to the elevation of our experiment sites, the two geological beds pertinent to this project are the Crouse and Threemile limestones which begin at 380m and 390m in elevation, respectively. The Crouse limestone is composed of medium-hard limestone layers interbedded with shale. Within Konza, this unit is 10 meters thick and weathers into platy blocks (Mudge and Burton, 1959). The erosion of thin shale interbedded within the Crouse limestone creates a subtle and thin bench feature (Smith, 1986). The Threemile unit is a massive hard limestone with an interbedded layer of shale in the lower portion of the unit, this bed is 2.5 meters in thickness within Konza. The Threemile limestone forms one of the most prominent bench features of the Konza landscape and is notable for an abundance of chert nodules and rounded shoulders (Mudge and Burton, 1959). This limestone is extremely resistant to erosion because of its chert content (Smith, 1991).

Methods

The methods used for this research began with scouting through the different watersheds within the Konza Prairie Biological Station to find the ideal experiment site. The ideal hillslope for this experiment would be frequently visited by bison, have many rocks naturally placed on it, as well as a steep enough slope that there would be potential for downslope movement if the rocks were to be interacted with by the bison (Figure 3). The hillslope that we ended up choosing met these requirements because it had many rocks on many steppes within the overall slope, the fact that it had many steppes was also beneficial because it allowed us to see if the bison were more active on the higher or lower bedrock benches of the overall hillslope. We also chose the hillslope because of the fence line that ran along it. An experiment conducted in the Flint Hills ecoregion of Kansas determined that bison grazing is a large contributor to increasing amounts of bare ground cover (Grudzinski, et al., 2015). A sizable portion of bare ground was found near the fence line in bison grazed watersheds (Grudzinski, et al., 2015). This experiment previously conducted in the Konza Prairie allowed us to make a reasonable assumption that the bison would favor grazing and moving along the fence lines, pursuing us to set up our experiment along a fence line. Additionally, we attached 3 trail cameras to this fence line in hopes of capturing images of bison interacting with our experiment. Watershed N1A was chosen as our experimental site (Figure 4). This abbreviation means that this watershed is natively grazed and annually burned (LTER, 2017). Because ungulates are drawn to recently burned grasslands, Watershed N1A was chosen because it had been burned at the beginning of the season and would most likely be an active place for bison (Raynor, et al., 2015). To better understand the distribution of rock sizes on a slope we gathered the lengths, width, and thickness of each rock in cm. The size and shape data of the rocks was used to build an idea of the different size rocks that existed on the hillslope so that when it came to gathering rocks for the experiment, we could make sure that there was an accurate representation of the rocks that naturally exist on the hillslope.

Figure 3: Location of experiment sites within the blue rectangle. Fence line is along the west side.

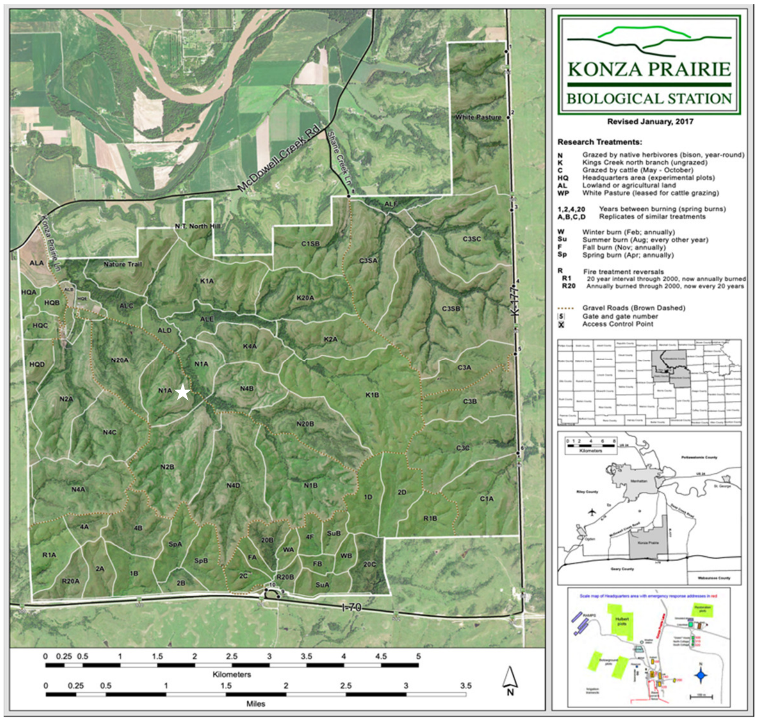

Figure 4: Map of the Konza Prairie Biological Station separated into distinct watersheds. Each watershed has been labeled and a key is located on the right side of the figure. A county map and measuring tool are also included. The star, located in watershed N1A, indicates the watershed we conducted our research in. Figure altered from Konza Prairie Biological Station (LTER, 2017).

At the two experiment sites, one upper and one lower, 60 total rocks were randomly selected from the surrounding area. This random selection was done for monitored blocks to be representative of the selected locations. Selected rocks were marked with a green stripe of paint on one side and a red stripe on the other to monitor rotational movement. The rocks were then placed in lines perpendicular to the fence posts. The blocks were oriented in a line, about 2-3 feet apart from one another, so the red painted line was perpendicular to the fence post. The posts act as a baseline to measure block movement along the slope. Once all the rocks had been placed, three separate game cameras were placed along the fence line to capture images of the bison to see if they were in fact interacting with the rocks. The cameras and rocks were checked at least once a week for four weeks to see if there had been any rock movement since the previous check-in. During each check-in the images were downloaded from the game and each line of rocks were observed to check for any signs of movement. If there was movement, the amount of movement was measured based on the original baseline with fence post. At the end of the four weeks, all the game cameras were collected, and final measurements were taken. Each rock's size and shape were also recorded. The movement data from throughout the four weeks was then analyzed to determine the overall movement for each rock within the four weeks and the average amount of movement for all the rocks.

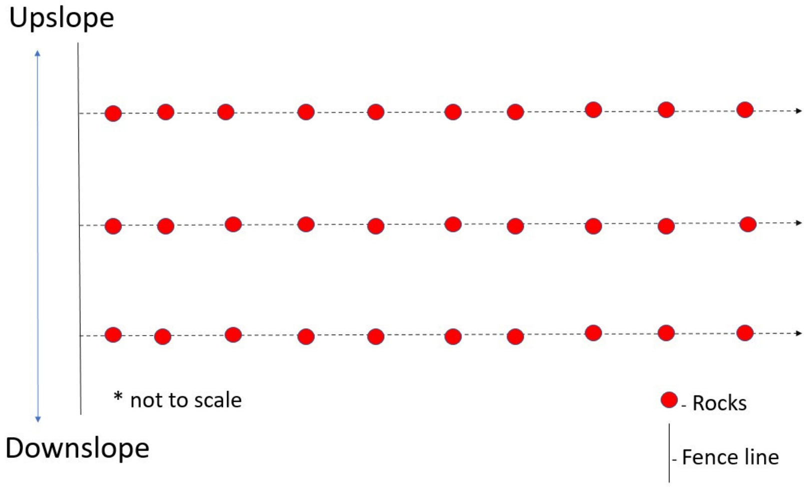

Figure 5: Diagram of rock placement at each site. Each line contains between 9 and 11 rocks distributed evenly across in a horizontal line. Red circles are rocks, and the vertical line is the fence line. The figure is oriented with top being upslope and the bottom being downslope.

Figure 6: This photo shows Kamryn, Grace, Gibson, and Richard painting green and red stripes on either side of the rocks used in our experiment. This photo was taken in watershed N1A before setting up the lateral lines of our experiment.

Figure 7: This photo shows Gibson and Richard placing rocks into lateral lines at the lower site so that the red stripes painted upon them are in line with the fence post off camera.

Results

Rock Movement

In the initial stages of the research, no rock movement was logged in the upper or lower sites along the hillslope. The dates where no observation of change was observed began March 29th, 2022 and continued until April 23rd, 2022. On April 23rd, 2022, rock movement was recorded at the lower site of the hill slope involving the top row, middle row, and bottom row. The direction of the rock movement is associated in a positive and negative direction, positive being movement downslope, and negative as movement upslope from initial position. Measurements of rock movement also includes the measurement of distance from initial position, type of movement, shape of the rock and if the rock was flipped from red initial side to green underside. On April 30th, 2022, significant rock movement along the upper and lower sites of the slope were observed. Lower site data can be seen in Table 1 and upper site data can be seen in Table 2.

Table 1: This table shows the recorded rock movement over a four-week period in the lower site of watershed N1A. Rock number and movement direction, lateral movement (cm) from initial position, and rock shape are included for all rocks in the top, middle, and bottom rows. Rock movement data was recorded on April 30th, 2022.

Table 1: Rock Movement over a four-week period in the Lower Site

Rows	Rock # with movement direction	Lateral Movement from Initial Position	Shape
Top	Rock #1: Positive	3 cm Down Slope	Flat Cubic
	Rock #2: Positive	10 cm Down Slope	Triangular
	Rock #3: Negative	3 cm Up Slope	Flat
	Rock #4: Flipped, Positive	20 cm Down Slope	Cubic
	Rock #5: Negative	3 cm Up Slope	Circular
	Rock #6: Flipped, Rotate	Stationary	Spheric
	Rock #7: Rotation	Stationary	Flat Rectangular
Middle	Rock #2: Rotate	Stationary	Rectangular
	Rock #3: Rotate	Stationary	Cubic
	Rock #4: Positive	6 cm Down Slope	Triangular
	Rock #5: Positive, Rotation	6 cm Down Slope	Cubic
	Rock #6: Positive	3 cm Down Slope	Cubic
	Rock #7: Rotation	Stationary	Cubic
	Rock #8: Positive	12 cm Down Slope	Flat Rectangular
	Rock #9: Positive	12 cm Down Slope	Rectangular
Bottom	Rock #3: Positive	4 cm Down Slope	Flat Rectangular
	Rock #4: Rotate	Stationary	Flat Rectangular
	Rock #11: Positive	11 cm Down Slope	Rectangular

Table 2: This table shows the recorded rock movement over a four-week period in the upper site of watershed N1A. Rock number and movement direction, lateral movement (cm) from initial position, and rock shape are included for all rocks in the top, middle, and bottom rows. Rock movement data was recorded on April 30th, 2022.

Table 2: Rock Movement over a four-week period in the Upper Site

Rows	Rock # with movement direction	Lateral Movement from Initial Position	Shape
Top	• Rock #3: Rotation • Rock #4: Positive • Rock #5: Negative • Rock #11: Positive	• Stationary • 5cm Down Slope • 2cm Up Slope • 10cm Down Slope	• Rectangular • Flat Rectangular • Cubic • Flat Rectangular
Middle	• Rock #4: Rotation • Rock #7: Negative • Rock #9: Positive • Rock #10: Rotation	• Stationary • 2cm Up Slope • 2cm Down Slope • Stationary	• Cubic • Cubic • Cubic • Circular
Bottom	• Rock #1: Positive • Rock #2: Positive • Rock #3: Positive • Rock #4: Positive • Rock #6: Positive • Rock#7: Positive • Rock #8: Positive • Rock #9: Rotation • Rock#10: Positive • Rock#11: Rotation Positive	• 32cm Down Slope • 5cm Down Slope • 6cm Down Slope • 5cm Down Slope • 3cm Down Slope • 6cm Down Slope • 5cm Down Slope • Stationary • 12cm Down Slope • 20cm Down Slope	• Rectangular • Circular • Cubic • Flat Rectangular • Rectangular • Circular • Rectangular • Circular • Rectangular • Circular

Rock Clast Size

Rock shapes can be categorized into different shape types based on the flatness, elongation, and equancy of the sides. L is the length of the longest part of the rock, I is the intermediate length or length perpendicular to L, and S is the shortest axis or depth (Szabó and Domokos, 2010). The shape of the rock is determined by the relationship between elongation, I/L, and flatness, S/L. The distribution of these relationships is depicted in Figures 9 and 10 below, as well as the overall distribution of rock size, based on the intermediate length, in Figure 8 below.

Table 3: This table shows rock clast size for every rock located within the three transects in the lower site. This table includes the rock number, length x width x thickness (cm), and the row the rock is located in.

Table 3: Rock Clast size

Lower Site	Rock #	Length x Width x Thickness (cm)
Top Row	• Rock 1	• 7x7x2.5
	• Rock 2	• 7x5x3
	• Rock 3	• 12x9x2.5
	• Rock 4	• 6x5x2.5
	• Rock 5	• 11x5x2.5
	• Rock 6	• 4.5x3.5x4
	• Rock 7	• 8x4x6
	• Rock 8	• 9x4.5x2.5
	• Rock 9	• 7x6x2.5
Middle Row	• Rock 1	• 9x9x2
	• Rock 2	• 9x6x2
	• Rock 3	• 8.5x4x2.5
	• Rock 4	• 9x4x3.5
	• Rock 5	• 7x7x3
	• Rock 6	• 8.5x7x2
	• Rock 7	• 7x6x2
	• Rock 8	• 10x5x3
	• Rock 9	• 8x5.5x2
Lower Row	• Rock 1	• 6x5x3
	• Rock 2	• 8.5x6.5x2.5
	• Rock 3	• 10.5x8x3
	• Rock 4	• 10.5x8.5x3
	• Rock 5	• 9.5x6x2
	• Rock 6	• 13x5.25x3
	• Rock 7	• 9x8x2
	• Rock 8	• 7x8x2
	• Rock 9	• 9x6x2
	• Rock 10	• 10x4x3
	• Rock 11	• 7x7x1

Table 4: This table shows rock clast size for every rock located within the three transects in the upper site. This table includes the rock number, length x width x thickness (cm), and the row the rock is located in.

Table 4: Rock Clast Size

Upper Site	Rock #	Length x Width x Thickness (cm)
Top Row	• Rock 1	• 15x10x4
	• Rock 2	• 15x10x2
	• Rock 3	• 24x14x5
	• Rock 4	• 30x30x5
	• Rock 5	• 25x14x2
	• Rock 6	• 11x10x4.5
	• Rock 7	• 24x17x2
	• Rock 8	• 8x8x3
	• Rock 9	• 25x15x5
	• Rock 10	• 20x14x10
Middle Row	• Rock 1	• 15x14x5
	• Rock 2	• 36x15x6
	• Rock 3	• 26x19x3
	• Rock 4	• 21x15x9
	• Rock 5	• 14x10x5.5
	• Rock 6	• 12x10.5x2
	• Rock 7	• 21x20x3
	• Rock 8	• 17x17x9
	• Rock 9	• 21x20x5
	• Rock 10	• 19x11x6
Lower Row	• Rock 1	• 12x7x5
	• Rock 2	• 12x10x7
	• Rock 3	• 20x19x9
	• Rock 4	• 27x12xx5
	• Rock 5	• 10x12x5
	• Rock 6	• 10x8x5
	• Rock 7	• 21x12x5
	• Rock 8	• 22x21x2
	• Rock 9	• 39x31x5
	• Rock 10	• 40x32x2
	• Rock 11	• 30x21x5

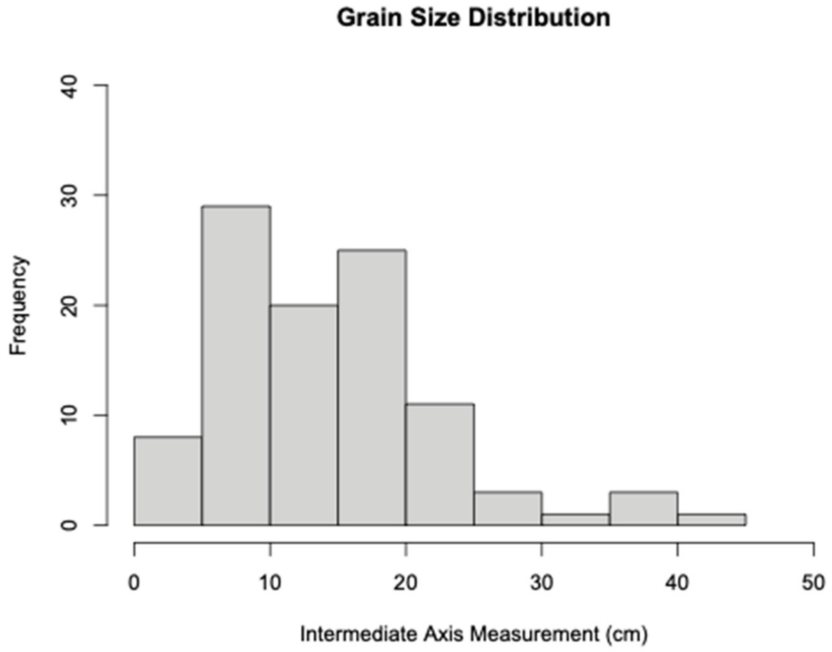

Figure 8: This figure shows rock size distribution based on the intermediate axis measurements (second largest axis(I)) of the rocks used for the experiment.

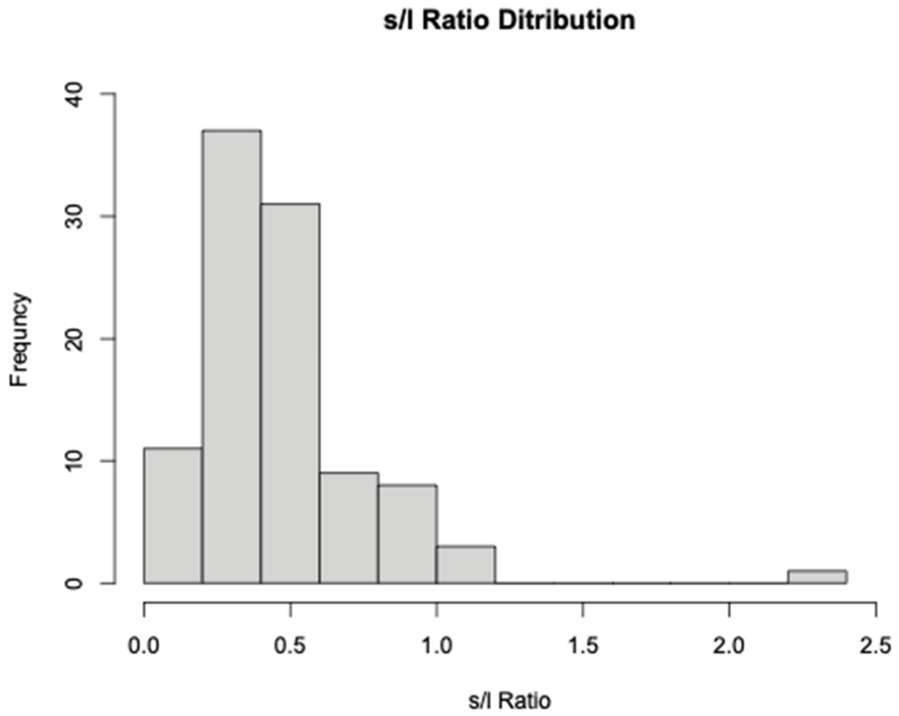

Figure 9: This figure depicts the ratio between side s (shortest axis) and side I(intermediate axis) of the rocks used for the experiment.

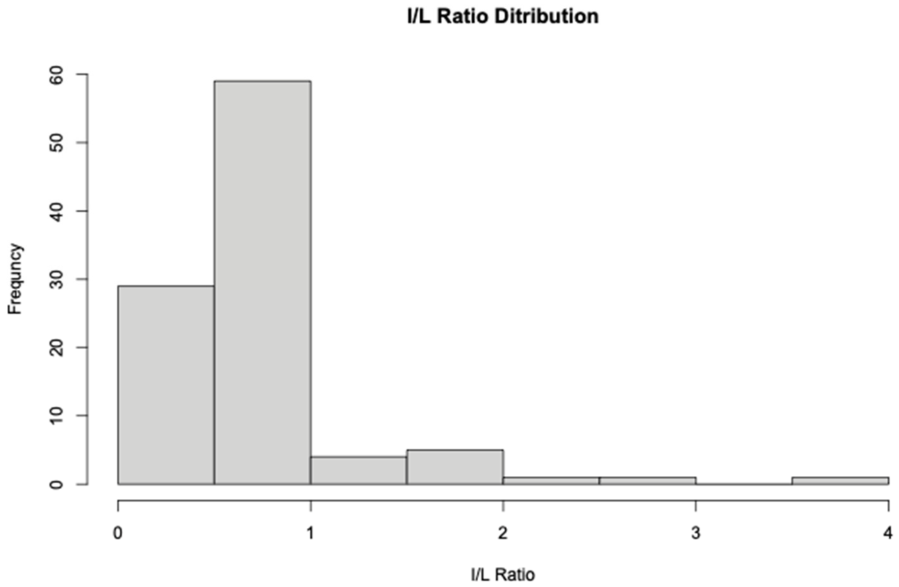

Figure 10: Depicts ratio distribution between side I (Intermediate axis) and L (longest axis) of the rocks used for the experiment.

Bison Frequency

Our experiment, located in watershed N1A in the Konza Prairie, utilized 60 rocks of varying shapes and sizes to conduct our research (Table 3 and Table 4). 31 rocks were placed in 3 transects in the upper site and 29 rocks in 3 transects in the lower site (Figure 3). Of these 60 total rocks, 32 rocks were recorded as being altered during the 4-week period.

$$\frac{32\ total\ altered\ rocks}{60\ total\ rocks} = .54 = 54.0\%\ bison\ interaction$$

Of these 32 altered rocks, 18 were located at the upper site and 18 were located at the lower site. The 18 lower site altered rocks were comprised of 10 rocks laterally moved (upslope or downslope), 5 rotated rocks, 1 rock flipped over and rotated, and 1 rock flipped and laterally moved (downslope) (Table 1). 7 of the 18 rocks were cubic, 6 of the 18 were flat, 2 triangular, 1 circular, 1 spherical, and 3 rectangular (Table 1). Of the 10 laterally moved rocks, 8 were moved downslope and 2 were moved upslope.

The 18 upper site altered rocks included 13 rocks moved laterally (upslope or downslope), 4 rotated rocks, and 1 rock moved laterally (downslope) and rotated (Table 2). 5 of the 18 altered upper site rocks were cubic and 3 of the 18 were flat. The remaining 10 rocks were comprised of 5 circular rocks and 5 rectangular rocks (Table 2). 12 of the rocks moved downslope, 2 moved upslope, and the remaining 4 were stationary (Table 4).

The rocks used to conduct this experiment were of all varying shapes and sizes. The smallest rock length is 4.5 cm, and the largest length is 40 cm. The thinnest rock is 1 cm, and the thickest rock is 10 cm (Table 3 and Table 4). Figures 8, 9, and 10 above depict distribution and frequency of rock sizes found along the slopes.

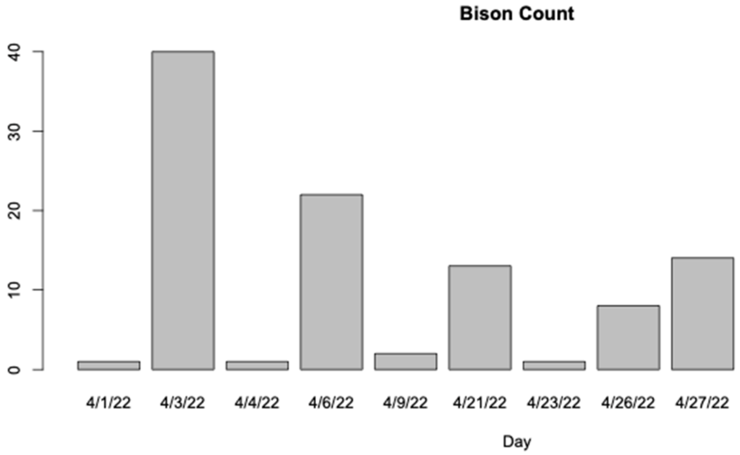

Figure 11: Frequency of bison visitation to the experiment site, per day for the month of April 2022. Days that had no bison visitation do not appear in the histogram.

Discussion

During the first two weeks of the experiment, no rock movement was recorded. Although no rock movement was recorded, we did record consistent bison activity along the hillslope using game cameras. As seen in the final two weeks of the experiment, rock movement was recorded. From pictures taken on April 27th, we believe that bison are the cause for rock movement as evidence from the pictures shows clear rock movement by a bison to one of our test rocks (Figure 12). We also believe other bison behaviors observed in the area could have caused the movement of the rocks. Due to the movement and complete overturning of a rock near a bison wallow, we believe wallowing is a factor for rock movement around hillslopes close to wallows. Although we believe bison could be a major factor in the rock movement along the hillslope there could be other factors that may have caused the rocks to move throughout the final two weeks.

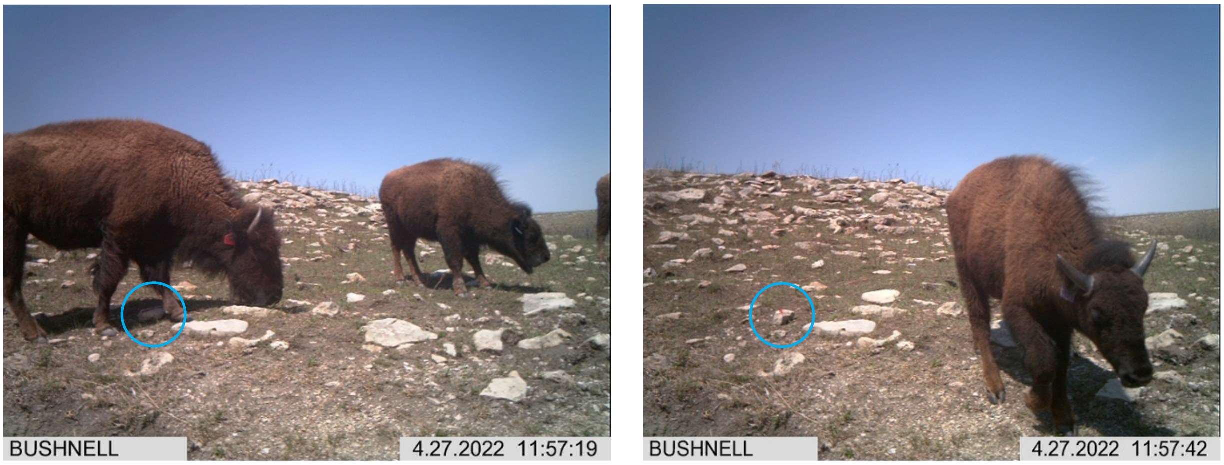

Figure 12: Both photos portray bison grazing the location where our experiment is set, determined by the visible red spray-painted rock. The picture on the right was captured 23 seconds after the left picture was taken and shows the red spray-painted rock in a different position. This is indicated by the blue circle, indicating direct contact between the bison and rock. The date and time of when the picture was taken is also include.

Evidence of other wildlife recorded from the game cameras could also point to other factors affecting the movement of the rocks. Although we do not have unambiguous evidence of wildlife other than bison moving the rocks, we do acknowledge the possibility that the recorded white-tailed deer, wild turkey, and other birds could have moved the rocks. Other environmental factors could also be the result of the rock movement recorded. Factors such as high winds and strong thunderstorms could have factored into the movement of rocks on the hill slope. The

Konza Prairie and surrounding areas had consecutive days of large rainstorms during our experiment and right before we went out to measure rock movement. Research has shown that rainfall can have a large impact on rock movement because of soil water content and soil infiltration. If soil water content is high, soil infiltration is slow; therefore, runoff generation from excess rain leads to soil erosion and soil erosion can lead to rock movement (Ai, Ning; Wei, Tianxing; et.al, 2015).

During the experiment we also noted the abundant bison activity at the site chosen. Throughout the experiment, we often observed bison near the experiment area or in the experiment area from pictures captured on the game cameras. Through analyzing the game cameras, we documented the number of bison observed at the experiment site for the day the pictures were captured (Figure11). Through personal observation and data analysis we found this hill slope was often visited by small groups of the main bison herd. As observed, bison frequently visited the site setting off the game cameras leading us to believe this site is a highly trafficked area for bison (Figure 12). Due to the evidence of nearby bison wallows, we assume this site must be a common rest site for the bison to visit. From the data collection of bison frequency and the pictures captured in Figure 12, we determined bison are the most likely cause of a majority of rock movement. As the site is frequently visited by bison, we have determined that an interaction rate of 54% occurred between the bison and test rocks due to the documented bison activity in the area over the four-week period.

With this experiment came specific limitations. When choosing our experiment site, we intentionally chose areas along the fence line in a natively grazed watershed because these areas are highly trafficked by bison (Grudzinski, et al., 2015). Due to this site location, our data could be heightened compared to a less-trafficked area. The watershed we utilized, N1A, is an expansive area meaning that had we of chosen an area away from the fence line, it is possible our bison interaction rate would not be as high as it is. Additionally, in both the upslope and downslope positions where we conducted our experiment, the rocky terrain consists of mostly imbedded rocks. In this experiment, rocks were harvested from the area and placed on top of the surface. Since the rocks were no longer imbedded into the soil, the interaction between the bison and rocks could be heightened. This experiment was conducted in short time frame, consisting of only 4 weeks. Had this experiment run longer, the bison and rock interactions could have been greater than recorded. Lastly, lateral movement was only measured two times during the entirety of this experiment. Photos were captured of bison moving both upslope and downslope, meaning that a rock could have been moved out of its initial placement from a bison moving one way on the slope and then returned to its initial position by a bison moving the opposite way. If this were to occur, the measurements recorded for lateral rock movement would be lower.

Implications of our research could be universally used when looking at tallgrass prairie systems around the world. Building off our data, future research can apply the results of this study to other tallgrass prairies around the world due to the similarities of the tallgrass ecosystems. As we see from our experiment, bison do interact with rock fragments along hillslopes (Figure 12). Using the evidence of bison interaction, other tallgrass prairies with large ungulate grazers, can conduct research to record data on these large grazers' role in interacting and shaping the ecosystems. Future research can also be built off our data, applying new techniques to a larger study area for longer periods of time. Other variables such as larger rock fragments, wildlife interactions outside of large grazers, and location in the landscape could be tested to develop a better understanding of how rock fragments are moved in tallgrass prairies.

Utilizing our data, other researchers can continue to unravel the undocumented mysteries of bison history and the bison's role in changing the tallgrass prairie landscape.

Conclusion

The Konza Prairie Biological Station provided a stable hillslope with free ranging bison to investigate our research groups hypothesis: do bison herds have an impact on the movement of rock fragments? To determine interaction, a hillslope was chosen and divided into an upper and lower slope. These slopes then had rocks placed in three parallel lines and game cameras were mounted to watch the hillslope. In the initial stages of our study, we had no bison interaction with rocks, but bison were frequent grazers at the study site and were caught on the game cameras. In the final two weeks of the experiment, interaction became more frequent and along with grazing the area, placed rocks began moving. From our data, we determined that 32 of the 60 marked rocks had been altered in some way, giving us a 54% bison interaction rate. Of the 32 rocks, exactly half were from the upper slope location and half were from the lower slope. 23 rocks moved laterally up or down the hillslope and rocks at both locations were flipped, rotated, or a combination of all three. The game cameras also captured direct bison interaction on April 27, 2022. In the first picture, the bison can be seen standing over a marked rock still in its initial position. The next picture shows the bison has moved and the marked rock has been rotated from its original position (Figure 12).

Bison contribute to a large amount of bare ground coverage and when interacting with the land, bison have an effect on soil properties (Grudzinski et al., 2016). Wallows created by bison are a common occurrence on the ground they graze and also have implications to the soil temperature and ability to support vegetation (McMillan, 1994). Our findings also support the interaction between bison and rock fragments on the Konza Prairie. Based on all the research presented it can be concluded that bison can act as a geomorphic agent on the Konza Prairie.

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