MBACI Monitoring Set-Up for Tallgrass Prairie Restoration on Kansas State University Campus

Natural Resources and Environmental Sciences (NRES) Capstone

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Abstract

Tallgrass Prairie once covered most of the Midwestern part of the United States, but due to urbanization, the area of native prairie has been significantly decreased. Restoration projects around the Midwest have been used to restore the native habitat and ecosystem services that the Tallgrass ecosystem provides. The NRES Capstone class has had groups investigate the potential for a tallgrass prairie restoration project on the campus of Kansas State University (KSU) to protect and conserve the local ecosystem. This study is a continuation of that by selecting the tallgrass restoration site and control sites that will be used in a BACI analysis of the restoration project. Multiple-BACI (MBACI) is used to compare an impact site with multiple control or reference sites. This was the best method for this research as the impact site has two distinct characteristics, urban and riparian areas. Multiple locations were examined as potential control sites at Konza Prairie Biological Station and on KSU campus. Two control sites were selected, The Meadow and a location on Konza Prairie, for comparison to the restoration (or impact site) of Coles Hall lawn located on the KSU campus, adjacent to Campus Creek. Soil data of the restoration site was also obtained and summarized to provide a base dataset for future research. Future NRES projects will be able to expand on this study by collecting additional quantifiable environmental data, such as infiltration rates and water quality, to examine how a prairie ecosystem would influence the Campus Creek riparian area on the KSU campus.

Introduction

Humans affect every ecosystem on this planet either by direct or indirect actions. For example, less than 10% of the United States (US) native ecosystems still exist making conservation of native land cover a vital component for maintaining ecosystem structure and function (Dodds et al. 2008). Grasslands are one of the most diverse and most productive ecosystems in the world and they cover 40% of the earth's terrestrial surface (Blackburn et al. 2021).

Urbanization

One example of an anthropogenic impact to native ecosystems, such as tallgrass prairie, is urbanization. Urbanization is an ongoing social experience where people move from rural areas to large urban centers. By 2050, it is estimated that 66% of the world's population will live in urban areas (Stanton 2020). This population migration has and will continue to have huge effects on the environment and human health. Noted environmental effects of urbanization include, but are not limited to, a shift in hydrology, as well as reduced water quality.

Urbanization affects the hydrology of its area with impervious surfaces and engineered streams leading to streams becoming "flashy" (McMillan et al. 2014). Flashy streams are those that quickly increase in flow during precipitation events, and then quickly drop to its low baseflow after the event ends. Urbanization also can negatively affect water quality in the watersheds they inhabit. Stormwater can enter streams or ponds through surface runoff or through drainage pipes. Runoff picks up any pollutants, nutrients, and organic matter that is on the concrete's surface. Storm drains deposit excess stormwater directly into streams or retention areas, which does not allow vegetation to filter out the pollutants and slow runoff speed (Thompson & Parkinson 2011).

Ecosystem Restoration

Recently, scientists have concentrated more on how to lower the amount of environmental degradation occurring due to urbanization. As a response to urbanization, natural resource managers now often use restoration projects to help mitigate the negative effects of anthropogenic impacts (Mahlum et al. 2017). The goal for many restoration projects goes beyond just restoring the native ecosystem but to restoring the goods and services that the native ecosystem provides (Dodds et al. 2008). Environmental services offered by these restoration projects include microclimate regulation, rainwater retention, flood control, promotion of wildlife and biodiversity, and improving air and water quality (Eastman et al. 2021).

Grassland Restoration

The Tallgrass prairie once spanned 170 million acres (about the area of Texas) in the US from Canada to Texas; however, due the growth of the American population and conversion of land, there is only 4% that remains in its natural form (Haukos N.D.). The largest remnant of Tallgrass Prairie is in the Flint Hills which stretches from Manhattan, Kansas down to Oklahoma. In terms of grasslands, native and restored grasslands provide a high commodity value due to hay production as well as increasing biodiversity (Dodds et al. 2008). Protecting the Flint Hills tallgrass prairie is part of the mission of Konza Prairie Biological Station which is situated just outside Manhattan, Kansas (Image 1). The Konza is co-managed by The Nature Conservancy and Kansas State University (K-State) for research and protection of the ecosystem. Several of the faculty at K-State partake in research at Konza and are pushing for more green spaces, as well as the revitalization of existing green spaces on campus using native prairie grasses through the K-State Sustainability Coalition (Eastman et al. 2021). Green spaces in urban areas refer to a network of natural areas that conserve functions of ecosystems that would usually be lost to impervious surfaces. Green spaces can conserve natural areas or can be implemented by humans such as rain gardens, green roofs, and constructed wetlands (Lee 2020). Natural areas can improve and conserve ecosystem services and provide natural beauty for residents to enjoy and be educated on (Ourloglou et al. 2020).

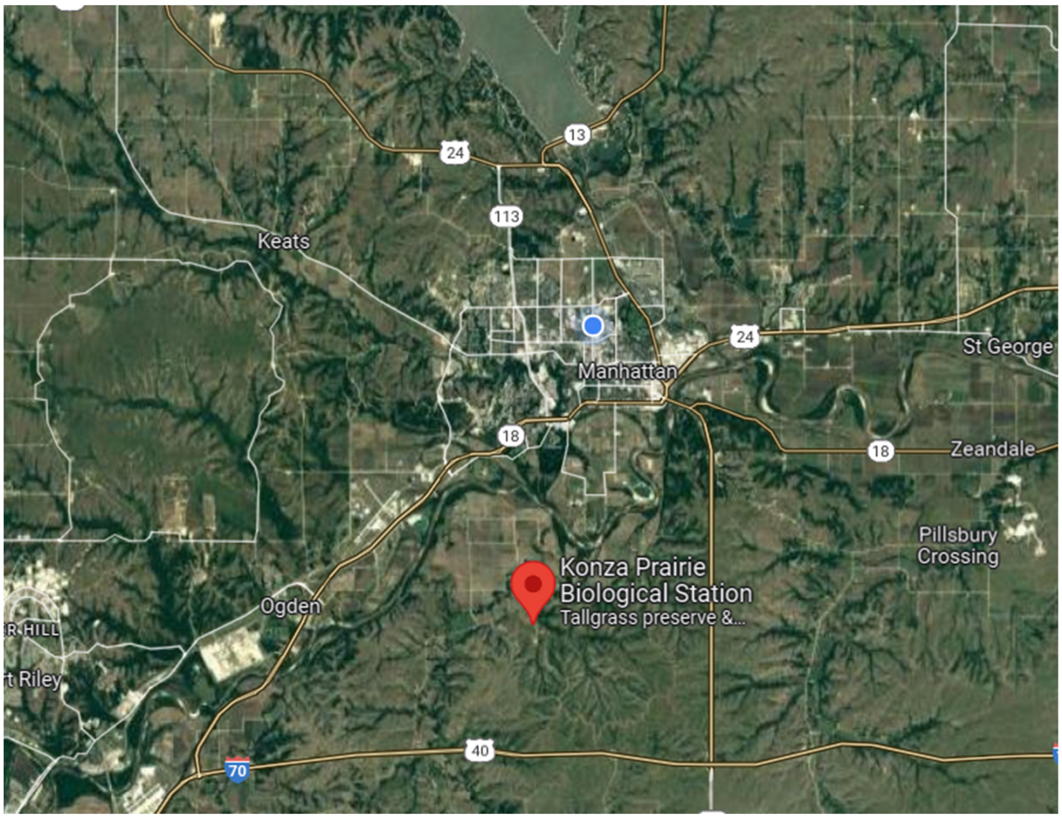


Image 1: A map that shows the location of Konza Prairie Biological Station relative to Manhattan, Kansas.

Riparian Restoration

Riparian restoration is also of high value in urban settings. Riparian zones are transitional ecosystems that allow for materials and energy to flow between aquatic and terrestrial areas. They constitute floodplains, the edge of streambanks, and on the streambank itself. (Liu et al. 2004). Many projects have been undertaken in rural areas, where farmers can lower the amount of fertilizer and soil runoff entering their water sources. Environmental scientists are making more efforts to understand how these ecosystems can improve urban environments and the humans that populate these areas. Although riparian ecosystems make up around 1% of the world's land cover, they carry much more weight in ecosystem services. The vegetation found in riparian areas can reduce erosion, slow down runoff, allow for infiltration, and serve as animal and fish habitats (Mohan et al. 2022).

In addition to riparian zone rehabilitation, the conversion of the grasses from cool-season, non-native turfgrass to native tallgrass prairies species also carries benefits. Previous studies have found that runoff reductions can be greatly improved by using natural vegetation instead of manicured turf grasses (Selbig & Balster 2010). One study compared infiltration rates between two rain gardens, one with native prairie grasses and one with turf grasses. The research found that the prairie rain gardens had an average infiltration rate of 6.50 in/hr., while the turfgrass grass plot had an average rate of 3 in/hr. The researchers attribute this improvement in infiltration due to depth and density of prairie grass roots, extending deeper into the ground and creating more pores and fissures that soak up more water and at a faster rate than turfgrass (Selbig & Balster 2010). Figure 1 shows soil moisture levels of the two plots, with the prairie rain garden having a higher overall soil moisture through time than the turfgrass rain garden.

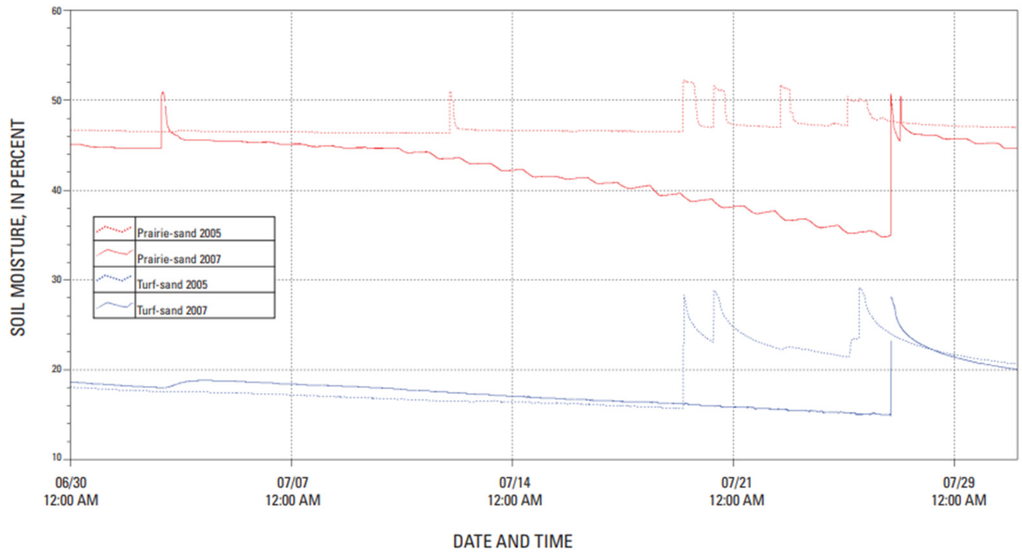


Figure 1: *Differences in soil moisture percentage between turf and prairie rain gardens. The moisture levels of the prairie grasses were taken at 2.6 feet under the grounds surface. The turf grass sample was taken 1.6 feet below the surface (Selbig & Balster 2010).*

Challenges of Ecosystem Restoration in Urban Areas

Outside of the benefits of riparian tallgrass restoration in an urban setting, there are challenges that must be considered before attempting any restoration or rehabilitation. One of these challenges is that urbanization tends to disrupt the chemical properties of soil (e.g., increased heavy metal concentrations), as well as the physical and biological properties (Pavao-Zuckerman et al. 2008). The chemical, physical, and biological differences between non-urban and urban soils are due to climate, organisms, parent material, topography, organic matter, human disruption, higher levels of atmospheric ozone, and carbon dioxide which affect plant physiology, among others. Other considerations and challenges are knowing how tillage, herbicide, and compost practices all affect soil health when trying to convert urban soil to healthier soil. For example, using some compost in the soil will increase the number of nutrients available for the plants but should be added over time as they may be depleted after a year (Rojas et al. 2021).

A main challenge of ecosystem restoration projects in urban settings is reinvasion of non-native species. Urban areas have foot traffic and trade which can transport alien vegetation to different ecosystems (Bonilla-Rodriguez et al. 2021). If these species can take advantage of inputs, such as pollutants or nutrients, better than native vegetation, then the alien species will quickly dominate the ecosystem (Bickart 2013). Active restoration should be implemented in urban areas while native grasses fully integrate themselves. Active restoration is a more hands on approach to restoration, where species are specifically planted, and unwanted species are targeted for removal. Passive restoration is hands off and involves removing environmental disturbances and allowing natural succession to occur. Urban areas have countless environmental disturbances, so a more focused and controlled approach is needed for successful restoration.

Other challenges include severe degradation of soils and native vegetation brought on by urbanization and inorganic waste (Bonilla-Rodriguez et al. 2021). Insects should also be considered as they are prone to removing more seeds sown into the ground than mammals within the first year following prairie restoration (Linabury 2019). Stream water quality will also need to be considered as it affects the riparian area, the whole watershed, and any organism that either lives in the stream or around it.

Monitoring of Ecosystem Restoration

A key component of a restoration project is the monitoring of the sites before and after the restoration has been completed. Monitoring is an extremely important part of a restoration project, but it is often overlooked or forgotten (Block et al. 2001). Monitoring can occur in a variety of ways that can be specified in a monitoring plan. Depending on the scale of the restoration project, remote sensing might be the best method to monitor due to the ability to see the whole area at once. Remote sensing is a process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance, this can be done from satellites or from planes equipped with specific equipment (USGS.gov 2022). This method is useful and easily done because most remote sensing data from satellites is easily accessible, the issue is when there is specific data that needs to be collected or the time between shots of the area is too long to get accurate data. In those cases, a drone could be used to collect data if it has the proper technology. Remote sensing is also useful for areas that are hard to access throughout the year (Meroni et al. 2017). The more widespread practice though is to do on the ground monitoring at the site to be able to collect the specific data and examine to see if there is something happening that was not accounted for. There are two main types of monitoring: confirmatory and investigative. Confirmatory monitoring aims to confirm the ecological expectation without looking at the deeper ecological systems. Contrast that with investigative monitoring which is more complex and requires collecting data to fully examine the results from the restoration (England et al. 2022). BACI is a form of investigative monitoring because it has more in-depth data collection and examination for both before and after the action(s) are taken. The control site(s) are then used to compare how the actions affected the impacted site(s). This helps with monitoring the site(s) afterwards to see what the impacts are of the actions and how they differ from the expected outcomes.

Project Objectives

The purpose of this report is to develop a monitoring program to assess the effectiveness of tallgrass prairie restoration on the K-State campus. As identified by Eastman et al., the four main goals of tallgrass prairie restoration are:

- Improve ecological function and condition,
- Reducing maintenance and associated costs,
- Improving ecological function and condition, and
- Improving the aesthetic of campus (2021).

Our project focuses on the first goal which is to improve the ecological function and condition. To quantitatively assess the effectiveness of tallgrass prairie restoration to improve the ecological function and condition, a Before-After Control-Impact Study (BACI) is established here. The purpose of our project this semester was to (1) determine the best form of BACI to be used and (2) select at least 2 control sites, similar to the characteristics of the restoration site for comparison in the BACI study. Finally, we began to collect environmental characteristic data of the Coles Hall lawn to assist future research teams in additional quantitative environmental data collection and analysis. These three objectives will be discussed in the following section.

Objective 1: Before-After-Control-Impact (BACI) Technique Review & Selection

A Before-After Control-Impact (BACI) is an effective method to evaluate natural and human induced perturbations on ecological variables when treatment sites cannot be randomly chosen (Connor et al. 2016). When setting up a BACI experiment there must be a control site and an impact site that data collected from both before the "impact" (restoration) occurs and after it occurs to be able to quantify its effect. "The ultimate goal of many ecological restoration projects is to return ecosystem structures, functions, and processes to "natural" or reference conditions" (Block et al. 2001, p. 293). BACI does this by comparing the impact site to a control site that has not been disturbed. The control and impact site should be as similar as possible to generate the best comparison data. There are new methods arising that use BACI as a base and expand to fit better in different circumstances. Four examples that were reviewed include: MBACI, Beyond-BACI, and BACIPS, and the causal model. This review aims to be a comparison of the different versions and help determine the best method for K-State campus tallgrass prairie restoration monitoring.

MBACI, or Multiple-BACI, is a BACI design that uses multiple control location rather than one reference site. The purpose for having multiple control sites is to look at the interaction variance at the control sites and compare it to impact site variance (Paul 2011). This method aims to limit variation due to space and time because it recognizes that there can be differences at the same site depending on the time that the data was taken. Using MBACI also allows for replication of experiments more easily than a traditional BACI that is not usually replicated because it is site specific. There is also the ability to, depending on the scope and experiment, create artificial control sites as to have more control over the variation (Angeler & Moreno 2006). Where BACI lacks the ability to be replicated and distinguish between impact and random events, MBACI is more suited for those types of research needs.

A Beyond-BACI method is set-up like MBACI because it also utilizes the multiple control sites. A beyond-BACI approach has been used for many studies that have variation due to time and space so that it is easier to determine what is human caused and what is not. The environment is a dynamic system that is always changing so a traditional BACI that only has one control site does not account for the normal change in the data. This method has been used to detect changes in the marine environment caused by diverse anthropogenic actions (Aguado-Giménez et al. 2012).

Another modified BACI that also tries to take out the temporal variability is a BACI – Paired Series (BACIPS). The way that the BACIPS is set up is that every impact site has its own control site that is supposed to be as close to the same as possible. Where BACIPS differs from other BACI methods is that the data collection for both control and impact sites are to be taken at the same time to distinguish natural spatial and temporal variability from variation induced by the environmental impact of interest (Thaiult et al. 2016, Ogren and Huckins 2015) The BACIPS can also be joined with a progressive-change method to generate models of the change in variation over time which could be useful for some long-term projects.

There is also another method proposed by Paul (2011) called the causal model. This method is similar to BACI except it eliminates both the spatial and temporal variation that might occur during data collection. The causal model is done by combining graph theory with statistics to look closer at the causes of the change. This model requires a wider understanding of the statistical methods. The causal model would be more suited for a large-scale project where there is likely to be more variation that a BACI design could not mediate.

Based on the review of these techniques, a MBACI design will be used because of the multiple control sites giving more insight into the results from urban restoration. This method best fits the study because it allowed for two control sites, one being urban restoration and another a native ecosystem, this allows for comparison between an urban setting and native setting. The other BACI methods were viable options, but they did not fully meet the needs of the complex impact site and limited resources. To set this up, there needs to be at least one urban restoration reference site as well as two natural prairie control sites to examine how a site on campus responds to tallgrass restoration. The MBACI impact and control site selection is discussed in the next section.

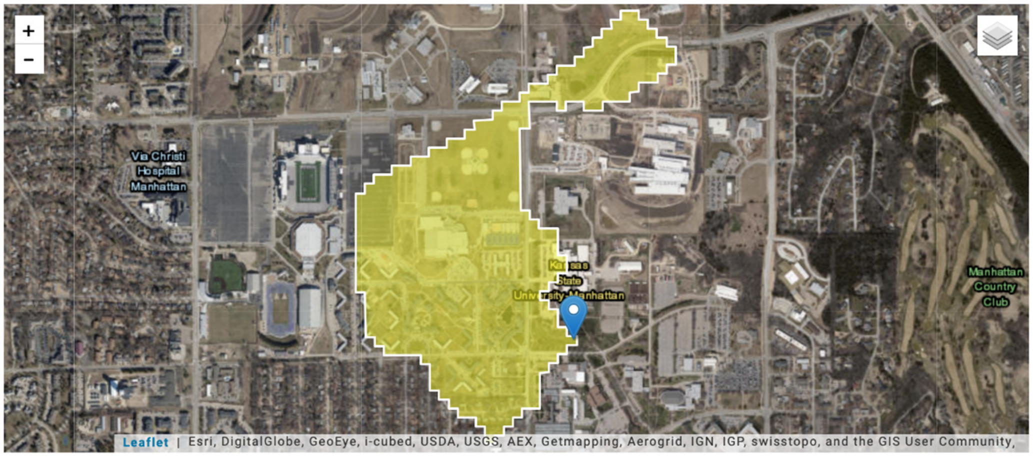
Objective 2: MBACI Site Selection

Tallgrass Prairie Restoration Site Description

A team of students in the spring of 2021 set out to determine sites on campus that would be suitable for restoration. They found that the lawn by Regnier Hall was the most suitable site (Eastman et al. 2021); however, after discussions with the leaders of the K-State Sustainability Coalition, the site chosen for future restoration is the Coles Hall lawn. Coles Hall lawn was preferred due to its potential to reduce flooding of Campus Creek that flows through the lawn and the east side of campus (Image 2). Due to being in an urban setting and encompassing the National Bio and Agro-Defense Facility (NBAF) in its watershed, one of the anthropogenic impacts that Campus Creek could experience is chemical runoff, which can affect the ecosystem processes and ecological integrity (Angeler & Moreno 2006). As stated earlier, restoration projects have the potential to enhance water quality and increase flood reduction, which are the main two concerns of the faculty involved (Skabelund, personal communication, February 3, 2022).

Image 2: the location of the impact site (Coles Hall), and the control site at The Meadow.

Coles Hall is currently inhabited mainly by turfgrass species, as well as a few trees. The drainage area is .25 square miles (Figure 2, below), and the area has a 5% slope. The main soil type for the impact site is 4050, Ivan and Kennebec silt loams, occasionally flooded, and is depicted below in Figure 3. The impact site on campus is mowed once a year (LARCP, personal communication, 2022). The collection method of these characteristics will be discussed further in the following section.



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	0.25	square miles
DRNAREA	Area that drains to a point on a stream	0.25	square miles
PRECPRIS10	Basin average mean annual precipitation for 1981 to 2010 from PRISM	33.7	inches

Figure 2: StreamStats watershed delineation for Coles Hall impact site.

Figure 3: Web Soil Survey map for Coles Hall watershed.

Site Selection Methods

Before the process of site selection began, several considerations and parameters were considered. Monitoring method, number of sites desired, project goals, and budget were all key factors in helping narrow down which site would be the best fit. Often, not enough focus is directed towards the initial set up of a project. If not done properly, this can hinder the progress and success of an entire project. “Ultimately, the subtle differences in goals and objectives will affect the hypotheses, study design, parameters measured, and other factors" (Roni et al. 2005, p. 15). As seen in the previous section, careful thought was put into selecting the most appropriate BACI approach, and in this case, MBACI was chosen. This affects site selection as it requires, in this case, two control sites rather than just one. The first control site selected was The Meadow, which is a one-half acre landscape adjacent to the Marianna Kistler Beach Museum of Art on K-State's campus (Canfield et al. 2018) (Image 2). This location was restored from turfgrass to native tallgrass prairie plants in 2013 by previous KSU students. The second control site chosen is located in the Konza Prairie Biological Station. This unique research station is home to a vast number of scientist-, faculty-, and student-lead experiments. Not only does a multitude of prior data exist in the Konza Prairie area, but more will continue to be collected in the future. This allows future NRES groups the ability to access already existing data if it proves to be beneficial to the target objectives of their research.

Based on discussions the K-State Sustainability Coalition, the enhancement of water quality and increase of flood reduction are two objectives that should be focused on during future NRES projects. Important parameters to consider based on these objectives are watershed area, soil type, land use, disturbances, and hydrology. The selection of The Meadow was done without strict analysis of these parameters. As it is also located on campus, contains the native prairie that is desired, and has previous data collected on-site, it was a suitable decision. The selection of the second site required a more in-depth process.

First, USGS StreamStats was used to delineate different watersheds in the Manhattan Area. As the impact site has a watershed area of about 0.25 square miles, that was the target watershed area for the control as well. Next, the application Web Soil Survey (WSS) provided the soil types in the delineated watersheds that had been found. Another step taken to select the control site was to compare the disturbances undergone at each location. To mimic the mowing of Coles Hall lawn, sites on Konza that house cattle throughout part of the year were given more consideration than those that did not. Burn patterns at Konza were also considered, but it was determined that grazing provides a more similar effect to mowing on the tallgrass than burning does. The burn and grazing patterns are shown in Figure 4. The final parameter investigated was watershed hydrology. The TR-55 method, completed with components from both StreamStats and WSS, was used to determine the hydrology of 3 possible sites along with the impact, Coles Hall. "Technical Release 55 (TR-55) presents simplified procedures for estimating runoff and peak discharges in small watersheds" (USDA-NRCS 1986, p. i). According to the Natural Resources Conservation Service (NRCS), while the method gives emphasis to urban areas, it also works great for small watersheds, both of which apply to the impact site.

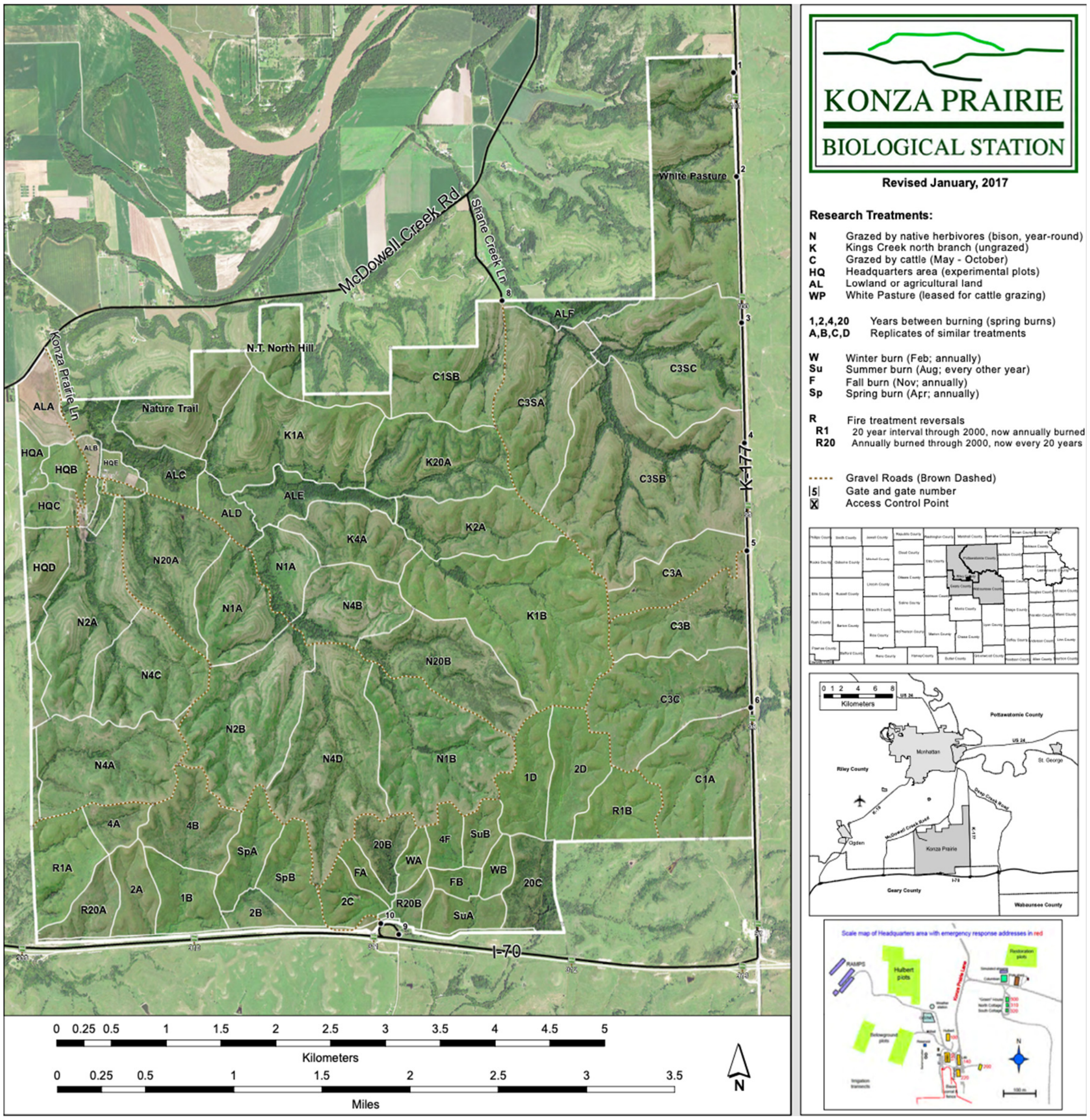


Figure 4: Konza Prairie Biological Station research treatments.

A rating system was used to aid in the selection of the second control site. Each parameter was rated on a scale from 1 to 5, with 5 being the highest and most similar to the impact site. The ratings were totaled up and the site with the highest final value was selected to act as the control. For watershed areas, ratings decreased as the area became farther from that of the impact site. Areas with 0.25 square miles were given a 5 rating, values within .1 square miles of the control were given a 4 rating, values within .4 square miles were given a 3 rating, up to 4.5 square miles was given a 2 rating, values greater than 4.5 square miles were given a 1, and unknown areas received a 0. For soil type, areas with 4050 soils were given a 5 rating, none were given a 4, other Ivan silt loams (such as 4051) were given a 3 rating, soil types that received a 2 or 1 were more dissimilar to 4050, and unknowns were given a 0. The burn rating was based on how often it was burned. Since the impact site is not burned, areas burned less received higher ratings. Unburned areas received a 5, areas burned every 20 years a 4, every 4 years a 3, every other year a 2, and unknown patterns a 0. Because no areas on Konza are mowed, no potential sites received a 5 rating for grazing. Areas with cattle partially through the year received a 4, ungrazed received a 2, and bison received a 1 due to year-round grazing and safety hazards, and unknown received a 0. Finally, hydrology was based on closeness of the TR-55 results. Values within 50 were given a 5 rating, around 100 a 3, and greater than 100 a 2. Equation 1 provides the ranking summation, where a rating of 25 points represents an ideal control site most similar to Coles Hall lawn:

$$\begin{aligned} Total\,Rating \;=\; & Watershed\,Size\,Rating \;+\; Soil\,Texture\,Rating \;+\; Burn\,Patter\,Rating \\ & +\; Grazing\,Rating \;+\; Hydro\log y\;\;Rating \end{aligned}$$

Results and Discussion

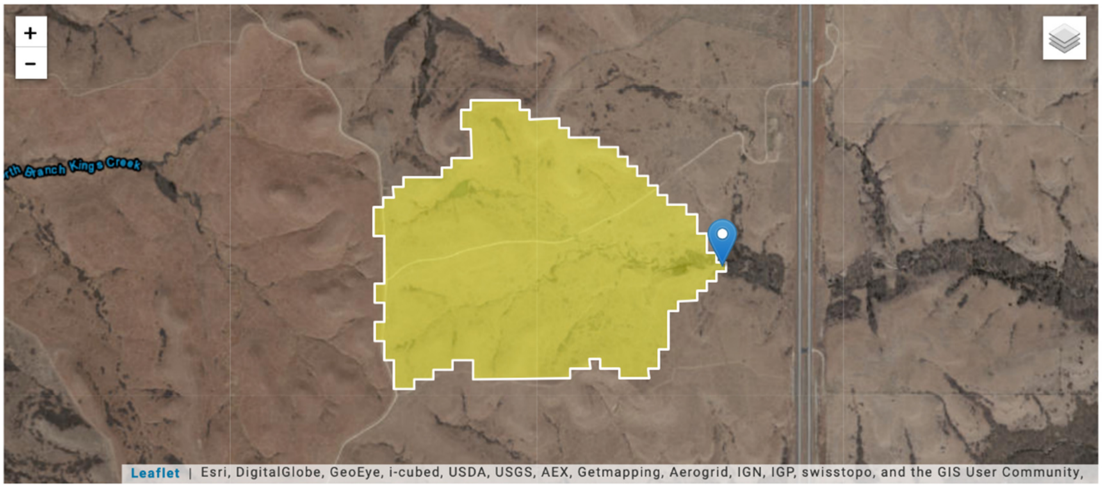
Table 1 below includes a list of all sites considered for selection as well as the impact and beach museum control sites, parameter values, rating for each parameter, sums, and final ranks. As seen in Table 1, there is a site within Konza that greatly matches that of Coles Hall. The Coles Hall impact watershed (Figure 2) is .25 square miles, and the Konza Prairie control site watershed pictured below in Figure 5 is also .25 square miles. In addition to the watersheds being the same size, they also contain similar soil texture. The Konza Prairie control site soil map (Figure 6, below) shows an area with soil type 4051, Ivan silt loam, channeled, which is similar to the Coles Hall soil type 4050 (Figure 3). The mowing at Coles Hall and cattle grazing at the Konza location provide similar disturbances. Although the Konza site is burned, it is minimal, being every 4 years and Coles Hall has the potential to undergo burning in the future if it is permitted. “The native area is cut down to the ground in early spring and has little maintenance throughout the year except for some weeding. There is a plan to possibly burn this area this spring if it is allowed” (Robinson, personal communication, April 14, 2022). The 2, 5-, 10-, 25-, and 100-year high flow events were extremely close in value between the impact and Konza site providing similar hydrology (Table 2). Table 3 depicts the TR-55 method results for the Coles Hall impact site. In addition, this site includes road access which will allow future groups and easier way to access this location to collect data (Image 3, below).

Latitude, Longitude	Location	Watershed Area	Watershed Rating	Main Soil Type	Soil Rating	Burn Pattern	Burn Rating	Grazing	Grazing Rating	Land Use	Hydrology Rating	Final Rating #	rank
39.1973188, -96.584338	Coles Hall, impact	0.25	5	4050/3919	5	unburned	5	Mowed	5		5	25	
39.1873280, -96.578826	Beach Museum, control	0.04		7213/3920									
39.09169°, -96.54178	Konza	0.25	5	4051	3	every 4 yrs, spring	3	Cattle, May-Oct	4		5	20	**1**
39.09355, -96.56506	Konza	0.4	3	4051	3	every 4 yrs, spring	3	Ungrazed	2		3	14	**2**
39.1020279, -96.5913298	Konza	2.42	2	4050	5	unburned	5	Ungrazed	2	lowland or ag land		14	**2**
39.1020279, -96.5913298	Konza	1.92	2	4050	5	unburned	5	Ungrazed	2	lowland or ag land		14	**2**
39.09573°, -96.57041	Konza	0.64	3	4051	3	every 4 yrs, spring	3	Ungrazed	2		2	13	**3**
39.11345, -96.55678	Konza	0.28	4	4550	2	unburned	5	Ungrazed	2			13	**3**
39.10989, -96.60981	Konza	6.6	1	4050	5	unburned	5	Ungrazed	2	Not in Konza		13	**3**
39.10771, -96.60784	Konza	6.54	1	4050	5	unburned	5	Ungrazed	2	lowland or ag land		13	**3**
39.10771, -96.60650	Konza	6.17	1	4050	5	unburned	5	Ungrazed	2	lowland or ag land		13	**3**
39.10404, -96.60309	Konza	5.07	1	4050	5	unburned	5	Ungrazed	2	lowland or ag land		13	**3**
39.10132, -96.59232	Konza	4.36	1	4050	5	unburned	5	Ungrazed	2	lowland or ag land		13	**3**
39.0881949, -96.5775611	Konza	0.29	4	4051	3	every 20 yrs, spring	4	Bison	1			12	**4**
39.11012, -96.55888	Konza	0.23	4		1	unburned	5	Ungrazed	2			12	**4**
39.11688, -96.56240	Konza	0.23	4	4590	1	unburned	5	Ungrazed	2	lowland or ag land		12	**4**
39.0878802, -96.5837134	Konza	0.48	3	4051	3	every 4 yrs, spring	3	Bison	1			10	**5**
39.0893919, -96.5874146	Konza	0.32	4	4051	3	every 2 yrs, spring	2	Bison	1			10	**5**
39.087033, -96.5759275	Konza	0.46	3	4590	2	every 20 yrs, spring	4	Bison	1			10	**5**
39.1020279, -96.5913298	Konza	4.45	2	4784	1	unburned	5	Ungrazed	2	lowland or ag land		10	**5**
39.09669°, -96.57182°	Konza	0.69	2	4051	3	every 2 yrs, spring	2	Ungrazed	2			9	**6**
39.08890°, -96.58931°	Konza	0.3	3	4051	3	every 2 yrs, spring	2	Bison	1			9	**6**
39.08036°, -96.60483	Konza	0.05	2	4051	3	every 4 yrs, spring	3	Bison	1			9	**6**
39.100812, -96.574209	Konza		0		0	every 2 yrs, spring	5	Ungrazed	2			7	**7**
39.098778, -96.613012	Konza		0		0	unburned	5	Ungrazed	2			7	**7**
39.101320, -96.574810	Konza		0		0	every 20 yrs, spring	4	Ungrazed	2			6	**8**
39.1077428, -96.6009056	Konza	6.16	1	4053	3		0		0			4	**9**

Table 1: Potential sites, parameters, and parameter weights.

Latitude, Longitude	Location	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	Score
39.1973188, -96.584338	Coles Hall	271	368	456	585	690	799	5
39.09355, -96.56506	Konza	388	555	703	923	1105	1295	3
39.09573°, -96.57041	Konza	403	577	731	960	1149	1347	2
39.09169°, -96.54178	Konza	259	366	461	602	719	841	5

Table 2: The hydrology of 3 control site options and the impact site. The numbers represent the Peak Discharge (cubic feet per second) of the output during high flow events due to storms that happen every 2-100 years.



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	0.25	square miles
DRNAREA	Area that drains to a point on a stream	0.25	square miles
PRECPRIS10	Basin average mean annual precipitation for 1981 to 2010 from PRISM	34.5	inches

Figure 5: StreamStats watershed delineation results for Konza Prairie control site.

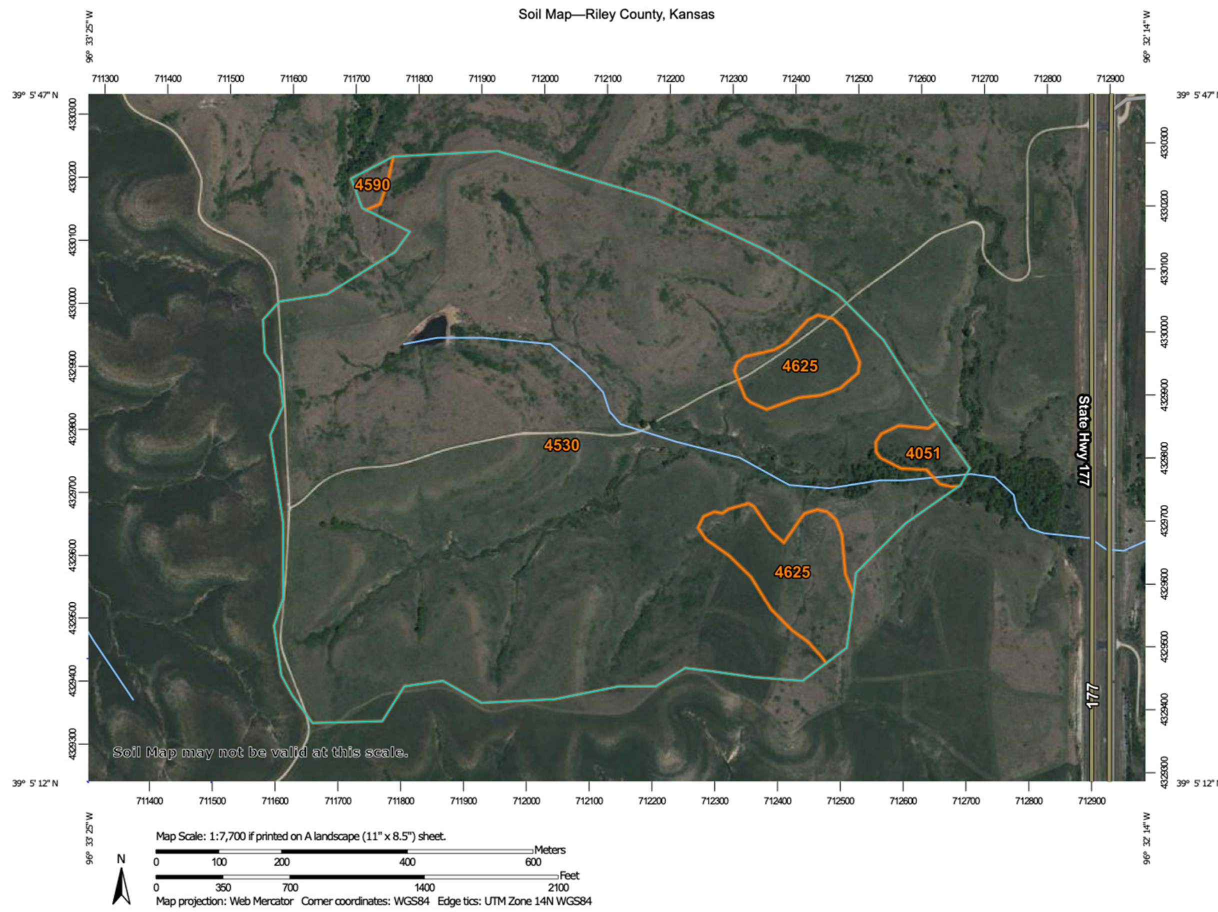


Figure 6: Web Soil Survey soil map for Konza Prairie control site.

USDA
NRCS

Hydrologic Summary Sheet

KS-ENG-137b
Rev. 12/15

Name	Campus Creek	Practice	
Legal Desc.		County	Riley
Designed by	NRES	Date	4/7/22
Checked by	KAB	Date	

Design Data:

Drainage Area	160	acres	0.25	square miles
Weighted Curve Number, CN	88			
Flow Length	4800	feet		
Watershed Slope	5	%		
Time of Concentration, Tc	0.63	hours		
Rainfall Type Zone	3			

Frequency (years)	2	5	10	25	50	100
24-hour Rainfall, P (inches)	3.33	4.16	4.89	5.94	6.79	7.67
Initial Abstraction, Ia (inches)	0.27	0.27	0.27	0.27	0.27	0.27
Ia / P	0.10	0.10	0.10	0.10	0.10	0.10
Runoff, Q (inches)	2.11	2.88	3.56	4.57	5.39	6.25
Unit Peak Discharge, qu (cfs/acre-inch)	0.80	0.80	0.80	0.80	0.80	0.80
Peak Discharge, Qp (cfs)	**271**	**368**	**456**	**585**	**690**	**799**

Table 3: TR-55 results for Coles Hall impact site.

Image 3: depiction of road access to Konza Prairie control site.

Objective 3: Spring 2022 Restoration Site Characterization

To begin site characterization of the impact/restoration site at Coles Hall lawn, soil samples were retrieved and analyzed for soil moisture, bulk density, and texture. Methods and results are summarized below.

Soil Analysis Methods

Soil samples were taken from eight different locations on the Coles Hall lawn. Figure 7 shows where each of the samples were obtained. The goal was to collect some data on each side of the stream, as well as both near and far from treed areas.

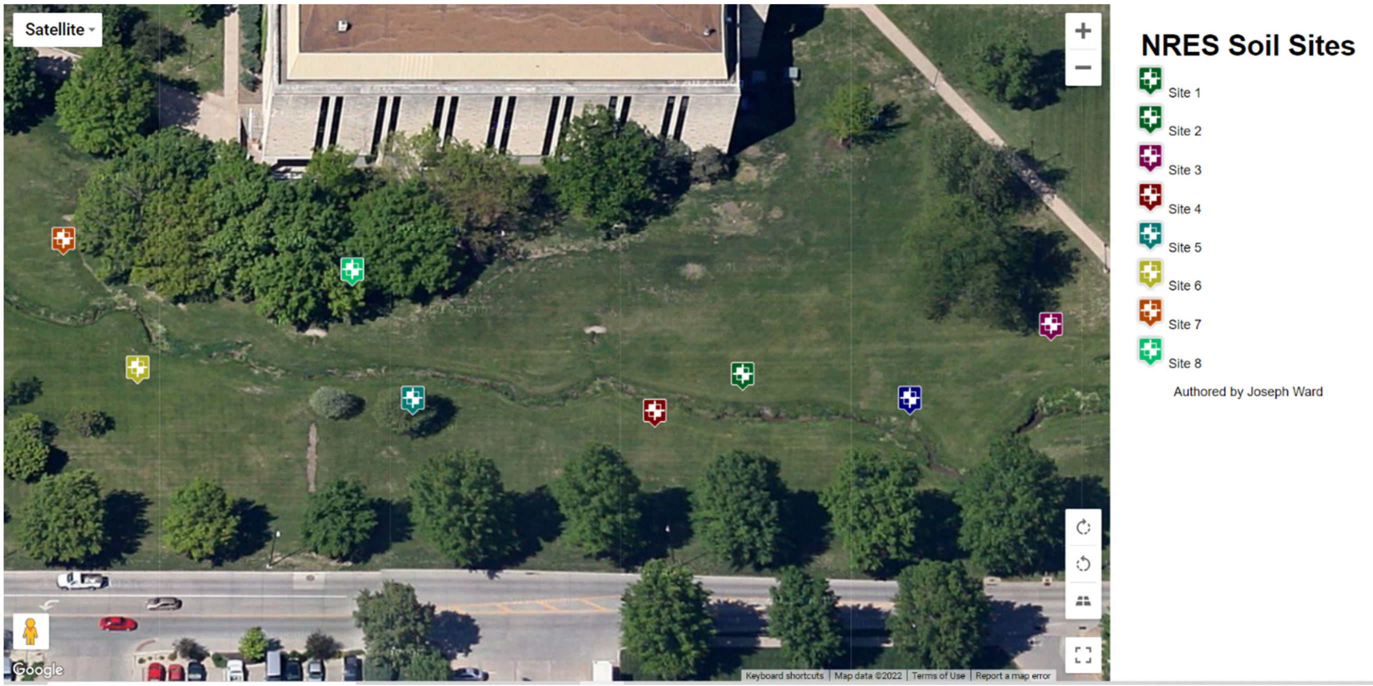


Figure 7: A map that shows the locations of the different soil samples taken at Coles Hall.

To analyze the soil properties, a 2-cenimeter diameter soil sampling probe was used to obtain samples to a depth of 15-cenimeters. Soil properties obtained from this sample included bulk density, soil moisture, and soil texture. The bulk density is obtained by dividing the mass of the dry soil sample by its total volume. Soil moisture, or the gravimetric water content (GWC), is calculated by subtracting the weight of dry soil by the weight of water within the moist soil and dividing it by the weight of the dry soil. The process included weighing the container for the soil sample, and then adding the wet soil sample to determine its mass. After the wet soil mass was determined, it was added to an oven at a temperature of 105 °C and kept there over the weekend to evaporate any liquid in it. The dry soil mass was then recorded and used for the calculation above.

For soil texture, the hydrometer method was used to conduct a particle size analysis in relation to their settling rates in an aqueous solution (UW 2004). In this data collection, a 'blank' was used along with the two samples that are being tested. The ‘blank’ sample contained 1000mL of water and no additives. To begin the hydrometer method, the soil sample must be ground into a fine dust and weighed in grams. The soil is then added to water and dispersing agent and stirred for one minute. The mixture is then added to a 1000 mL cylinder and is filled with water until the 1000mL mark is reached. After the mixture is gently shaken in the cylinder for 30 seconds, an initial density reading is recorded at exactly 40 seconds after the hydrometer is placed in the solution. The hydrometer is then removed after the first reading and set aside, the temperature for each sample and blank sample should be taken and recorded. At this point, the sand has settled, and the sample must sit undisturbed for 6 hours and 52 minutes in order for the silt particles to settle. After this exact amount of time has passed, the same procedure as above is followed for the next readings. This information was then used to calculate the percentage of sand, silt, and clay to determine soil texture type. Soil texture classification of sites #6 and #8 were obtained (see Table 5).

Results & Discussion

Table 4 below includes the precise locations, bulk density, and GWC of each sample that was collected. Bulk density is an important feature to determine when trying to affect infiltration rates. Soils with a higher bulk density have more tightly packed soils which causes there to be fewer large pores and an overall lower pore volume (Bigham, personal communication, April 2022). These qualities cause the soil infiltration rate to be lower, with the opposite being true as well. Soils with a lower bulk density have more pore volume and a higher infiltration rate. The bulk density values range from 1.029g/cm^3 to 1.396g/cm^3 and the GWC values range from 17.37% to 32.51%. It is expected that the soil at the Konza Prairie control site will have a lower bulk density than that of Coles Hall due to the lower soil disturbance and the lack of urbanization at or near the area. Bulk density is also affected though by livestock and burning practices, both of which can increase bulk density (USDA-NRCS 2008b). Since the Konza Prairie control site will have both cattle through some parts of the year and burning every 4 years, measurements and calculations will need to be done to confirm or deny this assumption and identify the bulk density of the soil. The texture classification of the soil samples taken at Coles Hall were both silty clay loam and were taken on each side of the creek. These are shown in Table 5 below. The results from Web Soil Survey do not exactly align with this due to limited resources. When using the soil texture along with the values calculated through the hydrometer method, the soil texture was on the line of being silty clay loam and silt loam. The difference in percentages that separate the two texture classes is very slim which can also be impacting the texture results to be different. Coles Hall Lawn is described as 4050 soil type by WSS, which is Ivan and Kennebec silt loams, occasionally flooded (Figure 3). It is noted by the National Cooperative Soil Survey Program, an endeavor of the NRCS, that there are certain limitations to WSS and further onsite testing may need to be done for more accurate and specific results (USDA-NRCS 2016). Since the texture analysis was done on-site, the team is confident with their results of silty clay loam classification. As both samples #6 and #8 were found to be the same classification by the texture analysis performed, silty clay loam, it can be assumed that this is the soil type for the remainder of the sample locations on Coles Hall lawn. By comparing Figures 3 and 7, it can be seen that all eight soil samples collected in this study are within the area that was characterized as soil type 4050 by WSS. Because WSS classified the entire area as Ivan and Kennebec silt loams, the team classifying all eight soil sample locations as the same soil type as well is reasonable.

Sample (Can #)	Lat, Long	Can Mass(g)	Water, Soil, & Can Mass (g)	Water & Soil Mass (g)	Dry Soil & Can Mass (g)	Dry Soil Mass (g)	Bulk Density (g/cm^3)	Gravimetric Water Content
#1 (S2C)	39.19732 N, 96.58372 W	22.35	90.98	68.63	79.14	56.79	1.205	20.85%
#2 (T1D)	39.19728 N, 96.58347 W	47.7	109.24	61.54	96.18	48.48	1.029	26.94%
#3 (T1B)	39.19740 N, 96.58326 W	34.62	107.57	72.9	92.51	57.89	1.228	25.93%
#4 (S6B)	39.19726 N, 96.58385 W	22.23	86.95	64.72	76.15	53.92	1.144	20.03%
#5 (S2B)	39.19728 N, 96.58421 W	31.19	105.95	74.78	92.41	61.24	1.300	22.12%
#6 (T4D)	39.19733 N, 96.58462 W	21.89	109.07	87.18	87.68	65.79	1.396	32.51%
#7 (S1A)	39.19754 N, 96.58473 W	30.95	106.01	75.06	90.43	59.48	1.262	26.19%
#8 (S3B)	39.19749 N, 96.58430 W	21.88	92.57	70.69	82.11	60.23	1.278	17.37%

Table 4: The Bulk Density and the gravimetric water content data for 8 locations at the impact site that were collected from both sides of the creek on the same day.

Sample #	#6	#8
Soil Sample Weight (g)	47.72	47.52
Blank-Temperature 1 (˚C)	32	32
Blank Density 1 (g/L)	4	4
Mixture Temp. 1 (°C)	36	36
40 Sec Density (g/L)	36	35
Blank-Temperature 2 (°C)	28.5	28.5
Blank Density 2 (g/L)	4	4
Mixture Temp. 2 (°C)	28.7	28.6
6 Hr. 52 Min Density (g/L)	23	15
% Clay	25.27242246	29.58754209
% Silt	50.83822297	44.73905724
% Sand	23.88935457	25.67340067
Soil Texture	Silty Clay Loam	Silty Clay Loam

Table 5: The soil texture classification of soil samples #6 and #8 using the hydrometer method.

Soil texture classification is an important measurement regarding infiltration rates. As mentioned above, soils with a higher bulk density in turn have lower infiltration rates. This can cause flood rates and runoff to be higher. "By reducing water infiltration into soil, compaction can lead to increase runoff and erosion from sloping land or saturated soils in flatter areas" (USDA-NRCS 2008a, p. 3). Bulk density can also affect plant growth. Table 6 below describes the relationship between bulk density and plant growth.

Soil Texture	Ideal bulk densities for plant growth (grams/cm^3)	Bulk densities that affect root growth (grams/cm^3)	Bulk densities that restrict root growth (grams/cm^3)
Sands, loamy sands	< 1.60	1.69	> 1.80
Sandy loams, loams	< 1.40	1.63	> 1.80
Sandy clay loams, clay loams	< 1.40	1.60	> 1.75
Silts, silt loams	< 1.40	1.60	> 1.75
Silt loams, silty clay loams	< 1.40	1.55	> 1.65
Sandy clays, silty clays, clay loams	< 1.10	1.49	> 1.58
Clays (> 45% clay)	< 1.10	1.39	> 1.47

Table 6: General relationship of soil bulk density to root growth based on soil texture (Source: USDA-NRCS 2008a).

As the ideal bulk density values shown in Table 6 for silty clay loams is <1.40 g/cm^3, and the silty clay loam bulk density values gained in this study range from 1.029g/cm^3 to 1.396g/cm^3, it can be assumed that they are ideal for plant growth. Bulk density calculations suffice for the conclusions reached in this research project, but more data may need to be collected and more calculations run to meet the specific needs of future projects.

Future Research

All restoration projects should have goals that they can use to determine whether the project was a success or if more work needs to happen. Future teams will need to create formal goals for what they expect to happen for flood control and water quality as well as any other areas of interest. All goals formed should be backed by data from other sources stating what is a reasonable expectation for the after-action impact.

While this project focused on finding control sites and consideration for restoration for future researchers, it is essential to realize that this project could lead to other in-depth studies. Some of these topics could be over macroinvertebrate health and ecosystem functions, stream water quality, water quality in relation to macroinvertebrates, and so forth. North American Prairie is one of the most endangered biomes within this continent and is not well studied. Humans have had a major impact on these stream networks with the input of dams, agricultural land, urbanization, etc. Freshwater ecosystems in managed landscapes harbor a variety of invertebrate species, where aquatic insects are one of the major contributors to overall biomass production and to the transfer of energy between the aquatic and terrestrial ecosystems (Galic 2013). Riparian vegetation is important for restoration projects because it benefits the biodiversity and ecosystem functioning. This also poses as a barrier for species, this way they are not getting out of their breeding grounds and potentially dying. However, it is known that when vegetative cover located downstream changes it affects stream communities especially if it becomes loaded with detritus from the upland streams. Microbes are the main reason for nutrient cycling in these streams since canopy cover is limited and the clear waters allow for light to penetrate the bottom. (Dodds et al. 2004).

Another attribute to investigate would be whole watershed land cover in relation to nutrient concentrations as this would also affect macroinvertebrate populations and water quality. During different seasons different nutrients would be more prevalent than others due to soil absorption and surface runoff or potentially “pulses” of sediment-bound nutrients during high flow. Agricultural and/or urban lands are the most important predictors of water quality variability. The use of buffers or other passive land uses in headwater streams may have the potential for deterring pollution downstream (Dodds and Oakes 2007). These streams also have the potential to carry harmful herbicides and insecticides in which the accumulation of these is more than likely to reduce availability of aquatic insect prey and increase exposure to insect-borne pesticides to insectivores since insects carry the pesticides through metamorphosis (Kraus 2021).

One goal of our project was to quantify the differences in infiltration rates between our control site on Konza and study site on Coles Hall. While our group did not compare infiltration and runoff rates between the control and experimental sites, previous research has shown that prairie grasses have much higher soil moisture percentage and infiltration rates (Selbig & Balster 2010). Future groups could measure bulk density levels at our control sites and compare them with our findings from Coles Hall, which can indicate how quickly water will infiltrate the soil.

A factor that greatly influences the ecosystem value of riparian areas is the age of restoration. Older restored areas will have much more beneficial ecosystem services. Its vegetation will be denser, and their roots will reach deeper into the soil. This will increase infiltration rates, soil moisture capacity, while also lowering runoff speed. Previous studies have found that longer established sites retain more nitrogen than younger sites, providing for more vegetative growth and energy for the ecosystem's organisms (McMillan 2014). Future research could be conducted to determine how ecosystem functions differ between the long established Konza sites and a future Coles Hall tallgrass prairie plot.

Conclusion

Overall, this team was able to build a sturdy MBACI monitoring program for future research and NRES teams to build from. This was done by selecting the method by which to conduct the research (i.e. MBACI) and by selecting control sites that will be used for data collection and comparison in the future. Furthermore, the collection of the "before" soil data in the MBACI method provides a means for analyzing site conditions for future teams during and at the completion of their research. Ultimately, more considerations will need to be made to produce the most successful outcomes of a restoration project. Human interventions, ecology, pollution, soil factors, etc. are all relevant when keeping in mind best practices for the implementation of tallgrass prairie restoration in urban settings. Using the information and data obtained during this initial research, it is the hope of this team that the Kansas State University campus will soon be home to more native tallgrass and will be a part of the bigger goal that is the restoration of our prairies.

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