Ecosystem Services & Cost-Benefit Analysis - Tallgrass Prairie versus Lawn

Brittany Ettlemen, Emme Mount, Joey Pentola, Sarah Raugewitz, and Andrew Woodrum
Kansas State University
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ABSTRACT

The main objective of this study is to provide an analysis of economic costs and benefits for tallgrass prairie restoration lawn areas, as well as showcase ecosystem services associated with each to assist stakeholders on their decision whether to restore portions of the K-State campus back to prairie land. Through an extensive literature review, ecosystem services, water usage, carbon sequestration, and maintenance practices were compiled for tallgrass prairie and turfgrass ecosystems. Tallgrass prairie offers more ecosystem services than lawn species, requires less water in terms of maintenance, has the same carbon sequestration numbers as lawn and will require less overall maintenance, and therefore less overall cost. These results indicate that restoring a turfgrass plot to a native tallgrass prairie plot would cost less to maintain and increase the ecosystem services for that area.

INTRODUCTION

Addressing climate change has been a rising challenge as people, communities, companies, and even countries have continued to contribute to negative environmental impacts that threaten the future of the planet. There are large scale movements and government-funded projects, including the Zero Carbon Act that New Zealand passed in 2019 to implement climate change policies that push the country toward being carbon neutral by 2050 (Ministry for the Environment, 2021). Combined with large scale projects, local governments and institutions are creating their own climate and environmentally friendly initiatives (Allison, 2004). Kansas State University (K-State), specifically, has invested in many projects to curb their carbon footprint and contributions to waste management like the Campus Race to Zero Waste recycling competition, previously known as ‘Recyclemania’, installing bins that separate paper, plastic, and other waste materials, and educating students on how to properly dispose of e-waste or electronic waste. Most of the campus initiatives are focused towards managing and educating the community about waste and carbon emissions, including sustainable land management and native vegetation restoration projects. Scientific research has been conducted over the years to determine whether or not restoring native vegetation has a positive effect on the climate. Through this research, Zhu et al. (2019) determined that precipitation and temperature were the two dominant climate factors directly affected by native vegetation restorations and additions in landscapes.

Stakeholders at K-State are interested in developing a native tallgrass prairie restoration site on the main campus in Manhattan, Kansas and have enlisted the students in the Natural Resources and Environmental Sciences (NRES) secondary major to assist them in their decision. Thus, this study aims to critically analyze the costs and benefits of both keeping a traditional lawn and installing a native tallgrass prairie plot on campus. In addition, ecosystem services, are evaluated to determine which choice, lawn or tallgrass prairie, is better for the environment and university. These ecosystem services include carbon sequestration and storage, biodiversity, habitat, flood control, nutrient cycling, climate regulation, and recreational services.

Determining whether restored tallgrass prairie ecosystems can be successfully measured and deemed beneficial to both the environment and social communities has been a question on researchers' minds for decades (Allison, 2002). As this project progressed throughout the semester, many topics were explored regarding historically relevant restoration projects and their decision and policy making processes that either worked or were not beneficial to the ecosystems addressed. Additionally, it was important to define and categorize significant ecosystem services and their monetary values to help determine if investing in a tallgrass prairie restoration would be economically worth it. When analyzing data on ecosystem services, a variety of information was found on previously used methodology when studying the services, carbon sequestration, water usage, biodiversity and habitat.

The NRES Capstone course has conducted many different studies and analyses based on real-life applications. However, no one project has attempted to analyze and determine whether keeping traditional manicured lawns on campus or investing in a tallgrass prairie restoration plot is better for a portion of K-State's main campus in Manhattan, Kansas. Analyzing the costs and benefits of both lawns and tallgrass prairies specifically for K-State's campus makes this study one of a kind; and assessing the ecosystem services attached to both lawns and tallgrass prairies also sets this study apart from other published research. Additionally, this study has been conducted by students from a variety of disciplines including Agronomy, Biological Systems Engineering, Horticulture, and Parks and Recreation. With a multidisciplinary perspective, this study is able to address a wide range of issues that affect the environment, biological and social communities, culture, and short- and long-term planning.

Thus, the main objective of this study is to provide an analysis of economic costs and benefits for tallgrass prairie restorations in lawn areas. Partnered with this objective is the evaluation of the ecosystem services associated with both lawns and tallgrass prairies to assist stakeholders in their decision whether it is efficient to invest in a tallgrass prairie restoration plot. Through the analysis, recommendations on how much a tallgrass prairie restoration is most likely to obtain the highest return, economically and with co-benefits such as carbon sequestration, habitat, biodiversity, and recreation, on stakeholder investments as well as policy-relevant information can be provided. Based on the gathered information and skillset of the NRES student group, it is hypothesized that a native tallgrass prairie restoration site ultimately has more economic benefits and beneficial ecosystem services than current traditional lawn on campus.

2) LITERATURE REVIEW

2.1 Historical Decision-Making of Ecological Restoration

Examining historically relevant restoration projects can help organizers, scientific researchers and stakeholders develop a sense of what may work best for them regarding timeline, project scale and cost, and community involvement (Gerla et al., 2012). This analysis of previously recorded ecological restoration projects can also assist teams anticipate any challenges in budgeting or anticipate data that can be measured immediately upon restoring a plot of land (Dissanayake and Ando, 2014). On the other hand, when looking at past cases it is important to note that each project is different as values, goals, and perceived benefits will not be the same to the present group.

Through review of the literature, it was found that many ecological restoration projects were difficult to measure in terms of success. For example, in 2002 a survey of the third oldest tallgrass prairie restoration in the Midwest demonstrates the difficulty of achieving a ‘complete restoration’ (Allison, 2002). Essentially, it is common for stakeholders to see that ecological restoration can be successful, however that success cannot be measured overnight. It takes many years and factors into consideration, making it hard for stakeholders to make decisions on moving forward with a project knowing it could take years to see a visible change (Grman et al., 2013). Thus, a group investigating historical cases and the decisions associated with them will be able to take this information and convey it to stakeholders and community members to demonstrate the uncertainty involved in ecological restorations.

2.2 Under a Policy Perspective

As ecological restoration projects continue to rise in popularity among local governments and institutions, leaders have a say in the implementation and must consider policies in conjunction with the project (Suding, 2011). Ecological restoration policies are complex and driven by many rationales, and in some instances, it's difficult to visualize these when creating policy (Baker and Eckerberg, 2016). In assessing past restoration projects, it has been found that in all project goals or outcomes, an underlying value is represented. Values can be an important aspect of environmental and ecological initiatives and it is important to identify and incorporate them into these meaningful projects (Allison, 2004). In an evaluation of ecological restorations, researchers found a variety of rationales linked to values and actions taken in specific instances. Table 1 presents a few of these cases (Baker and Eckerberg, 2016).

Table 1. Understanding Rationales (Baker and Eckerberg, 2016)

Rationale	Underlying Value	Action
Return to past	Historical fidelity	Reintroduction of species assemblages and habitats, such as wolf, grasslands, and prairie
Address environmental change	Modernist	Remediation efforts at industrial or quarry site
Comply with environmental standards or existing legislation	Regulatory	Brownfield land management Mitigation, such as creation of new ecosystem to replace one destroyed elsewhere
Restore Ecosystem Services (ESS)	Utilitarian – nature as “capital” Anthropocentric ‘New Conservation”	Soil, seagrass or coral restoration
Promote novel ecosystems for climate change adaptation	Pragmatic	Assisted migration/deliberate movement of species in anticipation of shifting climatic envelopes

Table 1 is just a preview of Baker and Eckerberg’s work on historic evaluation of ecological restoration projects. Because of their work, groups working towards restoring native ecosystems can identify the rationale in policy decision-making and link it to potential values and subsequent actions to satisfy the community or government leaders as well as the project goals and outcome themselves.

2.3 Goals and Measurable Outcomes

When addressing – or discussing - ecological restoration projects in stakeholder settings or community groups, it is important to understand how to set attainable goals. An analysis of previously held restoration projects can help those individuals understand what a reasonable goal or outcome may be for their specific project. It is important to note that many goals and perceived benefits from projects like these are heavily influenced by social norms and attitudes (Coon et al., 2020). When this is taken into account, it can become difficult to identify clear goals for the group and the project. Within the literature reviewed, it was discovered that when presenting or planning the ecological restoration project to outside investors or stakeholders who may have very little scientific knowledge or backgrounds, acknowledging the timeline and most important outcomes are crucial to the success of the project. Additionally, addressing the uncertainties that lie within a project, including weather or climate shifts, allows decision-makers in the space to better understand what is measurable and attainable in the restoration project (Baker and Eckerberg, 2016).

2.4 Scenario-Based Planning

Scenario-based planning, also referred to as participatory scenario planning (PSP), is defined as “a coherent, internally consistent, and plausible description of a potential future trajectory of a system” (Oteros-Rozas, et al., 2015). This tool, not unlike its more formal modeling systems that report hard data and statistics, is used in restoration projects to clarify and discern social-ecological feedback in addition to potential surprises that are not usually identifiable in hard data. These scenarios presented in projects are incredibly influential as it allows for a variety of options to be viewed and analyzed by the group – which could potentially speed up the decision-making process (Suding, 2011). To elaborate, when a group decides on one single scenario to present, they dedicate a large amount of time to gathering data, researching the plot of land, and debating the costs and benefits. If that scenario is presented to stakeholders and then subsequently vetoed, valuable time is lost and the group must restart with a new plan.

2.5 A Bridge Between Scientific Researchers and Community Members

A huge benefit of utilizing scenario-based planning methods is allowing community members to contribute to the project and its goals. In an analysis of community participation in natural resource management and ecological restorations, it was determined that encouraging the participation of local people and using their knowledge significantly enhanced the systemsthinking approach desired in these types of projects (Waylen et al., 2015). By bringing in scientific researchers and developers and pairing them with community members that will be experiencing the change an ecological restoration brings, organizers can hear from both a social and/or cultural perspective as well as a data perspective. Part of the enhancement through community involvement is the concept of storytelling through presented scenarios (Oteros-Rozas et al., 2015). Storytelling can be of cultural significance to communities and should hold a place at the table when it comes to restoring native ecosystems to a piece of land. Through the incorporation of storytelling in scenario planning, all involved in the planning process have the opportunity to address many issues and concerns not commonly addressed in formal, data heavy modeling.

2.6 Recommendations in Utilizing Scenario Planning

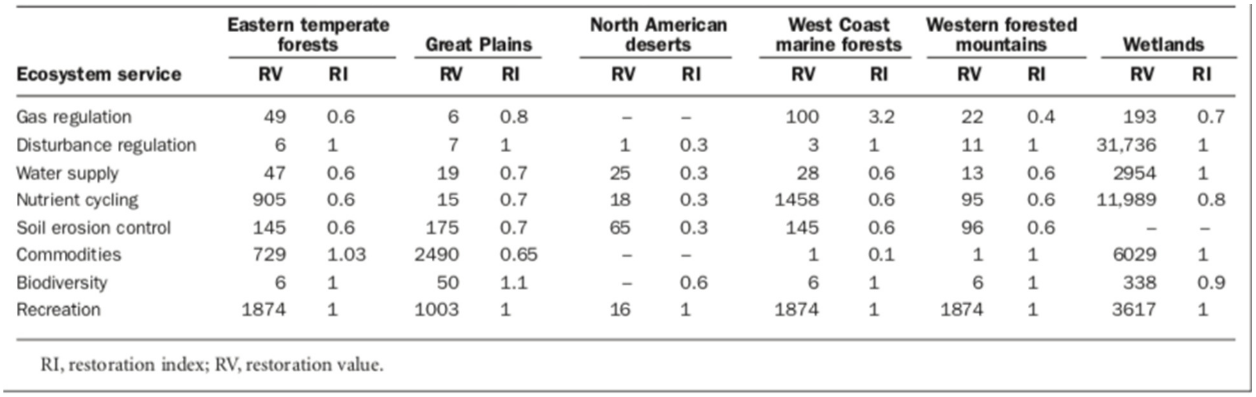
Since the concept of scenario planning is still new to the scientific community, in ecological restoration especially, there has been a call for an exploration and analysis of case studies in which the tool was used. Elisa Oteros-Rozas and her fellow researchers took up this call and compiled insights and processes used in over 20 case studies from around the world. Through this extensive examination, Oteros-Rozas and her team generated a series of recommendations on when starting a project as well as implementing it in the field. These recommendations included, but are not limited to, 1) the use of qualitative and quantitative data; 2) actively engaging with stakeholders to determine goals, outcomes, and desired benefits of the project; 3) identifying "drivers of change" which cover demographics, governance, etc., and 4) hosting workshops or meetings to explore scenarios and dive into data analysis (Oteros-Rozas et al., 2015).

2.7 Ecosystem Services Classification

In *Nature's Services: Societal dependence on natural ecosystems*, Daily (1997) defines and gives examples for the four types of ecosystem services, provisioning, regulating, cultural and supporting. While the potential list for all services an ecosystem can provide is innumerable, a handful of key services are usually the focus when assessing an ecosystem. Provisioning services are those that can be extracted from nature, and examples include food, fuel, drinking water and medicinal benefits. These are the tangible services that are the easiest for humans to see and understand. Provisioning services have well defined values because of how the economy puts them on the market (Abson and Termansen, 2010). Regulating services are slightly more complex. They are services that moderate nature and its mechanisms, like pollination, water purification, flood control, and carbon sequestration. These are more scientific in nature, and are difficult to value, however, because of the changing climate, carbon sequestration is being evaluated for monetary value. These are often not thought about as a service until the process is interrupted. The next category is cultural services, which are based on emotion, societal value, tradition, and their interactions between humans. They are non-material benefits that contribute to human development, such as hiking, bird watching, and fishing. Cultural services involve recreation, the building of knowledge and how humans can interact with nature to produce creativity. Lastly, there are supporting services. These services are the foundation of all other services. These are the underlying natural processes of Earth, like photosynthesis, the water cycle, and decomposition (Daily, 1997). Each of these four groups work together to provide benefits to humans in different capacities.

The literature differs when considering how to evaluate these different services. In their paper, “Valuing Ecosystem Services in Terms of Ecological Risks and Returns,” Abson and Termansen (2010) concluded that defining a value for provisioning and regulating services can do the most for conserving ecosystems because a clear economic value can be obtained. The other services are harder to assign a clear value to and operate more on the risk of losing the service, (Abson and Termansen (2010). This can conflict with additional research that seeks to calculate a value for all ecological services. Table 2 shows the calculated values for the different ecosystems in the United States, including services such as recreation that would fall into cultural services (Dodds et al., 2008).

Table 2. Values of Ecosystem Services for Different Ecosystems (Dodds et al., 2008)



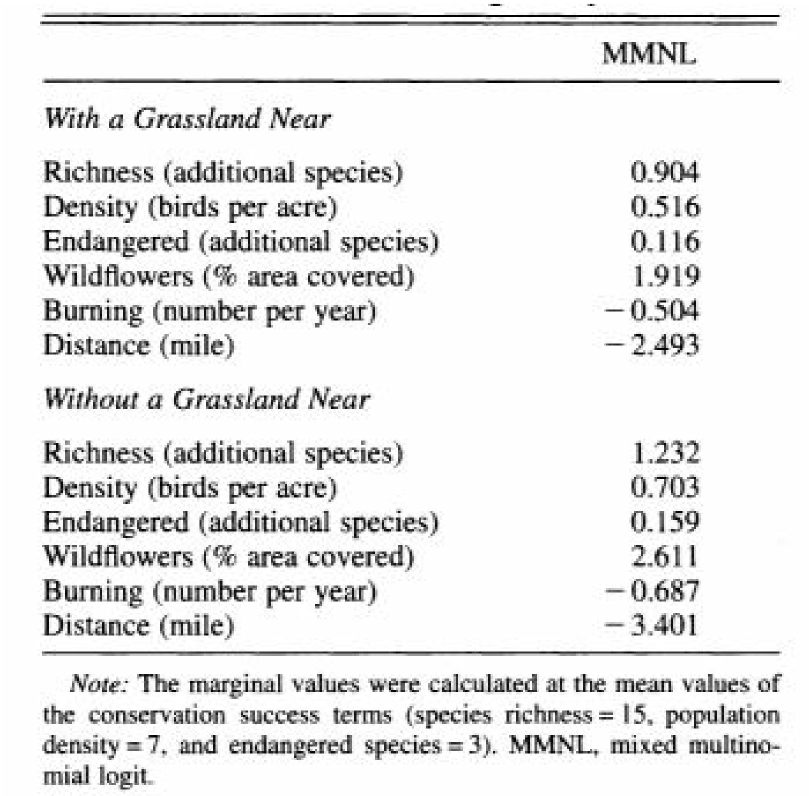
Ecosystem service	Eastern temperate forests		Great Plains		North American deserts		West Coast marine forests		Western forested mountains		Wetlands	
	RV	RI	RV	RI	RV	RI	RV	RI	RV	RI	RV	RI
Gas regulation	49	0.6	6	0.8	–	–	100	3.2	22	0.4	193	0.7
Disturbance regulation	6	1	7	1	1	0.3	3	1	11	1	31,736	1
Water supply	47	0.6	19	0.7	25	0.3	28	0.6	13	0.6	2954	1
Nutrient cycling	905	0.6	15	0.7	18	0.3	1458	0.6	95	0.6	11,989	0.8
Soil erosion control	145	0.6	175	0.7	65	0.3	145	0.6	96	0.6	–	–
Commodities	729	1.03	2490	0.65	–	–	1	0.1	1	1	6029	1
Biodiversity	6	1	50	1.1	–	0.6	6	1	6	1	338	0.9
Recreation	1874	1	1003	1	16	1	1874	1	1874	1	3617	1

RI, restoration index; RV, restoration value.

2.8 Tallgrass Ecosystem Services

The term tallgrass prairie is not in reference to one single species, but the term grassland is synonymous with tallgrass prairie ecosystems. Zhao et al. (2020) thoroughly reviewed a large amount ofarticles published dating back to 1970. 380 articles were reviewed in order to accurately display the scope of grassland ecosystem services, known as GES. Trends show that GES are increasing throughout the years, and that a total of thirty-three different GES were mentioned in the articles reviewed. Main services included carbon sequestration, forage production and water erosion control(Zhao et al., 2020). This is not to say that tallgrass has so many more ecosystem services to offer than their lawn counterpart, but a thorough review like the one from Zhao et al. (2020) was not found for lawn ecosystem services. In addition, also noted in this article is that grassland ecosystems are humans' primary source of meat and dairy products and make up for roughly one-third of the total terrestrial ecosystems carbon, so their impact is seen worldwide (Zhao et al., 2020). Much like the lawn ecosystem services, it is difficult to value GES. However, in *Land Economics*, Dissanayake and Ando et al. (2014) studied how consumers are more or less willing to pay for land based on the proximity to a grassland. This Table 3 shows the comparison of the marginal values with and without grassland near.

Table 3. Marginal change per attribute for which consumers are willing to pay $1 (Dissanayake and Ando et al., 2014)



	MMNL
With a Grassland Near	
Richness (additional species)	0.904
Density (birds per acre)	0.516
Endangered (additional species)	0.116
Wildflowers (% area covered)	1.919
Burning (number per year)	− 0.504
Distance (mile)	− 2.493
Without a Grassland Near	
Richness (additional species)	1.232
Density (birds per acre)	0.703
Endangered (additional species)	0.159
Wildflowers (% area covered)	2.611
Burning (number per year)	− 0.687
Distance (mile)	− 3.401

Note: The marginal values were calculated at the mean values of the conservation success terms (species richness = 15, population density = 7, and endangered species = 3). MMNL, mixed multinomial logit.

As seen in Table 3, consumers are more willing to pay for land when there are grasslands nearby, somewhat successfully "valuing" the GES (Dissanayake and Ando et al., 2014).

2.9 Methods of Evaluating Ecosystem Services

There are currently many different methods for evaluating ecosystem services in economic terms. Even though these methods are very time consuming, they also create a baseline. Each method evaluates the ecosystem services in a different way, so you are comparing grades of services that were evaluated on different rubrics. Below are a handful of the methods that current researchers are using to try to evaluate ecosystem services and give them a monetary value.

In their study, Greenhalgh et al. (2017) critically analyzes the Cost-Benefit Analysis (CBA) when used to evaluate ecosystem services and tries to address some common issues within this method such as the monetization of environmental values and which values to include, as well as the consequences of irreversible decisions. The methodological approach followed in this assessment evaluated the use of an ecosystem services framework and community participation to identify the key set of costs and benefits to include in a CBA (Greenhalgh et al., 2017). The authors found that by using a structured ecosystem services framework to determine which costs and benefits to include in a CBA, it can result in fewer key values being missed. This method did not however overcome the obstacle of irreversible decisions (Greenhalgh et al., 2017).

Chang et al. (2021) applied a new appraisal method for evaluating ecosystem services. It recognizes that our lack of ability to accurately show economic value for ecosystem services directly results in the neglect of said ecosystems. To test out their Public Appraisal Method (PAM) they used Wuyishan City as their study site. This site provides many ecosystem services as well as is habitat for many plant and animal species. They used data from a few sources and put that data through the current appraisal methods such as Traditional Comprehensive Method (TCM) and compared that to the results from the new PAM. The steps are to categorize real service, build a virtual market, conduct the public appraisal, and output pricing list. The PAM implementation needs to objectively introduce the functions of each ecosystem service to be evaluated, and then ask the respondents to judge the value of all services from an objective standpoint (Chang et al., 2021). They found that the PAM gave a valuation of $181.6 billion/year while TCM gave a valuation of $222.3 billion/year. The main reason for this price difference was the supporting and provisioning services, mainly reflecting the biodiversity component. The PAM method greatly underestimated the value of biodiversity. TCM adds up all of the different species when creating their appraisal for biodiversity which means the more species the more money it is worth, while PAM enables the public to identify the survival and maintenance costs of species categories. The more detailed the classification, the higher the value accounting results (Chang et al., 2021).

Saarikoski et al. (2016) compares the traditional CBA to the Multi-Criteria Decision Analysis (MCDA) when it comes to evaluating ecosystem services. The authors gathered data on both forms of evaluation and critically analyzed them both. CBA aims to value all impacts over the lifetime of project alternatives in monetary units, discounted to a specified year, making it possible to screen or rank alternatives by a single monetary measure, while MCDA is used more for research problems and geared towards finding a solution to a single problem. The results of this paper showed that MCDA performs better than CBA when it comes to evaluating ecosystem services. MCDA does a very good job of being able to take into account many different aspects of services such as ecological, economic, cultural and also moral aspects and it is better suited to assist in a debate between stakeholders in how to solve a particular problem (Saarikoski et al., 2016).

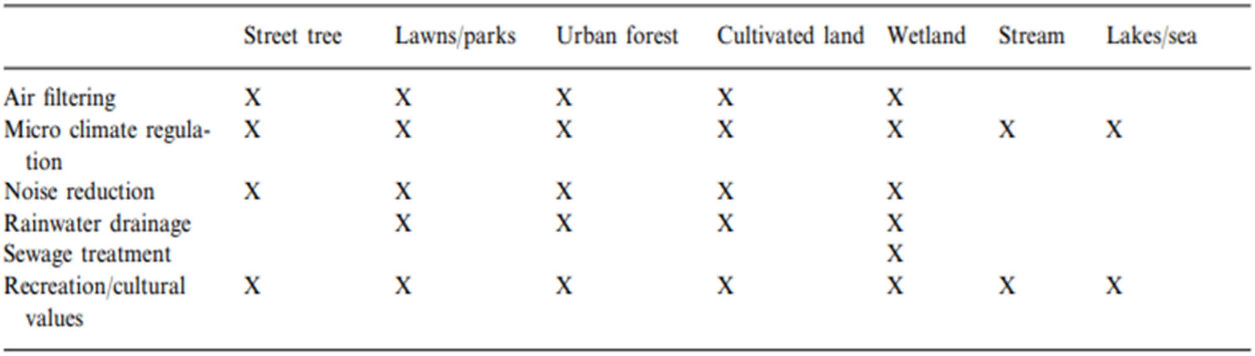
Turk et al. (2017) at revegetation in newly constructed electric transmission line right-of-way (ROW). More specifically, they looked at using a seed mix with native herbaceous species versus a seed mix with exotic herbaceous species. They analyzed data from a feasibility study of ROWs planted with the native seed mix as well as information from the Tennessee Valley Authority about the revegetation and maintenance costs. They found that initially the cost of revegetating the native grass species was 5% more expensive, however the maintenance required goes down over time. The native grass species would eventually reduce maintenance costs by 10-17% (Turk et al., 2017).

Through this review, it can be seen that there is a wide variety of possible ways to evaluate the economic value of ecosystem services. However, some methods and combinations of methods are very timely and can be confusing to carry out. This research will be very important for future projects because with the proper method it is possible to directly communicate the value of these ecosystem services in economic terms to someone who might not understand the scientific importance. In other words, money may speak louder than scientific facts.

2.10 Turfgrass Ecosystem Services and Carbon Sequestration

While it is not generally seen as a naturally occurring ecosystem, the urban lawn does provide its own ecosystem services. Lawns provide regulating services by preventing soil erosion and flood control. They also provide cultural services through being aesthetically pleasing to the public (Monteiro, 2007; Selhorst and Lal, 2013). Turf grass provides services in cooling capacity, oxygen production, carbon sequestration, a potential to decrease pollution, and reduction in water runoff (Monterio, 2007). For this research, the term “lawn” will be in reference to the Kentucky bluegrass species. This is a very common species used for lawns and parks around the United States, and all data will be in reference to this specific species. In *Ecosystem services in urban areas* by Bolund et al. (1999), they analyze ecosystem services provided by ecosystems located inside urban areas. The list includes street trees, lawn/park, urban forest, cultivated land, wetland, stream and lakes/sea. Table 4 shows graphically the different services that these ecosystems have been known to provide and which services are provided by the specific ecosystem (Bolund et al., 1999).

Table 4. Urban ecosystems generating local and direct services (Bolund et al., 1999).



	Street tree	Lawns/parks	Urban forest	Cultivated land	Wetland	Stream	Lakes/sea
Air filtering	X	X	X	X	X		
Micro climate regulation	X	X	X	X	X	X	X
Noise reduction	X	X	X	X	X		
Rainwater drainage		X	X	X	X		
Sewage treatment					X		
Recreation/cultural values	X	X	X	X	X	X	X

Table 4 shows that the lawn/park ecosystem has the capability of providing air filtration, micro-climate regulation, noise reduction, rainwater drainage, and recreation/cultural values (Bolund et al., 1999). Considering that the area in this study is going to be located in the middle of a college campus, this "urban" characterization allows for a direct comparison to the services that the lawn provides currently on K-State campus.

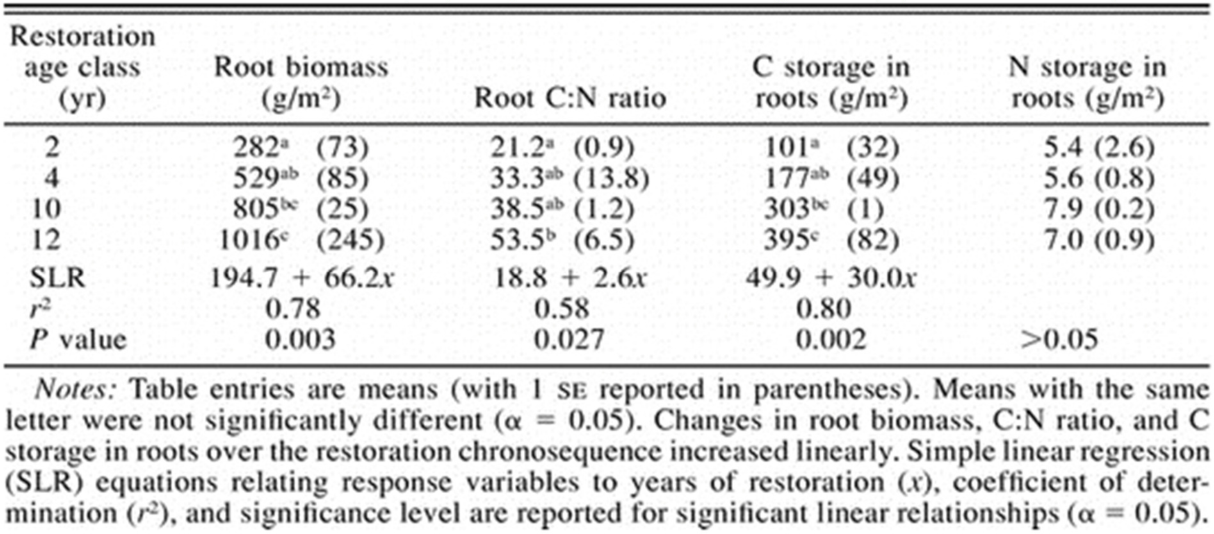
With all of these ecosystem services, costs are also involved in the maintenance and creation of lawns. There are hidden carbon inputs in the maintenance of lawns such as mowing, and additional use of fossil fuels can dent the benefit of carbon sequestration (Selhorst and Lal, 2013). Additional fertilizers are often applied to ornamental lawns which can be detrimental to the environment and how lawns are created also have an impact on how they interact with rain events and management, (Cheng et al., 2014).

Between lawns with topsoil and the ones with only subsoil, the water runoff initiation time was shorter while the runoff volume and sediment loss was much larger in the subsoil plots (Cheng et al., 2013), showing that how urban lawns are developed also matters. Organic and inorganic fertilizers also play a part in the runoff process. In the same study, Cheng et al. (2013) showed that the amount of inorganic phosphorus runoff was higher on the subsoil plots than the topsoil plots. How the lawn is used also has an impact on its role in the environment. Townsend-Small and Czimzik (2009) conducted a study examining the carbon sequestration and nitrogen content in ornamental lawns and athletic fields. Soil cores were taken at defined intervals to measure organic carbon and nitrogen content. It was shown that turf grass emits more N_2O because of the higher frequency of fertilization and that these athletic lawns have a lower value for carbon sequestration because of the frequent mowing. Ornamental lawns had a higher carbon sequestration because of the lower amount of maintenance associated with it (Townsend-Small and Czimzik, 2009).

2.11 Prairie Ecosystem Services and Carbon Sequestration

In contrast with the urban lawn, the tallgrass prairie is a natural landscape; and contains many of the same ecosystem services. Like the urban lawn the tallgrass prairie provides recreation, carbon sequestration, nutrient cycling, soil erosion control, but to a different degree. Studies documenting the restoration of grasslands have come to the forefront examining the recovery of such services. The reclamation of such lands was done in Nebraska on lands that formerly grew dryland corn and other grains (Baer et al., 2002). Baer and their associates (2002) found that the restoration of these lands increased the C microbial biomass, C mineralization and that within 12 years of being restored the carbon sequestration was brought back up to the current level of sustained native grasslands as can be seen in Table 5

Table 5 Biological measures (root biomass, C:N ration and C and N storage in roots from grasslands restored for 2, 4, 10, and 12 yr (n=2 grasslands for each age class) (Baer et al., 2002)



Restoration age class (yr)	Root biomass (g/m^2)	Root C:N ratio	C storage in roots (g/m^2)	N storage in roots (g/m^2)
2	282^{a} (73)	21.2^{a} (0.9)	101^{a} (32)	5.4 (2.6)
4	529^{ab} (85)	33.3^{ab} (13.8)	177^{ab} (49)	5.6 (0.8)
10	805^{bc} (25)	38.5^{ab} (1.2)	303^{bc} (1)	7.9 (0.2)
12	1016^{c} (245)	53.5^{b} (6.5)	395^{c} (82)	7.0 (0.9)
SLR	$194.7 + 66.2x$	$18.8 + 2.6x$	$49.9 + 30.0x$	
r^2	0.78	0.58	0.80	
P value	0.003	0.027	0.002	>0.05

Notes: Table entries are means (with 1 SE reported in parentheses). Means with the same letter were not significantly different ($\alpha = 0.05$). Changes in root biomass, C:N ratio, and C storage in roots over the restoration chronosequence increased linearly. Simple linear regression (SLR) equations relating response variables to years of restoration (x), coefficient of determination (r^2), and significance level are reported for significant linear relationships ($\alpha = 0.05$).

Table 5 shows that overtime the root biomass of the restored prairie increased, which in turn increased the carbon and nitrogen storage. The composition of these fields changed from C_3

to mostly C_4 plants over the 12 year period with the percentage of grass cover increasing from less than 20% at the 2 year period to approximately 80% by the end of the study with the inverse of that relationship taking place for the percentage of forbes (Baer et. al., 2002). This change in prairie composition may account for a change in soil organic carbon after an extended period of time. Another restoration study was conducted in Illinois on a longer running restoration project of 33 years. Ampleman et al. (2013) found that through different plot compositions of all forbs, all grasses and mixed with age variations from oldest to youngest, there was a loss in the total organic carbon for all the grass plots over the 33 years. This is due to the cost of carbon through maintained burning of the prairie for maintenance which offsets the carbon sequestration provided by the vegetation. Having a mix of forbs and grasses mitigates this maintenance because of their efficacy in nutrient cycling (Ampleman et al., 2013).

2.12 Pollinators

Pollinators play an important role in nature and can be readily found in almost all ecosystems. An estimated 80% of plants rely on animal pollination for seed (Harmon-Threatt and Chin, 2016). Many articles analyzed the effects of restoration practices on pollinators. For instance, bees and prairie seem to be linked. Usually, more prairie grasses available means that more bees are present. Bee diversity is also known to increase with more diverse plant communities (Harmon-Threatt and Chin, 2016). The results showed that a larger site increases the amount of bees, but the surrounding sites are a factor as well. If the surrounding area is habitable and suitable for bees, the larger species of bees that can travel a longer distance will also visit surrounding areas (Harmon-Threatt and Chin, 2016).

Bees are not the only pollinators to consider; butterflies also play an important role and can be seen more abundantly in greater biodiverse areas. In their study, Myers et al. (2012) found that butterflies were six times more abundant and twice as species rich in the more biomass rich experiment plots than the plots with just switch grass and warm season grass plots. Blackmore (2019) compared butterflies' usage of green roofs in comparison to an urban prairie park and found that even though butterflies were more abundant on the green roof, which they used for foraging, they traveled between sites for other biological purposes such as nesting. This again shows that biodiversity is key, correlating to the study performed by Harmon-Threatt and Chin (2016), which suggests that pollinators will travel amongst sites to suit their needs. So not only is diversity key amongst sites, but the more sites available will see the greatest activity.

Despite pollination being so important, many people view invertebrates such as bees negatively. Largely because some invertebrates cause disease and crop damage (Prather et al., 2013). However, invertebrates provide a variety of supporting and regulating services to any ecosystem. Thus, attracting them to a restoration plot would be a key value to any conservation practice. They occupy a variety of trophic levels and interact with my trophic groups, from primary producers to top predators, besides having a large impact on ecosystem services (Prather et al., 2013).

2.13 Restoration Practices

When creating a restoration plot, seed choice and dispersal is important. As biodiversity is key, a diverse seed mixture is typically the best choice. Incorporating hardy native prairie plants into reclamation seed mixes can increase the value of the ecosystem for pollinators and wildlife, and potentially improve soil conditions more quickly than non-native plantings alone (Swab et al., 2017). In the same study, Swab et al. (2017) found that the native seed mix produced more diversity and species richness in the first year in comparison to the traditional seed mixture. This study looked at seeding reclaimed mine land which typically has poor soil quality. Another study found that native grasses will grow even in poor soil. In a study done in an urban setting they found that even an urban wasteland is suitable habitat for grassland species (Fischer et al., 2013). Thus, while soil quality is important, even in areas with poor soil, restoration practices can be accomplished.

2.14 Tallgrass Prairie Management Systems (*burning vs. mowing)*

To properly manage a tallgrass prairie above ground, biomass management must be taken into account. The three main strategies for tallgrass prairie management are prescribed burning, grazing and mowing, each having their own pros and cons. The below ground biomass is just as important as the above ground. As can be seen in Figure 1, mowing, burning and grazing have an effect on the root biomass.

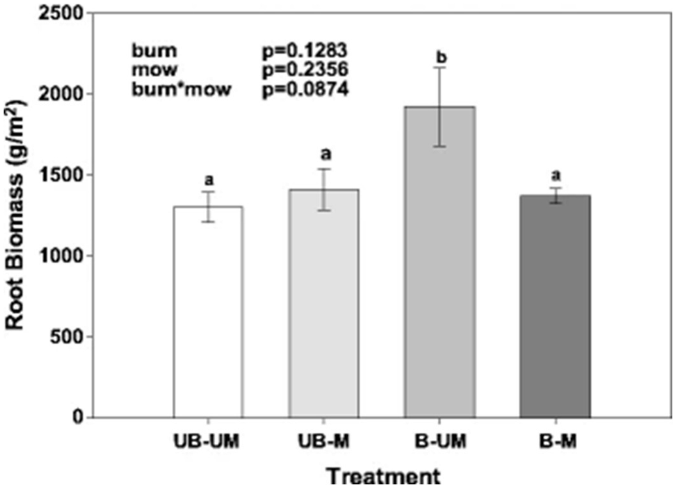
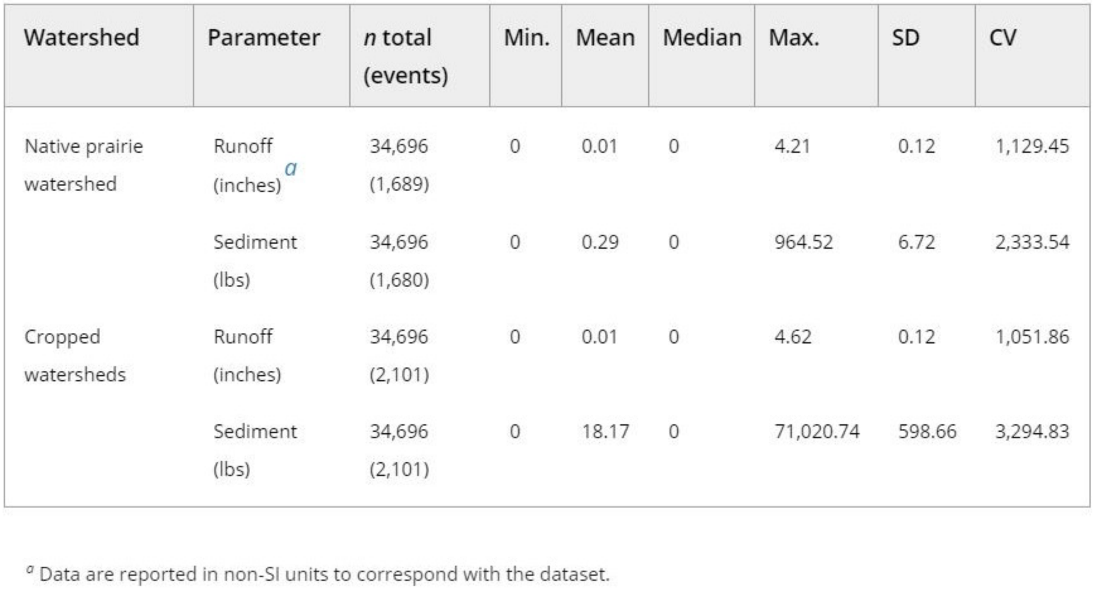


Figure 1. Cumulative Root Biomass (0-90 cm) (Kitchen et al., 2009)

Figure 1 shows that the burning and unmowed plots had a higher root biomass than the other plots of unburned/unmowed, unburned/mowed, and burned/mowed. While the burning increased root biomass, the mowing treatment shifted root biomass to shallower depths (Kitchen et al. 2009). This decreased root biomass is not as ideal as the characteristic depth of the burned prairie. A similar study conducted in Germany in which North American prairie grasses are planted in public spaces was conducted. There was also a concern of whether burning or mowing would be best for the restored prairie and for the public spaces (Schmithals et. al, 2014). Schmithals et al. (2014) concluded that if a mowing-only treatment is conducted, weeds will have a higher chance of taking over the plot; however, the plots that had additional burning treatments had no significant differences than the mow-only plots. With that, the management costs of burning were higher than a mowing and weeding labor (Schmithals et. al, 2014).

2.15 Erosion and sedimentation effects in Tallgrass Prairie

According to Nelson et al. (2020), tallgrass species were studied to see the effects of erosion and sedimentation when watersheds were cropped. They recorded numbers for rainfall, sediment, pH, nutrients, runoff, etc.. Figure 2 shows the difference in runoff and sediment loss in native prairies and cropped watersheds (Nelson et al., 2020). In this case, the cropped watersheds had a much higher sediment loss than the native prairie. These numbers were used for a baseline of tallgrass watershed runoff and sedimentation (Nelson et al., 2020).



Watershed	Parameter	*n* total (events)	Min.	Mean	Median	Max.	SD	CV
Native prairie watershed	Runoff (inches)[a]	34,696 (1,689)	0	0.01	0	4.21	0.12	1,129.45
	Sediment (lbs)	34,696 (1,680)	0	0.29	0	964.52	6.72	2,333.54
Cropped watersheds	Runoff (inches)	34,696 (2,101)	0	0.01	0	4.62	0.12	1,051.86
	Sediment (lbs)	34,696 (2,101)	0	18.17	0	71,020.74	598.66	3,294.83

[a] Data are reported in non-SI units to correspond with the dataset.

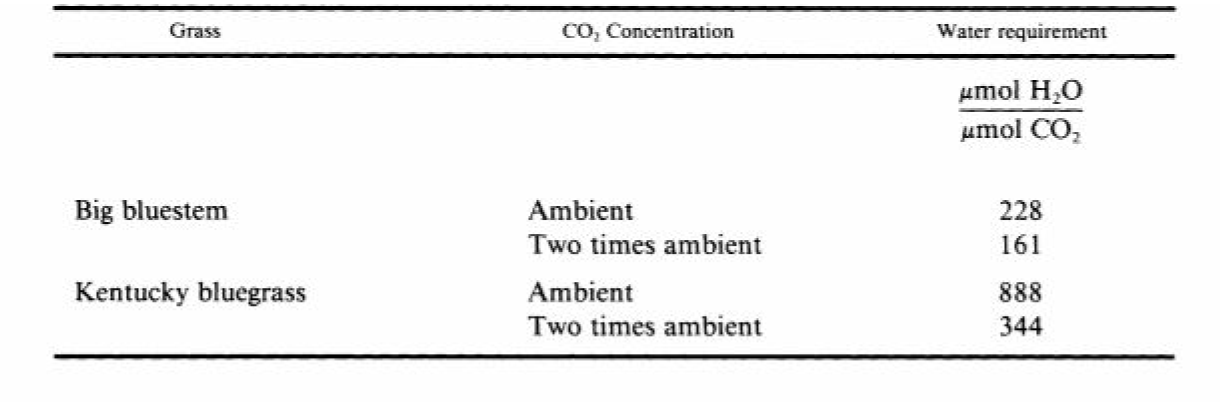
Figure 2. Descriptive statistics for daily runoff data from native tallgrass prairie and cropped watersheds in 1977-1999 (Nelson et al., 2020)

Another group of researchers wanted to see how climate change was affecting tallgrass erosion rates, which may be accelerating due to the weather changes. Xue et al. (2011) conducted experiments testing different plots of tallgrass prairie ecosystems, using control versus warmed plots. They found that from November 1999 to April 2009, the average relative erosion depth induced by clipping was 1.65±0.09 and 0.54±0.08 mm yr^{-1}, respectively, in warmed and controlled plots. The soil erosion rate in the warmed plots was 2148±121 g m^{-2} yr^{-1} compared to 693±113 g m^{-2} yr^{-1} in the control plots. In the warmed plots, soil organic carbon was lost at a rate of 69.6±5.6 g m^{-2} yr^{-1} compared to 22.5±2.7 g m^{-2} yr^{-1} in the control plots. In the warmed plots, total nitrogen was lost at a rate of 4.6±0.4 g m^{-2} yr^{-1} compared to 1.4±0.1 g m^{-2} yr^{-2} in the control plots (Xue et al., 2011). These numbers show how much erosion is happening on tallgrass prairie ecosystems, and what the numbers could look like in the future if climate change continues to increase.

2.16 Kentucky Bluegrass Water Data

Wang et al. (2007) studied the waterlogging tolerance of Kentucky Bluegrass and how this state affects the species. Overall, the conditions of Kentucky Bluegrass when waterlogged is very detrimental. In this condition, the quality of the grass declined, chlorophyll production decreased, and pH decreased (Wang et al., 2007). Unfortunately, this does not bode well for turfgrass on campus because of how often large rainfall events leave Manhattan in a waterlogged state. The most important data about Kentucky Bluegrass water consumption comes from He et al. (1992) (Table 2). This table compares the water requirement for Big Bluestem, a tallgrass species, and Kentucky Bluegrass. The experiment they tested how each species responds to CO_2 concentration and how that would change the amount of water they need to survive and grow.

Table 6. Water requirement for big bluestem and Kentucky bluegrass on a tallgrass prairie in Manhattan, Kansas, as affected by CO2 concentration in the fall of 1989 (He et al., 1992).

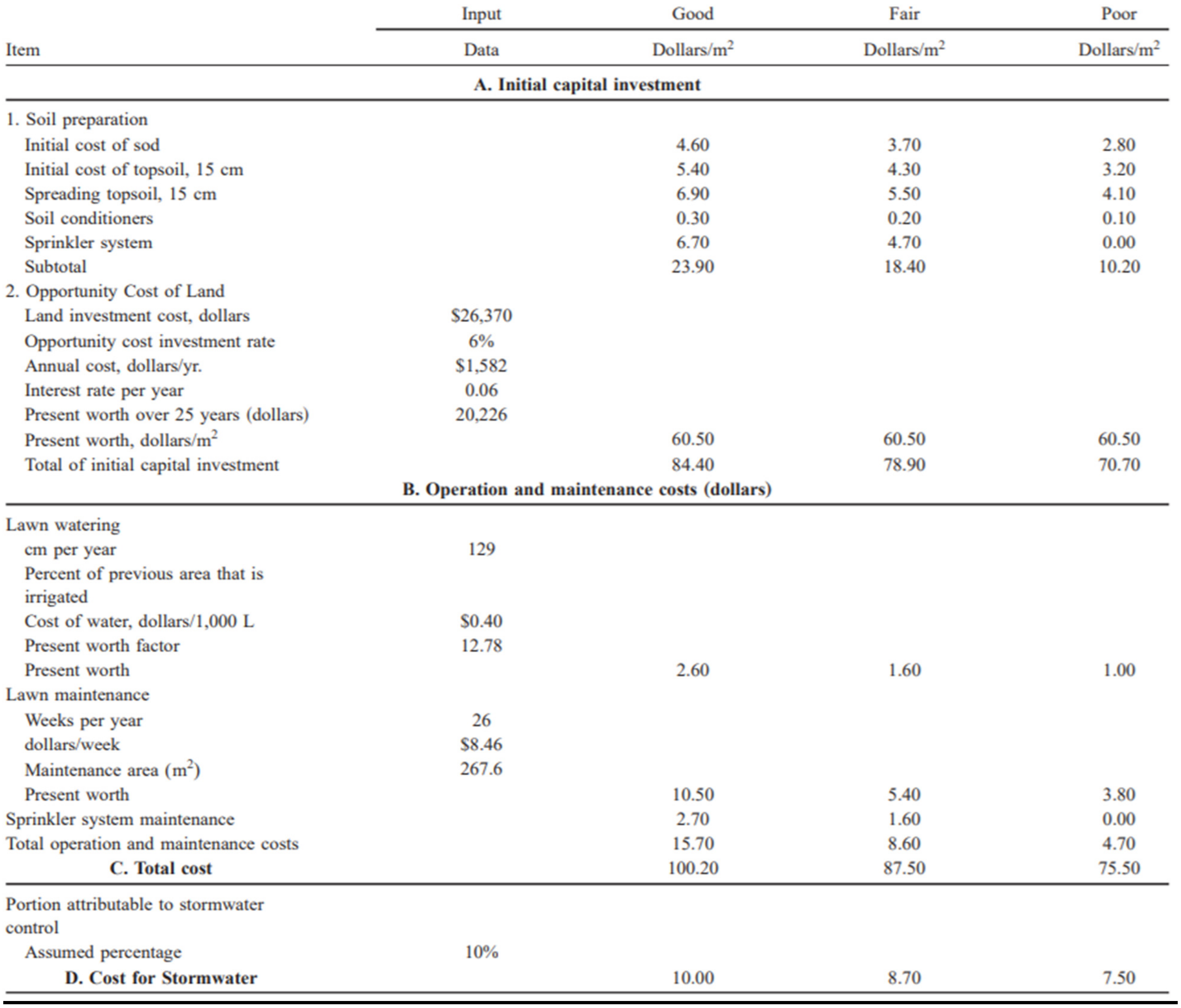


Grass	CO_2 Concentration	Water requirement
		$\frac{\mu mol\ H_2O}{\mu mol\ CO_2}$
Big bluestem	Ambient	228
	Two times ambient	161
Kentucky bluegrass	Ambient	888
	Two times ambient	344

The important numbers here however are the ambient calculations. These calculations were taken during “normal” conditions for each ecosystem, and it shows a massive difference in water required. Tallgrass only needed 228 units, whereas Kentucky Bluegrass needed 888 units, showing that in conditions that these ecosystems encounter most often, tallgrass species require much less water to survive than that of lawn species (He et al., 1992). However, this data is slightly outdated, and therefore not as reliable as more recent information would be.

Sample et al. (2003) evaluated best management practices in regard to land management in an attempt to value these practices and with a specific cost. Table 7 shows the cost analysis performed of landscaping a medium density lot that consists of a lawn species. It is sectioned into good, fair, and poor, which is the quality of the land that is being evaluated. As shown in Table 7, the team analyzed the initial capital investment as well as operation and maintenance costs for this specific situation (Sample et al., 2003).

Table 7. Cost Analysis of Landscaping for Medium Density Lot (Lawn species) (Sample et al., 2003)



Item	Input Data	Good Dollars/m^2	Fair Dollars/m^2	Poor Dollars/m^2
A. Initial capital investment				
1. Soil preparation				
Initial cost of sod		4.60	3.70	2.80
Initial cost of topsoil, 15 cm		5.40	4.30	3.20
Spreading topsoil, 15 cm		6.90	5.50	4.10
Soil conditioners		0.30	0.20	0.10
Sprinkler system		6.70	4.70	0.00
Subtotal		23.90	18.40	10.20
2. Opportunity Cost of Land				
Land investment cost, dollars	$26,370			
Opportunity cost investment rate	6%			
Annual cost, dollars/yr.	$1,582			
Interest rate per year	0.06			
Present worth over 25 years (dollars)	20,226			
Present worth, dollars/m^2		60.50	60.50	60.50
Total of initial capital investment		84.40	78.90	70.70
B. Operation and maintenance costs (dollars)				
Lawn watering				
cm per year	129			
Percent of previous area that is irrigated				
Cost of water, dollars/1,000 L	$0.40			
Present worth factor	12.78			
Present worth		2.60	1.60	1.00
Lawn maintenance				
Weeks per year	26			
dollars/week	$8.46			
Maintenance area (m^2)	267.6			
Present worth		10.50	5.40	3.80
Sprinkler system maintenance		2.70	1.60	0.00
Total operation and maintenance costs		15.70	8.60	4.70
C. Total cost		100.20	87.50	75.50
Portion attributable to stormwater control				
Assumed percentage	10%			
D. Cost for Stormwater		10.00	8.70	7.50

This data identifies costs for implementing and maintaining a medium density lawn lot in different conditions. The total initial capital investment as well as maintenance costs for a good lawn would be around $185 per year and decreases with each degradation of quality. This is solid data, however it is difficult to compare to what tallgrass prairie numbers might look like due to the difference in maintenance methods. Tallgrass is usually burned and allowed to grow in natural conditions with minimal watering, so the maintenance would look much different for tallgrass versus lawn.

According to Brennen et al. (2007), the cost of producing and maintaining lawn greenness consists of up-water costs and maintenance costs. Lawn maintenance costs generally comprise mowing, fertilizing and weeding. Colmer and Short's (2001) experimental data on volume of grass clippings in relation to irrigation treatment revealed a linear relationship between water and production, so a linear relationship between irrigation and mowing cost can be assumed. The researchers interviewed a turf production company and a mowing company to develop cost assumptions for lawn maintenance at two levels of irrigation, based on pre-restrictions experience and the current 'two day per week' water restrictions (Solomon and Mustard, 2006), and then estimated a straight-line relationship as a function of irrigation. The total unit cost of water is the sum of these lawn-maintenance costs and the direct price of water. Perth consumers face inclining block tariffs, and marginal water costs vary between #0.45 and #1.2/kL (kiloliters), depending on the total level of household consumption. The team used a marginal price of#0.91/kL which is the price that is likely to be paid by a consumer with an average sized household and the garden watering quantities we analyze in this study (Brennen et al., 2007). This data is used to help bring more cost data to lawn maintenance, however this data is from a study conducted in Australia, which should be taken into account in comparison.

3) METHODOLOGY

A study on a site at the K-State main campus was performed (Figure 3). The study site was chosen based on the following criteria: 1) educational opportunities presented, 2) visibility of the restoration, and 3) ease of access for maintenance by staff and students. Data and literature collected for this project were compiled over a number of weeks using different databases for a wide variety of sources. The project members conducted their own searches that were then developed into individual literature reviews and integrated into this report. Outside sources such as the Grounds Maintenance Department at K-State and Konza Prairie Biological Research Station were consulted on the current practices being utilized for maintenance. The study site resides in the blue area (Figure 4). Figure 4 represents a map of the Zone 3 provided by K-State Grounds Maintenance staff. Results were formulated from the literature and data review, in addition with the information gathered from the K-State Grounds Maintenance Department.

Figure 3. Aerial Photo of Selected Site.
Source: Google Earth

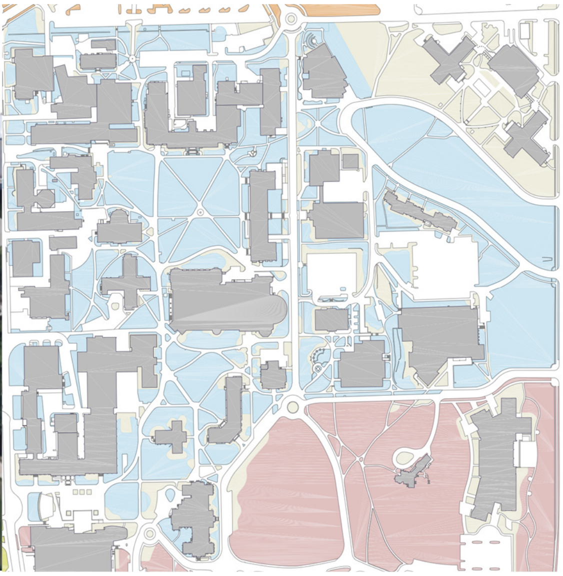


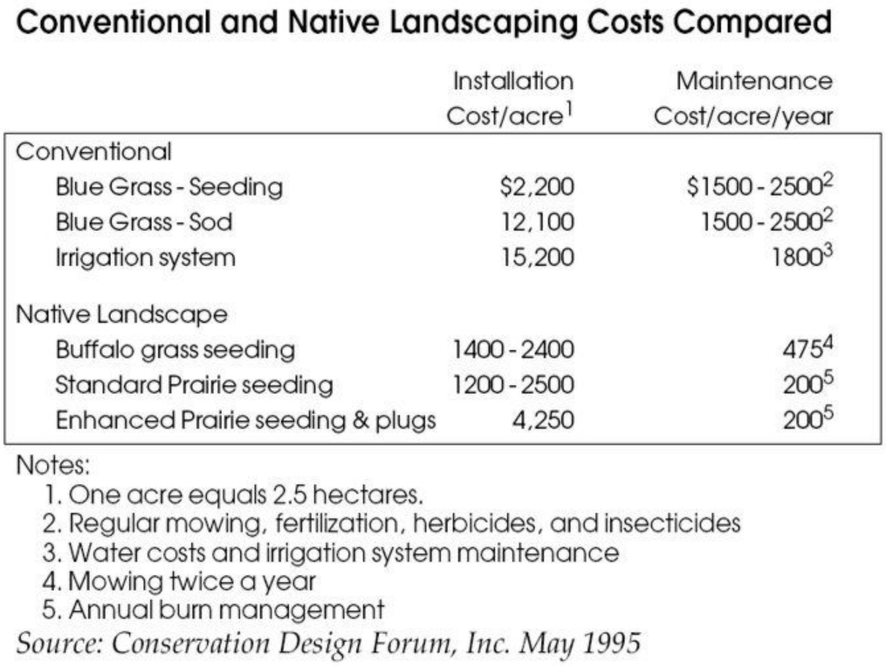
Figure 5. Map of KSU Grounds Zone 3
Source: KSU Grounds and Maintenance

4) RESULTS AND DISCUSSION

Based on the literature that was reviewed, the ecosystem services between the tallgrass prairie and the turfgrass ecosystem are similar, but they operate at a different degree. In terms of biodiversity the tallgrass prairie has a higher number of diverse plant species which in turn increases the number of bees present (Harmon-Threatt and Chin 2016). According to He et al. (1992), the water needed to maintain a lawn is greater than what it would take to maintain a prairie plot. The same relationship is seen when looking at runoff and sediment loss. The prairie plots had less total runoff and less sediment loss in pounds than the Kentucky Bluegrass plots.

After consulting with Grounds and Maintenance Department at K-State, it was concluded that the university spent roughly 14,000 hours on labor from January 1st to December 31st , 2020. The total labor costs was $408,717.16 for this specific year. For Zone 3 the total labor costs were $78, 458.94 in 2020. These include costs related to mowing, fertilizer application, tree maintenance, and irrigation installation and repair. In a separate study, Turk et al. (2017), found that native grass restoration reduced maintenance costs by 10-17%. Based on this data, it can be concluded that restoring the site on campus would reduce overall maintenance costs. If the site is restored as a tallgrass prairie, irrigation also can be reduced to maintain this area. The mowing of that plot would be significantly reduced in the number of hours needing to be mowed as well as maintenance on equipment.

The National Parks Service estimates that during the first year a prairie will only need to be mowed 3 to 4 times during the growing season. Looking at long term maintenance they suggest only mowing once. This similar result can be seen in Figure 5, which shows that the native landscape is cheaper to maintain (Malin, 1995).



Conventional and Native Landscaping Costs Compared

	Installation Cost/acre[1]	Maintenance Cost/acre/year
Conventional		
Blue Grass - Seeding	$2,200	$1500 - 2500[2]
Blue Grass - Sod	12,100	1500 - 2500[2]
Irrigation system	15,200	1800[3]
Native Landscape		
Buffalo grass seeding	1400 - 2400	475[4]
Standard Prairie seeding	1200 - 2500	200[5]
Enhanced Prairie seeding & plugs	4,250	200[5]

Notes:
1. One acre equals 2.5 hectares.
2. Regular mowing, fertilization, herbicides, and insecticides
3. Water costs and irrigation system maintenance
4. Mowing twice a year
5. Annual burn management

Source: Conservation Design Forum, Inc. May 1995

Figure 5. Conventional and Native Landscaping Costs Compared (Malin, 1995)

The literature reviewed also suggests that burning is the most ecologically beneficial way to maintain and control tallgrass prairie. Burning practices are typically done once a year, which would continue to cut maintenance and labor costs. The Konza Prairie Biological Research Station also burns each year. The number of people needed is typically based on the equipment and size of the land. They use a group of fourteen at minimum, with two teams. Each team needs two drivers, three to four hosers, and one to two lighters. In addition, they prefer extra eyes to watch for any problems or switch out if anyone gets tired. While Konza uses a large group of people for their burning practices, they also have a lot of land to cover.

Based on this information provided by Amanda Kuhl, a research assistant for the Konza Long Term Ecological Research Department, it would be estimated that a group of three to four would be sufficient for burning a plot of land with the size of the study site (0.02ha). Fertilizer for a tallgrass prairie is also not necessary as it will induce the growth of invasive weeds in the plot, (Bailey and Martin, 2007) reducing costs of fertilizer and labor hours for fertilizer application. Bailey and Martin (2007) also explained that with mechanical maintenance, some hand weeding and removal of unwanted species will be needed. On larger scale, this would not be viable and burning would be a better option.

In addition, to maximize the desired education aspect of the restoration plot, it is important to use a diverse seed mixture. Literature suggests that a diverse seed mixture during the planting stage, will result in a species rich environment, which will invite a greater amount of the pollinators, as well as the growth of various herbaceous species (Bailey and Martin, 2007). This will allow for not only a visually appealing plot with rich vegetation, but an opportunity to educate the public on various species of flora and fauna.

5) CONCLUSION

The planning and implementation of a restoration project can be overwhelming and complex for stakeholders who have little to no experience with restoration. Researching past historically relevant restoration projects with native vegetation gives organizers a better understanding of the issues, guidelines, and what potential plans should look like if they are looking for the best immediate and long-term results. Analyzing previous restoration projects allows for stakeholders and organizers to compare their own site characteristics, project goals, and other outcomes and decide the best course of action through past experiences.

Additionally, the inclusion of scenario-based planning can address unforeseen problems, anticipate any concerns from stakeholders and the community, and present different options that allow for true participation in the project as a whole. When it comes to researching the two species in question, both species have benefits in terms of ecosystem services, but as the research shows, tallgrass prairie has more services to provide than lawn species.

There is not one method for valuing ecosystem services economically that is nationally accepted. Due to the services having intangible benefits and different people having differing views on which services are beneficial and to what degree, attributing cost values to ecosystem services is a difficult practice. Many different methods need to be used in order to see the many different aspects of ecosystem services and get a true outlook on what they bring to an environment.

After being replaced and restored, tallgrass prairie has equal numbers of carbon sequestration with that of lawn species, meaning that making the switch will not have any negative impacts on carbon sequestration. Tallgrass species also increase root biomass in plots previously held by lawn species, which in turn increase carbon and nitrogen storage.

For a restoration plot to be successful, biodiversity is key. As shown in the literature review, the more species rich an area is, the more ecosystem services that area can provide. In regard to maintenance of both species, it is worth noting that tallgrass prairie does not require soil to be in pristine conditions in order to thrive in an urban environment. It is also worth noting that burning for tallgrass prairie maintenance is the preferred method for low cost and high-quality tallgrass. However, considering the proximity to the general public given the chosen area to implement the species into, safety concerns means mowing would be the better maintenance method. If burning were to be chosen, the initial cost would eventually lead to money saved by the university over a steady mowing maintenance method. For lawn maintenance, frequent mowing leads to the loss of some ecosystem services provided, as shown in the literature review.

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