# AN ECOLOGICAL CASE AGAINST DEVELOPMENT: REMOTE SENSING ANALYSIS OF ECOLOGY AND VEGETATION AROUND SPRING LAKE, TEXAS, USA

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I dedicate this to my parents, Dr. Sansom, and our planet, upon which we depend for happiness.

Abstract:

Anthropogenic development is negatively affecting global ecosystems by removing habitat, toxifying the earth, and reducing biodiversity. Humans are dependent on healthy ecosystems. Thus, our own activity threatens our survival as we continue to test the limits of the living earth system. Ecosystems are complex, nested systems, which means the local affects the global and vice versa. This study looks at the ecological health of the terrestrial ecosystem around Spring Lake, San Marcos, Texas via remote sensing of vegetation and offers a comparative analysis of outcomes for land management practices based on the conclusions of those analyses. The land management practices being compared are: wildland vs. recreation field (golf, baseball, etc.).

# 1. Introduction

Texas State University (herein referred to as the university) is a public Emerging Research University in San Marcos, Texas, USA (Texas State University 2017). Our grounds include karst Edwards Aquifer fed lentic, environmentally sensitive Spring Lake, and proximal terrestrial ecosystem (figure 1). Spring Lake is an isolated system with a high degree of endemism (U.S. Fish and Wildlife Service 1996) that hosts eight species listed as federally endangered or threatened (The Meadows Center 2017) and feeds the lotic San Marcos River.

Humans have occupied San Marcos Springs since the late Pleistocene (Hooge, 2013). In the Anthropocene, San Marcos Springs were used for a variety of industrial and commercial uses that degraded site environmental quality (U.S. Army Corps of Engineers 2005).

The Meadows Center is an environmental education and research center in a structure that used to be part of historical Aquarena Springs Theme Park (herein referred to as Aquarena Springs). The main attraction of Aquarena Springs was Spring Lake. During Aquarena Springs' time, site ecological health took a backseat to the allure of profits, and environmental quality suffered. Environmental degradation has occurred at the site due to industrial and commercial exploitation (U.S. Army Corps of Engineers 2005).

Some of the former theme park site, previously a mix of impervious cover and buildings has been converted to wild grassland (figure 2). The purpose of this thesis is to examine the success of that restoration in terms of improving ecological health, make improvements to its methodology, and advocate for a restoration of the riparian zone around Spring Lake.

Moreover, the purpose of this study is to demonstrate development and or further degradation of the riparian and surrounding zone into recreation fields would be an ecologically damaging choice via a comparative analysis of two land management practices for the riparian zone around Spring Lake: wildland and recreation field(s).

## *Problem*

In 2011-2012, native grass seeds were planted on part of the site during a restoration of the site to recreate pre-European arrival native grassland conditions (The Meadows Center 2012). There is little data on the success of that restoration, however a qualitative assessment of the restored area that I performed in spring 2017 indicated that biomass and biodiversity is high but ecological value is impeded by proliferation of invasive exotics species (Shannon 2017).

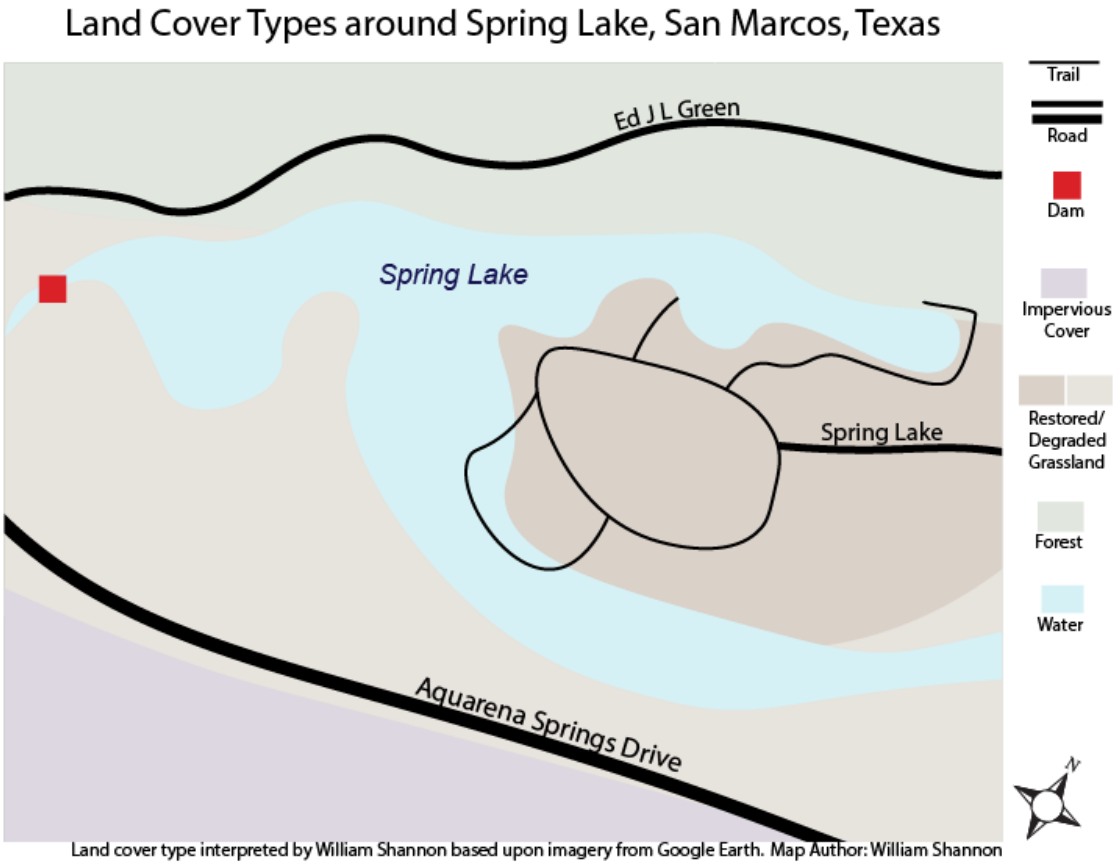


Figure 1. Land cover types around Spring Lake based on a qualitative assessment

A golf course that was part Aquarena Springs (and is now fallow) degrades riparian habitat (U.S. Army Corps of Engineers 2005) on the south shore of the Sink Creek slough adjacent to the grassland restoration site.

Development such as the dam structures, Aquarena Center, and golf course hinder(ed) site ecology and biodiversity. The environmental and ecological impacts of the Aquarena Center and dam have caused invasive species proliferation and water quality

issues. At Spring Lake nonpoint source runoff pollution, introduction and proliferation of invasive species, riparian habitat fragmentation, fluvial fluxes, and accumulation of sediment have caused habitat loss for protected species. Proliferation of invasive and exotic species, construction of the Spring Lake Dam, Aquarena Center, TXST Golf Course and alterations to the surrounding environment have negatively impacted the Spring Lake ecosystem (U.S. Army Corps of Engineers 2005).

Ecosystem services respond to environmental change and management (Kohler et al 2017). Ecosystem services produced in the study area link human and ecological systems (Kohler et al 2017). Endangered species in Spring Lake and the San Marcos River are dependent on a complex, nested ecosystem rooted in the proximal environment. Management of the proximal environment around Spring Lake is critical to those species.

The university has conducted a feasibility study for the development of recreation fields in the Sink Creek Slough riparian zone (Sink Combs Dethlefs 2016). Development of recreation fields at the site would increase nonpoint source runoff pollution, fragment riparian habitat, destabilize the terrestrial-aquatic interface, and negatively affect the survival of endangered species. Thus, I recommend that the are being considered for recreation field development be restored to an ecologically healthy wildland condition.

## II. Global Context

The global populous is increasingly urbanized (Population Reference Bureau 2016), with urbanites comprising about 50% of the total population (United Nations 2015), up from 3% in 1800 (Population Reference Bureau 2016). Urban development

degrades ecosystems (Bullock et al 2011), imperils biodiversity (Hutyrac, Güneralpa & Setoa, 2012), human well-being, and tests planetary boundaries (Steffen et al 2007). Biodiversity loss, linked to habitat loss (Habitat Loss 2014), is the most severe realm of anthropogenic impact (Steffen et al 2011), which makes preserving global biodiversity an important local endeavor.

# III. Environmental Science

The atmosphere, hydrosphere, biosphere, and lithosphere comprise the environmental. Life depends on and interacts with elements of the environment (Environmental Science 2013).

## *Pedology*

Site soil type is Tinn Clay which is deep and poorly drained. In areas adjacent to fluvial bodies, it provides wildlife cover (U.S. Army Corps of Engineers 2005). Mollisols are grassland soils characterized by a mollic epipedon created over time by plant roots (University of Idaho n.d.)

### Rhizosphere

The rhizosphere is the biologically active area of soil around plant roots that contains a diverse organism with complex interactions. The rhizosphere may play a significant role in the structure of soil communities (Grasslands: Types, Biodiversity and Impacts 2009).

## *Biology*

### Biodiversity

The most severe global anthropogenic impacts have occurred in the realm of biodiversity loss (Steffen et al 2011). Habitat loss, which affects populations and decreases species richness and patch connectivity, is thought to be a major contributor to biodiversity loss (Habitat loss: causes, impacts on biodiversity and reduction strategies 2014).

## *Geography*

The site, technically within the Northern Blackland Prairie, is near the border between that ecoregion and the western adjacent Balcones Canyonlands (Ecoregions of Texas 2005).The study area is 22 acres of lake, 10 acres of floodplain, (U.S. Army Corps of Engineers 2005).

Hays County, the county that contains Texas State University and the study site, is the region's fastest growing county (San Antonio Express News 2017). The Texas Hill Country contains three of the nation's fastest growing counties and the Austin-San Antonio corridor will become a metropolis (Forbes 2017). This is concerning because urbanization changes the hydrological dynamics of drainage basins (Miller and Hess 2017).

## *Hydrology and Hydrogeology*

San Marcos Springs emanate from the Edwards Aquifer and emerge in impounded Spring Lake that is the headwaters of the San Marcos River. Some of the water that emerges at San Marcos Springs comes from 200km to the west (Hubbs 1995).

### Water Quality

The Aquarena Center, golf course, and related impermeable surfaces negatively impacted water quality in Spring Lake via runoff (U.S. Army Corps of Engineers 2005).

In 2010, 26 ac/ft/yr were used for irrigation out of an allotted 100 ac/ft/yr (Spring Lake Management Plan, no date).

Lake Algae has increased over the past 15 years based on a visual assessment (Sansom, 2017). Dissolved oxygen has decreased over the past 21 years (figure 3).

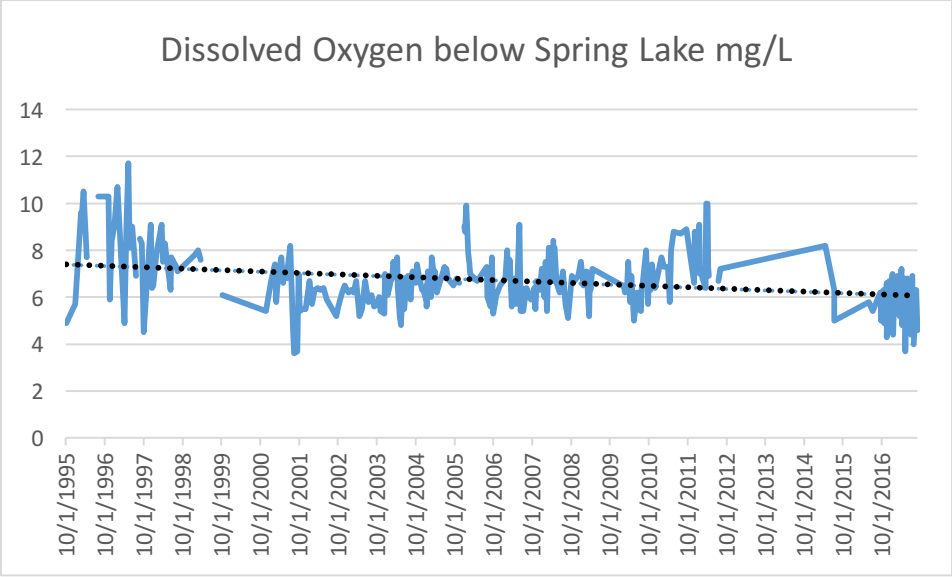


Figure 3. DO below Spring Lake showing a negative trend. Data from Texas Stream Team.

## *Land Management*

Ecosystem services, which connect ecological and human systems, respond to environmental change and management (Kohler et al 2017). The grounds and golf course should be managed in a way that does not jeopardize ecology or endangered species. (Spring Lake Management Plan no date).

Spring Lake and proximal ecosystem would be best managed as a wildland riparian zone, not a golf course. A golf course would have lower biodiversity and provide reduced ecosystem services that are important to the survival of endangered species that are protected by federal law.

### Economic and Health Turn

Grassland restoration is essential to regional socioeconomic sustainability (Shengqiang and Kai 2017). Human economic activity is dependent on ecosystem services. Further, development of a wildland at the site with low-density recreation trails would allow for recreation enjoyment of the area in a way that does not negatively impact the environment. In this way, the wildland development at the site directly competes with one of the underlying principles of recreation field development: increasing human happiness through recreational enjoyment. The wildland alternative, however, offers more ecosystem services. Student health is dependent on biodiverse ecosystems. In kind, biodiverse ecosystems are dependent on students not trampling them, mowing them, or building a soccer field and/or an apartment complex there.

## Grasslands

Grasslands are ecosystems with forage plants that include sedges and grasses. They can be natural (Funk & Wagnalls New World Encyclopedia 2016). Gibson defines seven threats to grasslands globally: agriculture, fragmentation, invasive non-native species, fire or a lack of, desertification, urbanization and domestic livestock (Gibson 2009).

### Blackland Prairie

The site is within the Blackland Prairie (Ecoregions of Texas 2005). The Blackland Prairie is a grassland (Texas A&M Forest Service 2017) that is temperate to subtropical (World Wildlife Foundation 2017). Conversion to agricultural use has destroyed much of the world's temperate grasslands (Thomas and Orr 2002). Originally, the Blackland Prairie covered around 3.1 million acres at the southern tip of the North American prairie. Today it covers 1% of the former area (World Wildlife Foundation 2017).

### Management Strategies

In a test conducted near San Marcos, TX, application of imazapic herbicide significantly increased seedling density of native grasses but was not an effective management solution as it did not eliminate exotic C4 bluestem grasses (Mittelhauser, Barnes & Barnes 2011).

A study looking at influences on the distribution of King Ranch Bluestem *(Bothriochloa ischaemum)* on the Edwards Plateau found that grazing and fire disturbance did not affect the distribution of the species. *Ischaemum* did not show a

preference for any habitat type and its presence was correlated with lower species diversity and richness, making it an aggressive invasive that will continue to persist in that region (Gabbard & Fowler 2006).

**Riparian Vegetation and Biofiltration**

Restoration of a vegetated riparian zone increases vegetation biofiltration and floodwater storage (U.S. Army Corps of Engineers 2005, Donovan et al 2016) and can remove metals from runoff (Zhang et al 2013).

Spatial distribution of aquatic species is linked to the presence of aquatic vegetation (Tolman et al 2014). Healthy riparian zones are characterized by diverse plant communities. Recreational development is a threat to plant diversity in riparian zones (Natural Resources Conservation Service 1996).

Ecological function at the site is hindered by a small riparian corridor along Spring Lake and a golf course in the riparian zone has destroyed wildlife habitat. (U.S. Army Corps of Engineers 2005).The golf course has degraded riparian habitat that would otherwise support endangered species in Spring Lake via biofiltration, mitigation of runoff, and environmental quality. Ecosystem services that the terrestrial ecosystem around Spring Lake generate are important to Spring Lake and endemic aquatic species and management of the riparian zone affects the survival of aquatic species.

**Fire Ecology**

Fire is a critical earth system process. 80% of fires occur in grasslands. (Leys, Commerford, & McLauchlan 2017). Fire has been suppressed at the site for a long time.

In an east central Texas study, controlled burns of a tallgrass Blackland prairie resulted in lower catch rates for pygmy mice (*Baiomys taylori*) and cotton rats *(Sigmodon hispidus)*, and higher catch rates of deer mice *(Peromyscus maniculatus)* (Kirchner et al 2011).

### Golf Courses

Golf courses are green spaces that can increase the ecological value of urban areas (Gramig and Ganguli 2015) and can provide ecosystem services and monetary revenue (Bartlett and James 2011). In 63% of cases, golf courses had higher ecological value than other forms of green-space development (Colding and Folke 2008), but actively maintained golf courses have a lower mean vegetation height, plant biodiversity, and Mean Organic Soil Content than do abandoned courses (Worster 2008). Locating golf courses adjacent to woodlands and bodies of water increases landscape composition variability and may be beneficial for amphibians and pollinators (Colding and Folke 2008). However, none of these strategies are more beneficial that managing the area next to spring lake as a wildscape. Site golf course development resulted in the destruction of riparian and aquatic habitat (U.S. Army Corps of Engineers 2005).

## IV. Native Prairies Association of Texas Interview

Native prairie restoration takes a long time and you must be patient. You can't expect a climax prairie to occur in two years. Depending on the site, different restoration tactics may be appropriate. For the reason, it is best to test various tactics on a small test plot site.

Two popular methods are scraping the top two inches of soil off with a bulldozer and herbicide application. Because of the environmental sensitivity of the Spring Lake site, herbicide is not a good option. Additionally, because the desired outcome is the removal of turfgrass, which typically has a shallow root system, scraping is a good idea.

A bottom-up approach is needed because of the fundamental role of soil in grassland ecosystems. Mycorrhiza and roots assist in the conversion of chemicals.

Gilgai create microclimates with various species occupying the unique physical niche created by the elevation change. There are various theories about Gilgai creation. One theory proposes that they are uniformly distributed features created by shrinking and swelling soils. The other theory is that they resulted from trampling by Buffalo (Quast 2017)

## V. Remote Sensing and GIS

Remote sensing is the observation of phenomena from afar. Satellites or airplanes typically serve as the sensor vehicle (NOAA 2009). Drone remote sensing is increasing in prevalence (Xie et al. 2013) in the environmental science community (Toro 2017).

Global change research requires an understanding of the earth's surface (Jung et al, 2006). Vegetation fundamentally supports life. Management of vegetation is facilitated by spatial information about vegetation composition (Xie et al. 2013).

Remote sensing will be used in this study to analyze vegetation composition and structure of the landscape via NDVI, a metric of vegetation health.

Spatial information can be collected and examined using Geographic Information Systems, known by the acronym GIS (Geographic information system (GIS) (2016)). Figures 4 through 7 are pictures of the site obtained through Google Earth's 3D dataset.


Figure 4. Area overview showing grassland degradation (right, front) and restored area (far left center). Note the extensive riparian degradation marked by relatively homogenous, mowed vegetation (turf grass).


Figure 5. New restoration focus area


Figure 6. Previous restoration area. Note the high biomass and species diversity


Figure 7. Recreation Fields adjacent to Spring Lake. Mowed, homogenous turf grass offers little in terms of ecosystem services and biofiltration of runoff from widespread adjacent impervious cover

## *Normalized Difference Vegetation Index*

Normalized Difference Vegetation Index (NDVI) is a metric of vegetative health that calculates the reflectance of Near-Infrared (NIR) and visible light. The output of the calculation is a number between -1 and 1. -1 is water, 0 is a landscape devoid of vegetation, and 1 is a rainforest or other high-primary-productivity landscape. The formula for NDVI is:

$$NDVI = (NIR - VIS)/(NIR + VIS)$$

(NASA 2017)

## *Methodology*

I used imagery that recorded the visible and near-infrared bands to run an NDVI analysis via ERDAS Imagine, a remote sensing software (figures 8-14).

Figure 8. Imagery: Chlorophyll (red) as an indicator of vegetation. NIR&Visible

Figure 9. NIR&Visible

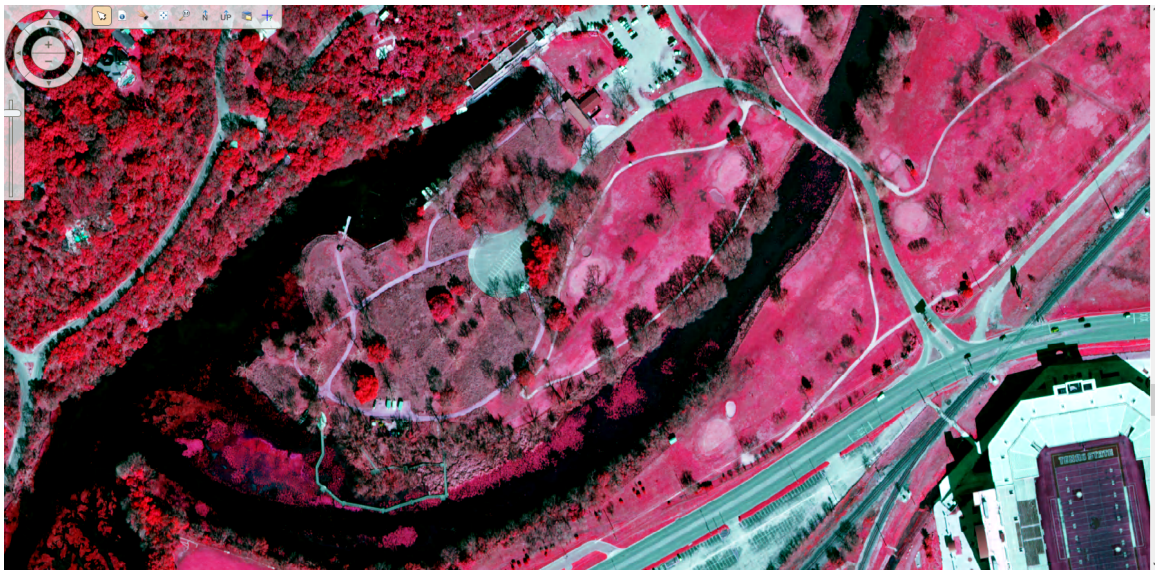

Figure 10. NIR&Visible

Figure 11. Output NDVI


Figure 12. NDVI


Figure 13. NDVI

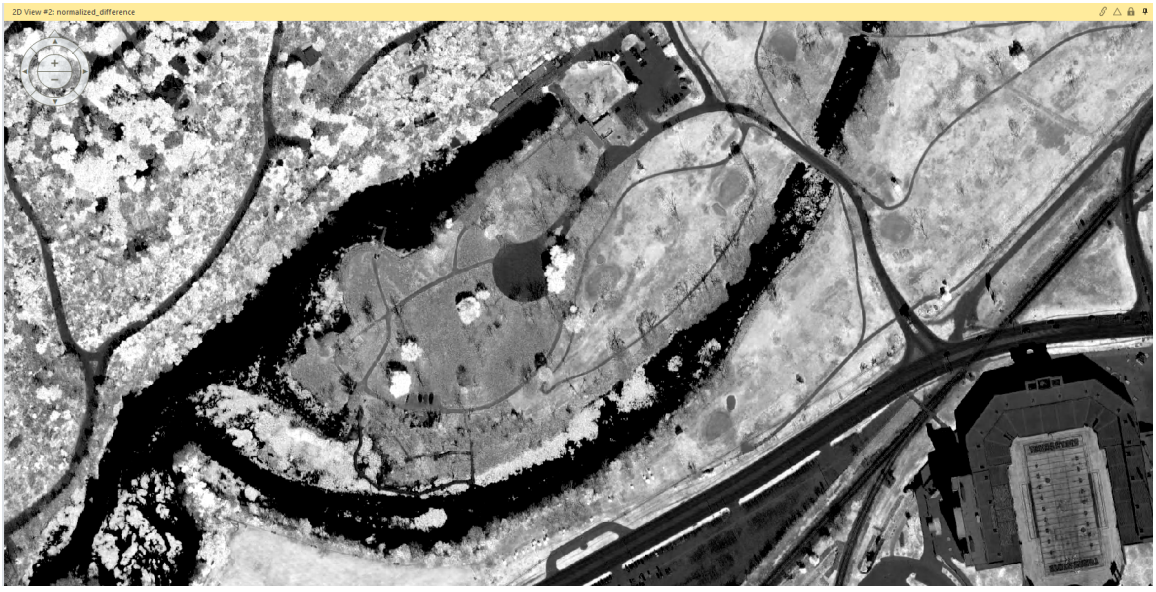

Figure 14. NDVI

## VIII. Conclusion

The results of this study indicate that the wildland areas around Spring Lake provide more vegetative biomass and ecosystem services for the proximal Spring Lake ecosystem. Thus, the choice of how to manage the riparian zone around Spring Lake is a choice of two options:

**Option A**, the recommended option, is to return the study area to a wildland. This provides more protection for the lake, the river, provides more biodiversity, can be used academically in the future for ecological studies, and increases ecosystem services which support human health. Management of the riparian zone as a wildland would increase biodiversity, wildlife habitat and ecosystem services.

**Option B**, development of recreation fields, results in less biodiversity, has a detrimental impact on the lake and river via ecological degradation, and offers less ecological academic value. Management of the riparian zone as a golf course would decrease biodiversity, wildlife habitat and ecosystem services.

## IX. Discussion

The earth is imperiled by anthropogenic environmental degradation that is the sum of many small-scale events. Combined, the effect of these events on the living earth system has been catastrophic. In the same manner, the solution to this degradation is the

combined effect of many small (local) events. Thus, the seemingly insignificant importance of management of this site is part of a bigger picture of global sustainability. Returning the site around Spring Lake to as much of a wildland condition as we can is a necessary and important step in rejuvenating the landscape and restoring healthy ecology. Further, the unique flora and fauna of the site, including eight species federally listed as endangered or threatened, makes it an irreplaceable piece of global biodiversity and thus it should be a high priority for conservation.

The question of land management at the site is simultaneously a question of science and philosophy: with science we are able to produce quantifiable metrics of vegetative health like (NDVI and others) and make observations about and decisions based on the variable outcomes of land management practices. We are also able to evaluate data with visual aids to facilitate management decisions. In unison, philosophy and science can provide a closer examination of our value system.

The question is this: Do we prioritize anthropogenic recreation activities over the right-to-life of other beings that support our existence and happiness, or do we shift our framework to place value on that which sustains all human life?

Even without putting self-interest first, I would hope that empathy for other beings and respect for their right-to-life would bring about a reconsideration of plans to construct recreation fields around Spring Lake. The eight organisms in the lake/river federally listed as endangered or threatened are important pieces of global biodiversity.

For that matter, all life in the ecosystem is an important piece of global biodiversity, because all life is interdependent.

This question we face will be important question in an ever-developing world with a seemingly insatiable desire for wealth and resource extraction. Our current value system and subsequent operations are placing immense pressure on the living earth system.

We should set an example for how to care for nature. This isn't just about breathing clean air, or drinking clean water, or being able to grow food from plants in healthy soil. Philosophically this transcends that. This is about acting with compassion and love in ways that seek to understand, affirm, and heal other organisms as well as ourselves. It is also about recognizing that our health, wellbeing, and happiness is in part dependent on others, and not just humans, or animals, but plants and all other life forms.

If we develop the land around Spring Lake, then we cannot call ourselves an environmentally-minded university. We will have to call ourselves a development-minded university with an immense neglected ecological inheritance.

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