Evaluating Ecosystem Services at Wild Basin Wilderness Preserve

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Abstract

As increasing anthropogenic development encroaches on natural areas, the quantification of poorly-understood ecosystem services, or the conditions and processes through which natural ecosystems (including the species that make them up) sustain and fulfill human life, stands to play a crucial role in the protection and conservation of these places. The research conducted over the past year assessed ecosystem services provided by Wild Basin Wilderness Preserve and studied the variation of services across habitat types to determine which habitat types should be prioritized or which should be restored to maximize the benefits we receive from ecosystems. Furthermore, this research has laid the groundwork for future students to study ecosystem services in more depth at Wild Basin or other urban forests in the Austin region.

Introduction

According the Millennium Ecosystem Assessment (2000), ecosystem services are projected to get significantly worse over the next fifty years. The difficulty associated with quantifying ecosystem services has led to them being left out of development and policy decisions, which can result in costly outcomes for urban forests and green spaces. Urban forests are extremely important habitats for ecosystem services, especially in metropolitan areas because they can help mitigate the effects of human activities that occur in these densely populated regions, such as transportation, energy production and industrial processes. Austin and the surrounding regions are some of the fastest growing regions in the United States, with 157 people moving to Austin every day (Theis 2016). Austin is a city well known for its urban green spaces and the recreational value they bring the city, but rapid development threatens them. The demand for housing and hotels in Austin has continues to increase and finding the space for this population growth can occur at the expense of urban forests and green spaces. Wild Basin Wilderness Preserve is a popular urban forest in Austin, used for research and recreational and educational activities. It was restored from a landfill in the 1970s by a group of four women who had formed the "Now or Never" group (St. Edward's University, SEU). Over forty years later, it is now a thriving forest for species like the threatened golden-cheeked warbler, making it truly a model habitat for land management restoration (SEU). However, it is in a prime location for growth, and some developers hope to convince lawmakers that the golden-cheeked warbler is no longer endangered so that Wild Basin and the surround Balcones Canyonland Preserve, which covers thousands of acres of prime West Austin real estate, can be developed for profit (Montgomery 2015). There is currently little research into small-scale spatial variations of ecosystem services, as these analyses are often limited by the scale of spatial data. The breakdown of services provided by the individual ecosystems within Wild Basin could likewise prove valuable.

Background

Forests and the ecosystems they support have been altered at an unprecedented rate over the past fifty years, largely due to anthropogenic causes (Millennium Ecosystem Assessment, MA 2000). These gains in human well-being and economic development have led to the degradation of many ecosystems (MA 2000) and urban forests are an area at the height of this degradation (Escobedo *et al.* 2011). Urbanization is driving pollution and carbon dioxide concentrations in the atmosphere, which contributes to regional and global climate change (Escobedo *et al.* 2011). Urban forests can mitigate these effects through air quality regulation, microclimate regulation, and carbon sequestration. Ecological literature on urban

forests connects ecosystem functions to benefits for human health, comfort, and happiness (Escobedo *et al.* 2011).

According to the Millennium Ecosystem Assessment (2000), ecosystems services are the benefits people obtain through ecosystems, which have been divided into four categories: provisioning, regulating, supporting, and cultural. Our study focused on regulating and supporting services. Regulating services are benefits obtained from the regulation of ecosystem processes, such as air quality regulation and erosion control (MA 2000). Supporting services are those necessary to ecosystem functions and services, like photosynthesis, carbon sequestration, nutrient cycling, and soil formation (MA 2000). Evaluating these ecosystem services is an increasingly important task for land management (Martinez-Harms *et al.* 2015). However, it is still difficult to evaluate and quantify these services, and many of them are not considered in management decisions (Martinez-Harms *et al.* 2015). We evaluated three ecosystem services provided by an urban forest preserve: carbon sequestration, air quality regulation, and microclimate regulation.

A lot is known about the carbon cycle and forests, however there are still many gaps in our knowledge (Bellassen *et al.* 2014). As a supporting ecosystem service, carbon sequestration contributes to climate mitigation. During photosynthesis, carbon dioxide is fixed and stored as biomass in trees, making the trees a sink for carbon dioxide (Nowak *et al.* 2013). With the number of cities conducting annual greenhouse gas inventories increasing and Austin, Texas being one of the greenest cities in the United States, the city has a lot to gain from urban forests. Last year, students from the Environmental Management and Sustainability Master's program at St. Edward's University, estimated the carbon sequestration services provided by Wild Basin Wilderness Preserve to be worth $344,062,842 (Gamboa *et al.* 2014). Urban forests have the ability to store significant amounts of carbon and urban growth threatens this and the other ecosystem services urban forests provide, such as the protection of watersheds, air quality regulation and noise reduction (Pearce 2001, Bolund *et al.* 1999). As land cover changes occur due to the increased rate of urbanization, carbon storage will decrease as the amount of trees decrease (Raciti *et al.* 2014).

Local climate and and weather can be effected by the city and studies have shown that these differences have been quantified when compared with surrounding country-side (Bolund *et al.* 1999). The urban heat island effect can occur when cities or metropolitan areas are significantly warmer than surrounding rural areas due to the large amount of heat absorbing surfaces, in combination with high amounts of energy use in the city (Bolund *et al.* 1999). Urban forests and natural areas in cities can mitigate this effect. One large tree can transpire 450 liters of water a day, and this consumes 1000 megajoules of heat energy through the evaporation process (Bolund *et al.* 1999). Through this, trees can significantly reduce summer temperatures in the city (Bolund *et al.* 1999). Furthermore, urban forests can help decrease energy use in houses for heating and cooling by providing shade in the summer and reducing wind speed in the winter (Bolund *et al.* 1999). This microclimate regulation service is categorized under the regulating category and it is one of the most important services urban vegetation can provide.

Air pollution is another problem raised by the transportation and energy use in cities. Numerous studies have demonstrated that urban forests can reduce atmospheric pollution, such as ozone, carbon monoxide, nitrogen oxides, sulfur dioxide, and other particulate materials (e.g., Baumgardner *et al.* 2012). This reduction is due to vegetation filtering pollution and particulates from the air and this filtration increases with more leaf area (Bolund *et al.* 1999). Past research has also found that the location and structure of the vegetation can have an influence on filtration abilities, with larger more diverse urban forests having more significant air filtering capacities. It is evident urban vegetation provides air quality regulation, but the level of this service varies based on local situations and with Austin being one of the fastest growing cities in the United States, its risk for a loss of these services due to development is high.

In light of the predicted effects of climate change, it will be important for our cities to use climate conscious urban planning strategies. In cities where there is rapid development, it is important to study multiple ecosystem services. Doing this can show the value of natural areas or wilderness preserves like Wild Basin. Not only can these areas have significant economic value, they can provide recreational and aesthetic benefits. The value of ecosystem services, like air quality regulation, microclimate regulation, and carbon sequestration can outweigh the value of development and provide concrete evidence if these urban forests are threatened in the future.

The previous study conducted at Wild Basin provided groundwork to further evaluate the ecosystem services provided there (Gamboa *et al.* 2014). This study focused primarily on the economic value of carbon sequestration, one potentially powerful way to demonstrate the importance of ecosystem services. Building off of these foundations, this research aimed to assess ecosystem services within Wild Basin. Specifically, we looked at the variation of services across different habitat types at Wild Basin: woodland, semi-open grassland, and near-riparian. Looking at different habitat types is important in showing what types of landscapes should be prioritized or ways in which landscapes can be restored to provide greater ecosystem services. By answering the question "How do ecosystem services vary across habitat types at Wild Basin?" we've laid groundwork for future students and researchers to study ecosystem services further in the increasingly important urban forests in and near Austin, Texas. We expected to find higher temperatures in areas with less tree canopy cover (semi-open grasslands), as well as higher concentrations of nitrogen dioxide. We also expected woodland areas to have greater amounts of carbon sequestration.

Methods

Study Area

Wild Basin is a 92 hectare wildlife preserve located approximately 16 kilometers west of downtown Austin, TX, at the eastern edge of the Edwards Plateau near the Balcones fault zone. This is an area where ecosystems change dramatically across relatively small scales; the wildflower-dotted prairies east of Austin are quickly replaced by the forests and cliffs of Texas Hill Country, a region consisting of a weathered carbonate-rock landscape characterized by hills and ledges. The carbonaceous ledges and steep slopes of this area support enhanced biogeochemical nutrient cycling and significant water retention, supporting a relatively lush biosphere (Woodruff & Wilding 2008). The endangered golden-cheeked warbler values Wild Basin as one of its favored nesting grounds, drawn by the ashe juniper (*Juniperus ashei*) forest that covers most of the preserve. Other major tree species found in Wild Basin include *Ilex vomitoria, Garrya linheimeri, Ligustrum lucidum, Diospyros texana, Quercus fusiformus, Quercus buckleyi,* and *Quercus sinuata*, with distribution dependent on ecosystem type (Gamboa *et al*. 2014).

As stated previously the three habitat types we focused on for this study were: semi-open grassland, near-riparian and woodland. As made obvious by the name, the vegetation in semi-open grasslands is made up primarily of grasses, with various shrubs and few trees scattered throughout. Near-riparian ecosystems are those located near a river or stream, and are often associated with increased biodiversity. Vegetation in these habitats vary, but at the near-riparian grid points we collected data at, the vegetation was densely populated with trees. Lastly, woodland ecosystems have vegetation that is mostly made up of trees, which is the ecosystem we were most interested in because we expected to see a higher degree of ecosystem services from it.

Plots measuring .01 hectare radius were established at each of thirteen previously delineated grid points in Wild Basin (Fig. 1). All thirteen of these points were measured for variables specific to iTree Eco, described below. Six of these plots (points 2, 3, 5, 7, 8, and 9) were chosen for measurement of humidity, NO_2, and continuously (30 minute intervals) for temperature to provide equal representation for the three ecosystem types found at Wild Basin. These three ecosystem types are woodland (grid points 2 and 5), semi-open grassland (grid points 3 and 7), and near-riparian (grid points 8 and 9).



Figure 1: Map of Wild Basin's 13 grid points.

Field measurements

Data collection as recommended by the iTree Eco manual was conducted at five grid points by Gamboa *et al.* in spring 2014 and the remaining eight grid points were collected by St. Edward's University undergraduates in the summer of 2016. All shrub and tree species were identified and the average height measured. Tree height measurements were taken using a clinometer. Each tree was tagged for ID and diameter at breast height (DBH) was measured for individuals larger than 2.54 cm. Percent crown dieback, percent crown missing, and amount of light exposure were also measured. All of these data were used in the iTree Eco calculations to determine total carbon sequestered.

Air quality and microclimate data were collected at six representative grid points over a period of three weeks in autumn 2016: 29 October 2016 - 19 November 2016. Thermochron iButton devices (hereafter iButton; DS1921G model, Maxim Integrated) were used to collect temperature data continuously. The technology consists of a small, round metal button which is placed in the field and later simply plugged into a computer to review data. However, because the field site was located in sunny Texas and the metal iButtons are susceptible to skewed measurements if left in sunlight to heat up, potentially expensive radiation shielding was required. We made simple radiation shields by stacking two white plastic funnels around a piece of rope tied to a clothespin holding the iButton inside. The rope was then tied to a tree branch at each of the six representative plots and left to measure temperature every half hour for three weeks. At each grid point, an Aeroqual Portable Ozone Monitor, with a separate NO_2 sensor head attachment (hereafter Aeroqual; series 200), was used to collect air quality data. A Kestrel Pocket Weather Tracker (hereafter Kestrel; 4500 NV model, Kestrel Meters) was used to measure a snapshot of temperature and humidity at the same time the NO_2 measurements were collected.

Data processing and analysis
iTree Eco v5.0 is a software application designed to analyze field data in order to determine the economic value of ecosystem services provided by forests. For purposes of this study, we focused on the amount of carbon sequestered.

Climate data were downloaded from the six grid point iButtons at the end of the sampling period.

The temperature and humidity data collected with the Kestrel and the Aeroqual NO_2 data were used for each of the grid points.

We tested for significant differences between the habitat types for our representative ecosystem service variables using one-way ANOVA tests. All statistical analyses were performed using R (version i386 3.3.2).

Results
We found that humidity was significantly different by habitat type ($F_{2,113}$= 26.24, p<0.0001). A post-hoc Tukey HSD test showed that the grid points in woodland ecosystems were significantly more humid than those found in semi-open grassland (p<0.0001) and near-riparian (p<0.0001).

For the temperature data collected by iButtons every half hour, we found that maximum temperature per day was significantly different by habitat type ($F_{2,129}$= 8.24, p=0.0004). A post-hoc Tukey HSD showed that grid points in semi-open grasslands had significantly higher daily maximum temperatures than those in near-riparian (p=0.0002) and woodland habitat types (p=0.0364).

The air quality measurements of NO_2 showed no significant differences between habitat type. The Kestrel temperature measurements taken simultaneously with NO_2 showed no significant differences between habitat type.

Temperature data collected every 30 minutes from the iButtons showed definitively higher temperatures among plots in semi-open grassland habitats (signified by shades of orange), while near-riparian plots (signified by shades of purple) were the coolest. This trend was evident in daily snapshots (e.g. Fig. 2) as well as in maximum temperature trends for each day across the entire study period (Fig. 3).

Statistical analyses were also conducted on the iTree Eco outputs of biomass and carbon sequestered, habitat type, and LiDAR-derived canopy height (indicated to be interchangeable with field measurements of canopy height for iTree Eco analysis by Gamboa *et al.* 2014). A significant relationship was found between habitat type and canopy height ($F_{2,10}$=10.61, p=0.0034). A post-hoc Tukey HSD showed that grid points in semi-open grassland had a significantly lower average canopy height than grid points in woodland (p=.0087) and riparian (p=.0079) habitats. Grid points within near-riparian zones, however, exhibited extreme variance, and a second test was conducted with these grid points excluded. The ANOVA indicated that semi-open grassland still had almost significantly lower canopy height than woodland ecosystems ($F_{1,9}$=13.527, p=.0059).

An analysis of variance carbon sequestered by habitat type showed near-significance ($F_{2,10}$=3.11, p=0.891) but because the iTree Eco data were highly variable, this test was also run excluding near-riparian grid points. This second analysis indicated no significant relationship.

An analysis of variance also indicated no significant relationship between iTree-estimated biomass and habitat type, whether near-riparian zones were included or excluded.

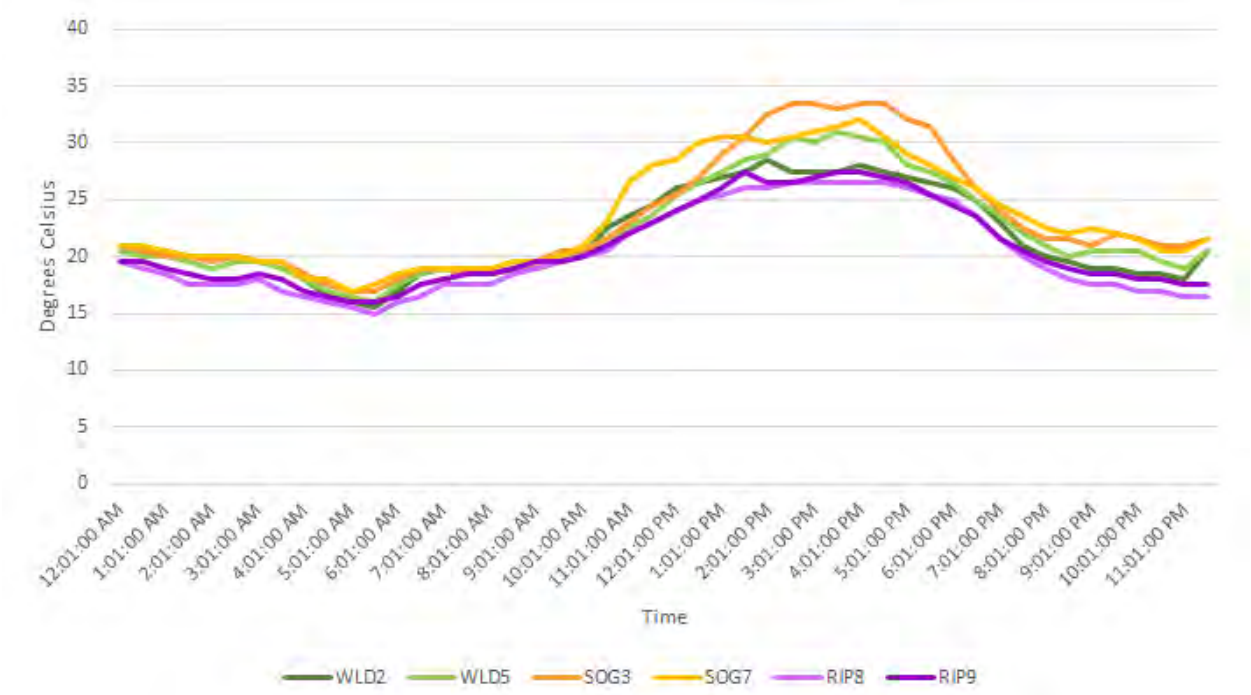

Figure 2: This graph shows temperature for October 29, 2016, every thirty minutes, colored coded by ecosystem type. Woodland (WLD 2 & 5)—green. Semi-open grassland (SOG 3 & 7)—red/orange. Near-riparian (RIP 8 & 9)—purple.

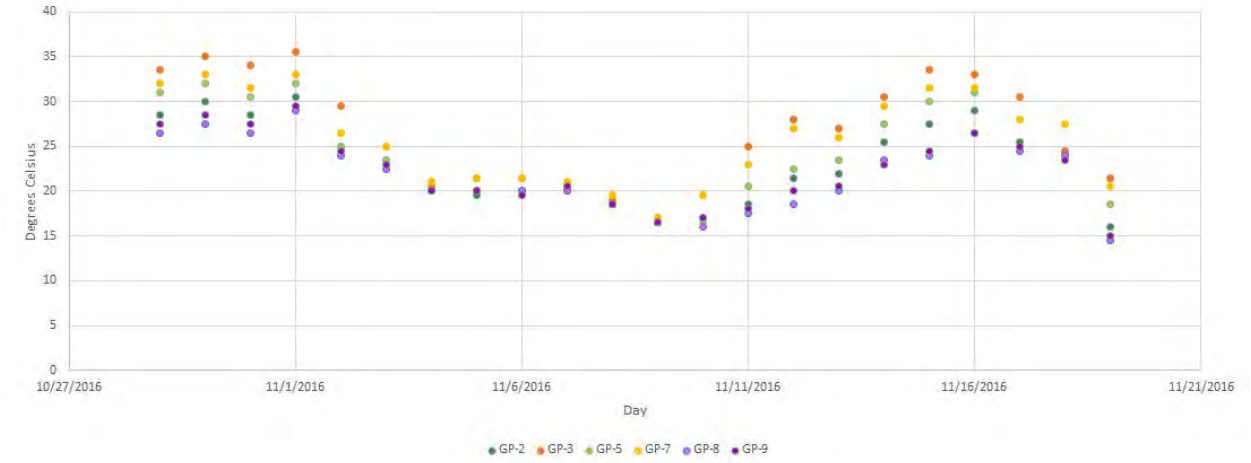

Figure 3: This graph shows the maximum temperature by day for each grid point. The grid points are color coded by ecosystem type: woodland—green, near-riparian—purple, semi-open grassland—orange.

Discussion

The statistical analyses indicated that woodland ecosystems were significantly more humid than the other habitat types, including those near riparian areas. Higher humidity can be indicative of lower temperatures. The continuous temperature data does display that there were differences between ecosystem types, with the maximum daily temperature being highest at the semi-open grassland habitat grid points. This shows the importance of the capability of areas with higher tree canopy cover to provide

cooler temperatures. In areas with typically high temperatures, this microclimate regulation service provided by forested areas can be significant.

There was no significance in air quality measurements collected between the habitat types. One reason for this could be due to a small sample size, of both grid points and individual measurements taken. Another reason could be that NO_2 does not vary at such small spatial scales. An analysis of different tree species could be used to analyze whether the makeup of trees at the grid points have different capabilities of removing pollutants from the air, such as NO_2.

The only significant relationship indicated by the statistical analysis of carbon sequestration data was that of habitat type and height, which was expected due to the lack of trees in semi-open grassland ecosystems. No significant relationship was indicated between LiDAR-derived canopy height and iTree outputs of biomass or carbon sequestered, although Gamboa *et al.* (2014) indicated an unspecified positive relationship between canopy height and carbon sequestered. Our data set was larger and exhibited far more variability than that of the previous research (Fig. 4).

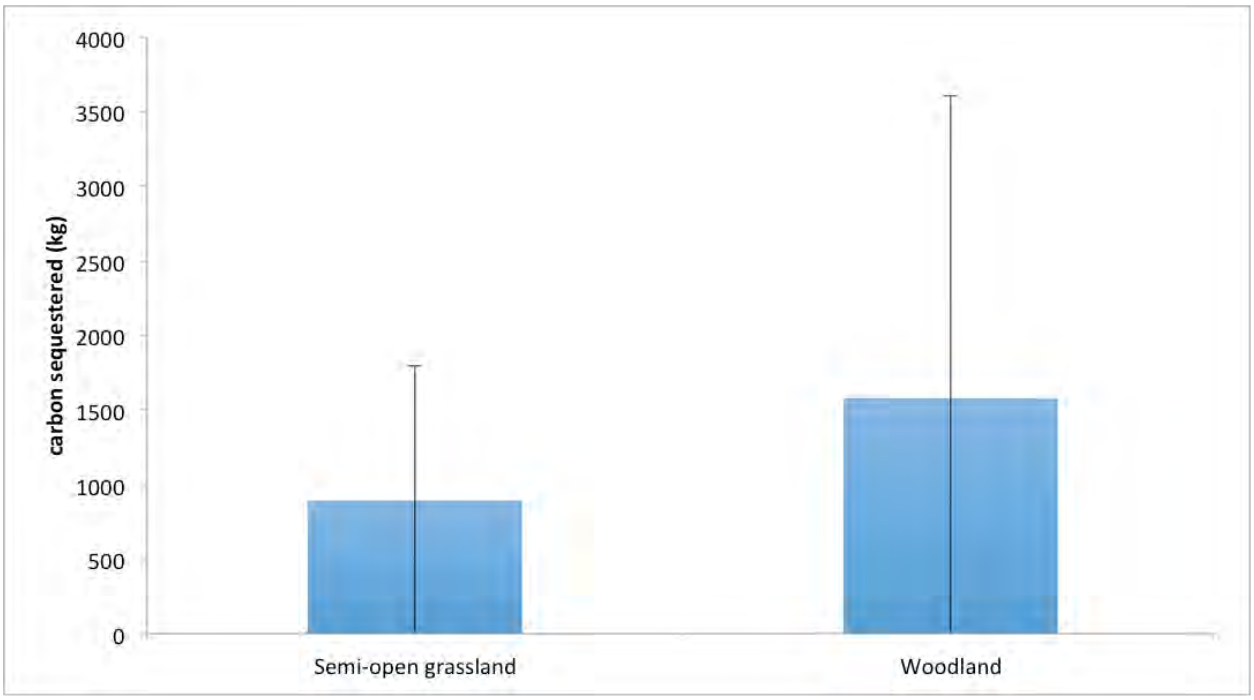

Figure 4: Graph depicting the variability of carbon sequestered by each habitat type. Near-riparian habitats were not included in this analysis as there were only two grid points and the variability was even more extreme than semi-open grassland and woodland.

Conclusion

Our analyses suggest that forested areas, like woodland and near-riparian habitats, are significant determiners of microclimate regulation in urban areas. Trees in these ecosystems contribute both significant shade and humidity and can be used to combat the urban heat island effect. While these trees also contribute significant value in air quality services via carbon sequestration and NO_x mitigation, we were unable to show any noticeable variation of NO_2 levels between habitats, but future studies may look to compare iTree outputs with field measurements of other pollutants such as ozone.

Data collected for the iTree Eco inputs were noted to be highly variable by time collected. A data set of five grid points by Gamboa *et al.* collected in the winter/spring of 2014 appear to consist of notably

higher amounts of carbon sequestered even when normalized over plot area (which varied marginally from grid point to grid point), as compared to a data set of the remaining eight grid points collected by St. Edward's undergraduate students in the summer of 2016. Near-riparian grid points were especially variable and were thus excluded from statistical analysis (Fig. 4). Possible reasons for the variance between data sets are time of year, human error, or spatial variability of biomass. In future studies, we recommend that grid point data be collected all during the same season and by the same surveying group. Direction of slope should also be determined for each gridpoint as this could possibly affect biomass at each site. Because the iTree Eco data take so long to collect, a larger field group would benefit this project.

Our data may may also indicate that tree biomass is highly variable across small-scale spatial variation of habitat. This project grew from a question regarding the value of ecosystem services across small-scale habitat variation within a landscape. Because the amount of carbon sequestered is positively related to vegetative biomass, the value of ecosystem services may vary widely within small-scale spatial variations as well. These data suggest that the valuation of ecosystem services provided by various habitats within a small area may require data collection at many more grid points in order to analyze a true representative sample.

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