Ecosystem Services in New York City

Creating a sustainability index to compare sustainability and ecosystem services in New York City parks

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Abstract

New York City parks were originally built as an escape from the harsh city environment. Today, they still serve that function, but have the potential to impact the city, its citizens, and the environment in more specific ways. This study demonstrates how viewing New York City parks as ecosystem service providers creates new opportunities for communities. The sustainability index developed to score these parks’ ecosystems is a simple indicator of complex conditions, allowing communities to assess and improve their parks’ ecosystem services without an advanced knowledge of sustainability. This index can create stronger, more ecologically stable park systems that increase a community’s sustainability by reducing their energy use, improving air quality, and limiting stormwater runoff.
Introduction

Climate change, rapid urbanization, and the need for healthy urban ecosystems

Cities around the world are growing in both size and number. By 2050, it is estimated that the global population will reach nine billion people with seventy five percent of the population living in cities (UN, 2016). As people begin to live in higher densities, the environmental demand placed on cities will also expand.

Increasing urbanization is a double edged sword when addressing concerns of environmental stability and sustainability. Generally, high population densities result in a decreased resource demand as people utilize fewer environmental resources per person. Cities have the greatest potential to increase global sustainability by reducing demand and reliance on nonrenewable resources. But they currently doing more harm than good. According to the United Nations’ report on human settlement, urban centers are the greatest contributor of greenhouse gases. They are responsible for 70 percent of emissions while occupying only two percent of land (UN, 2016).

Cities are primed for a sustainability revolution but many cities are not pursuing this opportunity to its fullest. This is due to rapid population increase and the demand for fast paced development. These factors have created and maintained cities built without foresight, perpetuating environmental problems including the heat-island effect, air and water pollution, stormwater runoff, and excessive energy use. These conditions degrade the environment and the citizens’ health unless specific measures are taken, including greening cities by planting more trees and developing parks and green spaces.

The expansion and proper management of green infrastructure in cities will reduce their harmful effects. Sustainable green spaces improve human well-being and provide necessary ecosystem services. When properly planned, green space bring improvements in air quality, stormwater overflow, temperature, and carbon sequestration. They also increase biodiversity, which stabilizes these services over time. Green spaces also provide a number of societal benefits by improving the mental and physical health of those who use them (Chiesura, 2004).

Cities are rarely thought of as ecosystems, but each tree, shrub, and park provides valuable ecosystem services to the people that live there. The ecosystem services generated within them have a global effect as cities are the largest emitters of greenhouse gases. Anything done to mitigate their emissions have worldwide effects.

For the purpose of this study, I focused on New York City to determine the impact parks can have on the local and global environment if properly managed to increase ecosystem services and biodiversity. The study focused on Washington Square Park and Union Square Park to comparatively study the ecological services generated by them. Measuring their ecosystem services required the creation of a sustainability index to comparatively measure the ecological services generated each park. The index can be used to evaluate other parks and green spaces for relative sustainability and ecosystem services and to identify opportunities ways to improve them. This sustainability index can be used on other parks in New York City.
and other metropolitan areas. It provides a standard measure by which urban areas can set goals to reduce environmental demand and enhance ecological production.

New York City Parks are Ecosystems

New York City is seldom viewed as an ecosystem given a population of 8.5 million people in a landscape filled with high-rises, cabs, trains, buses, and the non-stop glow of city lights (NYC.gov, 2016). But nestled between the buildings and people are parks and green spaces that produce valuable ecosystem services. Across the five boroughs there are nearly 30,000 acres of natural spaces, of which 35 percent is protected land (Forgione, Pregitzer, Charlop-Powers, & Gunther, 2016). The sustainability, biodiversity, and ecosystem services generated by these natural spaces is severely understudied.

New York City’s parks have a history of being highly manicured and filled with non-native species, lowering their ecological utility (Chiesura, 2004). Their alternative has the potential to generate critical ecosystem services to mitigate the negative environmental impacts of their city. They can also be developed to protect and stabilize New York City’s microclimate in the face of climate change. It is in the best interest of urban communities to protect and fortify their natural resources as they provide vital ecological services.

Research increasingly demonstrates the link between healthy urban ecosystems and improvements in residential and environmental health (Chiesura, 2004). Studies have shown that time spent outside in natural areas is correlated with reduced stress, providing a sense of peace and calm that even helps medical patients recover quicker (Maller, Townsend, Pryor, Brown, & St Leger, 2006). Spending time outdoors in natural spaces has also been shown to reduce disease and increase overall health by reducing stress induced high-blood pressure and increasing fitness of citizens that use the parks to walk, run, and exercise more often than they would alone in an unnatural setting (Grazuleviciene et al., 2015).

Green spaces also provide physical health benefits. Well planted parks purify city air (Nowak, Crane, Stevens, & Walton, 2007). Urban forests reduce localized temperature by providing shade to the park and surrounding buildings through nightly cooling by evaporation and the daily absorption of heat from the sun. Urban forests also directly improve air quality by absorbing pollutants and indirectly by reducing energy consumption, keeping pollutants out of the air (Nowak et al., 2007).

Trees in urban areas reduce city noise, increase property values, and improve neighborhood aesthetics (Nowak et al., 2007). Well managed park systems also improve water quality and reduce stormwater runoff by providing drainage alternatives to the non-porous asphalt that cities are built on (Nowak et al., 2007).
The Sustainability Index

Overview

Urban ecosystems and ecological services are severely understudied. There is currently no system in place to measure the ecosystem services and sustainability of green spaces in urban environments. Developing a better understanding of what ecosystem services parks generate can give us direction for how to improve urban green spaces. If urban parks were managed for ecosystem services and sustainability, cities would be able to reduce the impacts of climate change and mitigate the harmful effects of living in cities. This would also restore ecosystems that have been damaged due to human development, invasive species, and pollution.

The sustainability index was created to calculate the ecosystem services and sustainability of a park based on four measurable criteria: percent canopy cover, percent impermeable surfaces, percent native species, and the Shannon-Weiner diversity index. The four criteria within the index are each weighted negatively or positively and are added together to find a final number. The higher the number, the greater sustainable impact and the more ecosystem services generated.

I chose to include these four criteria because they have the largest impact on both ecological services generated and sustainability over time. I also chose these four criteria based on accessibility. A citizen science effort could easily measure the canopy cover and impermeable surfaces with the help of a single ecologist or forester to identify the trees and calculate the Shannon-Wiener index. While there is no doubt that there are more ways to quantify ecosystem services in an urban environment, this process is easily replicated and can be done on a large scale. It gives cities an easy way to understand how their parks and green spaces are performing ecologically and how they can improve.

Criteria

Canopy cover

Canopy cover refers to any part of a tree including branch, stem, or leaves that cover the ground when viewed from above (O’Neil-Dunne, 2010). Canopy cover is weighted positively in the index and is used as indicator of ecosystem services generated. Establishing a strong canopy cover is crucial in urban areas that are trying to improve quality of life and the environment. According to the USDA Forestry Service, New York City has a current canopy cover of 21 percent with the potential to double or even triple that based on spatial analysis (O’Neil-Dunne, 2010).

Trees in cities have been shown to significantly impact human health and environmental quality, as well as sequester or store significant quantities of greenhouse gas emissions (Nowak, Crane, Stevens, & Walton, 2007; Dexter H. Locke et al., 2010; Nowak, Crane, & Stevens, 2006). Increasing canopy cover and planting more trees decreases stormwater runoff and impermeable surfaces, reducing the heat island effects and saving energy by cooling the
city. Trees also help to improve air quality by absorbing harmful particulate matter and reducing the local ozone. An increase in trees has also been shown to reduce crime and noise pollution (Dexter H. Locke et al., 2010). Trees beautify neighborhoods and helps improve overall well being of a community. If canopy cover can be increased in every park or green space, these ecological services can be increased creating a healthier environment for both people and biota.

Impermeable surfaces

Impermeable surface refers to any surface that is impenetrable by water and can include asphalt, concrete, brick, stone, as well as compacted soil. All of these are often found in urban environments. Impermeable surfaces are weighted negatively in the index because of their contribution to the urban heat island effect.

The urban heat island effect occurs when an urban area is hotter than surrounding rural or suburban areas. Urban heat island occurs because of human modifications to the environment that offset natural energy balances. This causes positive feedback loops that increase the local temperature.

The majority of New York City’s original green space has been replaced with impermeable surfaces that limit the evapotranspiration cycle, which is responsible for temperature regulation in an environment (Susca, Gaffin, & Dell’Osso, 2011). Most often, impermeable surfaces in cities are asphalt, which decreases the albedo in an urban environment. This results in more heat being absorbed than reflected, further increasing the temperature (Susca et al., 2011). Unlike trees or green cover, which lower temperatures through shade provision and evapotranspiration, impermeable surfaces only increase temperatures which results in poorer air quality and more energy usage to keep buildings and people cool. Reducing the amount of impermeable surfaces through increase tree cover or by use of green infrastructure would significantly impact the heat-island effect, offsetting energy use and improving air quality.

Native tree species

Native tree species include any species that are indigenous to the United States and native to the USDA growing zones in and near New York City. Percent native tree species are weighted positively in the index because a higher proportion of native trees results in a more stable ecological system. Native species will grow in the New York City region with or without human help. Therefore, they require less water, energy, and resources to grow and maintain than ornamentals or non-natives that may need more care to thrive in an a foreign environment. Having more native species in a park can have a cascading effect on the biological diversity of the area, providing more habitat diversity for other native species. Increasing native species in an urban parks may not have a direct impact on ecological services generated but it does increase sustainability, ensuring that ecosystem services can be generated into the future.
Shannon-Wiener diversity index

Lastly, the Shannon-Wiener diversity index is utilized in the sustainability index to measure tree species diversity. Shannon-Wiener index is also weighted positively as a diverse park ecosystem is more stable and sustainable over time. If a park has a high percentage of native species, but few varieties in species, the park is now susceptible to disease outbreak and invasive take-over. Increasing the biological diversity of an urban ecosystem increases the stability of that system overtime, aiding in moments of environmental disaster, disease, or invasives species competition (Nielsen, van den Bosch, Maruthaveeran, & van den Bosch, 2014).

A higher diversity index also provides greater habitat and niche diversity, increasing the overall biodiversity of a region and resulting in a more stable ecosystem. More stable ecosystems provide more reliable ecosystem services. If parks increase their biodiversity, they will reduce energy and water costs by creating more stable systems overtime.

Location & Methods

Location

Washington Square Park and Union Square Park were the study sites. These sites were chosen because they are similar in size according to Google Maps. Washington Square Park has a perimeter of .55 miles and Union Square Park has a perimeter of .44 miles. The two parks were also chosen because they have different use cases. Union Square Park is both a park and bazaar while Washington Square Park functions solely as a park with no sale stands. Using two different parks of similar proportion supported the development of the sustainability index.

Methods

Species Composition

In order to collect data on each park, preliminary research was done to determine if any existing tree data had been collected. A previous study by an urban forester in New York City had mapped every tree in Washington Square Park by documenting the species, diameter, and other important notes (Seamans, 2015). WSP Eco Map (http://www.wspecoprojects.org/) was used to gather tree species data for Washington Square Park, including native species and the Shannon-Wiener index.

Grids were overlaid on park maps to create 136 quadrants of the same size. My intention was to survey randomized quadrants in each park and compare. I used a Google’s random number generator to generate quadrants to examine for each park. The quadrants were approximately 2,500 square feet.

I went to Union Square Park with a diameter measurement tape to measure and identify the trees within the proposed quadrant space but upon arrival found the quadrants were not accessible due to holiday market set up and groundskeeping projects. As I was unable
intimately identify the trees, I photographed 25 trees to use with iNaturalist (https://www.inaturalist.org/home).

Out of the 25 trees photographed, 14 were successfully identified and confirmed by the iNaturalist scientific community or myself. Being unable to get closer to the trees made identification difficult. Without proper access to the park, I could not use the quadrants I had intended. Instead, I walked around the inner perimeter photographing and in-situ identifying as many trees as possible.

I estimated my study area of Union Square park to identify a plot on the eastern side of Washington Square Park to study. Two of the random quadrants were included in this plot. I used WSP Eco Map to identify this plot’s trees.

Using the data collected at each park, I determined the percent native species of each and then determined the Shannon-Wiener index utilizing the formula (image: Beals, Gross, & Harrell, 2000):

\[ H = -\sum_{i=1}^{s} p_i \ln p_i \]

The Shannon-Wiener index (H) is a measure of species diversity in a community. The index accounts for both abundance and species evenness. The proportion of the species \( i \) is relative to the total number of species \( p \) and is then multiplied by the natural log of \( p \). The resulting product is then summed and multiplied by a -1 to give the index. The Shannon-Wiener index is only useful in comparison, which is why two parks were needed to be studied for creation of the sustainability index. The larger the Shannon-Wiener index the greater the biodiversity of the community.

Canopy and Impermeable Surface

i-Tree was utilized to calculate the percentage of canopy cover and impermeable surfaces (https://www.itreetools.org/). i-Tree is a free web platform that quantifies tree structure, threats, and ecosystem services and it is built upon current, peer-reviewed, public domain science (i-Tree, 2017). i-Tree utilizes a Google Maps aerial image and randomly generates sample points, zooming in on each so that the user can determine what the spot is from a predefined list of cover types. I used the following cover types: tree-cover, not-tree cover, impermeable surface, shrub, and grassland. i-Tree Canopy recommends using 500-1000 survey points to have a more accurate cover estimate and each park contained 550 survey points. After the survey is complete i-Tree provides a table of ecosystem services generated by the estimated tree-cover in the area as well as percent of each cover type. i-Tree also provides latitude and longitude coordinates for each point, but these were not needed or used for this study.

Sustainability Index

After collecting the species composition and canopy data from each park, the totals and results were used in the sustainability index. Any percentages were converted from percent to tenths for easier calculations (i.e. 65% is equal to 6.5) and the Shannon-Wiener index result was
unchanged as it is already is an ideal format. The results from each survey were then put into a table and summed utilizing the weights given for each criteria (see Table 1 below).

### Table 1: Sustainability Index Score Card

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Original Number</th>
<th>Tenths Place and weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Canopy Cover</td>
<td>%</td>
<td>+ 0.0</td>
</tr>
<tr>
<td>Shannon-Wiener Index</td>
<td>0.00</td>
<td>+ 0.0</td>
</tr>
<tr>
<td>Impermeable Surfaces</td>
<td>%</td>
<td>- 0.0</td>
</tr>
<tr>
<td>Percent Native Species</td>
<td>%</td>
<td>+ 0.0</td>
</tr>
<tr>
<td><strong>Total Score</strong></td>
<td><strong>00.0</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Definitions

**Green Space**  
refers to vegetated spaces in urban areas. Green spaces can include open spaces such as parks of any size, gardens, and rooftop gardens or parks.

**Green Infrastructure**  
Infrastructure that is implemented into a space with the intent to better the environment. Green infrastructure can include rooftop gardens, urban agriculture, greenhouses, as well as plant walls and other structures that aid ecosystem services or reducing urban demands or impacts.

**Tree Canopy**  
refers to the layers of leaves, branches, and stems that cover the ground when viewed aerially.

**Ecosystem Service**  
Any resource that humans benefit from that the environment naturally produces regardless of human wants or needs (i.e. food production, nutrient cycling, aesthetics).

### Canopy Survey Definitions:

- **Impermeable Surfaces (I)**  
  Refers to altered surfaces that cannot absorb water or liquids. Most often asphalt, concrete, compacted soils, brick, and rock.

- **Tree Cover (TC)**  
  Same definition of tree canopy; refers to the layers of leaves, branches and stems that cover the ground when viewed aerially.

- **Not Tree (NT)**  
  Different than impermeable surfaces. NT refers to any surface that could possibly become tree-cover, but is currently either compacted soil or an unclear image that is likely grassland or tree-cover.

- **Shrub (S)**  
  Any image that was not big enough to be a tree or not grassland. Such as flower beds with a variety of plants.

- **Grassland (G)**  
  Grassy spaces that are not brown, shrubs, or tree cover and green in color.
Results

Washington Square Park generates more ecosystem services and has a higher sustainability index score than Union Square Park. Washington Square Park had double the canopy cover and half the impermeable surfaces as Union Square Park (see Graph 1 and Graph 2). Washington Square Park had a Shannon-Wiener index of 2.5 and Union Square Park had a Shannon-Wiener index of 1.6, indicating that Washington Square Park has greater overall species diversity (see Graph 3).

Union Square Park had greater native species cover at 84 percent than Washington Square Park at 75 percent (see Graph 3). Although Union Square Park had a higher native species percentage according to the Shannon-Wiener index Union Square Park had less overall species diversity, which reduces the parks overall score. Washington Square park had 54 percent canopy cover with 32 percent impermeable surfaces whereas Union Square park had 36 percent canopy cover with 58 percent impermeable surface (see Graph 1 and Graph 2).

According to i-Tree, Washington Square Park removes 14.38 pounds of PM2.5 and 99.09 pounds of PM10 and 295.38 pounds of ozone annually, all of which improve the air quality in the area (see Graph 1). Washington Square Park aids in mitigation of several greenhouse gases as well (see Graph 1). i-Tree estimated according to the canopy cover estimate that Washington Square Park removes 5.45 pounds of carbon monoxide, 29.70 pounds of nitrogen dioxide, 18.72 pounds of sulfur dioxide and sequesters 20.12 tons of carbon dioxide annually. i-Tree also estimated that 759.38 tons additional carbon dioxide are stored in the trees in the park.

In comparison, Union Square Park removes fewer than half the amount of air pollutants annually at 5.99 pounds of PM 2.5, 41.26 pounds of PM10, and 124.19 pounds of ozone (see graph 2). Union Square Park also did not remove as many pounds of greenhouse gases annually, at again fewer than half the amount annually at 2.27 pounds of carbon monoxide, 12.37 pounds of nitrogen oxide, 7.79 pounds of sulfur dioxide, and 12.54 tons of carbon dioxide sequestered in the trees. Union Square park stores fewer than half that amount of tons of carbon dioxide in its trees in comparison to Washington Square Park at 316.21 tons.

Union Square Park received a lower sustainability score than Washington Square Park at 9 and 13.1 respectfully (see Table 4 and Table 5). Union Square Parks' lower score indicates that it produces fewer ecosystem services and is less sustainable overtime as it has a low diversity index.

Limitations

The goal of this study was to gain insight into urban ecosystems and ecosystem services, which are understudied. In order to determine the ecosystem services delivered by each park, I relied on the data and information on I-Tree, which collects data from the peer-reviewed public domain. Estimating ecosystem services in this way is adequate for the purpose of gaining a preliminary understanding, but more study would need to be done to develop a detailed understanding how ecosystem services can be increased and better utilized in urban environments.
As this study is a preliminary study into a topic with limited research, the scope of the research is narrow. Going forward, I would analyze the entirety of both Washington Square Park and Union Square Park instead of sections of each. Union Square Park also proved difficult to study at the time as it was undergoing groundskeeping and the majority of the trees were unreachable making accurate tree identification difficult. Future studies should map Union Square Park and any park of interest as WSP Eco Map did so that a better estimate of native species and biodiversity can be gained.

One additional limitation of the study is that i-Tree only calculates ecosystem services generated by trees. Additional study and research would be needed to determine the impact decreased impermeable surfaces and biodiversity would have on ecosystem services and greenhouse gas emissions. While it is generally assumed that decreasing impermeable surfaces will have a beneficial effect on the local environment and temperature due to increases in evapotranspiration and albedo, and thus cooling, I was unable to definitively measure this impact in this study. Likewise, the effect biodiversity has on ecosystem services is debated and understudied within the scientific community. However, it is safe to assume for this study that a biodiverse ecosystem will be more stable over time than a ecosystem lacking diversity. Whether biodiversity increases ecosystem services needs further study.
Graph 1: Washington Square Park Cover Class by Percent

Table 2: Washington Square Park Ecosystem Services

<table>
<thead>
<tr>
<th>Abbr.</th>
<th>Benefit Description</th>
<th>Value (USD)</th>
<th>±SE</th>
<th>Amount</th>
<th>±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>Carbon Monoxide removed annually</td>
<td>0.23 USD</td>
<td>±0.01</td>
<td>5.45 lb</td>
<td>±0.21</td>
</tr>
<tr>
<td>NO2</td>
<td>Nitrogen Dioxide removed annually</td>
<td>0.40 USD</td>
<td>±0.02</td>
<td>29.70 lb</td>
<td>±1.17</td>
</tr>
<tr>
<td>O3</td>
<td>Ozone removed annually</td>
<td>20.70 USD</td>
<td>±0.81</td>
<td>295.83 lb</td>
<td>±11.61</td>
</tr>
<tr>
<td>PM2.5</td>
<td>Particulate Matter less than 2.5 microns removed annually</td>
<td>42.80 USD</td>
<td>±1.68</td>
<td>14.38 lb</td>
<td>±0.56</td>
</tr>
<tr>
<td>SO2</td>
<td>Sulfur Dioxide removed annually</td>
<td>0.07 USD</td>
<td>±0.00</td>
<td>18.72 lb</td>
<td>±0.73</td>
</tr>
<tr>
<td>PM10*</td>
<td>Particulate Matter greater than 2.5 microns and less than 10 microns removed annually</td>
<td>15.03 USD</td>
<td>±0.59</td>
<td>99.09 lb</td>
<td>±3.89</td>
</tr>
<tr>
<td>C02seq</td>
<td>Carbon Dioxide sequestered annually in trees</td>
<td>1,061.84 USD</td>
<td>±41.68</td>
<td>30.12 T</td>
<td>±1.18</td>
</tr>
<tr>
<td>C02stor</td>
<td>Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)</td>
<td>26,772.23 USD</td>
<td>±1,050.90</td>
<td>759.38 T</td>
<td>±29.81</td>
</tr>
</tbody>
</table>
Graph 2: Union Square Park Cover Class by Percent

<table>
<thead>
<tr>
<th>Cover Class</th>
<th>Description</th>
<th>Abbr.</th>
<th>Points</th>
<th>% Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree</td>
<td>Tree, non-shrub</td>
<td>T</td>
<td>202</td>
<td>36.7 ±2.06</td>
</tr>
<tr>
<td>Non-Tree</td>
<td>All other surfaces</td>
<td>NT</td>
<td>14</td>
<td>2.55 ±0.67</td>
</tr>
<tr>
<td>Shrub</td>
<td>shrubs</td>
<td>S</td>
<td>4</td>
<td>0.73 ±0.36</td>
</tr>
<tr>
<td>Impervious</td>
<td>concrete, etc.</td>
<td>I</td>
<td>320</td>
<td>56.2 ±2.10</td>
</tr>
<tr>
<td>Grassland</td>
<td>Grassy or green area</td>
<td>G</td>
<td>10</td>
<td>1.82 ±0.57</td>
</tr>
</tbody>
</table>

Table 3: Union Square Park Ecosystem Services

<table>
<thead>
<tr>
<th>Abbr.</th>
<th>Benefit Description</th>
<th>Value</th>
<th>±SE</th>
<th>Amount</th>
<th>±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>Carbon Monoxide removed annually</td>
<td>0.10 USD</td>
<td>±0.01</td>
<td>2.27 lb</td>
<td>±0.13</td>
</tr>
<tr>
<td>NO2</td>
<td>Nitrogen Dioxide removed annually</td>
<td>0.17 USD</td>
<td>±0.01</td>
<td>12.37 lb</td>
<td>±0.69</td>
</tr>
<tr>
<td>O3</td>
<td>Ozone removed annually</td>
<td>8.62 USD</td>
<td>±0.48</td>
<td>123.19 lb</td>
<td>±6.89</td>
</tr>
<tr>
<td>PM2.5</td>
<td>Particulate Matter less than 2.5 microns removed annually</td>
<td>17.82 USD</td>
<td>±1.00</td>
<td>5.99 lb</td>
<td>±0.34</td>
</tr>
<tr>
<td>SO2</td>
<td>Sulfur Dioxide removed annually</td>
<td>0.03 USD</td>
<td>±0.00</td>
<td>7.79 lb</td>
<td>±0.44</td>
</tr>
<tr>
<td>PM10*</td>
<td>Particulate Matter greater than 2.5 microns and less than 10 microns removed annually</td>
<td>6.26 USD</td>
<td>±0.35</td>
<td>41.26 lb</td>
<td>±2.31</td>
</tr>
<tr>
<td>CO2sec</td>
<td>Carbon Dioxide sequestered annually in trees (Note: this benefit is not an annual rate)</td>
<td>442.16 USD</td>
<td>±24.75</td>
<td>12.54 T</td>
<td>±0.70</td>
</tr>
<tr>
<td>CO2stor</td>
<td>Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)</td>
<td>11,148.18 USD</td>
<td>±623.93</td>
<td>316.21 T</td>
<td>±17.70</td>
</tr>
</tbody>
</table>
Graph 3: Comparison of Species Composition in USP and WSP

Table 4: Sustainability Scorecard of Washington Square Park

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Original Number</th>
<th>Tenths Place and weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Canopy Cover</td>
<td>54%</td>
<td>+ 5.4</td>
</tr>
<tr>
<td>Shannon-Wiener Index</td>
<td>2.5</td>
<td>+ 2.5</td>
</tr>
<tr>
<td>Impermeable Surfaces</td>
<td>32%</td>
<td>- 3.2</td>
</tr>
<tr>
<td>Percent Native Species</td>
<td>75%</td>
<td>+ 7.5</td>
</tr>
<tr>
<td><strong>Total Score =</strong></td>
<td></td>
<td><strong>13.1</strong></td>
</tr>
</tbody>
</table>

Table 5: Sustainability Scorecard of Union Square Park

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Original Number</th>
<th>Tenths Place and weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Canopy Cover</td>
<td>36%</td>
<td>+ 3.6</td>
</tr>
<tr>
<td>Shannon-Wiener Index</td>
<td>1.4</td>
<td>+ 1.4</td>
</tr>
<tr>
<td>Impermeable Surfaces</td>
<td>58%</td>
<td>- 5.8</td>
</tr>
<tr>
<td>Percent Native Species</td>
<td>84%</td>
<td>+ 8.4</td>
</tr>
<tr>
<td><strong>Total Score =</strong></td>
<td></td>
<td><strong>9.0</strong></td>
</tr>
</tbody>
</table>
Discussion and Conclusions

Washington Square Park generates more ecosystem services and has a higher sustainability index score, and is thus more sustainable overtime. Washington Square Park scored higher than Union Square Park because it had double the canopy cover and half the impermeable surfaces. Washington Square Park also had double the species diversity in comparison to Union Square Park, which indicates more stability overtime.

While Washington Square Park did score well on the sustainability index it is by no means a perfect score. For example, a park with high scores in every category – canopy cover of 90 percent, impermeable surface area of 10 percent, 90 percent native tree species, and a Shannon-Wiener index of 3 – would have a score of 20 points. A Shannon-Wiener diversity index of 3 is considered high because it is above average for New York and New Jersey, which have a median and mean index for species diversity between 2.67 and 3.00 (Cowett & Bassuk, 2017). A score of 20 points would likely look like a pocket preserve in an urban area. Comparing a near perfect score of 20 to a score of 13.6 indicates Washington Square Park could be improved.

The sustainability index is an easily replicable and meaningful way to rate parks to determine their ecosystem services and sustainability while also highlighting areas in need of improvement. One way that Washington Square Park could improve would be to replace all of the impermeable asphalt pavers with permeable pavers. If Washington Square Park replaced with infrastructure which allowed water to pass it, through the score would increase from 13.1 to 16.3. Other ways in which Washington Square Park could improve their score would be to plant more native trees, increasing canopy and native species cover. Likewise, if Union Square Park were to replace half of the impermeable surfaces with permeable pavers the score would rise from 9 to 11.6.

While these improvements may seem small and insignificant, the impacts are great. Reducing impermeable surfaces in a city reduces the heat-island effect, improves air quality, and reduces pollution from overflow. Increasing canopy cover improves air quality, sequesters greenhouse gases, provides noise barriers, reduces the heat-island effect, saves energy, and improves overall wellbeing for those in the community. Ensuring that our urban park systems have a healthy and diverse native species population will ensure that the ecosystem services delivered by the park are stable over time.

In conclusion, if all parks were scored for sustainability and ecosystem services using the scorecard developed here, we would have a better idea of where opportunities for improvement are in these parks. Increasing ecosystem services and sustainability in our urban parks generates greater quality of life by reducing pollution, increasing aesthetics, and lower temperatures and also lowers costs by reducing expenditures. Assuming that most parks in New York City have a sustainability index score between the ranges of Washington Square Park and Union Square Park suggests that there is plenty of room for improving these areas for the benefit of the environment and people. Future research and studies are needed to better understand urban ecosystem services.
References


O'Neil-Dunne, J. (2010). A report on the city of new york's existing and possible tree canopy..USDA Forest Service: Northern Research Station.

