Valuing the ecosystem services provided by Knoxville's Urban Wilderness

by

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Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

Homeowners, businesses, and governments in Knoxville and Knox County enjoy quantifiable economic value from the KUW in a variety of ways. This study demonstrates that the KUW contributes an estimated $3.4 million in annual cost savings and economic benefits through the provision of seven ecosystem services: water supply, water quality, flood mitigation, wildlife habitat, pollination, air pollution removal, and carbon sequestration. The most valuable ecosystem service (nearly $1.4 million annually) is support of wildlife habitat on the KUW's forests, wetlands, and pastures. Water-related benefits of the KUW include over $265,000 in annual cost savings from water supply services and nearly $1.2 million each year in water-quality enhancements provided by the forests, pastures, and wetlands in the KUW. If all the forested open space in the KUW were developed, area residents would experience an additional $290,379 in pollution-related impacts annually. In addition to these annual ecosystem service benefits, forested open space also stores an estimated $2.2 million in carbon. In other words, if all of the trees in the KUW were burned, the carbon stored in their tissue released into the atmosphere would cause $2.2 million in damages. These estimates should help elected leaders, policy makers, and the public make more informed decisions about future development and dispel arguments that undeveloped open space contributes nothing to local economies.

1. INTRODUCTION

1.1 Purpose of the Report

One of Knoxville's most valuable assets is its natural landscapes. Unfortunately, policy debates and land development decisions often ignore or at best undervalue the substantial economic, environmental, and health benefits generated by public open space such as parks, nature preserves, and trail systems. Many of these benefits are quantified by markets. The property value "premium" associated with real estate near public open space can be quantified using housing markets. The value residents and visitors to the area place on recreation opportunities provided by public open space can even be proxied by the amount spent to visit the area. However, market values capture only a portion of the total benefits generated by the public open space. For example, forested open spaces support wildlife, reduce regional air pollution, enhance water quality, sequester carbon and even help promote mental health. Visitor spending will not reflect the true value of recreational opportunities for local residents that live near the public open space. Non-market values of public open are difficult to quantify but often constitute a large portion of the total value attached to open space. A better understanding of the benefits provided by public open space can improve land-management decisions and address the common misperception that undeveloped or protected open space is a wasteful use of land that contributes nothing to local economies.

This report draws on well-known research techniques to place a dollar value on seven types of ecosystem services provided by Knoxville's Urban Wilderness (KUW): water supply, water quality, flood mitigation, wildlife habitat, pollination, air pollution removal, and carbon sequestration and storage. The KUW is a unique combination of parks, open spaces, and over 50 miles of trails and greenways covering 1700 acres near downtown Knoxville's south waterfront

(see Figure 1). The ecosystem services provided by the KUW arise naturally and automatically from the natural landscapes within the KUW. Replicating or replacing these services would be costly. These types of ecosystem services are often referred to as green infrastructure due to their ability to offset other more traditional forms of infrastructure such as storm water systems or flood walls. The analysis that follows estimates the value of these services.

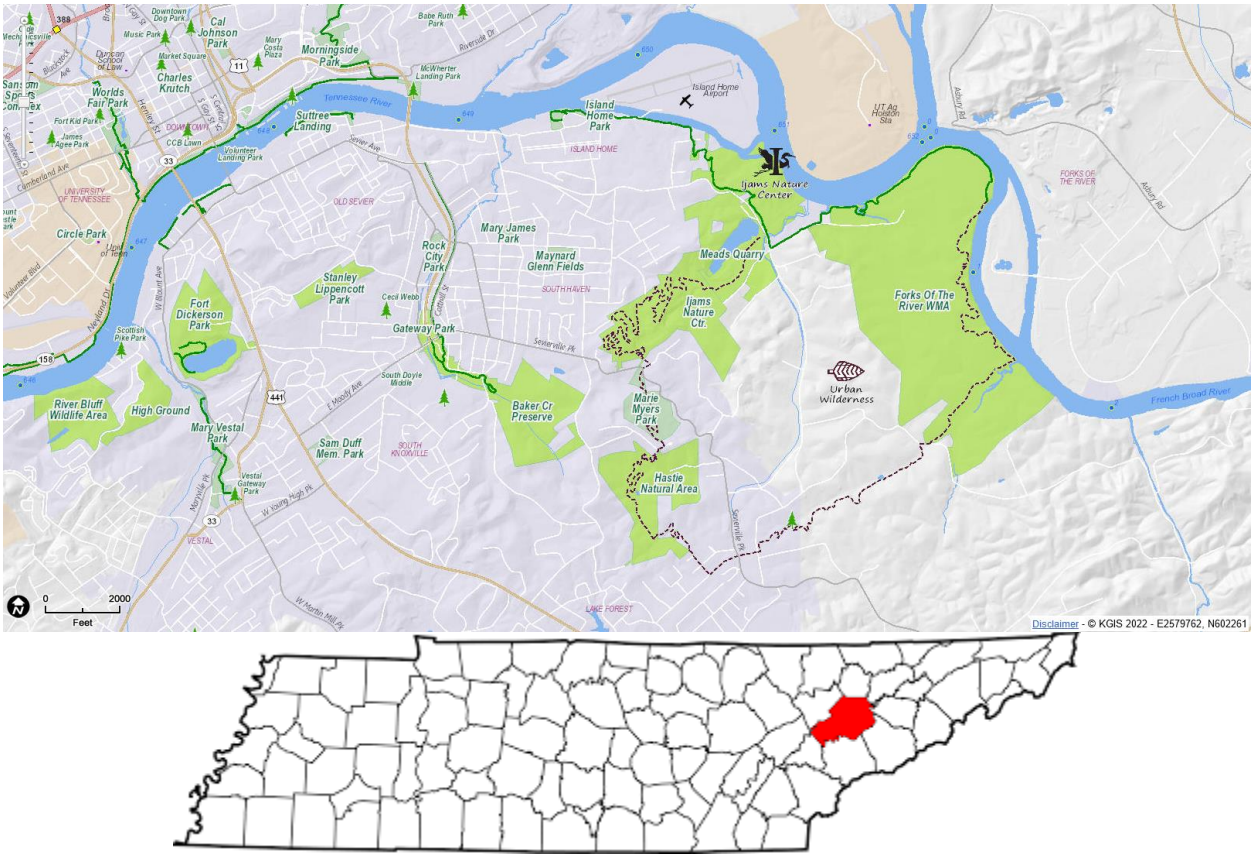

Figure 1. Location of KUW in South Knoxville in East Tennessee

This study makes no policy recommendations. Instead, the estimates of the economic value of the ecosystem services produced by the KUW are intended to inform land-use and development decisions in Knoxville and Knox County. Specifically, these estimates will provide a more complete depiction of the full range of environmental benefits provided by the natural

areas within the KUW and counter the common and incorrect assumption that the economic value of natural parks and wilderness areas is zero.

1.2 Description of KUW

An emerging trend in sustainable urban development is the growth of "urban wilderness" areas (Kowarik 2018). These areas, also known as "urban wildscapes" and "intended wilderness", are defined as relatively large tracts of land that are set aside for the specific goal of allowing long-term ecological succession. An example is the KUW which provides a variety of economic, social, and ecological benefits to area residents and businesses as well as visitors from across the country.

The KUW is a unique collection of land parcels owned by city, county, and state government, non-profit foundations, and private landholders (see Figure 2). It covers over 1700 acres and is composed of multiple parks including the Forks of the River Wildlife Management Area, Ijams Nature Center, Marie Myers Park, Baker Creek Preserve, Hastie Natural Area, Anderson School Trails, Fort Dickerson Park, River Bluff Wildlife Area, High Ground Park and private land easements. The KUW contains historic sites, quarries, and natural playgrounds and allows for multiple outdoor activities such as hiking, trail running, mountain biking, climbing, paddle boarding, swimming, wildlife viewing, and zip lining in elevated adventure trails. Construction and development are currently underway for an extension of the KUW, the Urban Wilderness Gateway Park, which will create additional spaces for natural play areas, events, pedestrian and mountain biking trails, a bike park, and parking and access points.

The extent, variety, and proximity to downtown make the KUW unmatched in the United States. Few cities outside the Rocky Mountain region have trail systems or bike parks within 10

miles of downtown with as many trail miles as the KUW.

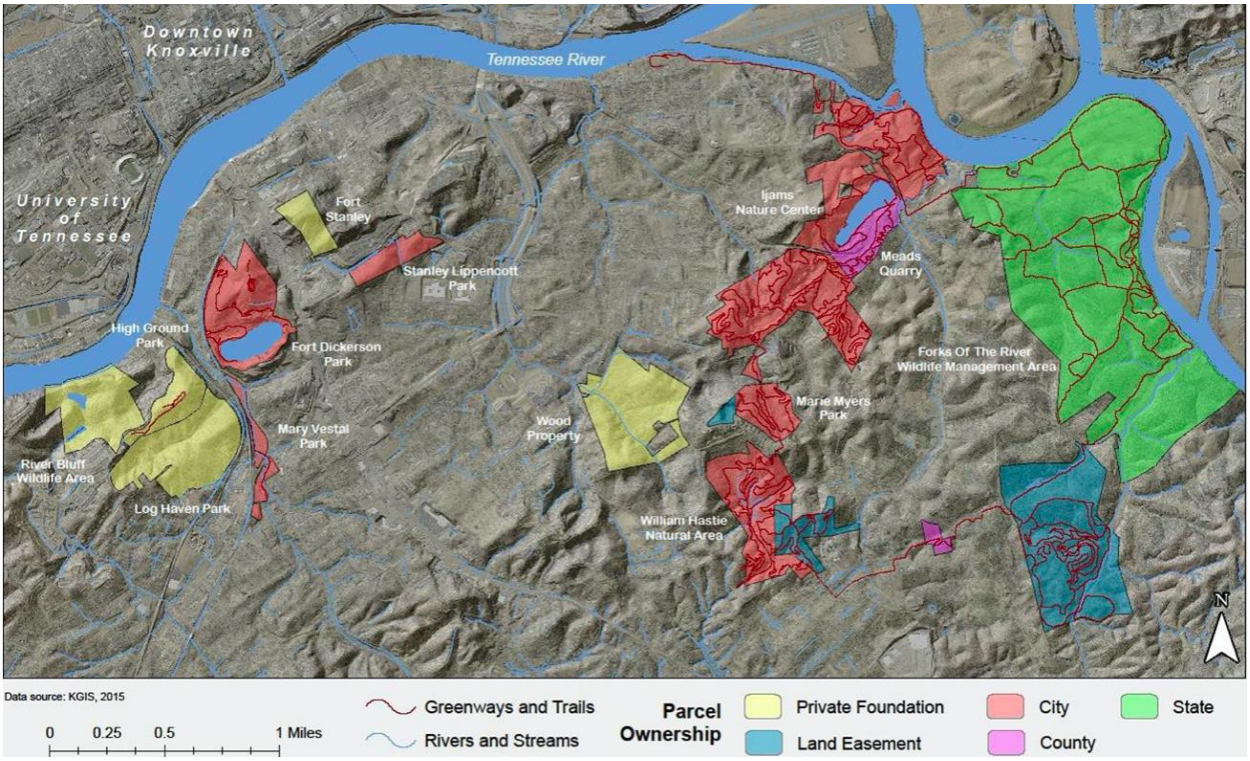

Figure 2. Map of KUW and Types of Ownership

1.3 Study Scope

Here we define the scope of our study by distinguishing between a benefit or service provided by open space and the value of that benefit. Table 1 illustrates the different benefits provided by open space and the way these benefits generate economic value.

Open space benefits fall into one of five categories: 1) economic activity, 2) property values, 3) health, 4) recreation, and 5) ecosystem services. Each of these open-space benefits can create economic value in four ways:

Table 1. Open space benefits and the subsequent values generated

		Ways open space creates economic value			
		Wealth generation	Tax revenue	Avoided costs	Willingness to pay
Open space benefits	Economic activity	✓	✓		
	Property values	✓	✓		
	Health			✓	
	Recreation	✓			✓
	Ecosystem services			✓	✓

1. **Wealth generation** such as higher property values and earnings generated by industries dependent on open space (i.e., agriculture, forestry, and tourism)
2. **Tax revenues** such as increased property-tax revenues due to higher property values or sales-tax revenues from the sale of agricultural and forestry commodities.
3. **Avoided costs** such as the dollars that would be spent to improve water quality or mitigate floods in the absence of open space.
4. **Willingness to pay**, which captures what individuals would be willing to pay for recreational activities or wildlife habitat if these services were not provided by open space.

The first two categories are value generated by the presence of open space, while the last two are economic costs avoided by the presence of open space. For example, a city or town may be forced to expand or improve stormwater infrastructure if large areas of forest are developed into a parking lot. Residents are generally willing to pay to run and bike in city parks and greenways even though they often do not have to pay any access fee to enjoy these recreational pursuits. While all four categories are viewed as the economic value created by open space, the last two—avoided costs and willingness to pay—are not based on actual monetary transactions. Unlike wealth generation and tax revenues, avoided costs and willingness to pay should be viewed not as actual income generated but as the value that residents, non-residents, businesses and local

governments gain from open space benefits above what they must already pay for these benefits (which is often zero).

The primary objective of this study is to estimate the economic value of the ecosystem service benefits provided by the KUW (see last row of Table 1). Open space also provides value in the form of ecosystem services such as clean-water provision, flood control, and air-pollution mitigation. If open space were developed, the region would be forced to spend money to replicate these ecosystem services. Knoxville and Knox County enjoy significant cost savings from the natural landscapes found on the KUW. This study does not account for other potentially important benefits of the KUW such as economic activity, impacts to property values, and benefits from recreation and exercise in the KUW. See Sims et al. (2015) for details on the recreation values provided by the KUW and Welch et al. (2022) for details on the KUW's impact on property values. As such, the values presented in this report should not be interpreted as wealth generation or tax revenues.

2. METHODOLOGY

Estimates in this report are based on existing studies that estimate the continuous flow of value created by the ecosystem services water supply, water quality, flood mitigation, wildlife habitat, pollination, air pollution removal, and carbon sequestration and storage (Costanza, et al. 2006;Nowak, et al. 2006;Nowak, et al. 2007). The quality of these services and the values placed on them vary depending on the type and amount of land cover present in an area. Geographic information system (GIS) data is used to inventory the type and amount of land cover present in the KUW. A summary of the land cover inventory is provided in Table 2 and Figure 3.

Table 2. KUW by land cover type

Primary land cover type	Secondary land cover type	Percent of KUW*
Developed		
	Open space	5
	Low intensity	0
	Medium intensity	0
	High intensity	0
	Total	**5**
Forest		
	Deciduous	64
	Evergreen	20
	Mixed	3
	Total	**87**
Wetlands		
	Woody wetlands	<1
	Emergent herbaceous wetlands	0
	Total	**<1**
Shrubland/Herbaceous		
	Shrub/scrub	1
	Grassland	2
	Total	**3**
Planted/Cultivated		
	Pasture/Hay	4
	Cultivated Crops	0
	Total	**4**
Riparian Buffers**		**1**

** numbers do not sum to 100 due to rounding*

*** Riparian buffer defined as any of the above land cover types within a 25 foot buffer around rivers and streams*

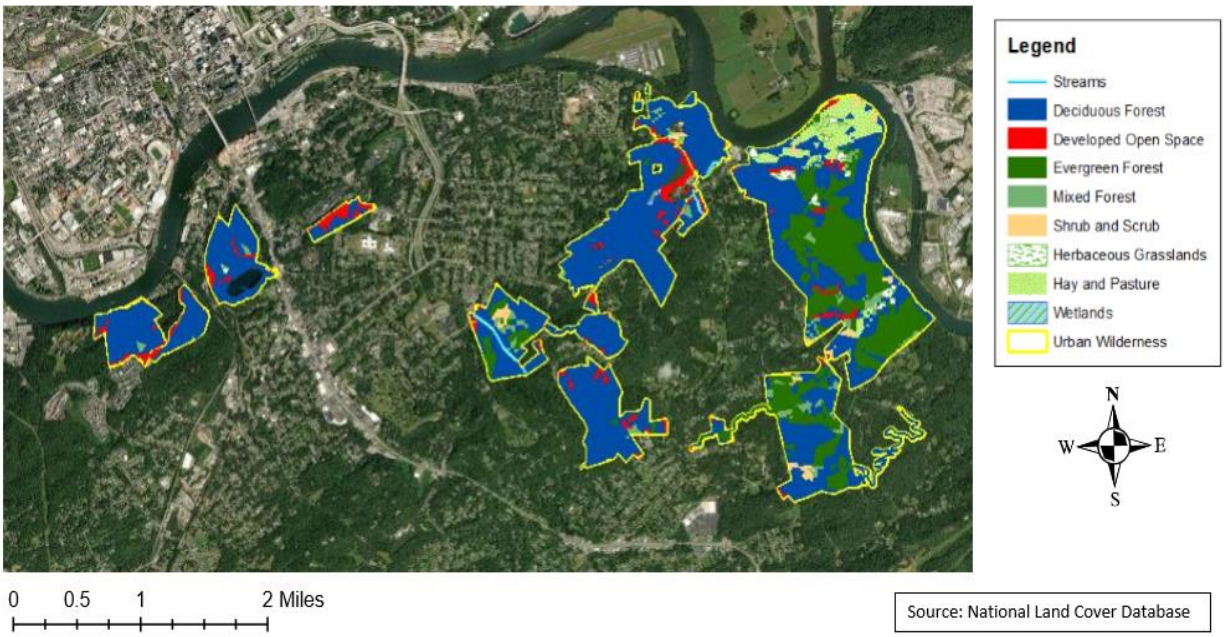

Figure 3: KUW by Land Cover Type

Values associated with each of the ecosystem services were applied to the land-cover inventory to produce total value estimates for the entire KUW. Dollar values approximating the economic value of each of these ecosystem services are based on peer-reviewed studies that value these services on a per acre basis. High, low, and mean dollar values are typically reported in the literature to reflect uncertainty. We use mean estimates for our analysis but acknowledge the considerable uncertainty in these measures. These total values represent either 1) the costs avoided by not having to artificially replace the ecosystem services currently provided by the KUW or 2) the damages that would be caused if the KUW did not provide these ecosystem services.

3. SUMMARY OF ECOSYSTEM SERVICE VALUES

The KUW study area is characterized by nearly 1,600 acres of natural open space ranging

from forests and wetlands to pasture. Together, these green open spaces contribute an estimated $3.4 million in annual cost savings and economic benefits through the provision of seven ecosystem services: water supply, water quality, flood mitigation, wildlife habitat, pollination, air pollution removal, and carbon sequestration. Table 3 shows how these benefits are allocated across ecosystem services. The allocation of benefits across the different types of ecosystem services depends on the amount and type of land cover in the KUW. For example, water quality services are supplied by nearly 93 percent of the land cover in the KUW. All dollar values in Table 3 are annual and recurring. In addition to the annual ecosystem service benefits in Table 3, forested open space also stores an estimated $2.2 million in carbon. In other words, if all of the trees in the KUW were burned, the carbon stored in their tissue released into the atmosphere would cause $2.2 million in damages.

Table 3. Ecosystem service values in KUW by land cover

	Acres	Forests	Wetlands	$ per year Pasture and cropland	Riparian buffers	**Total**
Water supply	1,424	$228,689	$3,088	--	$33,425	**$265,202**
Water quality	1,473	$1,175,714	$1,676	$2,992	--	**$1,180,382**
Flood mitigation	94	--	$6,643	--	$1,531	**$8,174**
Wildlife habitat	1,499	$1,294,969	$226	$78,114	--	**$1,373,309**
Pollination	1,565	$227,286	--	$1,636	--	**$228,922**
Pollution removal	1,403	$290,379	--	--	--	**$290,379**
Carbon sequestration	1,403	$69,924	--	--	--	**$69,924**
Total	**320,512**	**$3,286,960**	**$11,633**	**$82,742**	**$34,956**	**$3,416,291**

Source: Costanza et al. (2006), Nowack et al. (2006), Nowack et al. (2007), Baker Center calculations

3.1 Water Supply

A variety of ecosystem functions work together to provide for continuous recharge of fresh, clean water. The soil and canopy cover of forests helps store water, replenish streams and reservoirs and recharge underground aquifers by preserving natural runoff patterns, enhancing

water retention in the soil, enhancing natural recharge, and preventing siltation of water bodies that alter surface water flow patterns and instream storage volumes. These types of ecosystem services are known as green infrastructure due to their ability to offset more costly built infrastructure such as traditional "gray" storm water systems. Water supply services are correlated with the amount of forest, wetlands, and riparian areas (Costanza, et al. 2006). The land cover on over 88 percent of the KUW (1,424 acres) has been associated with this type of ecosystem service. The more those land cover types are present, the greater the water supply benefits provided. Thanks to the abundant forests, wetlands, and riparian areas, the KUW provides over $265,000 in annual cost savings from water supply services. Table 3 provides the value of water supply services by land cover type.

3.2 Water Quality

Forests, wetlands, and pastures serve as a buffer between polluting activities and water supplies. The complex of soil, water, and vegetation that makes up these land-cover types work to filter and mitigate several types of waste including pathogens, excess nutrients, metals, and sediments from entering the water supply. Nearly 93 percent of the land cover in the KUW (1,473 acres) has been shown to improve water quality. The water-quality enhancements provided by the forests, pastures, and wetlands in the KUW total nearly $1.2 million each year. This service is driven largely by the amount of forest, wetlands, and pasture in the KUW. The more of these types of land cover types, the larger the water quality benefits provided by the KUW. Area residents would be forced to make costly investments to expand existing water filtration and treatment facilities without the water quality benefits these types of land cover provide. These services are also important for ensuring that groundwater wells, a source of household drinking water for many area residents, are a safe and reliable source of water. Table

3 presents a breakdown of the benefit derived from water quality services by land cover type.

3.3 Flood mitigation

Many types of land cover work to mitigate the effect of extreme flooding. The types of soils and vegetation present on wetlands and riparian buffers work to reduce the risk of damaging floods by trapping and holding stormwater. Over 1 percent of open space in the KUW (19 acres) has been associated with flood mitigation services. These types of ecosystem services are known as green infrastructure due to their ability to offset more costly built infrastructure such as traditional "gray" storm water systems. Were the KUW to be devoid of wetlands and riparian buffers, residents and local governments would be forced to make costly investments to expand and improve existing stormwater infrastructure systems. Replacing the flood mitigation services provided by wetlands and riparian buffers in the KUW would cost $8,174 each year. Table 3 shows the types of land cover responsible for these benefits.

3.4 Wildlife habitat

Many types of land cover in the KUW are known to serve as habitat for a diverse array of plants and animals. Contiguous areas of forest and wetlands harbor species that people value for hunting, wildlife viewing, and aesthetic benefits. Even cropland can provide forage opportunities for species such as deer and turkey. It is important to note that the values presented in this section differ from the other ecosystem service values since these values are not an avoided cost. Values in this section estimate the amount of money that people would be willing to pay to preserve wildlife on open space in the study region. Specifically, the values reported in this section are based on minimum willingness-to-pay values from the research literature (Costanza, et al. 2006). As a result, the estimates reported in this section should be viewed as a

conservative estimate of the benefits derived from the preservation of wildlife habitat on open space. Using these minimum willingness-to-pay values reveals that wildlife habitat provided by the KUW has an estimated value of nearly $1.4 million each year. Table 3 provides the wildlife habitat values by land cover type.

3.5 Pollination

One critical ecosystem service provided by open space is the support of bees and other insects that pollinate crops and other vegetation. The plants that grow on cropland, forest, and pasture have been shown to provide important habitat to sustain natural insect populations. Healthy, intact insect populations move pollen from plant to plant to aid in reproduction. The total annual cost to replace the pollination services provided by the KUW is $229,000. Table 3 shows the types of land cover responsible for these benefits.

3.6 Air Pollution Removal

Poor air quality is common in many parts of the study area. Particulate matter, ozone, sulfur dioxide, and other regional pollutants can cause a variety of respiratory ailments including asthma, damage buildings and plants, and give rise to unhealthy and unsightly smog. Trees mitigate air pollution through botanic respiration processes that remove pollutants from the air. This analysis includes benefits derived from the removal of five different pollutants: ozone (O_3), particulate matter (PM-10), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO).

The KUW contains over 1,400 acres of forests that provide pollution removal services. Trees remove different pollutants at different rates. For example, trees are very efficient at removing particulate matter. A single acre of forested open space removes over 30 pounds of

particulate matter (PM-10) per year. However, a single acre of forested open space removes only 1.8 pounds of carbon monoxide per year. Table 3 presents the tree-cover acreage and amount of pollutants removed in the KUW. The variation in pollution removal amounts reflects the varying ability of trees to remove different pollutants.

Table 4. Air pollution removal benefits in the KUW

	O_3	PM-10	NO_2	SO_2	CO	**Total**
Amount removed (tons)	18.50	20.66	9.01	6.27	1.16	**55.60**
Value ($ per year)	$124,911	$93,151	$60,844	$10,362	$1,111	**$290,376**

Source: Nowack et al. (2006), Nowack et al. (2007), U.S. Forest Service (2010), Baker Center calculations

The economic benefit of the pollution removal amounts in Table 3 depends on how harmful each of these pollutants is to human health and ecosystem function. For example, a ton of ozone causes negative impacts that total $6,752 annually while a ton of carbon monoxide causes only $959 in negative impacts. Using these per-ton external costs of pollutants and the total amount of pollution removed in Table 3, it is estimated that trees in the KUW annually provide $290,379 in air pollution removal benefits. If all the forested open space in the KUW were developed, area residents would experience an additional $290,379 in pollution-related impacts annually. Table 4 presents the benefits generated for the removal of each pollutant.

3.7 Carbon Sequestration and Storage

In addition to alleviating the impacts of regional pollutants like ozone and sulfur dioxide, forested open space also helps reduce the impacts of atmospheric greenhouse gases linked to climate change. Table 5 presents estimates of the tons of carbon sequestered and stored by trees on forests in the KUW as well as the value of these carbon sequestration and storage services. Through the natural process of photosynthesis, trees mitigate the impacts of climate change by

removing (sequestering) atmospheric carbon from carbon dioxide. A growing tree pulls carbon from the air. Every year, new tree growth on an acre of forest land sequesters 2,555 pounds of carbon. The benefits of sequestering carbon are encapsulated in a concept known as the social cost of carbon (Sims 2014). According to the EPA, the social cost of carbon is an estimate of the economic damages associated with a small increase in carbon emissions, conventionally one metric ton, in a given year. This dollar figure also represents the value of damages avoided for a small emission reduction. Using a $43 per-ton value for the social cost of carbon, it is estimated that the value of this sequestered carbon is nearly $70,000 per year. This estimate measures the monetary damages associated with the carbon that was sequestered in the forests of the KUW. These monetary damages include the impacts of atmospheric carbon on various aspects of the broader economy such as changes in agricultural productivity, human health, property damage from increased flood risk, damages from sea level rise and more frequent storms, energy availability constraints in the industry, changes in needs for heating and cooling, and threats to consumers from price increases. Because this carbon is taken out of the air, these monetary damages are avoided simply by the presence of forests.

In addition to removing carbon from the atmosphere, trees also store carbon in their above- and below-ground tissues, which is another way trees regulate the amount of carbon in the atmosphere and counteract carbon emissions from human sources such as the burning of fossil fuels. As long as the trees are alive, the carbon they store is kept out of the atmosphere. Based on dendrology studies of the carbon storage abilities of different tree species in different growing regions, forested areas in the KUW are storing a total of over 51,000 tons of carbon. Using a $43 per-ton value for the social cost of carbon, if the carbon currently stored in trees on the KUW were released into the atmosphere, it would cause $2.2 million in damages. Since this

carbon is currently stored and these damages are being avoided, this represents an additional benefit of forested open space. Unlike the other ecosystem service benefit estimates in this report, carbon storage is a one-time benefit and not a continuous flow of benefits. Thus, carbon sequestration is reported in dollars per year, but carbon storage is reported in total dollars in Table 5.

Table 5. Estimated carbon storage and sequestration benefits

	carbon sequestration	carbon storage
Amount (tons)	1,626	51,329
Value	$69,924 per year	$2,207,133

Source: Nowack et al. (2006), Nowack et al. (2007), U.S. Forest Service (2010), Baker Center calculations

4. CONCLUSION

The 1700 acres of natural environments within the KUW generate clear benefits. Homeowners, businesses, and governments in Knoxville and Knox County enjoy quantifiable economic value from the KUW in a variety of ways. This study demonstrates that the KUW contributes an estimated $3.4 million in annual cost savings and economic benefits through the provision of seven ecosystem services: water supply, water quality, flood mitigation, wildlife habitat, pollination, air pollution removal, and carbon sequestration. These estimates should help elected leaders, policy makers, and the public make more informed decisions about future development and dispel arguments that undeveloped open space contributes nothing to local economies.

5. REFERENCES

Costanza, R., et al. 2006. *The Value of New Jersey's Ecosystem Services and Natural Capital.* . Trenton, NJ: New Jersey Department of Environmental Protection, Division of Science, Research, and Technology.

Kowarik, I. Urban wilderness: Supply, demand, and access. Urban For. Urban Green. 2018, 29, 336–347

Nowak, D.J., D.E. Crane, and J.C. Stevens. 2006. "Air pollution removal by urban trees and shrubs in the United States." *Urban forestry & urban greening* 4:115-123.

Nowak, D.J., et al. ``Assessing Urban Forest Effects and Values." U.S. Department of Agriculture, U.S. Forest Service, Northern Research Station.

Sims, C. "What are the Benefits of Federal Carbon Reduction Policies and How Well Do We Know Them?". Howard H. Baker Jr Center for Public Policy Policy Brief 3.14.

Sims, C.; Davis, R.; Kim, B. Economic Potential of South Knoxville's Urban Wilderness; Howard H. Baker Jr. Center for Public Policy White Paper: Knoxville, TN, USA, 2015.

Welch, J. G., Sims, C. B., & McKinney, M. L. (2022). Does an Urban Wilderness Promote Gentrification? A Case Study from Knoxville, Tennessee, USA. *Sustainability*, *14*(2), 973.