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FOREST CANOPY BENEFITS IN SMALL URBAN AREAS OF LOUISIANA

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Abstract. Urban forests provide many benefits to areas in which they grow, sequestering carbon, mitigating pollution and rainfall runoff, and helping conserve energy. It is crucial that urban trees be managed to maximize the benefits they provide. However, not all urban areas have the capacity, staffing, or infrastructure to adequately manage these areas. Many smaller urban areas are largely unaccounted for in benefit assessment of urban areas within a state. This study presents the estimated benefits of 10 small urban areas in Louisiana that illustrate the tree coverage and benefits of small urban tree cover. i-Tree Canopy was utilized to provide coverage estimates and benefits through photo-interpretation of 500 randomly allocated points within each city. Percent tree cover ranged from 11.2%-41% in the 10 cities; estimates of air and atmospheric pollutant mitigation and carbon sequestration and storage were also obtained. These estimates are important considerations for small urban areas because they demonstrate the importance and need for forest management that optimizes community benefits provided to the public.

Keywords: i-Tree Canopy, municipal management, small urban areas, urban canopy benefits.

1 Introduction

Forestry is of vital economic importance, particularly in the southern United States, which produces a majority of the nation's forest products. Forestry has a multi-billion dollar economic impact in most southern states (Jefferies, 2016); in Louisiana, for example, greater than half the land area is forested and the value of products is estimated at over eight billion US dollars (American Forest and Paper Association, 2017). Beyond the commercial benefit are ecosystem services inherent to the growth of trees and forests – i.e., non-timber goods, cultural benefits, and impacts on air and water quality – which are important considerations in the total economic impact of a forest (Sills et al., 2017). Sustaining and managing healthy, productive, forests therefore has both economic and societal importance.

Often overlooked in the valuation of forestry to a state's economy is the financial benefit of an urban forest canopy. The benefits of urban forests are numerous, serving to reduce air pollution (Nowak et al., 2013b; Nowak et al., 2014), mitigate rainfall interception and storm water runoff (Xiao et al., 1998; Xiao and McPherson, 2016), and increase carbon sequestration and storage (Nowak et al., 2013a; Russo et al., 2014; McPherson et al., 2017). Urban forests have also been linked to increased property values (Donovan and Butry, 2010), potential reductions in crime (Kuo and Sullivan, 2001; Wolfe and Mennis, 2012), and health benefits (Dwyer et al., 1992; Nowak et al., 2014). It is therefore important to consider the various benefits of urban forests to give a full accounting of the value of forests within a state.

The majority of the attention in the research and assessment involving the urban forest canopy and its many benefits have typically involved large cities (Sjöman et al., 2012; Nowak et al., 2013a, 2013b; Donovan et al., 2016; McPherson et al., 2016; Endreny et al., 2017; Nowak et al., 2018a), although benefits of community forests are also gaining consideration in total state assessments (Nowak and Greenfield, 2018). Establishing the benefits of forests and trees found within smaller urban areas, whether exurbs or economically distinct micropolitan areas, warrants recognition as well. Unfortunately, literature proved limited regarding this perspective.

Urban tree canopy cover in the southern United States, and in Louisiana in particular, is 30% and above at the county level for a majority of the counties (Nowak et al., 2010). Where increased urbanization (i.e., increased population density) or sprawl occurs in an urban area, it is intuitive that canopy cover would consequently decrease, likely from increased fragmentation (Cai et al., 2013). Increased urbanization and sprawl surrounding larger urban centers (e.g. Atlanta, GA) are expected outcomes; however, urbanization and sprawl are also expected to impact smaller cities (Terando et al., 2014). As population and population density levels rise, it will become increasingly important to adequately manage urban forests to maximize their benefits (Livesley et al., 2016).

Smaller cities, often outside of the influence of major metropolitan areas, are often given little consideration and their urban forest resources are little managed. Smaller municipalities typically have not possessed a capacity for adequately assessing and maintaining their urban canopy (Dickerson et al., 2001). Some cities lack both the funding and staffing necessary to execute a sustained management program or they are unaware of the resources and assistance available (Lewis and Boulahanis, 2008; Grado et al., 2013; O'Herrin and Shields, 2016). Varying degrees of tree maintenance are practiced throughout cities in the southern United States, with 81% reporting a department for tree maintenance; however, only 59% reported a person assigned to tree maintenance (Lewis and Boulahanis, 2008). Larger towns in Mississippi reported greater interest in urban forestry projects although funding and staffing were issues (Grado et al., 2013). Cities in Texas, similarly, have few staff (1.4 average staff members in towns with populations between 30,000-90,000), and few towns with a management plan or budget allocation to urban forest programs (O'Herrin and Shields, 2016).

i-Tree Canopy is one of a suite of tools available for use in the assessment of urban tree canopy. It provides users a straightforward means of obtaining initial estimates of urban cover types and the benefits of tree canopy cover (Nowak et al., 2018b). This is a freely available web-based program that allows users to interpret randomly placed points on imagery provided by Google Earth within delineated boundaries. Such an initial assessment can provide a basis for more detailed inventory and assessment, for example incorporating i-Tree Eco to establish monitoring locations, assess the state of urban trees, and determine areas where action/management is warranted. Multiple issues can arise in urban areas with a lack of maintenance and management, including poor forest health (Groninger et al., 2002) and negative impacts to infrastructure (e.g., sidewalks, buildings, etc.). Municipal and community cooperation, in programs such as Tree City USA, has been found to aid smaller municipalities towards improving urban forest management (Berland et al., 2016). There are other resources available for developing plans and managing urban forests (Leff, 2016), yet often these resources are underutilized. Part of the issue may be a general lack of awareness of the land area occupied by forests within smaller municipalities. Subsequently, the benefits gleaned from the tree canopy present there are unknown. Therefore, the need to assess and document the current coverage and benefits of smaller (populations between 20,000-50,000) urban areas is present. The objectives of this study are to assess 10 small urban areas in Louisiana, to 1) determine current percent area by cover class and 2) the assess the benefits of urban tree canopy for pollution mitigation and carbon sequestration and storage purposes.

2 Methods

2.1 Study Areas

A baseline assessment of urban tree and forest benefits can be facilitated by evaluating tree (percent) cover (Nowak and Greenfield, 2018). This was the approach taken to study the benefits of small urban areas in Louisiana with populations ranging from 20,000 to 50,000 people. Cities were selected after meeting the following criteria. First, they needed to identify as an urban cluster, having 2,500 to less than 50,000 people (U.S. Census Bureau, 2010). There were 17 cities meeting this criterion in Louisiana. Second, these cities needed to be projected to continue to trend towards urbanization (population greater 50,000) and potentially continue to have their canopy cover fragmented, as described by Terando and others (2014). Nine of 17 cities met these conditions. A tenth city, Natchitoches, which has a population of just over 18,000, was also selected so that municipalities were distributed throughout Louisiana (Figure 1). These 10 cities represent approximately 441 km^2 of land and contain about 293,000 people. GIS shapefiles were obtained from the U.S. Census Bureau (2013) for delineating the boundary of each city. Each city boundary file was queried individually and checked to ensure the WGS84 projection system was used.

2.2 Data and Analysis

i-Tree Canopy (2019) was employed to assess land cover types within each city. Using each city's shapefile as an extent for assessment, cover classes within the city were defined. The cover classes specified for each city were trees, roads, buildings, impervious surfaces (e.g., parking lots, driveways, etc.), grass/herbaceous (including shrubs/landscaping near buildings), bare ground (e.g., areas of development, land that would be unavailable for tree/vegetative cover), and water. After defining cover classes, i-Tree Canopy utilizes the most recent imagery available via Google Earth to assist in assessing land cover. The most recent image dates for seven of the 10 cities were from 2018-2019; the exceptions were Sul-

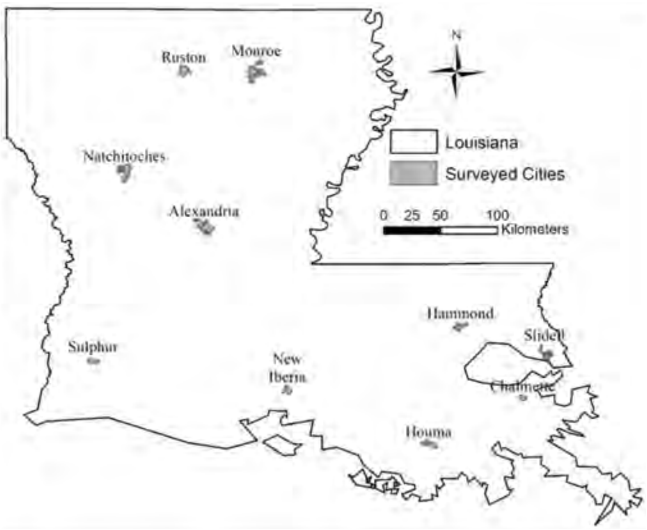

Figure 1: Cities in Louisiana assessed using i-Tree Canopy.

phur (December 2017), Natchitoches, and New Iberian (March 2016).

In this study, 500 randomly selected points were classified by the authors for the land cover type on which they fell within each city. Given the high spatial resolution of the imagery (i.e., ≤ 1.0 m), multiple interpreters were not utilized. After the image interpreter enters the land class for each point into the iTree software a percent cover, accompanied by a standard error, is calculated automatically for each cover class based on the number of points classified into a given cover class (see iTree Canopy User's Manual (2019) for specifics on area estimates and error calculations). The i-Tree Canopy program then estimates annual removals (by trees) of carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), particulate matter less than 2.5 microns ($PM_{2.5}$), particulate matter 2.5-10 microns (PM_{10}), and estimates carbon dioxide (CO_2) sequestration (annual rate). The physical units (e.g., tonnes removed or sequestered) are estimated from estimates of tree canopy area. These values are paired with currency estimates (in US dollars) based upon their social cost (in \$/t/yr) where the social costs are based upon potential health effects and related expenses and productivity losses, including mortality (Nowak et al. 2014).

The values (coverage and benefits) obtained for each city were summarized to provide an assessment of estimated ecosystem services/benefits provided by the urban canopy of each municipality. They were next normalized by city area population (US Census Bureau, 2018) to determine per capita benefits for each service.

Lastly, standardization was applied using equation 1:

$$z = \frac{x - \mu}{\sigma} \tag{1}$$

where z is the standardized value for each pollutant, x is the respective value of each pollutant, μ is the average pollutant value across all ten cities, σ and is the standard deviation of each pollutant across all ten cities. Because the levels of magnitude varied widely across pollutants, normalization and standardization provided opportunities to compare differences in coverage by land use types and benefit differences within the small urban areas. Standardization was only conducted on the economic values because they were inclusive of both physical and monetary units of measure. The cities were ranked based upon their cumulative (i.e. summed) standardized values. This was done on both the absolute and relative (per capita) levels. The rankings were then compared descriptively.

3 Results

The cities assessed in Louisiana vary substantially in their cover composition. Tree cover ranges from 11.2% (Houma) to 41% (Ruston) but total green space (combining trees and grass/shrub/herbaceous cover) ranges from 47% to 73.6%. Combined impervious surface ranged between 12.6% (Natchitoches) to 35.6% (Chalmette). For areas classified as bare ground, including building sites, areas covered by gravel (parking areas), and well sites, coverage was relatively uniform between all cities (between 2 and 8%). Water surface varied widely among cities, owing to some being nearer and/or incorporating more water area within their boundaries. Coverage ranged from 0.4% in Sulphur to 14.8% in Natchitoches (Table 1, Figure 2).

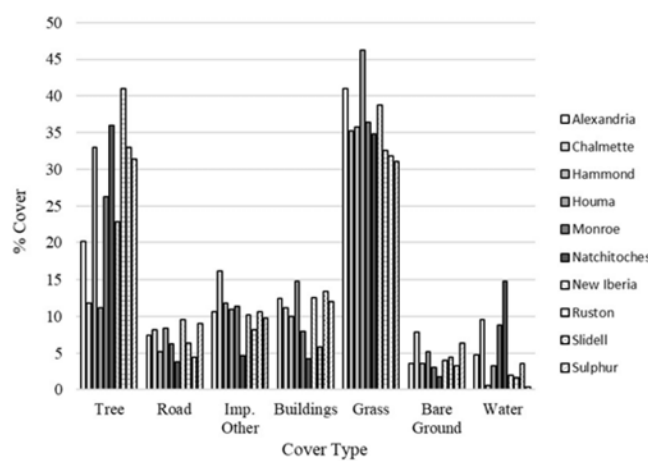

Figure 2: Distribution of cover types for each of the 10 cities assessed in Louisiana.

Table 1: Cover class by percent (standard errors in parentheses), percent green space, percent impervious cover, area, total population, and population density for each city assessed (Note: Cities are arranged by population density). Green space (% Green) is a combination of the tree and grass/herbaceous cover classes. Impervious surfaces (% Impervious) is a combination of the road, buildings, and impervious other classes.

	Chalmette	New Iberia	Houma	Slidell	Sulphur	Alexandria	Hammond	Monroe	Ruston	Natchitoches
Tree	11.8(1.44)	22.8(1.88)	11.2(1.41)	33.0(2.10)	31.4(2.08)	20.2(1.80)	33.0(2.10)	26.2(1.97)	41.0(2.20)	36.0(2.15)
Road	8.2(1.23)	9.6(1.32)	8.4(1.24)	4.4(0.92)	9.0(1.28)	7.4(1.17)	5.2(0.99)	6.2(1.08)	6.4(1.09)	3.8(0.86)
Imp. other	16.2(1.65)	10.2(1.35)	11.0(1.40)	10.6(1.38)	9.8(1.33)	10.6(1.38)	11.8(1.44)	11.4(1.42)	8.2(1.23)	4.6(0.94)
Buildings	11.2(1.41)	12.6(1.48)	14.8(1.59)	13.4(1.52)	12.0(1.45)	12.4(1.47)	10.0(1.34)	8.0(1.21)	5.8(1.05)	4.2(0.90)
Grass	35.2(2.14)	38.8(2.18)	46.2(2.23)	31.8(2.08)	31.0(2.07)	41.0(2.20)	35.8(2.14)	36.4(2.15)	32.6(2.10)	34.8(2.13)
Bare ground	7.8(1.20)	4.0(0.88)	5.2(0.99)	3.2(0.79)	6.4(1.09)	3.6(0.83)	3.6(0.83)	3.0(0.76)	4.4(0.92)	1.8(0.60)
Water	9.6(1.32)	2.0(0.63)	3.2(0.79)	3.6(0.83)	0.4(0.28)	4.8(0.96)	0.6(0.35)	8.8(1.27)	1.6(0.57)	14.8(1.59)
%Green	47	61.6	57.4	64.8	62.4	61.2	68.8	62.6	73.6	70.8
%Impervious	35.6	32.4	34.2	28.4	30.8	30.4	27	25.6	20.4	12.6
Area(km^2)	20.4	27.4	36.6	31.8	25.7	70.5	33.1	83.8	47	65
Population	22,907	30,292	33,784	27,755	20,237	47,954	20,325	48,938	22,154	18,176
Density	1,123	1,106	923	873	787	680	614	584	471	280

For individual cities, regardless of size or population density, either tree or grass/herbaceous coverage were the greatest single cover classes. Tree cover was greater in Ruston (41%), Natchitoches (36%), Slidell, and Hammond (tie at 33%); considering total green space Ruston (73.6%), Natchitoches (70.8%), and Hammond (68.8%) have the greatest percentages (Slidell has less grass/yard area than does Hammond). The three cities with the lowest impervious cover percentage are Ruston, Natchitoches, and Monroe with 20.4%, 12.6%, and 25.6%, respectively. The three lowest percentages for tree cover are Alexandria (20.2%), Chalmette (11.8%), and Houma (11.2%); these cities also have the lowest total green space (61.2%, 47%, and 57.4%, respectively). The greatest impervious coverage was found in Chalmette (35.6%), Houma (34.2%), and New Iberia (32.4%). Ranking cities by population density, the denser cities are found to have, generally, greater coverage of impervious surface. Compared with population density, there was a strong negative correlation (r) with percent green area (trees plus grass/herbaceous) and percent tree cover; conversely, there was a strong positive correlation with impervious percent cover (increasing population density, increasing impervious cover) (Figure 3).

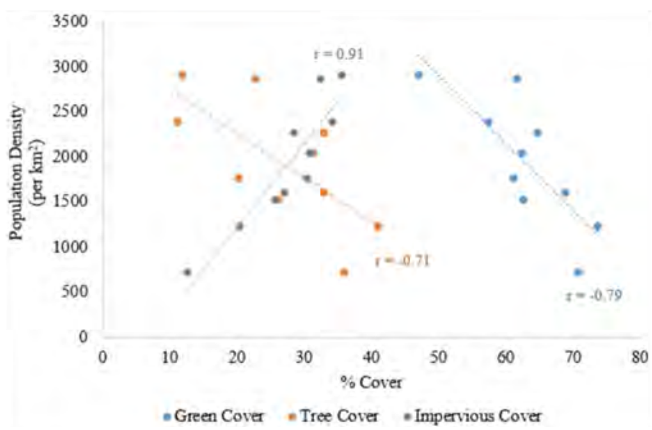

Figure 3: Correlation between population density and percent green cover, percent tree cover, and percent impervious cover for the 10 cities assessed in Louisiana.

The estimated benefits to these cities in terms of air quality and carbon mitigation may also be of interest to citizens and officials in the respective cities. Carbon monoxide removals, on average, ranged from 0.27 (±0.03) tonnes/year (Chalmette) to 2.39 (±0.15) tonnes/year (Natchitoches), with annual benefits to the cities between \$23 and \$223. The other air quality benefits in amounts (and dollar values) rank similarly – with Chalmette lowest and Natchitoches highest (Tables 2 and 3). For NO_2, removal amounts range from 1.33 to

Table 2: Annual benefits, in terms of amount (tonnes) and dollar values (USD) for Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Ozone (O_3), Particulate Matter less than 2.5 microns, Sulfur Dioxide (SO_2), and Particulate Matter between 2.5 and 10 microns, for each of the 10 cities assessed in Louisiana, Note: a a - indicates per capita tonne values less than 0.1 tonne and b a - indicates values less than $0.01.

		CO	**NO_2**	**O_3**	**$PM_{2.5}$**	**SO_2**	**PM_{10*}**
Alexandria	*Amount in MT (±SE)*	1.45 (0.13)	7.90 (0.70)	78.73 (6.99)	3.83 (0.34)	4.98 (0.44)	26.37 (2.34)
	Value(±SE) in USD	135.48(12.04)	233.25(20.73)	12,147.15(1,079.73)	25,110.38(2,232.00)	40.77(3.62)	8,818.52(783.86)
	MT/persona	-	-	-	-	-	-
	$/personb	-	0.01	0.25	0.52	-	0.18
Chalmette	*Amount in MT (±SE)*	0.27 (0.03)	1.33 (0.16)	13.29 (1.62)	0.65 (0.08)	0.84 (0.10)	4.45 (0.54)
	Value(±SE) in USD	22.86(2.80)	39.36(4.81)	2,049.91(250.64)	4,237.54(518.11)	6.88(0.84)	1,488.18(181.96)
	MT/persona	-	-	-	-	-	-
	$/personb	-	-	0.09	0.18	-	0.06
Hammond	*Amount in MT (±SE)*	1.1 1(0.07)	6.05 (0.39)	60.27 (3.84)	2.93 (0.19)	3.81 (0.24)	20.18 (1.29)
	Value(±SE) in USD	103.72(6.61)	178.57(11.38)	9,299.56(592.59)	19,223.9(1,225.00)	31.21(1.99)	6,751.24(430.21)
	MT/persona	-	-	-	-	-	-
	$/personb	0.01	0.01	0.46	0.95	-	0.33
Houma	*Amount in MT (±SE)*	0.42 (0.05)	2.28 (0.29)	22.71 (2.86)	1.11 (0.14)	1.43 (0.18)	7.60 (0.96)
	Value(±SE) in USD	39.08(4.92)	67.27(8.47)	3503.43(441.17)	7,242.23(911.98)	11.76(1.48)	2,543.40(320.28)
	MT/persona	-	-	-	-	-	-
	$/personb	-	-	0.1	0.21	-	0.08
Monroe	*Amount in MT (±SE)*	2.23 (0.16)	12.19 (0.92)	121.39 (9.11)	5.90 (0.44)	7.68 (0.58)	40.66 (3.05)
	Value(±SE) in USD	208.9(15.68)	359.65(26.99)	18,729.94(1,405.82)	38,718.22(2,906.08)	62.86(4.72)	13,597.46(1,020.59)
	MT/persona	-	-	-	-	-	-
	$/personb	-	0.01	0.38	0.79	-	0.28
Natchitoches	*Amount in MT (±SE)*	2.39 (0.15)	13.00 (0.77)	129.46 (7.72)	6.29 (0.37)	8.19 (0.49)	43.36 (2.59)
	Value(±SE) in USD	222.77(13.28)	383.53(22.87)	19,973.67(1,191.00)	41,289.24(2,462.01)	67.03(4.00)	14,500.37(864.64)
	MT/persona	-	-	-	-	-	-
	$/personb	0.01	0.02	1.1	2.27	-	0.8
New Iberia	*Amount in MT (±SE)*	0.64 (0.05)	3.47 (0.28)	34.48 (2.84)	1.68 (0.14)	2.19 (0.18)	11.55 (0.95)
	Value(±SE) in USD	59.34(4.88)	102.16(8.41)	5,320.49(437.83)	10,998.42(905.08)	17.86(1.47)	3,862.54(317.85)
	MT/persona	-	-	-	-	-	-
	$/personb	-	-	0.18	0.36	-	0.13
Ruston	*Amount in MT (±SE)*	1.96 (0.11)	10.70 (0.570)	106.50 (5.72)	5.17 (0.28)	6.74 (0.36)	35.68 (1.91)
	Value(±SE) in USD	183.28(9.83)	315.54(16.93)	16,432.78(881.58)	33,969.57(1,822.38)	55.15(2.96)	11,929.78(640.00)
	MT/persona	-	-	-	-	-	-
	$/personb	0.01	0.01	0.74	1.53	-	0.54
Slidell	*Amount in MT (±SE)*	1.07 (0.06)	5.82 (0.37)	57.92 (3.69)	2.81 (0.18)	3.67 (0.24)	19.40 (1.23)
	Value(±SE) in USD	99.68(6.35)	171.61(10.94)	8,936.96(569.49)	18,474.34(1,177.24)	29.99(1.91)	6,488.01(413.43)
	MT/persona	-	-	-	-	-	-
	$/personb	-	0.01	0.32	0.67	-	0.23
Sulphur	*Amount in MT (±SE)*	0.82 (0.05)	4.48 (0.30)	44.66 (2.95)	2.17 (0.15)	2.83 (0.19)	14.96 (0.99)
	Value(±SE) in USD	76.86(5.08)	132.32(8.75)	6,891.01(455.51)	14,244.98(941.62)	23.13(1.53)	5,002.69(330.69)
	MT/persona	-	-	-	-	-	-
	$/personb	-	0.01	0.34	0.7	-	0.25

Table 3: Annual benefits, in terms of amount (tonnes) and dollar values (USD) for Carbon Dioxide sequestered (CO_{2seq}) and Carbon Dioxide Storage (CO_{2stor}), for each of the 10 cities assessed in Louisiana.

		$\mathbf{CO_{2seq}}$	$\mathbf{CO_{2stor}}$
Alexandria	*Amount in MT (±SE)*	16,094.04 (1,430.56)	404,181.72 (35,926.71)
	Value(±SE) in USD	822,229.89 (73,085.97)	20,649,277.74 (1,835,462.96)
	MT/person	0.34	8.43
	$/person	17.15	430.61
Chalmette	*Amount in MT (±SE)*	2,715.98 (332.08)	68,208.32 (8,339.61)
	Value(±SE) in USD	138,756.69(16,965.33)	3,484,701.04 (426,062.99)
	MT/persoa	0.12	2.98
	$/person	6.06	152.12
Hammond	*Amount in MT (±SE)*	12,321.21 (785.14)	309,431.77 (19,717.88)
	Value(±SE) in USD	629,479.35 (40,112.24)	15,808,588.47 (1,007,368.86)
	MT/person	0.61	15.22
	$/person	30.97	777.79
Houma	*Amount in MT (±SE)*	4,641.78 (584.52)	116,572.45 (14,679.41)
	Value(±SE) in USD	237,144.20 (29,862.42)	5,955,580.61 (749,957.37)
	MT/person	0.14	3.45
	$/person	7.02	176.28
Monroe	*Amount in MT (±SE)*	24,815.74 (1,862.61)	623,216.33 (46,776.89)
	Value(±SE) in USD	1,267,813.64 (95,158.58)	31,839,557.62 (2,389,789.00)
	MT/person	0.51	12.73
	$/person	25.91	650.61
Natchitoches	*Amount in MT (±SE)*	26,463.58 (1,577.98)	664,599.93 (39,629.08)
	Value(±SE) in USD	1,352,000.61 (80,617.74)	33,953,808.32 (2,024,613.96)
	MT/person	1.46	36.56
	$/person	74.38	1,868.06
New Iberia	*Amount in MT (±SE)*	7,049.24 (580.09)	177,032.77 (14,568.33)
	Value(±SE) in USD	360,139.09 (29,636.47)	9,044,443.89 (744,282.99)
	MT/person	0.23	5.84
	$/person	11.89	298.58
Ruston	*Amount in MT (±SE)*	21,772.18 (1,168.02)	546,781.06 (29,333.41)
	Value(±SE) in USD	1,112,320.80 (59,673.17)	27,934,548.94 (1,498,617.29)
	MT/person	0.98	24.68
	$/person	50.21	1,260.93
Slidell	*Amount in MT (±SE)*	11,840.80 (754.53)	297,366.73 (18,949.06)
	Value(±SE) in USD	604,935.37 (38,548.23)	15,192,197.03 (968,090.62)
	MT/person	0.43	10.71
	$/person	21.8	547.37
Sulphur	*Amount in MT (±SE)*	9,130.05 (603.51)	229,290.03 (15,156.45)
	Value(±SE) in USD	466,446.41 (30,832.87)	11,714,219.62 (774,329.12)
	MT/person	0.45	11.33
	$/person	23.05	578.85

13.00 tonnes/year ($39-$384), for O_3 removal amounts range from 13.29 to 129.46 tonnes/year ($2,049.91-$19,973.67), for $PM_{2.5}$ removal amounts range from 0.65 to 6.29 tonnes/year ($4,238-$41,289), for SO_2 removal amounts range from 0.84 to 8.19 tonnes/year ($7-67), and for PM_{10} removal amounts range from 4.45 to 43.36 tonnes/year ($1,500-$14,500). In terms of carbon sequestration, values range from 2,716 to 26,464 tonnes/year valued at $139,000-$1,350,000 (per year); storage values (not annualized) range from 68,208 to 664,600 which are valued between $3,500,000-$34,000,000. On a per capita basis, the majority of these values are less than $1.00/person/year. For carbon sequestration and storage, the per capita value and benefit range from 0.119 tonnes/person/year ($6/person/year) to 1.46 tonnes/person/year ($74), and 2.98 tonnes/person ($152/person) to 36.57 tonnes/person ($1,868/person), respectively (Table 3). While per capita values vary with population, the benefits on a

Table 4: Benefit rankings, on a per capita and area basis, for Alexandria, Chalmette, Hammond, Houma, and Monroe, Louisiana. The pollutants assessed, from i-Tree Canopy output, are Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Ozone (O_3), Particulate Matter less than 2.5 microns, Sulfur Dioxide (SO_2), Particulate Matter between 2.5 and 10 microns, Carbon Dioxide sequestered (CO_{2seq}), and Carbon Dioxide Storage (CO_{2stor}). A – indicates per capita values less than 0.1 tonne.

		Alexandria	Chalmette	Hammond	Houma	Monroe
	Total	135.48	22.86	103.72	39.08	208.9
	Per Person	-	-	0.01	-	-
CO	Rank (per person)	-	-	1	-	-
	Per km^2 trees	9.51	9.49	9.5	9.53	9.51
	Rank (km^{-2} trees)	4	9	7	1	4
	Total	233.25	39.36	178.57	67.27	359.65
	Per Person	0.01	-	0.01	-	0.01
NO_2	Rank (per person)	2	-	2	-	2
	Per km^2 trees	16.38	16.33	16.35	16.41	16.38
	Rank (km^{-2} trees)	4	10	8	1	4
	Total	12,147.15	2,049.91	9,299.56	3,503.43	18,729.94
	Per Person	0.25	0.09	0.46	0.1	0.38
O_3	Rank (per person)	7	10	3	9	4
	Per km^2 trees	853.03	850.59	851.61	854.5	852.91
	Rank (km^{-2} trees)	4	10	8	1	5
	Total	25,110.38	4,237.54	19,223.90	7,242.23	38,718.22
	Per Person	0.52	0.18	0.95	0.21	0.79
$PM_{2.5}$	Rank (per person)	7	10	3	9	4
	Per km^2 trees	1,763.37	1,758.32	1,760.43	1,766.40	1,763.12
	Rank (km^{-2} trees)	4	10	8	1	5
	Total	40.77	6.88	31.21	11.76	62.86
	Per Person	-	-	-	-	-
SO_2	Rank (per person)	-	-	-	-	-
	Per km^2 trees	2.86	2.85	2.86	2.87	2.86
	Rank (km^{-2} trees)	3	10	3	1	3
	Total	8,818.52	1,488.18	6,751.24	2,543.40	13,597.46
	Per Person	0.18	0.06	0.33	0.08	0.28
PM_{10*}	Rank (per person)	7	10	3	9	4
	Per km^2 trees	619.28	617.5	618.25	620.34	619.19
	Rank (km^{-2} trees)	4	10	8	1	5
	Total	822,229.89	138,756.69	629,479.30	237,144.20	1,267,813.64
	Per Person	17.15	6.06	30.97	7.02	25.91
CO_{2seq}	Rank (per person)	7	10	3	9	4
	Per km^2 trees	57,740.86	57,575.39	57,644.62	57,840.05	57,732.86
	Rank (km^{-2} trees)	4	10	8	1	5
	Total	20,649,277.74	3,484,701.04	15,808,588.47	5,955,580.61	31,839,557.62
	Per Person	430.61	152.12	777.79	176.28	650.61
CO_{2stor}	Rank (per person)	7	10	3	9	4
	Per km^2 trees	1,450,089.73	1,445,934.04	1,447,672.94	1,452,580.64	1,449,888.78
	Rank (km^{-2} trees)	4	10	8	1	5

per-area basis are relatively similar for all categories (Tables 4 and 5).

Table 6 illustrates the standardized economic benefit findings derived from urban canopies. The total economic benefits derived across all pollutants were highest for Natchitoches (z = 12.21) and lowest for Chalmette (z = -10.48). The top four cities provided above average benefits while cities ranked five through ten provided below average benefits. Per capita benefits were likewise highest for Natchitoches (z = 18.11) and lowest for Chalmette (z = -8.00). However, only the top three cities yielded above average benefits on a per capita basis. The two largest cities by population, Alexandria and Monroe, both provided above average benefits in total, yet they generated below average per capita benefits. The economic benefits provided by Hammond's

Table 5: Benefit rankings, on a per capita and area basis, for Natchitoches, New Iberia, Ruston, Slidell, and Sulphur, Louisiana. The pollutants assessed, from i-Tree Canopy output, are Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Ozone (O_3), Particulate Matter less than 2.5 microns, Sulfur Dioxide (SO_2), Particulate Matter between 2.5 and 10 microns, Carbon Dioxide sequestered (CO_{2seq}), and Carbon Dioxide Storage CO_{2stor}. A – indicates per capita values less than 0.1 tonne.

		Natchitoches	**New Iberia**	**Ruston**	**Slidell**	**Sulphur**
	Total	222.77	59.34	183.28	99.68	76.86
	Per Person	0.01	-	0.01	-	-
CO	Rank (per person)	1	-	1	-	-
	Per km^2 trees	9.52	9.49	9.51	9.5	9.52
	Rank (km^{-2} trees)	2	9	4	7	2
	Total	383.53	102.16	315.54	171.61	132.32
	Per Person	0.02	-	0.01	0.01	0.01
NO_2	Rank (per person)	1	-	2	2	2
	Per km^2 trees	16.39	16.35	16.37	16.36	16.4
	Rank (km^{-2} trees)	3	8	6	7	2
	Total	19,973.67	5,320.49	16,432.78	8,936.96	6,891.01
	Per Person	1.1	0.18	0.75	0.32	0.34
O_3	Rank (per person)	1	8	2	6	5
	Per km^2 trees	853.58	851.28	852.76	851.95	853.9
	Rank (km^{-2} trees)	3	9	6	7	2
	Total	41,289.24	10,998.42	33,969.57	18,474.34	14,244.98
	Per Person	2.27	0.36	1.53	0.67	0.7
$PM_{2.5}$	Rank (per person)	1	8	2	6	5
	Per km^2 trees	1,764.50	1,759.75	1,762.82	1,761.14	1,765.18
	Rank (km^{-2} trees)	3	9	6	7	2
	Total	67.03	17.86	55.15	29.99	23.13
	Per Person	-	-	-	-	-
SO_2	Rank (per person)	-	-	-	-	-
	Per km^2 trees	2.86	2.86	2.86	2.86	2.87
	Rank (km^{-2} trees)	3	3	3	3	1
	Total	14,500.37	3,862.54	11,929.78	6,488.01	5,002.69
	Per Person	0.8	0.13	0.54	0.23	0.25
PM_{10*}	Rank (per person)	1	8	2	6	5
	Per km^2 trees	619.67	618.01	619.09	618.49	619.91
	Rank (km^{-2} trees)	3	9	6	7	2
	Total	1,352,000.61	360,139.09	1,112,320.80	604,935.37	466,446.41
	Per Person	74.38	11.89	50.21	21.8	23.05
CO_{2seq}	Rank (per person)	1	8	2	6	5
	Per km^2 trees	57,777.80	57,622.25	57,722.93	57,667.81	57,800.05
	Rank (km^{-2} trees)	3	9	6	7	2
	Total	33,953,808.32	9,044,443.89	27,934,548.94	15,192,197.03	11,714,219.62
	Per Person	1,868.06	298.58	1,260.93	547.37	578.85
CO_{2stor}	Rank (per person)	1	8	2	6	5
	Per km^2 trees	1,451,017.45	1,447,111.02	1,449,639.28	1,448,255.20	1,451,576.16
	Rank (km^{-2} trees)	3	9	6	7	2

tree canopy were below average in absolute terms, but on a per capita basis Hammond's tree canopy provided above average results. Comparing the cities ranking on absolute versus per capita bases illustrates the impact of percentage of tree canopy coverage and population, where municipalities with lower populations (Table 1) have a greater per capita benefit.

4 Discussion

Classifying the composition of urban environments across sizes and density is important for understanding ecosystem dynamics in these areas and the services they provide. For the 10 cities analyzed in Louisiana, there was a strong negative correlation between population density and tree and green percent cover and

Table 6: Standardized values and rankings for absolute and per capita benefits for all pollutants in each of the 10 cities assessed. Values listed are z values for each pollutant. Pollutant values are CO (Carbon monoxide), NO_2 (Nitrogen dioxide), O_3 (Ozone), $PM_{2.5}$ (Particulate matter less than 2.5 microns), SO_2 (Sulfur dioxide), PM_{10} (Particulate Matter between 2.5 and 10 microns), CO_{2seq} (Carbon dioxide sequestered), and CO_{2stor} (Carbon dioxide storage).

City	Alexandria	Chalmette	Hammond	Houma	Monroe	Natchitoches	New Iberia	Ruston	Slidell	Sulphur
Pollutant	*Standardized values based on absolute levels*									
CO	0.29	-1.31	-0.16	-1.08	1.33	1.53	-0.79	0.97	-0.22	-0.54
NO_2	0.29	-1.31	-0.16	-1.08	1.33	1.53	-0.79	0.97	-0.22	-0.54
O_3	0.29	-1.31	-0.16	-1.08	1.33	1.53	-0.79	0.97	-0.22	-0.54
$PM_{2.5}$	0.29	-1.31	-0.16	-1.08	1.33	1.53	-0.79	0.97	-0.22	-0.54
SO_2	0.29	-1.31	-0.16	-1.08	1.33	1.53	-0.79	0.97	-0.22	-0.54
PM_{10}	0.29	-1.31	-0.16	-1.08	1.33	1.53	-0.79	0.97	-0.22	-0.54
CO_{2seq}	0.29	-1.31	-0.16	-1.08	1.33	1.53	-0.79	0.97	-0.22	-0.54
CO_{2stor}	0.29	-1.31	-0.16	-1.08	1.33	1.53	-0.79	0.97	-0.22	-0.54
Cumulative Z Value	*2.3*	*-10.48*	*-1.3*	*-8.64*	*10.64*	*12.21*	*-6.34*	*7.73*	*-1.76*	*-4.35*
Rank	**4**	**10**	**5**	**9**	**2**	**1**	**8**	**3**	**6**	**7**
City	Alexandria	Chalmette	Hammond	Houma	Monroe	Natchitoches	New Iberia	Ruston	Slidell	Sulphur
Pollutant	*Standardized values based on relative levels*									
CO	-0.42	-1.01	0.18	-1.01	-0.12	2.25	-0.71	1.07	-0.12	-0.12
NO_2	-0.44	-0.94	0.24	-0.94	-0.1	2.26	-0.78	1.08	-0.27	-0.1
O_3	-0.46	-0.99	0.2	-0.94	-0.04	2.25	-0.71	1.11	-0.24	-0.18
$PM_{2.5}$	-0.46	-0.99	0.2	-0.94	-0.04	2.25	-0.71	1.11	-0.24	-0.18
SO_2	-0.26	-1.12	0.6	-1.12	-0.26	2.33	-0.26	0.6	-0.26	-0.26
PM_{10}	-0.46	-0.99	0.19	-0.94	-0.04	2.25	-0.71	1.11	-0.24	-0.18
CO_{2seq}	-0.46	-0.99	0.2	-0.94	-0.04	2.25	-0.71	1.11	-0.24	-0.18
CO_{2stor}	-0.46	-0.99	0.2	-0.94	-0.04	2.25	-0.71	1.11	-0.24	-0.18
Cumulative Z Value	*-3.41*	*-8*	*2*	*-7.77*	*-0.7*	*18.11*	*-5.29*	*8.28*	*-1.84*	*-1.38*
Rank	**7**	**10**	**3**	**9**	**4**	**1**	**8**	**2**	**6**	**5**
Rank Difference	***-3***	***0***	***2***	***0***	***-2***	***0***	***0***	***1***	***0***	***2***

a strong positive correlation between population density and impervious cover, which is expected as more populous cities tend to have greater building density and thus, fewer trees (Mills et al., 2015; Nowak and Greenfield, 2018). A key finding was the majority of cities analyzed, six of the ten, have a tree canopy coverage greater than 26%. Overall, the 10 city average percent tree cover was greater than 26%, greater than the previously reported average for Louisiana (Nowak and Greenfield, 2010). These outcomes indicated that smaller, less densely populated cities may be important for the preservation of average urban tree coverage in the state.

Urban forests and green space do not (typically) yield tradeable products but do have calculable, documentable services (Nowak and Walton, 2005; McPherson et al., 2017; Sills et al., 2017). Here, per capita pollution values were small but annual carbon sequestration and total storage values were high, eclipsing $1,000/person in two cities. These results are higher than previously published estimates (Nowak and Walton, 2005). City size and population are also important factors in the calculation of the benefits of the urban canopy. For example, Ruston and Natchitoches have the greatest per capita totals and values for carbon sequestration and storage. These values were high because 1) their total percent tree cover (41% in Ruston and 36% in Natchitoches) yield high sequestration and storage values and 2) their population density is low. Considering dollar value benefits, areal coverage of forest matters in terms of acreage covered by trees.

If a city has a larger area and does not have a proportionally larger percent tree cover, then the area-based benefit is affected. While Ruston and Natchitoches have greater per capita benefit for carbon storage and sequestration, the area-based values rank them 6^{th} and 3^{rd}, respectively. This is because these cities have a greater total acreage forested with a subsequently lower per area value and value estimates are based on a weight, dependent upon percent cover. It must also be pointed out that the area-based numbers are similar for all categories and cities. For example, in cities of smaller size like Chalmette, the tree cover is low (11.8%) and population density is high (>1,000), consequently, the area-based and per capita benefits are low. The ranges in tree cover, city size, and population illustrate the need to manage the urban canopy in these cities.

Smaller municipalities experience budgetary constraints that prevent adequate maintenance and management of urban trees. Benefits have historically been underestimated and management efforts poor throughout the urban ecosystem (Dwyer et al., 1992). While this has improved in some areas, many smaller communities, with extensive urban canopies, still suffer poor management which has a negative influence on the overall health of the canopy (Groninger et al., 2002). Barriers to adequately managing urban tree canopy in smaller municipalities continue will continue to be due to budget and a lack of expertise allowing for long-term planning and management (Nowak et al., 2010). Given the propensity of severe weather events in Louisiana (e.g. tornadoes, hurricanes, and ice storms) to damage or destroy trees, some residents may be willing to forego some benefits to prevent tree and limb failure damaging personal property. Future research will address insured losses and changes in property values as well as resident attitudes of mitigation measures. If population levels rise in smaller urban areas, adequate management will maximize benefits to the population within them. Adequate management may reduce the total areal coverage of the tree canopy but would efficiently manage the canopy to maximize benefits and minimize risk. This would occur through proper species selection, health assessment, pruning, planting, and removals of trees as needed (Nowak et al., 2010).

The growth of urban areas in Louisiana is projected to increase through 2050 (Nowak and Walton, 2005). This is driven by a variety of factors, primarily seeking higher ground and movement away from larger cities and waterfronts (Qiang and Lam, 2016). Increased urbanization and sprawl will increasingly fragment forests and could reduce canopy cover in urban areas as impervious surfaces (roads, buildings, etc.) are constructed to accommodate increasing population (Nowak and Walton, 2005). There has already been a slight decrease in urban tree cover within Louisiana along with the United States in general (Nowak and Greenfield, 2018). Further study is warranted to consider management strategies and resource availability to all municipalities. There are additional services to consider as well, including rainfall interception and runoff mitigation in a state prone to flooding, health benefits, and potential impacts on crime (Xiao and McPherson, 2016; Kondo et al., 2017). i-Tree Canopy does not provide estimates for benefits based on rainfall interception and runoff mitigation or impacts on crime. If models could be developed to relate such variables to percent canopy cover, they could be incorporated into i-Tree Canopy as a more robust estimate of the benefits of a tree canopy (McPherson et al., 2017).

Potential landscape-scale changes regarding climate, migration, and land use necessitate management of current urban forest and greenspace to maximize the benefits of these areas for citizens living within them. A significant shortcoming regarding management, particularly in small urban areas, is often cited as resource availability and accessibility – leaders that do not know what resources are available (Lewis and Boulahanis, 2008;

Grado et al., 2013). Similar sized municipalities in other states have few staff available for urban forest management (O'Herrin and Shields, 2016). A survey of mayors in small towns in the southern U.S. indicated that city councils, garden clubs, general population, and school children were all important groups in the promotion of tree planting and maintenance (Lewis and Boulahanis, 2008). In this endeavor, then, it is imperative that collaboration among municipalities, industry, and citizens be encouraged (see Leff, 2016). Tree City USA is one program some small municipalities may consider (Berland et al., 2016); however, in Louisiana, participation in this program has dropped from 23 cities (Ford, 2011) to 14 in 2018 (Arbor Day Foundation, 2018). Of the cities assessed, five were previously Tree City USA participants (Ford, 2011) (Alexandria, Hammond, Natchitoches, Ruston, and Slidell) but the present list only includes three (Alexandria, Hammond, and Slidell). Any indications as to presence or absence in this program is currently unknown. Future studies might assess motivations, and resource investment and availability, for participation in this or other related programs (Berland et al., 2016).

The ranking in standardized values in the per capita analysis varied from those based on total economic benefits. While Ruston had greater tree cover, Natchitoches emerged as the number one ranked benefactor of its urban canopy. The two largest cities, Monroe and Alexandria, ranked number two and four, respectively. While the urban canopy's benefit to Hammond was smaller than average overall, it was of more benefit individually than in Alexandria. Thus, an initiative that stimulated (or limited) urban forests would have a greater positive (or negative) effect on the citizens in Hammond than in Alexandria, relative to the population of each city. Higher per capita rankings suggest an increase in urban canopy would provide greater individual benefits. If the urban canopy were reduced, though, the impact experienced individually would be less in a city with lower per capita ranking.

Benefits relative to cost for maintaining and managing urban forests in California were approximately \$2.50:\$1.00 (McPherson et al., 2017). While the feasibility and level of maintenance required for smaller municipalities in Louisiana will vary, it is important for these areas to assess their urban canopy and develop some plan for continued monitoring and management (Koeser et al., 2016). There are potential conflicts of trees with buildings and utilities, including roots impacting sidewalks, parking areas, and municipal water. The branches of trees may overhang parking areas and create problems if dead limbs are left on trees. If nothing is done, these municipalities run the risk of having an unhealthy if not dangerous situation develop (Groninger et al., 2002) that might then make the urban forest, or portions of it, a hindrance rather than a benefit.

5 Conclusion

Urban tree cover and green space in small urban areas in Louisiana varies in relation to population density. Even in smaller cities with greater population density, there is still a positive benefit in terms of pollution mitigation and carbon sequestration and storage. It would be informative, and important next step, for future studies to assess the costs of maintenance and management of these cities versus the benefits gained in terms of total ecosystem services. In addition to the cursory surveys performed in the present study, an inventory of trees within these cities would provide insight into species distribution and benefit and guide planning and management for removals, plantings, etc., to maximize the benefits to these municipalities.

It would be useful to determine tree cover, and ideally inventory, for all urban areas in Louisiana. This would provide for the elucidation of the total benefits of small urban areas to the citizens of Louisiana. As urban populations continue to increase and if urban forest cover continues to decline (Nowak and Greenfield, 2018), accurate accounting and management of urban forests will become increasingly important. Determining the benefits of these and other urban areas will hopefully attract funding, support, and partners that will provide for the adequate management and maximize the benefits of the small urban canopy.

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