Using Meta-Analysis to Assess Benefits of Green Infrastructure Investments: Application to Small Urban Projects in Hinesville, GA

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Introduction

While built infrastructure has played a central role in modern societies for millennia, nature-based, or green, infrastructure has only gained modern prominence in the past several decades. The emergence of green infrastructure represents a tacit recognition of the limits of conventional built infrastructure, the economic and social costs of lost ecosystem services associated with land conversion and development, and the risks of climate change. The embrace of green infrastructure is based on an understanding of the diminution in ecological services due to loss of natural assets and reduced adaptative capacity of natural systems to respond to environmental change (Benedict and McMahon (2002)). Lost ecological services have resulted from conversion of natural systems, interruption of ecological process and function, fragmentation of the connectivity of green spaces, and degradation of soil, air, and water.

Green infrastructure investments include large scale public works, like maintenance or restoration of wetlands, dam removal and waterway rehabilitation, offline water storage, and sediment management measures (like prevention of soil erosion or beach and dune enhancement). These types of projects often entail sizable financial investments and involve multiple jurisdictional authorities. Other aspects of green infrastructure can be implemented on smaller scales by municipalities, households, or businesses; these include construction of bioretention ponds; urban agriculture, trees, and parks; green roofs, green walls, rain gardens, and rainfall harvesting; and use of permeable pavement or other investments to improve water infiltration, runoff flow reduction, and natural hydrologic function (Wise, Braden et al. (2010)). Augmenting and protecting green infrastructure can provide an array of socio-economic benefits, some of which are conventional (e.g. protecting roadways from intermittent or chronic flooding) and others that are less conventional (e.g. improvements in biodiversity, recreation, and aesthetics; enhancements in micro-climate and urban temperature regulation).

In this paper, we use existing meta-analysis results to value ecological benefits of green infrastructure investments in coastal Georgia. The short coastline of Georgia exhibits a wide array of development patterns and environmental conditions. Four of the fourteen barrier islands are densely developed tourist destinations, and the rest are largely preserved through public ownership or perpetual legal protection. Savannah and Brunswick are regional urban hubs, many small towns dot the landscape, while most other areas are still relatively undeveloped and bucolic. Due to lack of widespread development pressure and significant management efforts, the Georgia coast is home to almost 40% of the extant salt marshes along the US east coast. Despite the preservation of extensive green infrastructure features, however, many developed areas and urban centers are located in low-lying and low-relief areas that are threatened by rising sea levels and intensifying precipitation patterns. To better understand how green infrastructure practices can be effectively integrated into human development to enhance the resilience of these developments and to protect the larger-scale green infrastructure benefits of local ecological systems, we investigate the economic efficiency of proposed site-scale green infrastructure elements in the City of Hinesville, Georgia.

This analysis is part of a regional effort to enhance community resilience in Coastal Georgia, in part through the use of green infrastructure practices funded by National Oceanic and Atmospheric Administration (NOAA) Office of Coastal Management, and which is being led by the Georgia Coastal Management Program at the Georgia Department of Natural Resources, Coastal Resources Division. The green infrastructure elements analyzed are the result of a separate community-driven downtown planning effort conducted by the city and the local development authority. The results of the public input component of this plan highlighted interest in redeveloping the city's central downtown green space, known as Bradwell Park, as well as a desire to leverage available resources to make use of that redevelopment to increase the community's resilience to stormwater flooding and protect the downstream environment. The design team participating in that planning process incorporated a series of small-scale green infrastructure elements into a conceptual redevelopment plan. Then working with the city's engineer, that concept was built out into preliminary design for the park.

In order to explore the net economic benefits of this type of green infrastructure design, in which development or redevelopment opportunities are utilized to enhance the use natural systems in the built environment, the authors conducted a benefit-cost analysis. Detailed cost data are derived in scoping and assessment of planned project elements. Benefits are estimates from a meta-analysis of urban green infrastructure projects (Bockarjova, Botzen et al. 2020), which we tailor to our study site. We conduct sensitivity analysis with regard to a number of factors (discount rate, benefits measures) and find that green infrastructure investments in Hinesville, GA are welfare-enhancing, producing positive net benefit between $657,000 to just over $5 million (under a range of plausible benefit scenarios).

The rest of paper is organized as follows. Section Two presents a background discussion on the use of green infrastructure and review relevant literature. Section Three provides details on projects planned at the study site. Section Four introduces the methods utilized to estimate benefits and costs, while Section Five provides an overview of our results. Section Six offers discussion and conclusions.

Background and Literature

Green infrastructure investments typically center around improvements in hydrological flow and function, but can also provide enhancements in vegetation, soil quality and quantity, habitat, recreation opportunities, and aesthetics. For example, preservation and restoration of green spaces and use of permeable paving materials are very helpful in decreasing the risk of flash floods since these investments intercept rainfall and improve water penetration into soil and substrate. Controlling for precipitation level, urban areas with impervious ground cover (50-90%) can absorb 13-60 percent of rainfall, whereas forested area can absorb 87 percent of rainfall (Kaye, Groffman et al. 2006, Pataki, Carreiro et al. 2011). Aside from flood control, restoration of urban wetlands can improve water quality, increase recreation opportunities, enhance aesthetics, and conserve biodiversity (Zhou et al. 2013). Green spaces, roofs, and walls reduce the urban heat island effect, decrease ambient temperatures, can decrease energy needs, and cut carbon emissions (Akbari 2002, Nicholson-Lord 2003, Gill, Handley et al. 2007). Improvements in ecological services may also enhance human health status and decrease mortality (Maas, Verheij et al. 2006, Mitchell and Popham 2008), while providing habitat for animals and improving biodiversity (Fuller, Irvine et al. 2007). A deep literature on property values reveals that real estate prices increase with proximity to green areas (Brander and Koetse 2011), with green space being particularly valuable in urban areas, but less so in rural areas (where such natural amenities are already plentiful) (Kriesel 2010). In addition, property values decrease due to flood risk (Landry 2008, Samarasinghe and Sharp 2010, Rambaldi, Fletcher et al. 2012), though the effect of flood risk depends upon frequency of flooding and other market dynamics (Hallstrom and Smith 2005, Carbone, Hallstrom et al. 2006, Bin and Landry 2013, Atreya and Ferreira 2015).

In assessing potential investments in public projects to promote green infrastructure, the economic practice of benefit-cost analysis (BCA) can provide helpful guidance to inform decision makers whether the economic value of investments justify the economic costs. From an analytical perspective, important characteristics of green infrastructure investments and adaptation to climate change include ubiquity of impacts, intangibility of some effects, the prevalence of non-marginal changes (i.e. discrete, potentially large changes in levels of amenities or risk), long timeframes, and uncertainty (Sussman, Weaver et al. 2015). These difficulties interact with conventional challenges, such as valuing non-market effects, assessing low-probability/high-impact outcomes, and choice of an appropriate discount rate (Sussman, Weaver et al. 2015). Moreover, since most adaptation measures cannot eliminate climate and weather risks, analysts must address residual risk in assessment of green infrastructure measures (Neumann, Hudgens et al. 2011).

Li, Mullan et al. (2014) review recent developments and applications of BCA with implications for climate risk management and adaptation decision making. They find that BCA has been used mostly to conduct project-based appraisals, with much less focus on evaluating adaptation decisions. Challenges related to BCA for climate change adaptation include long-time frames of analysis, the importance of intangible effects, and the need to grapple with Knightian uncertainty (i.e. situations in which probabilities are unknown, and perhaps unknowable, at least within the time frame relevant to decision making) (Sussman, Grambsch et al. 2015). Uncertainty may be particularly great at the regional and local levels, precisely where many adaptation actions take place. Use of BCA for assessment of green infrastructure investments must recognize the approaches formulation on individual/household welfare as a basis for decision making and appreciate the distinction between efficiency and equity (Sussman, Weaver et al. 2015). Given these complexities, Li, Mullan et al. (2014) recommend BCAs of climate adaptation-relevant decisions that employ multiple analytical methods, due to the complexity of adaptation decisions and the diversity of adaptation measures and decision-making contexts. Sussman, et al. (2015) suggest the use of Robust Decision Making (RDM), which uses Monte Carlo simulations to stress-test competing policies against scenarios that are most relevant for success.

Elmqvist, Setälä et al. (2015) assess monetary and non-monetary benefits of investments in green infrastructure in terms of improvements in urban landscapes, social welfare, biodiversity augmentation, and urban resiliency. Green infrastructure provides urban ecosystem services in habitats such as parks, urban forests, cemeteries, vacant lots, gardens and yards, campus areas, and stormwater retention ponds. They highlight the ecological, social, and economic advantages of investing in urban green infrastructure. Using benefit transfer (described in detail below), one can assess the economic impacts of urban woodlands and green spaces on stormwater flows and pluvial flooding (Xiao, McPherson et al. 1998, McPherson 2003) and the recreation and amenity benefits they create (Pataki, Carreiro et al. 2011).

Kousky and Walls (2014) investigate the benefits and costs of preserving floodplains as a flood mitigation strategy along the Meramec River in St. Louis County, Missouri. They estimate the opportunity costs (loss of development or other land-use that would have occurred absent preservation), avoided flood damages, and the capitalization of proximity to protected lands into nearby home prices. To estimate avoided flood damages, they undertake a parcel-level analysis using the Hazus-MH flood model, a GIS-based model developed for FEMA that couples a hydrology and hydraulics model with a damage model relating flood depths to property values. Kousky and Walls examine the distribution of damages across parcels, demonstrating that careful spatial targeting can increase the net benefits of floodplain conservation. In addition, they estimate a hedonic property price model and find that the increased property values for homes near protected lands are more than three times larger than the avoided flood damages, stressing the continued importance of more traditional conservation values. The proximity benefits alone exceed the opportunity costs; the avoided flood damages further strengthen the economic case for floodplain conservation.

Cooper, Garcia et al. (2016) conduct BCA for construction of an earthen berm in the Meadowlands Region in Bergen County, New Jersey. The project is designed to mitigate flood risks associated with coastal storms. Th authors consider life cycle costs of the project, including land acquisition, upfront construction, restoration of wetlands, creation of recreation zones surrounding the berm, and ongoing maintenance. Project benefits include preserving life, preventing residential and commercial damages, protecting conventional infrastructure systems (transportation, power, water), and mitigating debris removal expenses. Incidental benefits include recreational and health impacts and ecosystem services from wetlands, which are assessed using benefit transfer methods. Aggregating and discounting benefits and costs over a 50-year time horizon, Cooper et al. (2016) incorporate climate change by increasing the risks of 100- and 500-year flood events; they find that the green infrastructure investment is welfare enhancing, with BC ratios exceeding 2 (4) for a 7% (3%) discount rate.

Vojinovic, Keerakamolchai et al. (2017) conduct BCA for green and grey (i.e. conventional) infrastructure options for areas with existing cultural heritage assets. They demonstrate how the intersections of flood protection, education, art/culture, recreation, and tourism can be incorporated in economic analysis for selection of multifunctional measures for flood resilience. They stress the importance of stakeholder involvement and conceptual landscape design in achieving ecologically sustainability and social acceptability in managing flood risk in areas with cultural heritage. Likewise, Alves, Patiño Gómez et al. (2018) propose a framework for the selection of green infrastructures based on a co-benefits analysis. The aim is to include the achievement of co-benefits and human well-being into decision-making for flood management and incorporate stakeholders' perceptions to define the most important benefits to be enhanced. De Groot, Blignaut et al. (2013) make ten recommendations to encourage the utilization of existing knowledge and to improve the incorporation of ecosystems into policy, planning, and funding for coastal hazard risk reduction. Zhou, Panduro et al. (2013) address climate change adaptation and extreme rainfall in urban areas by evaluating benefit and costs of four adaptation projects; they conclude that integration of open drainage basins in an urban setting is the best adaptation strategy compared to stormwater pipe enlargement and investments in small scale infiltration improvements.

Critical to our empirical approach is a recent meta-analysis conducted by Bockarjova, et al. (2020). They utilize value transfer functions from 60 empirical studies (encompassing over 40,000 observations) focused on economic value of urban green infrastructure projects across all six inhabited continents (with a majority in Europe, North American, and Asia). Their regression approach utilizes a standardized measure of WTP as the dependent variable and controls for determinants of urban green infrastructure values, including characteristics of the study and methods, types of investments, location and size of projects, and ecosystem services as independent variables (Bockarjova, Botzen et al. 2020). They find, for example, that urban parks produce annual economic values between $12,000 and $33,100 (US), and urban forested areas produced annual economic values between $2,250 and $3,000 (US). We describe their methods & results in detail below, but first discuss the study site.

Study Site and Projects

Hinesville is the county seat and largest city in Liberty County Georgia. Liberty County is located on the Atlantic Coast, though the city is approximately 25 miles inland. It is located on an ancient dune ridge that elevates it above much of surrounding terrain, and its downtown urban center is actually the headwaters for the coastal creeks that drain the area. This location provides some protection from coastal flooding and storm damage compared with other coastal communities, but it also means that stormwater runoff and other development impacts can affect larger parts of the coastal ecosystem. See Figure 1.

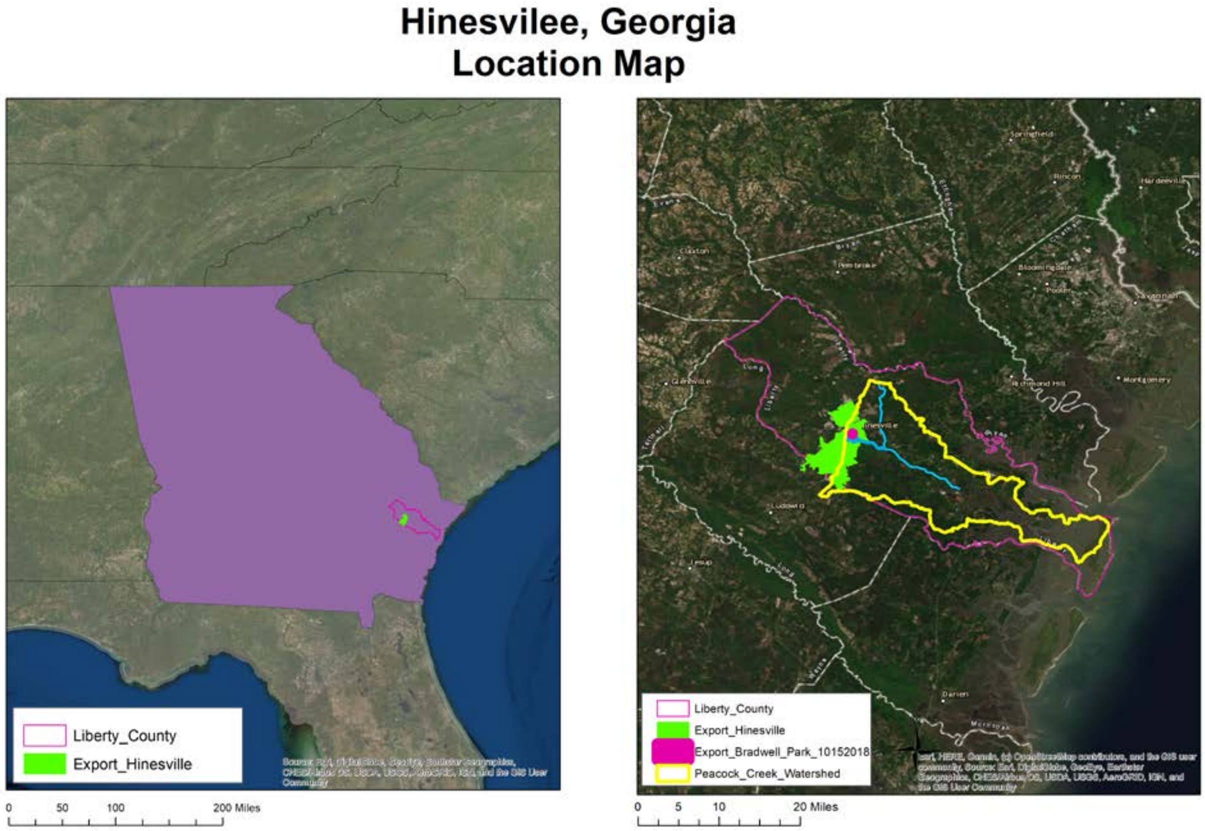

Figure 1: Location of Hinesville, GA and Green Infrastructure Projects

The population of Hinesville was 33,437 at the 2010 census and an estimated 33,273 in 2019. It covers 18.24 square miles (47.24 square km), and thus has a population density of 1,809.43/sq mi (698.62/km2). The median income for a household in the city was $35,013, and the median income for a family was $36,221. Males had a median income of $27,135 versus $20,813 for females. The per capita income for the city was $14,300. About 13.8% of families and 14.8% of the population were below the poverty line, including 20.9% of those under age 18 and 12.3% of those age 65 or over.

The specific site for the green infrastructure interventions is in Bradwell Park in downtown Hinesville. The part is an approximately one-half acre public space located amidst institutional and commercial developments. It is immediately adjacent to the Hinesville city hall, the Liberty County administrative offices, a regional bank, as well as restaurants, shops, and office buildings. It is one of the primary public spaces in the city as it hosts the weekly farmers market, festivals, concerts, and other public events. The development plan calls for a complete renovation of the entire park and the streets that surround it, entailing installation of 7,956 square feet of green space, mostly composed of bioswales and tree planning, but also including pervious pavers, drainage improvements and rain gardens. Figure 2 provides an artist rendition of improvements in the project area.

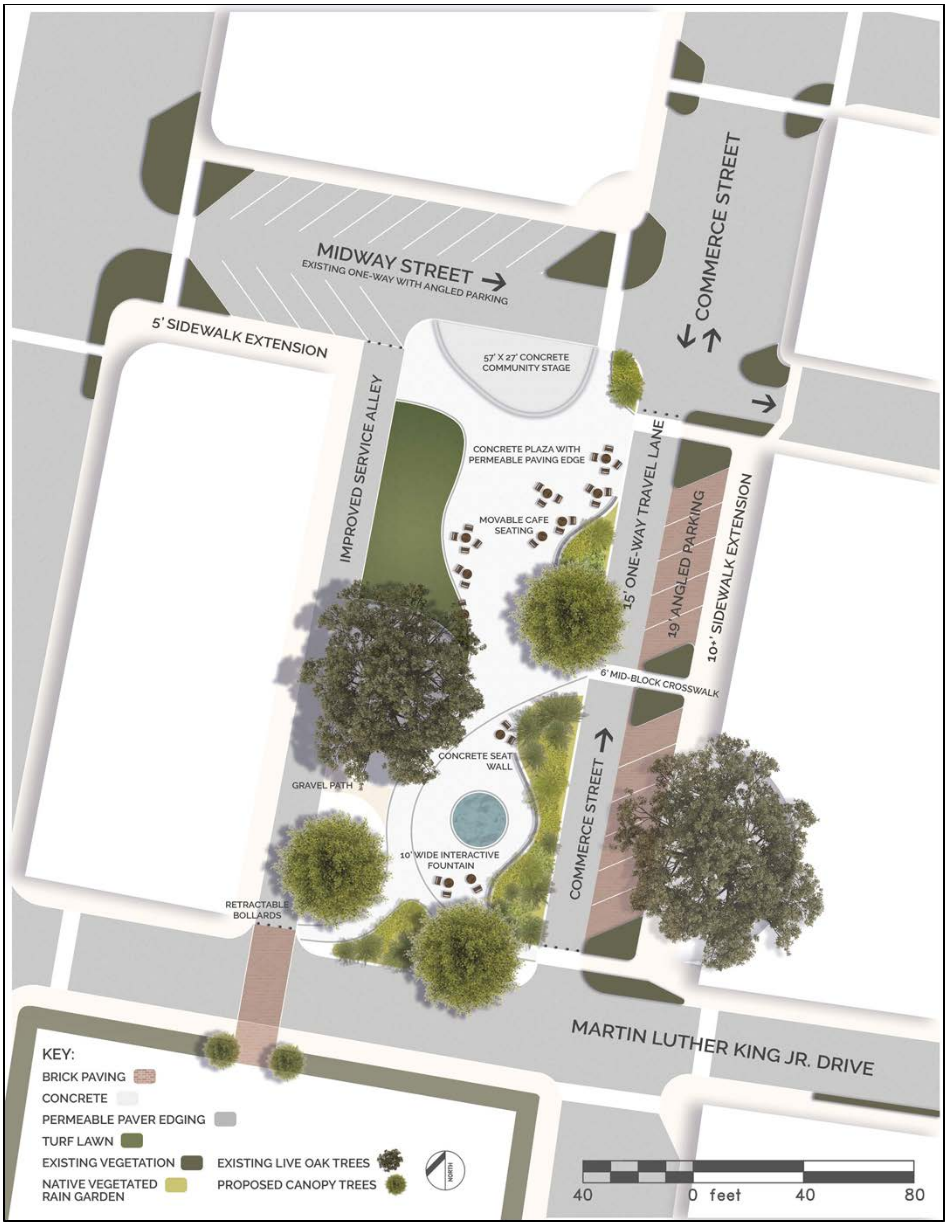

Figure 2: Green Infrastructure Projects in downtown Hinesville, GA

Methods

Economic assessment of green infrastructure investments in Hinesville/ Liberty County is built upon the basic principles of benefit-cost analysis (BCA). BCA is conducted by: 1) Clearly describing the project under consideration and any necessary assumptions that are needed to analyze the project; 2) Identifying relevant beneficiaries and others that will be affected by aspects of the project; 3) Carefully identifying all the negative (costs, inputs, and undesirable outcomes) and positive (benefits, outputs, and desirable use of residuals [e.g. recycling waste or utilizing something that would otherwise be discarded, inducing cost]) aspects of a particular project; 4) Empirically estimating [or in some other way simulating or approximating] social values of inputs/costs and outputs/benefits; 5) Identifying and documenting limitations of value estimates and intangibles or things that cannot be valued; 6) Keeping track of particular groups of “winners” and “losers” from project (to permit assessment of equity); and, finally 7) Comparing benefits to costs [net difference or ratio] and conduct sensitivity analysis to assess how robust results are to assumptions and uncertainties (while keeping account of intangible effects and equity issues). This approach to policy analysis is widely applied in the public sector and has been endorsed by numerous President’s Executive Orders 12044 (Carter), 12291 (Reagan), 12866 (Clinton), and 13563 (Obama).

The project under consideration is fine-scaled and place specific, so our analysis is focused on estimated project performance and cost metrics. Beneficiaries of these investments are residents of Liberty County; we recognize that, in addition, the project may have spillover benefits for visitors and may enhance tourism (which we currently note as an unquantified benefit). In evaluating benefits and costs, we use engineering estimates of the quantities and value of inputs (materials, land, labor), and identify project outputs (stormwater flows, overflow reductions, and aesthetics) associated with stormwater management, aesthetics, and provision of green spaces in downtown Hinesville. The benefits of such investments can include: 1) reduction in nutrient pollution in waterways; 2) improvements in groundwater recharge; 3) stormwater storage and conveyance; and 4) provision of greenspace. These benefits are assessed using benefit transfer measures; we are fortunate to have access to results of a meta-analysis that permit benefit assessment Bockarjova, et al. (2020).

The greatest limitation of benefit transfer is that value estimates are not specific to the population (residents of Liberty County) or projects (small-scale urban infrastructure) under study. The advantage of applying meta-analysis, however, is that descriptive variables can be used to tailor the results to the population and project under study. (More on this below.) Our preliminary review of stakeholders’ positions and inputs did not identify any specific groups that stood to lose from the projects under study, though diverse perspectives may arise during the review and vetting of this and other documents related to the project.

Assessing Benefits using Meta-Analysis

Synthesizing an extensive set of project evaluation data, Bockarjova, et al. (2020) are able to standardize measures of economic value for urban infrastructure investments, and they use meta-regression analysis to explore the variation due to observable factors (like project type, size, location), while employing statistical methods to control the influence of unobserved factors that vary across studies. Their data set includes value function from 60 economic studies that utilize responses from over 41,000 subjects across the globe (with the majority being in Europe, Asia, and North America). The primary equation of interest is given by:

$$WTP_{ij} = \alpha + \beta^{S} X_{ij}^{s} + \beta^{ED} X_{ij}^{ED} + \beta^{ESS} X_{ij}^{ESS} + \mu_j + \varepsilon_{ij} \quad (1)$$

where WTP_{ij} is the annual value of urban green infrastructure, per hectare (in 2016 USD); the subscript *I* indexes the value observation (first level), and subscript *j* indexes the study level. Thus, the regression model is multi-level and controls for unobserved study level influences by imposing a hierarchical structure on the error terms (μ_j associated with study *j* and ε_{ij}, which is observation specific). The multi-level modelling approach does not require independent and identically distributed residuals. The vectors *X* account for socio-economic and site attributes, as well as study characteristics (*S*); type of urban infrastructure investments (*ED*) [mutually exclusive characterization]; and the character of ecosystem services engendered by the project (*ESS*) [not mutually exclusive]. The α term is the regression intercept, and the β are coefficients to be estimated. The meta-data set includes 58 studies (thus, *j* = 1 to 58) and 147 observations (*I* = 1 to 147). In estimation, Bockarjova, et al. (2020) transform their covariates into centered logarithms [natural-log transform variables and take differences from ln-transformed means], natural log-transform dependent variable (*WTP*) [which, in effect, produces a log-linear regression model], and cluster standard errors [to permit study-specific heteroskedasticity].

Model diagnostics indicate statistical significance of the hierarchical variance structure, which supports the model specification (Bockarjova, et al. 2020). Quasi R-squared for the two primary models are 0.660 and 0.699. Overall, they find a highly significant and positive constant term (α), which, given their specification, reflects the average value of urban green infrastructure across all projects in their dataset. This amounts to $2,246 per hectare, per year (model 1). They find that economic values for green infrastructure are increasing in per-capita GDP and population density, while the value per hectare is decreasing in project size (indicating an increasing, but concave relationship between economic value and land area). They find positive values for urban parks, smaller values associated with recreation, but larger values stemming from cultural assets. They also find effects related to economic valuation methods (larger values for use of choice experiments and negative effects associated with using tax as the payment vehicle).

Following Bockarjova, et al. (2020), we use their meta-regression results to estimate economic benefits of urban green infrastructure in Hinesville, GA. We utilize their parameterized model fit to characteristics of Liberty County and attributes of the proposed investments in downtown Hinesville. The results are presented in Tables 1 and 2. Multi-level meta-regression model coefficient and standard error estimates are presented in the first two columns (with * indicating statistical significance). Except for the intercept term and dummy variables, the regression model is based on natural-log deviation in means, so to transfer values to Hinesville, the analyst must multiply the model coefficient ("Parm" in column 1) times the difference in natural-log covariates values (e.g ln(area of Liberty County) – ln(average area in study)). This procedure applies only to continuous variables (area, GDP, population density); the intercept term and dummy variables contribute in levels (as oppose to natural logs).

Table 1: Meta-regression Model 1 for Green Infrastructure: Hinesville, GA

	MODEL 1			**Meta**	**Hinesville**
	Parm	**SE**		**Mean**	**Deviation**
Constant	7.718	0.502	***	1	7.718
					0
ln(area)	-0.964	0.101	***	1474	6.9412096
ln(GDP)	1.527	0.358	***	23026	-0.7274086

ln(pop density)	0.241	0.07	***	396	0.13681395
CE	1.9	1.063	*	0.218	
Tax	-2.723	0.726	***	0.299	
Park	1.674	0.693	***	0.048	
Forest	0.059	0.705		0.408	
Small Urban	-0.144	1.639		0.054	-0.144
Green-grey	-0.589	1.502		0.095	
Blue	0.221	0.836		0.163	
Multi	0.231	0.808		0.156	
Var(L1)	0.959	0.213	**	**E[WTP]**	$1,115,279
Var(L2)	7.033	1.466	**		

The benefit transfer estimate is derived as

$$\widehat{WTP}_{Hinesville} = e^{\beta' X}$$
(2)

where

$$\beta' X = 7.718 - 0.964 \times [\ln(1.1) - \ln(1474)] + 1.527 \times [\ln(14300) - \ln(23{,}026)] + 0.241 \times [\ln(698.62) - \ln(396)] - 0.144$$

This shows how the base value of green infrastructure is based upon the mean value from the meta-analysis (represented by the constant term 7.718), but adjusted for natural-log differences in project size, GDP per capita, and population density, in addition to an adjustment for project type (coefficient on small urban). The third column in Table 1 presents the mean from the meta-analysis, while the fourth columns indicates the contribution to the estimate for Hinesville WTP as regression coefficient multiplied by difference in natural logs as depicted above. The exponential of the sum of terms in column four produces an empirical estimate of $1,115,279 per hectare of green infrastructure. This value is adjusted by multiplying the per hectare value by the fraction of a hectare associated with the projects (0.0551) for a project estimate of $61,451 per year. Note, this value estimate controls for project size, Liberty County population, county income, and project type (small urban green).

Table 2 presents results from Bockarjova, et al. (2020) Model 2, which includes covariate effects for ecosystem services. As indicated in Table 2, this meta-regression model controls for climate regulation, noise reduction, flood regulation, biodiversity/ habitat, recreation, aesthetics, and cultural value. In doing so, the model permits adjustments in the average value of urban green infrastructure for the presence or absence of the services identified in the valuation exercise. Results suggest negative adjustments for climate regulation, noise reduction, flood regulation, biodiversity/habitat, and recreation, and positive adjustments for aesthetics and cultural value. We first estimate benefit transfer values using only the coefficients in Model 1, then add the additional effects introduced by Model 2.

Table 2: Meta-regression Model 2 for Green Infrastructure: Hinesville, GA

	MODEL 2			**Meta**	**Hinesville**
	Parm	**SE**		**Mean**	**Deviation**
Constant	8.093	0.92	***	1	8.093
ln(area)	-0.952	0.09	***	1474	6.8548045
ln(GDP)	1.414	0.338	***	23026	-0.6735794
ln(pop density)	0.24	0.072	***	396	0.13624626
CE	1.741	1.003	*	0.218	
Tax	-2.612	0.751	***	0.299	
Park	2.414	0.906	***	0.048	
Forest	0.437	0.816		0.408	
Small Urban	0.715	1.41		0.054	0.715
Green-grey	-0.591	1.248		0.095	
Blue	0.586	0.757		0.163	
Multi	0.542	0.749		0.156	
Climate reg	-0.301	0.525		E[WTP]	$3,706,029
Noise reduct	-1.093	0.793			
Flood reg	-0.464	0.728			
Bio/habitat	-0.138	0.491			
Recreation	-1.35	0.581	**		
Aesthetics	1.174	0.799			
Cultural	1.22	0.598	**		
Var(L1)	0.992	0.217	**		
Var(L2)	5.746	1.416	**		

Ignoring the ecosystem service effects, but utilizing the coefficient estimates of Model 2 and following the same calculation presented in equation (2) produces a per hectare value of

$3,706,029. Scaling this number by the size of Hinesville, GA downtown green infrastructure project gives us an annual value of $204,202. Again, this estimate adjusts for project size, per capita GDP, and population density, while accounting for the small urban nature of the investment. Turning to Table 3, we introduce the additional coefficient estimated by Model 2 to account for ecosystem services engendered by the project. We include climate regulation, noise reduction, flood regulation, biodiversity/habitat provision, and aesthetics in our estimation procedures. The estimated per-hectare value is $1,628,991, which produces an estimate of $89,757 for the group of small projects in downtown Hinesville.

Table 3: Meta-regression Model 2 for Green Infrastructure: Hinesville, GA

	MODEL 2			**Meta**	**Hinesville**
	Parm	**SE**		**Mean**	**Deviation**
Constant	8.093	0.92	***	1	8.093
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Green-grey	-0.591	1.248		0.095	
Blue	0.586	0.757		0.163	
Multi	0.542	0.749		0.156	
Climate reg	-0.301	0.525		0.442	-0.301
Noise reduct	-1.093	0.793		0.517	-1.093
Flood reg	-0.464	0.728		0.673	-0.464
Bio/habitat	-0.138	0.491		0.782	-0.138
Recreation	-1.35	0.581	**	0.837	
Aesthetics	1.174	0.799		0.83	1.174
Cultural	1.22	0.598	**	0.51	
Var(L1)	0.992	0.217	**	**E[WTP]**	$1,628,991
Var(L2)	5.746	1.416	**		

Censoring for Small Size Projects
The meta-regression model estimated by Bockarjova, et al. (2020) uses a natural log transformation to capture returns to project size. This is a common functional form and makes intuitive sense in this application if additional provides area provides additional benefits, but at a declining rate. The authors do not report exploration of other functional forms, and the models they present exhibit high external validity. One potential problem in using their results for benefit transfer, however, is out-of-sample prediction that are not in the range of the data they use to estimate the meta-regression. Unfortunately, the authors do not report the range of project sizes in the data that are utilized to estimate their model. In their original working paper, however, they conduct demonstrative benefit transfer for project sites in Europe; part of this analysis includes forecasting benefit measures for a project that ranges from 1 to 27 hectares. This gives us confidence that small-scale projects can be addressed with their data, but one additional potential problem remains.

For projects that are significantly less than a hectare (as is the case for Hinesville), the natural log transformation on project size indicates that per-hectare values are extremely large, approaching infinity as project size approaches zero! This is clearly an undesirable feature of the functional form. To remedy this problem, we employ censoring at project size of one hectare. To accomplish this, we create a piecewise transfer function that follows the estimates of Bockarjova, et al. (2020) for project sizes between one hectare and infinity. But for project sizes below one hectare, we employ a linear function that maps from the origin to the meta-analysis estimate for one hectare (which varies between \$1.115 million and \$3.7 million in our transfer models). See Figure 3, which depicts the slope of the benefit transfer function for project size. Our assumption produces benefit transfer estimates that are defined as = fraction×value of singe hectare GI.

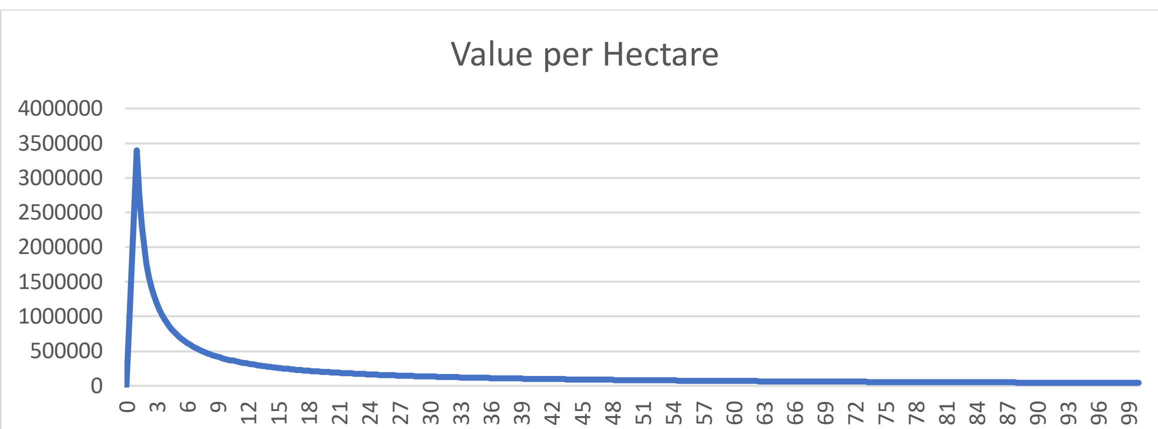

Figure 3: Meta-Analysis Transfer Function – value as a function of project area [hectares]

Assessing Costs of Green Infrastructure Investments
The projected costs of the Hinesville urban green infrastructure projects are presented in Table 4. Major physical inputs include pervious pavers, rain gardens, bioswales, and improvements in drainage. The inputs also include educational components (signage and a kiosk). The subtotal for physical inputs is almost \$146,000. Accounting for mobilization of capital inputs (1% of

subtotal), engineering costs (10% of subtotal), educational programs, program monitoring, and contingencies (10% of subtotal), produces a total project cost of $211,655.

Table 4: Projected Projects Costs for Green Infrastructure: Hinesville, GA

Item	Dimensions	Units	Unit cost	Cost
Pervious pavers	**2000**	**SF**	$24.00	$48,000.00
4" Underdrain indl stone bedding	**400**	**LF**	$55.00	$22,000.00
Rain Garden	**2516**	**SF**	$18.50	$46,546.00
Bio Swales	**720**	**SF**	$15.00	$10,800.00
Education Signage & Kiosk		LS		$12,500.00
Conc containment Wall	**300**	**LF**	$20.50	$6,150.00
SUBTOTAL				$145,996.00
Mobilization		0.01		$1,459.96
Contingency		0.1		$14,599.60
Engineering		0.1		$14,599.60
Education Program				$20,000.00
Monitoring				$15,000.00
			TOTAL	$211,655.16

In comparing benefits to costs, we assume a 50-year project life and apply discount rates of 3% and 7% (OMB Circular A-4).

Results

We consider the results in Table 3 to be our best estimates of economic value, as they are the most comprehensive in terms of estimated effects, but we conduct sensitivity analysis utilizing other results (to test robustness). Project construction, contingency, and engineering costs are allocated to the current time period, while education and monitoring are amortized over the project lifetime of 50 years. The benefit transfer estimate for returns from green infrastructure investments apply to year one after project completion and extend for entire 50 years. Benefit-cost estimates could be modified to account for more time necessary for project completion, but this is unlikely to affect the qualitative findings.

Table 5: Benefit-Cost Analysis of Green Infrastructure Projects in Hinesville, GA

	Benefits	Costs	Net Benefit
0	$0	$176,655	-$176,655
1	$87,142.72	$1,262	$85,881
2	$84,604.58	$1,225	$83,379
3	$82,140.37	$1,190	$80,951
4	$79,747.93	$1,155	$78,593
5	$77,425.18	$1,121	$76,304

6	$75,170.07	$1,089	$74,081
7	$72,980.65	$1,057	$71,924
8	$70,855.00	$1,026	$69,829
9	$68,791.27	$996	$67,795
10	$66,787.64	$967	$65,820
11	$64,842.37	$939	$63,903
12	$62,953.75	$912	$62,042
13	$61,120.15	$885	$60,235
14	$59,339.95	$859	$58,480
15	$57,611.60	$834	$56,777
16	$55,933.59	$810	$55,123
17	$54,304.46	$787	$53,518
18	$52,722.78	$764	$51,959
19	$51,187.16	$741	$50,446
20	$49,696.27	$720	$48,976
21	$48,248.81	$161	$48,088
22	$46,843.51	$157	$46,687
23	$45,479.13	$152	$45,327
24	$44,154.50	$148	$44,007
25	$42,868.44	$143	$42,725
26	$41,619.85	$139	$41,481
27	$40,407.62	$135	$40,273
28	$39,230.70	$131	$39,100
29	$38,088.06	$127	$37,961
30	$36,978.70	$124	$36,855
31	$35,901.65	$120	$35,782
32	$34,855.97	$117	$34,739
33	$33,840.74	$113	$33,728
34	$32,855.09	$110	$32,745
35	$31,898.15	$107	$31,792
36	$30,969.08	$104	$30,866
37	$30,067.06	$100	$29,967
38	$29,191.32	$98	$29,094
39	$28,341.09	$95	$28,246
40	$27,515.62	$92	$27,424
41	$26,714.20	$89	$26,625
42	$25,936.11	$87	$25,849
43	$25,180.69	$84	$25,097
44	$24,447.27	$82	$24,366

45	$23,735.22	$79	$23,656
46	$23,043.90	$77	$22,967
47	$22,372.72	$75	$22,298
48	$21,721.09	$73	$21,648
49	$21,088.43	$70	$21,018
50	$20,474.21	$68	$20,406
	$2,309,426.43	$199,252	$2,110,175

Table 5 presents an example of the benefit and cost calculations accruing over 50 years using our preferred benefit estimate and the present value of net benefits under a 3% discount rates. These results indicate net benefits over the project life of just over $2.1 million. Applying a 7% discount rate, net returns decrease to $656,680. Table 6 presents the BCA results for the other benefit estimates applying the two discount rates. In all cases, quantified net benefits are positive and could be as large as $5 million.

Table 6: Net Benefits of Green Infrastructure Projects in Hinesville, GA

Model	**3% Rate**	**7% Rate**
M1	$1,381,868	$656,680
M2	$5,054,818	$2,626,751
M2 w/ ESS	$2,110,175	$1,047,324

Discussion and Conclusions

Small scale urban green infrastructure (nature-based solutions) provide for local ecological services that should be accounted for in project assessment. While project costs are typically easy to estimate, project benefits are much more nebulous. Original research to assess benefits usually requires primary data collection and analysis, which can be very expensive. Benefit transfer provides an economical alternative, but the quality of benefit transfer estimates is highly dependent upon available data and techniques for "shoe-horning" to assess a given project. The best-case scenario for benefit transfer is to utilize a meta-regression that is estimated with a wealth of data and utilizes best practices in controlling for differences in empirical analysis that reflet project characteristics, study site attributes, and methodological aspects of individual studies.

Fortunately, a meta-analysis for urban green infrastructure projects was recently published in *Ecological Economics* Bockarjova, et al. (2020). The analysis therein applies appropriate methods to summarize existing estimates and predict ecological benefits. The meta-regression includes a mutually exclusive accounting of project type: park; forest; small-urban project; green-grey; blue; or multiple; as well as non-mutually exclusive accounting of ecological services that the project is expected to produce: climate regulation; noise reduction; flood regulation; biological benefits/ habitat; recreation; aesthetics; and cultural. As such, these results are well suited for assessing GI projects in Hinesville and other urban areas along the Georgia coast.

Utilizing a censoring protocol to account for benefits from small urban project (less than one hectare), we find evidence of substantial net economic benefit for GI projects in downtown Hinesville, GA. The present value of the flow of ecological benefits over a 50-year project life exceed the present value of project costs in all simulations examined, with net benefits ranging from $657,000 to over $5million. We expect the project may have tourism benefits that this analysis does not account for. This type of analysis can be applied to the Georgia coast, as well as urban areas in other parts of the state.

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