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Urban forests' potential to supply marketable carbon emission offsets: A survey of municipal governments in the United States

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ABSTRACT

This study assesses the motivation, willingness, and technical as well as managerial capacities of U.S. cities to store carbon and sell carbon offsets. Based on a national survey of urban foresters, arborists, and other officials responsible for urban forest management within U.S. municipal governments, results indicate that local governments are interested in selling carbon offsets. An estimated Probit discrete choice model shows that the chance of a city participating in carbon trading is positively influenced by a number of factors including: (1) level of urbanization, (2) management's knowledge of carbon sequestration, (3) revenue generation from offset sales, (4) population education level, and (5) familiarity with carbon market institutions such as the Chicago Climate Exchange (CCX). The cost of living, as reflected by median home prices, appears to be inversely related to the probability of participation. Currently, a number of cities have the technical and managerial capacity to establish quality carbon offset criteria such as enforceability, additionality, verifiability, and baseline establishment. However, many cities are still unaware of carbon sequestration opportunities, and there appears to be a fundamental disconnect to market participation. The results also suggest that municipal governments would gain from a better understanding of the costs and benefits associated with urban forest carbon storage.

1. Introduction

In recent years, the public has demonstrated increased concern over global warming and climate change issues. Rising atmospheric concentrations of greenhouse gasses (GHG) are considered the major cause of global warming. After water vapor, carbon dioxide is the major greenhouse gas emitted to the atmosphere, primarily through the fossil fuel combustion or deforestation (Schneider, 1989). Because of the apparent severity of the GHG problem, any initiatives that sequester carbon dioxide should be considered in developing climate change mitigation efforts.

Concurrently, markets for carbon offsets are emerging. Under cap and trade systems, businesses that need additional emission permits can purchase them from other firms. They can also purchase certified emission reductions or carbon offsets from other projects, including forestry, which capture atmospheric carbon dioxide and safely store it.

The Chicago Climate Exchange (CCX) is an example of an offset trading system in the North America, where interested sellers and buyers of carbon credits participate in a voluntary, but legally binding, scheme to trade carbon offsets. The CCX started an offset registry in 2003, with the total annual volume less than 1 million tons of carbon dioxide equivalents ($MtCO_2e$). Since then, the CCX has grown to encompass more than 30 million tons of carbon in 2008 (Chicago Climate Exchange, 2009). This makes the CCX the world's largest voluntary carbon trading program.

Since trees absorb atmospheric carbon in the form of carbon dioxide in the photosynthesis process, the idea of trees as a sink for atmospheric carbon has widely been recognized (Sedjo et al., 2001; Van Kooten and Sohngen, 2007; Bigsby, 2009). Research suggests that forests in the United States alone sequestered more than 750 million tons of carbon dioxide in 2003 (US EPA, 2005). In 2008, forest projects accounted for about 7 million tons of CCX trading volume, making forestry the second largest source of carbon offsets behind coal mine methane. With increasingly tighter environmental regulations, and the necessity for businesses to maintain a positive public image, the demand for offsets is likely to grow in the future.

In this context, urban forests appear to have a substantial potential to supply high quality carbon emission offsets. The urban area in the

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United States continues to grow. Nowak and Walton (2005) estimated that 3.1% of the nation's area was in urban uses as of 2000. Urban areas in the conterminous United States more than doubled in size since 1950. Moreover, Nowak and Walton (2005) projected that the urban share of land in the United States will increase to 8.1% by 2050. These urban areas currently maintain average tree coverage of 27% (Nowak et al., 2001), and consist of millions of trees along streets and in parks, riparian buffers, and other public as well as private areas. These trees are capable of storing atmospheric carbon if managed properly. Urban forestry research suggests that there are 4 billion urban trees in the United States (Nowak et al., 2001), and another 70 billion growing in metropolitan areas nationwide (Bratkovich et al., 2008). This suggests tremendous potential for storing carbon in urban forests and important opportunities for urban forestry.

Nowak and Crane (2002) estimated that urban forests in the coterminous United States can absorb 22.8 million tons of atmospheric carbon annually, which was equivalent to $460 million in revenue from selling carbon offsets. Based on this finding, the total carbon storage capacity in urban forests of conterminous United States was estimated at 700 million tons. Similarly, an earlier study suggested the total carbon storage capacity of United States urban forests was between 600 and 900 million tons (Nowak, 1994). These figures provide evidence that urban trees in the United States could serve as an important carbon sink.

There has also been an increasing interest among urban managers in participating in climate change mitigation initiatives, including carbon offset trading. The United States Conference of Mayors Climate Protection Center was established in 2007 to help municipal governments mitigate and reduce the impacts of global warming. The Center currently has more than 500 members who are committed to reducing their GHG emissions through various actions such as land use management and/or bi-partisan campaigning to establish a national emissions trading system. Moreover, eight municipalities, three counties, and two states have already enrolled in the CCX trading program indicating a growing interest at local level in carbon storage projects and offset trading.

Most forest carbon sequestration studies have focused on measuring the amount of carbon stored in urban forests and evaluating ecological aspects of sequestration. For example, Birdsey (1992), Jo and McPherson (1995), Hoover et al. (2000), Nowak and Crane (2002), Smith et al. (2004), Myeong et al. (2006), Pouyat et al. (2006), and Smith et al. (2006) focused on developing methods for estimating urban forests carbon sequestration capacity and storage potential. Alternatively, Rowntree and Nowak (1991), McPherson (1994), McPherson (1998), Jo and McPherson (2001), and Brack (2002) focused on discussing the ecological benefits of carbon sequestration through urban forest projects.

Several studies have also examined the economic and marketing aspects of forest carbon offsets. Birdsey (2006) discussed carbon accounting rules and guidelines as they relate to the carbon pools and carbon calculation methods in the U.S. forest sector. Call and Hayes (2007) compared major forestry-related carbon registries in the United States. Cathcart (2000) analyzed the effectiveness of Oregon's innovative Forest Resource Trust program to engage landowners to provide carbon offsets through afforestation efforts. Sedjo and Marland (2003) presented the concepts of permanent and temporary emission credits, where the latter would be derived by discounting the former. A similar analysis by Esuola and Weersink (2006) proposed carbon banking as a system in which carbon sink generators deposit their temporary and permanent credits and get paid for their savings by the bank. Despite substantial work in this area, none of the previous studies have assessed the interests and motivations of local cities and municipal governments in supplying carbon offsets based on carbon stored in urban trees.

Stricter environmental regulations and a growing need for businesses to maintain positive public image are likely to result in a higher demand for carbon offsets. Carbon sequestered through private and industrial forestry practices provides virtually all of the current carbon offset credits in the United States. Maintaining tree coverage and selling carbon credits could help municipal governments become more directly involved in the climate change issues, develop awareness, and provide revenues for protecting and managing urban forests. To date, however, the potential role of urban forests in carbon sequestration has been largely overlooked. Little is known about the knowledge, motivations, and interests of urban governments and forest managers in participating in carbon sequestration markets. To begin addressing this gap, this paper discusses the results of a nationwide local government survey designed to assess urban government awareness, interest, and capacity with regard to carbon offsets generated by urban forests. It also develops a statistical framework for predicting the likelihood of government participation in carbon offset trading.

2. Methods

2.1. Survey of municipal governments

A web-based nationwide survey was designed and implemented between November 2007 and January 2008 to determine the willingness, motivation, and ability of city and municipal governments to participate in carbon offset markets. Urban foresters, arborists, and other individuals responsible for the management of urban trees were identified and invited to participate in the survey. Contact information was obtained from the Society of Municipal Arborists (SMA), thus limiting selection to those cities with contacts to the organization. While potentially suffering from selection bias, this approach was adopted because of the preliminary nature of the research and limited resources for sampling. Hence, it should be noted that the analysis which follows is probably more applicable to innovators and early adopters than the population of U.S. cities at large.

The survey included a cover letter explaining the purpose of the survey and requesting participation. After two weeks, each survey recipient was provided with a reminder to complete the survey. Respondents were requested to report their understanding of the official positions of their municipalities, rather than expressing their personal views. Because responding to the survey may have required consultation among government officials, the web-survey-design allowed respondents to save part of their responses and to return at a later time to complete the survey.

The survey consisted of 27 questions covering three broad areas.[2] The first set of questions asked for current urban forest information and management practices, including the existence of resource inventory, the presence of a staff forester, or the existence of a forest management plan. The second group of questions assessed current interests and activities of local governments in climate change mitigation and participation in voluntary carbon reduction schemes. The final part of the survey included questions about city characteristics such as land area and population. Survey questions used a range of formats including categorical, open-ended, and Likert scales of various points (Likert, 1932).

2.2. Econometric model

A conceptual model was developed to identify the factors that influence the interest and motivation of local governments to participate in carbon offset markets. Since motivation of local governments to participate in carbon trading was expected to depend on their knowledge of carbon sequestration and markets, current climate change

[2] A copy of the survey is available from the authors, upon request.

mitigation activities, supplemental income needs, and social and political characteristics, the following model was developed:

$$\text{Willingness to sell carbon credits} = f\begin{pmatrix}\text{awareness, need for income, market} \\ \text{information, GHG reduction goal,} \\ \text{voluntary participation, population} \\ \text{density, cost of living, education,} \\ \text{vegetative coverage}\end{pmatrix} \quad (1)$$

The willingness to participate in urban carbon credit trading was denoted using a discrete choice variable, which indicated whether the city was currently interested in selling carbon. A five-point Likert scale was converted into a binary variable, recorded as 1 if a city was currently interested or very interested in selling carbon, 0 otherwise. A bivariate Probit regression can be used to model this dependent variable assuming an underlying latent continuous utility index variable for the city of Y^* (Greene, 2003) such that:

$$Y_i^* = \beta_0 + \sum_{k=1}^{k} \beta_k X_{ki} + \varepsilon_i \quad (2)$$

Where Y^* is the latent variable, which is not observed. However, the observable binary variable is represented as:

$$\begin{aligned} Y &= 1 \text{ if } Y^* > 0 \\ &= 0, \text{otherwise} \end{aligned} \quad (3)$$

$$Y_i^* \sim N(0,1)$$

The X_{ki} represent the values of the i cities to each of the k explanatory variables, β_0 represents the intercept parameter, $\beta_{\boldsymbol{k}}$ is a vector of regression coefficients, and ε_i is an independently distributed standard normal error term.

Then, the probability of a city being interested in participating in carbon trading is given by

$$P(Y = 1 | X_{ik}) = \Phi(\beta_i X_i - \varepsilon_i > 0) \quad (4)$$

Where Φ denotes the cumulative distribution function for the error term, ε_i. The marginal effects of the corresponding variables, which are a function of both the estimated parameters and the values of the explanatory variables, can be calculated as follows:

$$\frac{\partial E[Y = 1 / X_{ik}]}{\partial X} = \Phi\left(\beta' X\right)\beta \quad (5)$$

2.3. Variables

Eleven independent variables were used to explain the willingness of a city to sell carbon credits. There is little guidance in the literature as to what variables are important. AWARENESS was the respondent's rating (5 = very familiar, to 1 = not at all familiar) of their level of knowledge of carbon sequestration prior to reading the survey. This variable was included because the knowledge of technical and ecological aspects of carbon storage is important. A REVENUE variable was included to capture the importance of income from expected sales of carbon offsets (5 = extremely important, to 1 = extremely unimportant). A dummy variable, MARKET INFORMATION, took a value of 1 if the city is familiar or has used the Chicago Climate Exchange (CCX), 0 otherwise. This variable was included because having access to market institutions or information about the place to trade their carbon offsets would seem relevant to engage in carbon trading. The question listed CCX because it is currently the biggest and best known carbon market platform in the United States.

Another dummy variable, GHG REDUCTION, was used to assess if a city has any goals related to reducing its own carbon emissions. The variable took a value of 1, if the city has a goal of reducing GHG, 0 otherwise. Another dummy variable, VOLUNTARY PARTICIPATION, indicated whether the city had already participated in any kind of voluntary actions that would help mitigate global warming. Those actions may have included constructing energy efficient buildings (or remodeling existing ones to improve energy efficiency), using alternative fuel vehicles, or capturing landfill methane. POPULATION DENSITY measured the number of people in thousands per square mile of the city area. This variable was included to capture the level of urbanization. COST OF LIVING, the natural logarithm of the median value of owner-occupied housing units, was expected to capture the effect associated with the cost of living in the city. EDUCATION measured the percentage of city residents having a college level degree. This variable was included to control for the awareness and interests of city residents, who may press their government representatives to participate in climate change mitigation programs. Population density, housing value and educational data were obtained from the United States Census dataset. A FOREST variable, which captured the amount of forest area within the immediate city's surroundings, was included to assess how the surrounding landscape structure and quality may influence interest in selling carbon. Because such data are unavailable at the city level, we used the area of forestland within the county where the city was located as proxy. Similarly, a WATER variable, represented by the natural log of the city acres under water, was included to control for the land use characteristics of the city. Finally, the CITY AREA variable capturing the natural log of the city area was included to control for the effects related to the geographical size of the city. This information was obtained from the National Outdoor Recreation System database (NORSIS) (Cordell and Betz, 1997). Detailed variable definitions, means, and expected signs are presented in Table 1.

Table 1
Definition, mean and expected signs of variables.

Variable	Definition	Mean	Expected sign
WILLINGNESS TO SELL CARBON	Dummy variable, 1 if the city government is currently interested in selling carbon, 0 otherwise	0.19	–
AWARENESS	Level of knowledge about carbon sequestration prior to reading the survey, (1—not at all familiar, 5—very familiar)	2.72	Positive
REVENUE	Importance of potential income from carbon credits (1—extremely unimportant, 5—extremely important)	3.54	Positive
MARKET INFORMATION	Dummy variable, 1 if familiar with the market platform such as CCX, 0 otherwise	0.21	Positive
GHG REDUCTION	Dummy variable, 1 if the city currently has a goal of reducing its carbon emissions, 0 otherwise	0.36	Positive
VOUNTARY PARTICIPATION	Dummy variable, 1 if the city currently participates in other voluntary actions to reduce GHG, 0 otherwise	0.70	Positive
POPULATION DENSITY	City population in thousands weighted by the square miles of city area	2.91	Positive
COST OF LIVING	Natural log of the median housing dollar value of owner-occupied housing unit in the city	12.15	Positive/Negative
EDUCATION	Percentage of city residents with college level education	36.72	Positive
FOREST	Natural log of the acreage of forest coverage within the immediate surrounding of the city	10.14	Positive
WATER	Natural log of the city area under water	1.95	Positive/Negative
CITY AREA	Natural log of the city area	2.98	Positive

3. Results

Out of the total 299 surveys distributed, 22 were undeliverable or had wrong addresses. A total of 150 completed surveys were returned yielding an effective response rate of 54%. Respondents were uniformly distributed in terms of a city size. For example, about 21% of all respondents were from cities with population exceeding 100,000, and 27% of them were from cities with population between 50,000 and 100,000. About 31% of respondents represented cities with population between 20,000 and 50,000 and roughly 21% of the respondent cities had populations less than 20,000. Region-wise,[3] the sample was distributed with about 37% from the Midwest, 27% from the South, 31% from the West. However, respondents from the Northeast constituted only 6% of the total.

3.1. Technical and managerial capacities

Respondents answered questions about their current level of technical resources and managerial capacities in urban forestry. For example, when asked about the person responsible for the management of urban forest, 95 cities responding (63%) indicated that there was an official primarily responsible for the management of urban trees. These cities indicated that they either have a staff urban forester or arborist (85 responses), or that urban forests are overseen by head of other departments such as parks (6), public works director (3), or a consulting forester or arborist (1). However, only 22% of total respondents reported that their cities have a complete inventory of urban trees, while another 56% indicated that they have a partial or a component inventory of public trees, whereas the remaining 23% indicated no inventories.

Among the cities with tree inventories, 52% had updated their inventory within the past 2 years; another 26% had updated their inventory between 2 and 5 years ago. Inventory datasets were fairly comprehensive and contained detailed information. For example, more than two-thirds had information about species, diameter, and condition of trees. When asked about their future inventory plan, about 63% of total respondents said inventories will be conducted within the next 5 years. A narrow majority of respondent cities had formal urban forest management plans. About 37% of respondents had a written management plan that covers all of their publicly owned trees. Another 18% had a management plan that covers some of the public trees. The remaining 40% did not have a management plan. Some of the cities (roughly 30%) even had an urban forest risk management plan, which is important in management and utilization of urban trees in case of a natural catastrophe or man-made hazard. Such a plan would help in preventing tree destruction and better preserve the sequestered carbon.

3.2. Current activities and initiatives

Cities were fairly aware of a range of climate change mitigation options. Some of them had actively engaged in climate change mitigation activities. About 26% of respondents reported that reducing their carbon emissions is a priority program for their city. Another 11% reported that it is one of the goals, but has not yet become a priority, while 17% had discussed reducing their carbon emissions even though they did not have a defined goal. Only 20% reported that they neither have a goal of reducing carbon emissions, nor have they discussed it.

Many cities had participated in a range of innovative activities aimed at reducing GHG emissions. About 22% had constructed or remodeled energy efficient buildings. Additionally, 23% had begun using alternative fuel vehicles, 38% had carried out tree planting projects and about 11% had undertaken other projects such as landfill methane capture. Respondents were also asked about their knowledge of carbon sequestration and credits. About one-third (32%) were familiar or very familiar with carbon sequestration before reading the survey (Fig. 1). However, nearly half (45%) were either not familiar with, or unsure about, carbon sequestration. Less than a third of respondent cities (21%) were familiar with U.S. carbon market institutions such as CCX, while only 1% had actually used CCX for carbon trading purposes. Over one-third (34%) reported never hearing of CCX and another 44% were unsure about their knowledge of CCX (Fig. 2). Regarding interest in selling carbon offsets, 29 out of 150 cities noted that they were currently interested or very interested in carbon trading. Given that cities represented in the sample were associated with SMA, it is likely that the numbers above are somewhat higher than those that could be expected for cities with no SMA association.

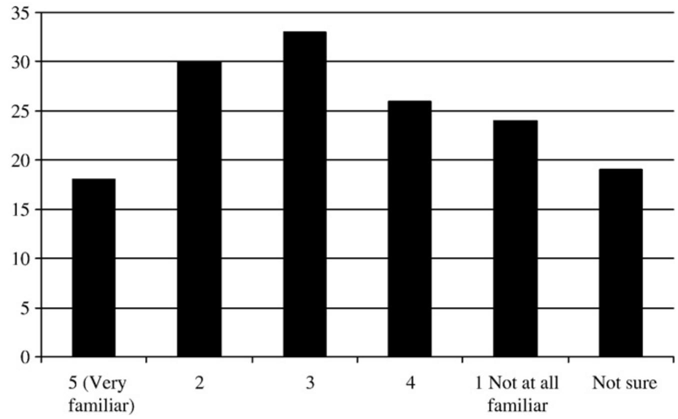

Fig. 1. Number of respondent municipal governments currently familiar with carbon sequestration and carbon credits prior to reading the survey.

3.3. Factors affecting willingness to participate in carbon offset trading

Current willingness of SMA-affiliated governments to sell carbon offsets from urban forests was modeled with a Probit regression. The results are presented in Table 2 with the coefficient and their *Z*-values in the first sub-column, and their respective marginal[4] effect and elasticity in the second and third sub-columns. Discussion of results for specific variables in the following sections will use either marginal effect or the elasticity. This is because some of the variables in our model are discrete in nature (i.e. binary or categorical based on Likert scale data), whose effect on outcome variable can be better explained using marginal effect than elasticity. However, elasticity has been used alternatively to interpret the effects of other continuous variables in the model.

Six out of 150 total responses were discarded because some questions were unanswered. The Wald test (χ^2 Statistic = 49.6, p value < 0.001) suggested that the variables included in the model were jointly significant. Reported z-values were computed using the White's robust standard errors, which are used to address the issue of heteroscedasticity in a cross-sectional dataset (White, 1980).

Among the individual coefficient estimates, 8 out of 11 explanatory variables were statistically significant (p < 0.10), with most having expected signs. Local governments' knowledge about carbon storage before reading the survey (AWARENESS) was positively related to their willingness to participate in carbon trading. Because the regression

[3] These regions correspond to four Census Regions of the United States Census Bureau.

[4] It should be noted that marginall effect and elasticity reported in this section are computed at the mean level of explanatory variables.

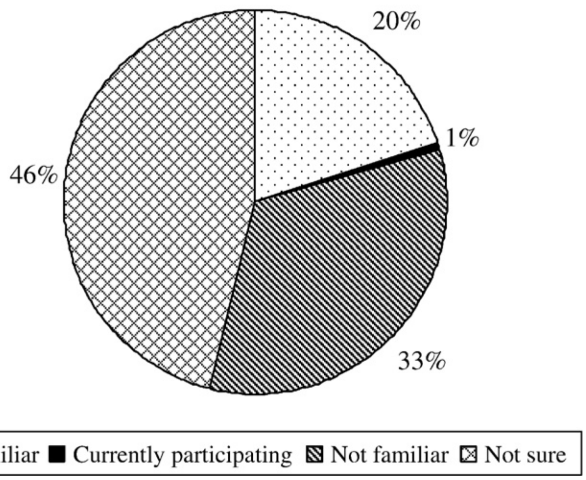

Fig. 2. Familiarity of municipal governments with carbon market institutions such as CCX.

coefficients are difficult to interpret, the computed marginals, reflecting the change in the probability of being willing to participate with respect to a one unit change in the explanatory variable, are reported. Hence, a one unit increase in the city's level of awareness (measured with a 1–5 Likert scale) results in an increase in the predicted probability of participation of 0.039, ceteris paribus. Similarly, for the REVENUE variable, which captures the local government's rated importance of income from expected sales of carbon credits was also positively associated with their interest to participate in carbon trading. The estimated marginal effect indicates that a one unit increase in the reported importance of income from carbon trading (measured in a 1–5 Likert scale) yields an increase in the predicted probability of participating of 0.080. Signs of the coefficients for both of these variables were consistent with economic theory.

Having information about carbon trading market platforms such as CCX also affected the local government's likelihood of participating in carbon trading. As expected, the coefficient on the variable capturing this information, MARKET INFORMATION was positive and statistically significant. The marginal effect revealed that cities having information about this market institution were roughly 17 percentage points more likely to participate in carbon trading than those without. A dummy variable capturing whether or not the city had a goal of reducing greenhouse gas imissions (GHG REDUCTION) did not have a significant effect. However, VOLUNTARY PARTICIPATION, a dummy indicating whether or not the city had participated in voluntary actions to reduce GHG, had a positive and significant effect on city's willingness to participate in carbon trading. Cities previously involved in such voluntary actions were 6.4 percentage points more likely to participate in carbon trading than others.

Table 2
Regression estimates from the bivariate probit model.

Variable	Coefficients (*Z* value†)	Marginal effect	(Elasticity)
Intercept	4.868 (0.960)	–	
AWARENESS	0.227** (1.970)	0.039	1.098
REVENUE	0.504*** (2.870)	0.086	3.178
MARKET INFORMATION	0.768** (2.300)	0.171	0.292
GHG REDUCTION	−0.139 (−0.430)	−0.023	−0.090
VOUNTARY PARTICIPATION	0.424 (1.210)	0.064	0.547
POPULATION DENSITY	0.200** (2.430)	0.034	1.023
COST OF LIVING	−0.992** (−2.240)	−0.171	−1.755
EDUCATION	0.042*** (3.720)	0.007	2.743
FOREST	0.015 (0.360)	0.002	0.028
WATER	−0.053* (−1.640)	−0.009	−0.094
CITY AREA	0.290* (1.630)	0.049	0.514
Pseudo *r*-square	0.329		
Log-pseudolikelihood	−48.505		
Observations (*N*)	144		
Wald χ^2 (9) Statistic	49.600***		
Correct predictions (%)	82.64		

Note: ***, ** and * indicate the significance of parameters at 1%, 5% and 10% level respectively.
† The *Z*-values are based on heteroscedasticity consistent robust standard errors.

Variables capturing a city's characteristics also significantly explained local governments' interests in selling carbon. A variable measuring the level of congestion, POPULATION DENSITY, was positively related with the city's interest in engaging in carbon trading. The estimated elasticity suggested that a 1% increase in population density (measured in thousands of people per square mile) of the city area was associated with a 1.02% increase in the city's likelihood of participating in carbon trading, ceteris paribus. The variable capturing the cost of living in the city, COST OF LIVING, was negatively associated with the city's willingness to sell carbon. The elasticity indicated, a 1% increase in the cost of housing in the city area was associated with a 1.76% decrease in likelihood of participating in carbon trading.

The EDUCATION variable, intended to capture the education level of cities' residents, had a positive effect on the city's willingness to participate in carbon trading. Elasticity measures suggested that a 1% increase in proportion of college graduates in the city population increased the city's likelihood of participating in carbon trading by 2.74%. The effect of the FOREST variable, which represented the amount of vegetative coverage in the city's surrounding county, was not statistically significant. Even though it was reasonable to expect statistical significance in this case, we used the forest area of the county in which the city was located as a proxy to represent the city's vegetative coverage. As expected, the coefficient on the WATER variable, which represented the natural log of city acres under water, was negative and marginally significant. This is probably because the cities with more area under water may have less forested acres to store carbon. Lastly, while the variable capturing the geographical extent of the city (i.e. CITY AREA) had a positive sign, the effect was also marginally significant.

Results from the regression model can be used to assess the likelihood of a municipal government's participation in carbon offset trading by combining the estimated coefficients with the relevant explanatory variables to predict the probability of participating in carbon trading for selected cities. For illustrative purposes, the predicted results for a dozen cities of varying sizes with SMA affiliation selected from four different census regions are presented in Table 3. With a couple of exceptions, our model yields some reasonable predictions. It indicates that some of the big cities in the northern and western part of the country such as New York, Chicago, and San Diego, have a higher likelihood of participating than big cities located in the southern part such as Atlanta or New Orleans. This variation is primarily driven by the difference in population density. Also, considering middle or small sized cities, for example, Portland, OR and State College, PA were more likely to participate in carbon trading than other similar size cities, such as Cooper City, FL in the South, Provo, UT in the West and Jefferson City, MO in the Midwest. An analysis of predicting variables indicate that this variation is due to underlying difference in the level of resident's education.

4. Discussion and conclusion

While previous studies of carbon sequestration through urban forestry have focused on quantification and benefit estimation aspects, this study examines factors related to interests, motivations, and capacities of potential carbon offset suppliers. Survey responses indicated that a significant number of local U.S. municipalities with SMA membership were already engaged in some kind of climate change

Table 3
Predicted likelihoods of participating in carbon offset trading for selected US cities.

Region	City	Likelihood	Region	City	Likelihood
Northeast	New York, NY	Highly likely	West	Provo, UT	Less likely
Midwest	Chicago, IL	Highly likely	Midwest	Lincoln, NE	Likely
South	Atlanta, GA	Less likely	South	New Orleans, LA	Less likely
Northeast	State College, PA	Highly likely	Northeast	Philadelphia, PA	Highly likely
South	Cooper City, FL	Less likely	West	Portland, OR	Likely
West	San Diego, CA	Likely	Midwest	Jefferson City, MO	Less likely

Note: Corresponding values of predicted probability for Highly Likely, Likely and Less Likely were $p>0.75$; $0.75\geq p\geq 0.50$, and $p<0.50$ respectively.

mitigation initiatives and some were enthusiastic about carbon sequestration. Overall, the results indicate that these governments are fairly interested in selling carbon. However, there are a number of factors that currently influence their willingness to participate in selling carbon offsets. The analysis revealed that cities located in densely populated areas with a higher proportion of college-educated residents were more likely to participate in carbon markets. This in turn implies that their willingness to participate in carbon markets was likely driven by the degree of urbanization, and the awareness and interest of their voting constituents. Their willingness to participate in carbon selling also depended on their previous engagement in voluntary actions for GHG reduction, understanding of urban forest carbon sequestration, familiarity with carbon market institutions (e.g., CCX), and importance of revenue from expected carbon offset sales. The negative effect of cost of living on their willingness indicate that governments located in less affluent neighborhoods appear more interested in carbon trading schemes; this may also be related to revenue needs.

As far as the need for income is concerned, future increases in market prices of offset credits possibly resulting from a passage of mandatory regulations may further increase their motivations. However, the fact that only one-third of cities are currently familiar with the carbon sequestration and carbon offset trade, and more than two-thirds of them were unaware or had no market information, indicates the presence of an information barrier and fundamental disconnect to market participation. While agencies interested in promoting markets for carbon credits can have little or no control over the characteristics of the city, policy instruments could be devised to influence the willingness of potential suppliers to enter the market. For example, developing new or revising existing urban forestry extension programs could help local governments better understand the costs, benefits and technical details of urban forest carbon storage. Local governments may well be convinced by the fact that their investment in urban tree management could be compensated by the increased revenue from offset sales. In addition, the predictive model developed and discussed in this study could identify municipal governments likely to sell carbon credits, if not already doing so.

Our analysis also indicates that a substantial number of cities and municipalities with SMA affiliation do have technical and managerial capacities to incorporate carbon trading in their urban forestry programs. Nearly half of the cities did have technical resources that include a professional forester and a clearly designated official primarily responsible for handling the issues related to urban tree management. This indicates that carbon trading projects are likely enforceable in the local government units. Many cities currently have well written management plans for urban forests, which may provide a basis for inclusion of carbon trading in the future. Cities also have periodic inventories of their trees over the last few decades and most of them plan to update their inventories soon. Moreover, their inventories include some key information important in assessing carbon storage such as tree diameter, condition, and age. As a majority of cities currently have such information, they will face relatively low upfront costs associated with the initiation of carbon trading programs. For example, detailed inventory datasets and management plans will make it relatively straightforward to verify offset credits, and also to demonstrate the additionality of carbon storage through active management.

Some municipal governments also have risk management plans for their urban forests, which certainly contain some of the risk reduction options that would help minimize the loss of sequestrated carbon from forest fires or hurricane damage and maintain the permanence of sequestered carbon. Since carbon offset markets in the United States are at present mostly voluntary, purchasing firms would probably be interested in buying quality offsets that would achieve a real and verifiable reduction in GHG. Interestingly, our study indicates that a substantial number of local governments do have enough resources and capacity to establish, demonstrate, and meet major quality offset criteria including enforceability, verifiability, additionality, defined ownership, permanence, and baseline. The quality aspects of urban forest carbon offsets and associated ecosystem services such as clean air, water, aesthetics, and urban wildlife and avian habitat can make urban forestry offsets more socially appealing to local buyers than offset credits from rural forestry or non-forestry projects.

The research in this study suggests a number of avenues for future urban forest related carbon storage research. First, as our sample size is relatively small, it would be prudent to expand the scope of the present study to include more cities, particularly those with larger populations and greater income diversity. Next, as our sample is conditioned by affiliation with the Society of Municipal Arborists, it is likely that parameter estimates in this study are only applicable to the more innovative municipalities. Despite the likelihood of much lower response rates, it would be important in future work to expand the sample to include cities with and without SMA affiliation. This way a Heckman-type two stage model could be applied or an interactive model could be developed to identify and test for structural differences between those cities with and without SMA connection.

Another area of importance would be to establish forest cover variables specific to the city. Unlike the proxy used in this study, a more accurate measure of forest coverage for areas within city limits could improve the significance of this variable.

Finally, it would be interesting to extend this study by assessing the motivations of potential buyers. In doing so, one could assess corporations' willingness to offer a price premium for carbon stored in cities in which their facilities and offices are located, and in cities where product marketing or public image might be very important. From a theoretical perspective, it would be reasonable to expect a price premium because helping forest projects that provide various ecosystem services would help businesses earn social recognition and improve their green image.

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