BENEFITS OF URBAN GREENERY: A CASE STUDY FOR BUENOS AIRES CITY

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Abstract. Although in Buenos Aires urban trees are very much appreciated and it is widely acknowledged that they perform an important function in the city environment, there are no empirical studies about their role as both carbon dioxide sinks and household-energy consumption savers. In the present paper we present the results of calculating both the gross and net carbon sequestration, and the heating and cooling emission savings made through: tree shade, evapotranspiration and wind shielding for a sample of 15,856 street trees: The total net amount of CO_2 emissions from energy generation projected to be saved by the sampled trees in the next 40 years is estimated at 14,754 tonnes, and it will account for 25.8 % of the total amount of CO_2 sequestered. The maximum net CO_2 savings will be achieved in 16 to 20 years (2018-2022), followed by a decrease due to the increase of CO_2 releases by biomass decay and tree maintenance. The extrapolation of our results to the whole city shows that street trees can store half of the CO_2 emisssions produced by municipal solid waste. For Buenos Aires, a city with high rates of CO_2 storage per tree, energy savings and CO_2 sequestration are important features to be considered in urban planning and management.
Keywords: urban forest, CO_2 sequestration, CO_2 emissions reductions.

BENEFICIOS DA FLORESTA URBANA: um estudo de caso da cidade de Buenos Aires

Resumo: Em Buenos Aires as florestas urbanas são muito apreciadas e é amplamente reconhecido que elas desempenham uma função importante no ambiente da cidade, porém, não há estudos empíricos sobre o seu papel tanto como sequestradoras de dióxido de carbono e protetoras de consumo de energia doméstica. No presente trabalho, apresentamos os resultados de cálculo tanto sobre o seqüestro de carbono líquido e bruto, o aquecimento e o arrefecimento por meio de reduções de emissões: árvores de sombreamento, evapotranspiração, e vento de blindagem para uma amostra de 15.856 árvores de rua. O montante total líquido das emissões de CO_2 e a geração de energia prevista para serem salvos pelas árvores amostradas nos próximos 40 anos é estimada em 14.754 toneladas, e será responsável por 25,8 % da quantidade total de CO_2 seqüestrado. O máximo de redução de CO_2 líquido será realizado em 16 a 20 anos (2018-2022), seguido por uma queda devido ao aumento das emissões de CO_2 por decomposição da biomassa e manutenção de árvores. A extrapolação de nossos resultados a toda a cidade mostra que as árvores das ruas podem armazenar metade das emisssões de CO_2 produzido por resíduos sólidos urbanos. Para Buenos Aires, uma cidade com altas taxas de armazenagem de CO_2, por árvore, a economia de energia e o seqüestro de CO_2 são características importantes a serem considerados no planejamento e gestão urbana.

Palavras-chave: Floresta urbana, Seqüestro de CO_2 , Redução das emissões de CO_2 .

INTRODUCTION

Urban greenery is an important element which adds aesthetic, economic and environmental values to cities. Urban trees contribute directly to a healthy environment by the removal of airborne particulates and carbon dioxide, and by shading and wind protection they indirectly reduce the demand for heating and air-conditioning (Mc Pherson & Simpson, 1999). In this connection, trees along streets and urban parks are especially relevant for the mitigation of climate change in urban areas, where large quantities of energy are consumed in heating and cooling whereby significant amounts of CO_2 are released.

The amount of CO_2 stored by trees in an urban setting is proportional to canopy cover, tree densities, and tree-diameters (proportional to tree biomass). In urban forests tree growth rates are variable; they depend on differences among species, growing conditions -especially climate- and care (Mc Pherson & Simpson, 1999).

Nowak & Crane (2002) reported for the USA an average storage of 25 tonnes C/ha (for example 15.3 tonnes C/ha for New York, 35.7 tonnes C/ha for Atlanta). In the USA Birdsey & Heath (1995) estimated that carbon storage by urban trees is 4.4 % of the total stored in non-urban forests, which is an amount equivalent to the CO_2 emissions from total population of the USA in 5.5 months (Nowak & Crane, 2002).

The tree canopy effect on energy savings is of great importance in regions that mostly rely on fossil fuels for cooling and heating. In winter the tree canopy protects from excesive cooling by wind; in summer the projected shadow of leaves and branches depletes sun radiation and collaborates to reduce energy consumption (Heisler ,1986). Thereby a reduction of emissions associated with the production of electric power is a significant way that urban trees can collaborate to mitigate climate change. Akbari *et al.* (1989) have shown that planting trees and increasing the albedo of walls are the most cost effective means for reducing energy consumption in a city.

Mc Pherson & Simpson (1999) developed a model, using a standardized accounting process, to determine the effects of urban forests on current and future CO_2 reductions. Seoane & Evans (2001) adapted the model to the conditions of Buenos Aires using a hypothetical population of 50 trees.

There is a lack of information in Latin American cities of the amount of CO_2 sequestrated by urban trees. The purpose of the present paper was to estimate the total net CO_2 saved shade trees in Buenos Aires city using the model of Mc Pherson & Simpson (1999).

To fullfill this purpose we applied the foregoing methodology for calculating the carbon dioxide sequestration and reduction of energy CO_2 emissions by shade trees in the City of Buenos Aires.

METHODOLOGY

Study area: Buenos Aires (34º 37´S 58º 24´W) –the capital of Argentina– has a subtropical climate with a long warm season. It extends over 203 km^2, has aproximately 3 million inhabitants, 1.2 million homes and 1.5 million cars. Atmospheric emissions from public and private transport are the main source of contamination (Borthagaray & Prini, 2001; however, no estimations of CO_2 emissions have been made so far.

In 2002 we sampled by walking the shade trees of 1105 blocks in a centrally located area of the city (Flores and Caballito neighbourhoods,: 1549.6 hectares, 263247 inhabitants, 255.8 km of streets). This residential/commercial area represents 7.6 % of the whole city area and is representative of Buenos Aires. The tree-inventory was made in 2002; this year is the start-year (year 0) for the modelling.

We recorded the location of trees (street name and number), botanical names, stem diameter at 1,30 m height, tree height in meters, health condition (presence of illness) and stem inclination of trees along 2421 streets.

We used the model of Mc Pherson & Simpson (1999) as adapted by Seoane & Evans (2001) to assess the balance of CO_2.The inputs for the modelling were as follows:

Site and building data: We estimated the percentage cover values of trees and of buildings from aerial photographs. Because buildings differ in the efficiency with which they exchange energy with their surroundings, because of their construction characteristics (construction materials, windows area and insulation), the model considered 3 categories of *vintage* (similar age, construction type, floor area and energy efficiency characteristics due to insulation, heating and air conditioning equipment): 1. categories of vintage : built before 1950 (pre 1950), 2. built between 1950 - 1980 and 3. built after 1980 (post 1980). In the present study the building distribution by vintage was: 25 % pre 1950, 50 % 1950-1980 and 25 % post 1980.

Climate region. We chose the USA southeast climate region (city Charlotte NC), whose climate is similar to Buenos Aires'. Both cities have a Cfa climate following the Koeppen Climate classification: that means a humid subtropical, a mild mid-latitude climate with no dry season and a hot summer.

Electricity emission factor (tonnes CO_2/ MWh). We assumed a value of 0.8 for the whole year, which is representative of the energy mix used for generating electricity in Buenos Aires (Seoane & Evans, 2001).

Tree Data. Trees were classified by life form into *deciduous* or *evergreen*, and these by mature size into *large* (taller than 15 m), *medium* (between 10 and 15 m height) and *small* (shorter than 10 m) (Fig. 2,3,4). The number of trees in each one of those classes was recorded.

Tree location: All trees provided shade and climate benefits because they are located infront of the buildings (1,5-3m).

Survival rate, CO_2 sequestration, decomposition and CO_2 release for mature trees, depend overwehlming on tree growth rate. For our study, we used the factor for "Central Growth Zone" proposed by the model and a moderate survival of trees (longevity: 25-50 years).

Building energy use: We considered the conditioned floor area as the average amount of floor area cooled or heated. For the pre 1950 vintages we estimated that 25 m^2/unit was the conditioned floor area; and 50 m^2/unit for 1950-1980 and 75 m^2/unit for post 1980 . We set the shading fraction on neighboring homes to 0.2.

Cooling and heating equipment: We estimated the fractions of buildings having either central air conditioning or room air conditioning, or none of them. We used also an empiric correction factor to account for the fact that many homes use electric fans for ventilation in BuenosAires. As to heating the fraction of buildings heated with either natural gas, or fuel oil or electricity was estimated.

Annual energy consumption: We assumed a consumption by 18 kWh/m^2/year (Seoane & Evans 2001).

The model outputs the amounts of CO_2 either emitted to or removed from the atmosphere in 5-year successive periods for each one of the following processes:

1. **Shade–cooling** (shading benefit): energy savings due to tree shading.

2. **Shade-heating** (shading drawback): increase in heating-energy use due to the interception of sunshine in winter by evergreen trees.

3. **Climate-cooling**: savings in cooling energy due to tree evapotranspiration.

4. **Climate-heating**: increase in heating energy use due to local climate change.

5. **Windbreak-heating**: energy savings from heating due to wind shielding in winter.

6. **Sequestration.** Removal of CO_2 from the atmosphere.

7. **Total CO_2 released**: Emissions of CO_2 from woody biomass decay together with those released from tree urban stewardship.

8. **Net CO_2 saved**: Sum of processes 1 to 7. This sum may be either a positive number (saving of CO_2) or a negative one (loss of CO_2 to the atmosphere).

RESULTS AND DISCUSSION

In the studied area we observed 15856 trees; 96% of the trees are deciduous and mostly of small and medium sizes (**Figure 1**).

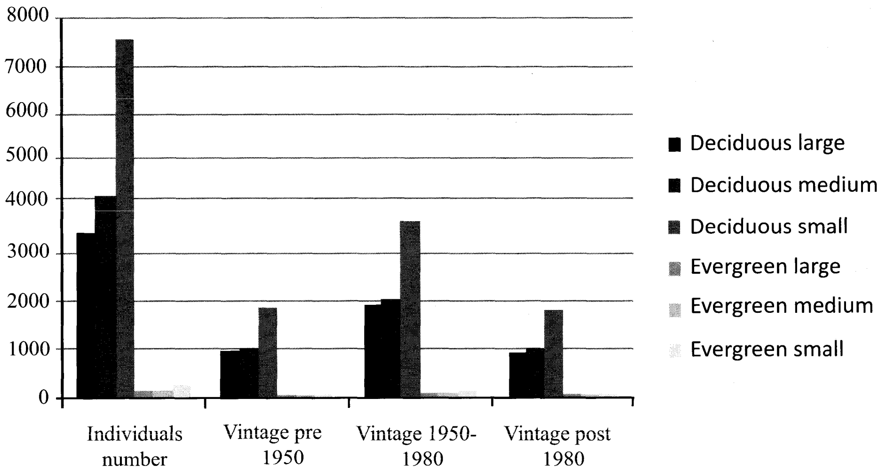

Figure 1.Tree numbers by type and by vintages

Table 1 shows the CO_2 reductions and releases estimated for each 5-year period and in each component process of the CO_2 cycle.

The total net amount of CO_2 saved (i.e. not emited to the atmosphere) for the entire 40 year period is estimated to be 14792 tonnes. At that point in time total releases (3919) will represent 25.8 % of gross sequestration (15187.56 t).

Table 1. Results obtained using the model. All values are expressed in tonnes of CO_2. Negative values (-): releases, Positive values: avoided emmisions.

Periods in years	1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	Total
Shade-cooling (1)	73.89	221.67	348.34	443.34	517.23	538.34	559.45	559.45	3261.71
Shade-heating (2)	-22.64	-36.94	-50.05	-56.01	-60.77	-61.96	-63.16	-61.96	-413.49
Windbreak-heating(7)	2.1	3.4	4.6	5.1	5.6	5.7	5.8	5.7	37.8
Climate-cooling (3)	4.82	19.28	43.37	67.46	86.74	101.20	113.24	118.06	554.17
Climate-heating (4)	0.72	2.89	6.50	10.12	13.01	15.17	16.98	17.70	83.09
Avoided energy use (∑1,2,3)	56.79	206.89	348.16	464.91	556.20	592.75	626.52	633.25	3485.50
Sequestration (5)	368.18	1288.64	2209.10	2669.33	2669.33	2347.17	2025.01	1610.80	15187.56
total released (6)	-95.57	-142.23	-265.34	-413.32	-557.80	-703.10	-820.86	-920.54	-3918.76
Net Sequestration	272.61	1146.41	1943.76	2256.01	2111.53	1644.07	1204.15	690.26	11268.8
Net CO_2 saved (∑1,2,3,5,6,7)	331.48	1356.69	2296.50	2726.05	2673.29	2242.48	1836.44	1329.19	14792.12

The maximum net CO_2 savings will be achieved in between 16 and 25 years with a decline later on because of CO_2 releases from tree decay and enhanced maintenance activities. For the 5 forthcoming years since the calculation of the model, net sequestration rate is 74 % of the gross carbon sequestration, due to the relative high proportion of trees of small and medium sizes (74 %). In 40 years the net sequestration rate will be 43 % representing a critical situation as tree decay increases.

For a projection of 40 years, savings due to evapotranspiration (554 tonnes CO_2) will represent 17% of savings by shade cooling (3262 tonnes CO_2). At the end of the projection, avoided energy use (633 tonnes CO_2) by savings in heating and cooling equals almost net sequestration (690.26 tonnes CO_2). This result shows also that old street trees might produce environmental benefits. As in the studied area, a small amount of evergreen trees had been planted, the relation "shade-heating" and "avoided energy use" is low (12 % on average). Therefore the disadvantage of using evergreen trees associated with winter shade (shade heating) represents less than 12. 67 % of the cooling savings from summer shade.

If we extrapolate our results to the 356,373 shade trees reported for Buenos Aires city (tree inventory, year 2000: www.buenosaires.gov.ar), the net CO_2 sequestration of the whole urban street trees could be estimated at 16.62 CO_2 tonnes/yr.

Our results are consistent with values reported in the bibliography and very similar to those from New York (15.33). In USA the mean value of CO_2 at a national level is 25.1 tonnes/ha of tree canopy. In Sacramento city with a dense tree canopy, the net yearly CO_2 sequestration was estimated at 46.9 ton/ha, while New Jersey City, a city with less urban greening, at 5ton/ha (Nowak & Crane 2002).

Our results showed the importance of the indirect effect of street trees on the urban environment. Energy savings and CO_2 sequestration are features to be considered, in urban planning and management specially in agglomerations like Buenos Aires, with high rates of storage per tree. Energy saving by shade is particularly important considering the present trend of increasing the cooling system based on air condition.

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