Carbon Dioxide Fluxes of Turfgrass Species in Urban Turfs in Hong Kong

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Abstract

The world is experiencing a historical shift in urbanization which has various consequences. The phenomenal urban heat island (UHI) effect, with both local and global effect on climate change can greatly affect our sensation of thermal comfort. One way to mitigate the UHI effect is urban greening, as plants can provide evaporative cooling and shading benefits. Besides, urban greenery can also sequester CO_2 in vegetation and soils. On the other hand, urban greenery systems which are under intense management and maintenance may contribute to the emission of CO_2 and other greenhouse gases.

We determined the C storage in 14 urban turfs in Hong Kong, which was 0.05 to 0.20 kg C m^{-2} for aboveground grass biomass, and 0.20 to 4.9 kg C m^{-2} for soils (to 15 cm depth). We also measured CO_2 fluxes for urban turfs in the wet season of 2012 and dry season of 2013 using a chamber-based technique. Our data demonstrated that grass species played a dominant role in CO_2 fluxes with seasonal changes, with respiration rates of all turfgrass species significantly higher in the wet season than in the dry season. Besides, maintenance practices of turfs in terms of fertilization and irrigation contributed to CO_2 emission, which may affect the C balance of urban greenery systems and their environmental benefits.

Key words: urban greenery, CO_2 flux, turfgrass, C balance, urban heat island effect

1. Introduction

A historic shift in urbanization has occurred recently. For the first time, global urban population has surpassed rural one and will continue to rise and reach 60% by 2030 (Grimm et al., 2008). With rapid urban development and population growth, global C flux pattern has undergone a dramatic shift in the past several decades and may play a critical role in global warming (Jo, 2002). Among C fluxes, CO_2 fixation by greenery has been widely used in urban landscaping to counteract the CO_2 emission problem (Zirkle et al., 2011). On the other hand, CO_2 emission from greenery may impact the C balance in urban ecosystems, and therefore has become an important factor in global C budget and climate change (Churkina, 2008 and 2012). Another contributor to the C budget of ecosystems is C emissions associated with management of urban greenery (Pouyat et al., 2002; Livesley et al., 2010). The release of all other greenhouse gases (GHGs) by greenery could also be affected by soil management such as fertilizer application and irrigation in urban lawns (Conant et al., 2001; Qian et al., 2003), subject to changes in other parameters such as soil types, moisture, temperature and other environmental conditions (Davidson et al., 2000; Jabro et al. 2008).

As such, net C balance has been assessed through quantifying C sequestrated in soil and vegetation in urban greenery systems, including green roofs (Getter et al., 2009), roadside planting (Kiran and Kinnary, 2011), golf courses (Selhorst and Lal, 2011), urban turfgrasses (Livesley et al., 2010; Qian et al., 2010; Selhorst and Lal, 2013). These studies underscore the importance of net C balance in urban ecosystem. Another important approach to evaluate the C balance of an ecosystem is C flux assessment based on chamber method, which is now widely used in many terrestrial ecosystems. Therefore, we investigated net ecosystem exchange (NEE) of CO_2 in urban with this C-flux approach, in an effort to help us better understand C pool and fluxes in urban ecosystems, and then hopefully guide better landscaping and urban planning.

2. Materials and Methods

2.1 CO_2 flux measurement method

An environmental gas monitor for CO_2 (EGM-4) (CO_2 gas analyzer using non-dispersive, infrared gas analysis coupled with microprocessor based signal processing), coupled with a soil respiration chamber and a canopy assimilation chamber (PP Systems, USA; Fig. 1) were applied to 14 urban turfs in Hong Kong with 5-10 replicates at each site. Turfgrass CO_2 exchange was measured during the wet season from August to September 2012, and dry season in January 2013.

Prior to measurements, the metal bases of the chambers were inserted 2 cm into the soil surface carefully to minimize the disturbance to surrounding grasses and roots. CO_2 fluxes were recorded at two minutes intervals with the accumulation of CO_2 within the chamber. The amount of photosynthetically active radiation (PAR, μmol m^{-2} s^{-1}) was recorded continuously with the light sensor installed inside of the chamber during CO_2 measurements. A fan within the chamber was designed to thoroughly mix the air during measurements. CO_2 fluxes were recorded 10 times on site, seven measurements under different PAR levels with the CPY-4 chamber and three measurements for dark respiration with the soil respiration chamber.

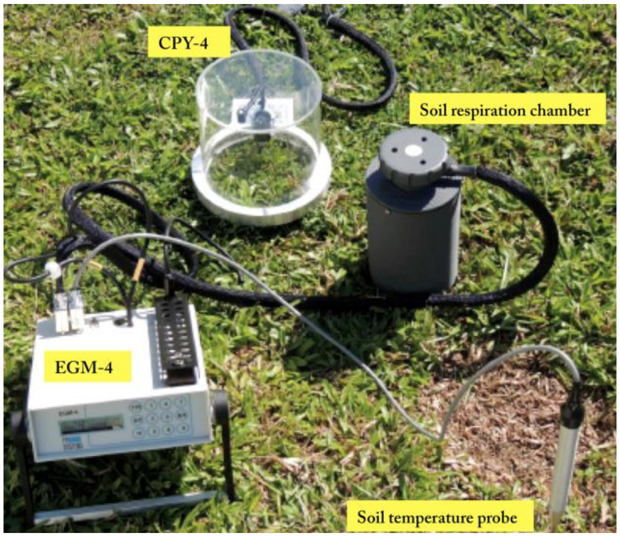

Fig. 1. Environmental gas monitor for CO_2 (EGM-4) with a canopy assimilation chamber (CPY-4), a soil respiration chamber and a soil temperature probe

2.2 Data analysis

The measured CO_2 flux by EGM-4 CO_2 analyzer represents net ecosystem exchange (NEE, g CO_2 m^{-2} h^{-1}) of CO_2 flux from the turfgrasses, soil and roots. Rs is ecosystem respiration (g CO_2 m^{-2} h^{-1}) measured by respiration chamber with PAR=0.

A positive value of NEE indicates that the ecosystem is a net source of CO_2 release when respiration (Rs) is dominating, whereas a negative value indicates the system is sequestering CO_2.

For each site, the relationship of NEE to PAR (CO_2 m^{-2} s^{-1}) for each turfgrass species fit well to a logarithmic model:

$$NEE= a*\ln (PAR) + b$$

where a and b represent the fitted curve parameters. There was one unique curve parameter sets derived for each species at all the turf sites both in the wet and dry seasons.

3. Results

3.1 C stock in turfgrasses

C concentrations of turfgrasses were from 41.9% to 45.9%, which was used for C density calculation.

The aboveground biomass (AGB) and C density of turfgrass in the studied turfs in Hong Kong are shown in Fig. 2. Turfgrass biomass ranged from 121 g m^{-2} in turf HKCC with *Cynodon dactylon* x *C. transvaalensis* to 508 g m^{-2} in turf UC with *Zoysia japonica*. Accordingly, C density of turfgrass was from 48.4 g C m^{-2} in HKCC to 203 g C m^{-2} in UC.

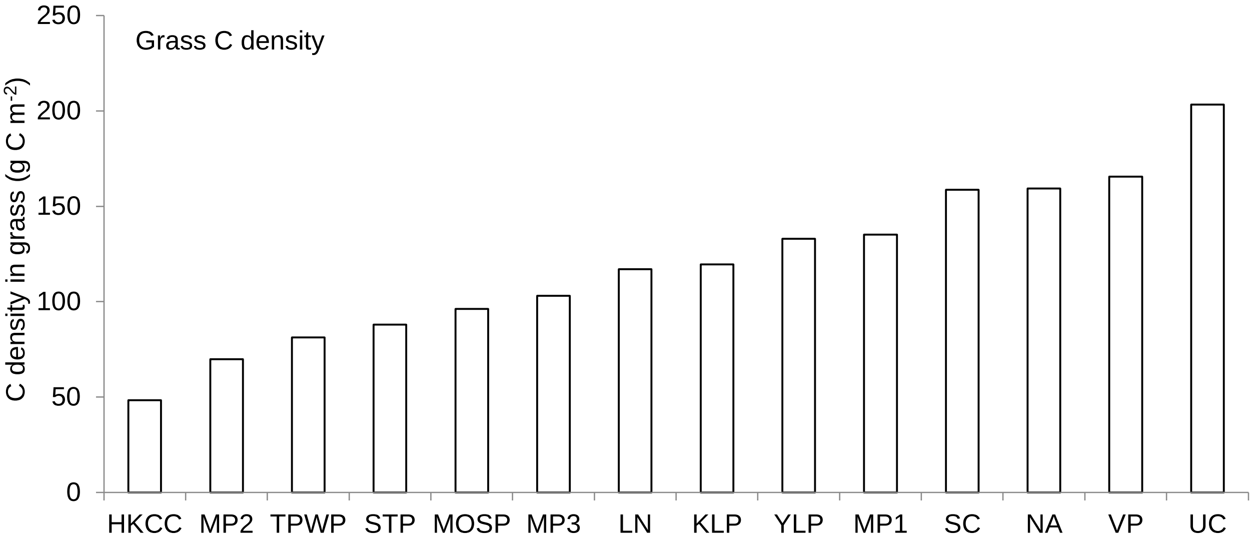

Fig. 2. Aboveground biomass (AGB) and C density of grasses in studied turfs

3.2 Vertical variation in soil C

Soil total carbon (STC) concentration equals to SOC because no inorganic carbon (IC) was detected in our soil samples with pH < 7.0, or close to 7.0. Soil C density peaked at 4.89 for soil 0-15 cm in NA.

SOC concentrations decreased with soil depth, with the highest value in the top layer of soil with depth 0-5 cm, followed by 5-10 cm, and the lowest value was detected in the depth of 10-15 cm. For 0-5 cm soil, SOC concentrations varied in the studied turfs, among which MOSP showed the highest value at 3.76%.

Similarly, SOC density varied among the studied turfs and decreased with soil depth (Fig. 3). The total amount of SOC density for soil 0-15 cm was the highest at 4.88 kg C m^{-2} in NA, while the lowest was 0.2 kg C m^{-2} in VP.

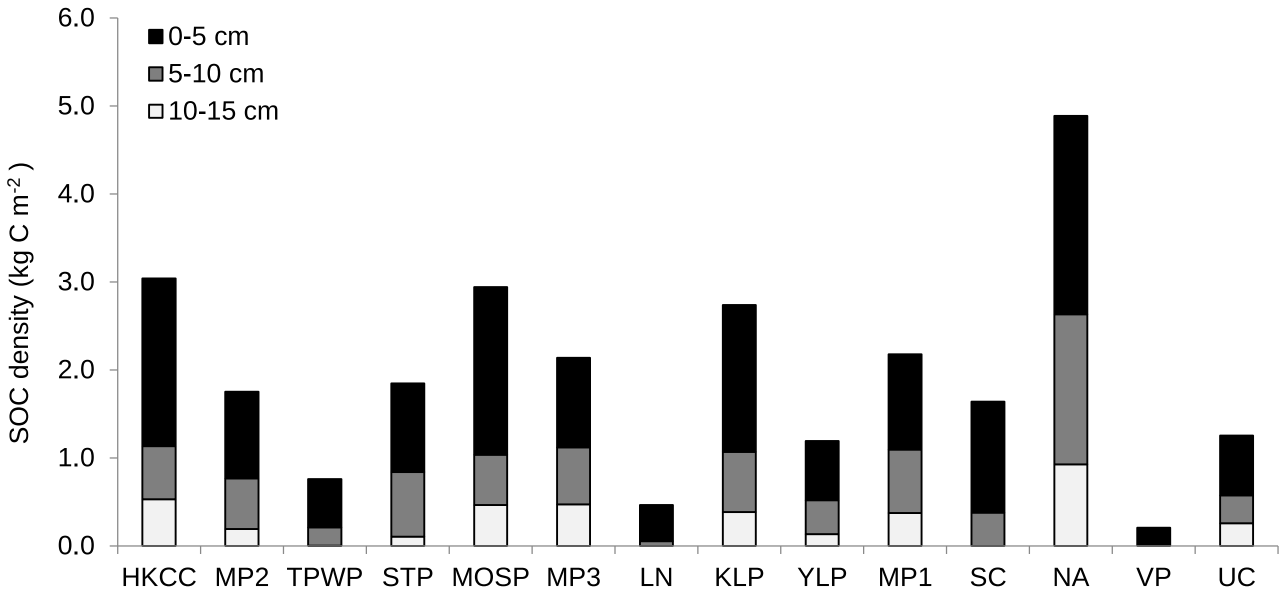

Fig. 3. SOC density for 0-5 cm, 5-10 cm and 10-15 cm in the studied turfs

3.3 Seasonal variation in CO_2 flux

We observed seasonal variations for NEE of CO_2. Wet season appeared to have generated relative higher values in the NEE of CO_2 than dry season in YLP, SC and VP for *A. compressus*, while *Cynodon dactylon* × *C. transvaalensis,* and *Z. japonica* had higher CO_2 flux in the dry season in HKCC and UC respectively. (Table 1). Turf system respiration rates were significant higher in the wet season than dry season, and decreased with the increase in soil C density among the sampling turfs in the wet season (Fig. 4). The same pattern is not obvious in the dry season in 2013 (from 0.67 to 1.40 g CO_2 m^{-2} h^{-1}), which was much lower than those in the wet season (1.18 to 3.21 g CO_2 m^{-2} h^{-1}) probably due to the lower plant productivity in the dry season.

Table 1. NEE of CO_2 at PAR 800 µmol m^{-2} s^{-1} in the studied turfs in the wet season of 2012 and dry season of 2013 (negative values denote CO_2 uptake by turfs)

Turf sites	Grass species	NEE (g CO_2 m^{-2} h^{-1})	
		(wet season)	(dry season)
HKCC	*Cynodon dactylon × C. transvaalensis*	-0.04	-1.90
TPWP	*A. compressus*	-0.84	-0.82
STP	*A. compressus*	-0.43	-0.58
MOSP	*A. compressus*	NA	-0.13
KLP	*A. compressus*	NA	-0.65
YLP	*A. compressus*	-1.1	-0.88
SC	*A. compressus*	-0.72	-0.58
VP	*A. compressus*	-1.1	-0.72
NA	*A. compressus*	NA	NA
MP1	*A. compressus*	NA	NA
MP2	*A. compressus*	NA	NA
MP3	*A. compressus*	NA	NA
LN	*Z. japonica*	NA	-1.09
UC	*Z. japonica*	-0.15	-1.16

NA: not available

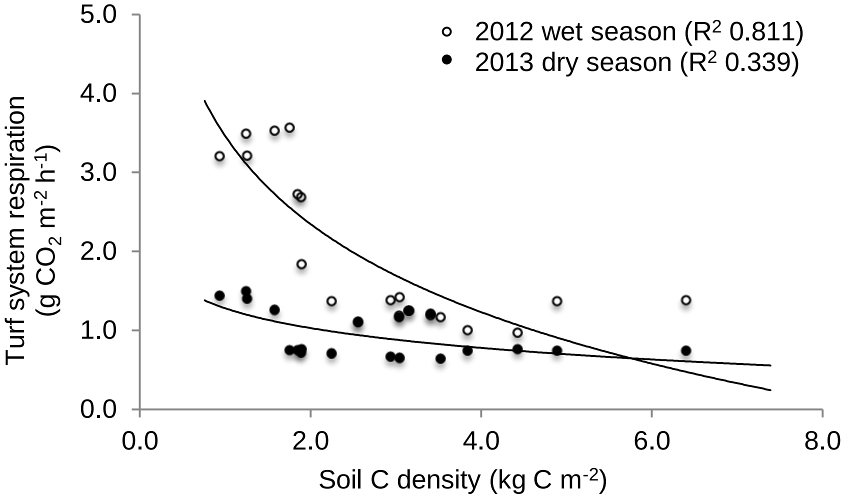

Fig. 4. Turf system respiration rates (g CO_2 m^{-2} h^{-1}) and its correlation with soil C density in turfs in wet season 2012 and dry season 2013 (from Kong et al., 2014)

4. Conclusions

Our results suggested that urban soil served as a C sink while it released CO_2 as well. CO_2 emission from soil surface was very sensitive to changes in soil moisture, with significant higher values in the wet season than dry season. Thus, irrigation was an important factor in controlling CO_2 release due to its role in altering soil moisture. Moderate watering is crucial in C emission and sequestration in soils, and overwatering should be avoided because it could accelerate CO_2 flux, shifting a turf system to a C source from C sink. Therefore, we propose that a rational design of maintenance schedule should be implemented for each turf based on its C stock and functional purposes to achieve a net C budget beneficial to the environment.

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