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Research Paper

Carbon dynamics of a warm season turfgrass using the eddy-covariance technique

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ABSTRACT

Despite their ubiquitous presence in the urban landscape throughout the United States, scant attention has been given to evaluate the magnitude of net carbon balance from turfgrasses. Warm season turfgrasses, in particular, have largely been understudied for their carbon sequestration potential. With questions being frequently raised on the environment friendliness of warm season turfgrasses, detailed and robust studies focusing on the carbon behavior of such systems are warranted. This study delves into the carbon balance of 'Tifway' bermudagrass, the extensively used warm-season turfgrass in Georgia and other subtropical and warm temperate areas. Using the eddy-covariance method, the amount of CO_2 captured by a highly managed turfgrass system was measured by deploying two eddy-covariance systems for the study period of 31 months. The results show that 'Tifway' bermudagrass is a net sink of carbon, sequestering it at the rate of 4.51–5.15 Mg C ha^{-1} yr^{-1}. The turf canopy as well as management activities carried out in the farm appear to have a powerful influence on the carbon behavior of the turf. Seasonal and monthly fluxes suggest that turf is an efficient assimilator of carbon during its active growth period of summer and fall months. The results show that the turf sequestered higher amounts of carbon than many agricultural crop systems, supporting the assertion that it is an efficient assimilator of atmospheric carbon.

1. Introduction

The world's population is increasingly concentrated in urban areas, leading to recent expansion in urban and built-in land use. By the end of 2014, fifty-four percent of the world's population was living in urban areas and this number is expected to increase to sixty-six percent by 2050 (data.worldbank.org). The proportion of the urban population is even higher (about 82% as of 2015) in the United States (data.worldbank.org). With urbanization, much of the pervious landscape (e.g. forests, agricultural lands) are being converted to both impervious surfaces (e.g. concrete) and to less pervious lands such as lawns, golf courses. Turfgrasses cover a land area of enormous magnitude in cities and megacities. They covered about 163,800 square kilometers, three times the area covered by irrigated corn, in the United States and about 5688 square kilometers in Georgia alone (Milesi et al., 2005). Currently, they make up about 20–30% of the urban landscape (Nowak et al., 2013). With the continued expansion of urban areas, the increasing percentage of land throughout the United States is expected to be converted into home lawns, recreational parks, golf courses and other greenbelts (Bandaranayake et al., 2003; Lorenz and Lal, 2009; Milesi et al., 2005; Qian and Follett, 2002). The rapid expansion of turfgrasses in the ever-growing urban areas not only exemplifies its popularity, but also highlights the necessity of research assessing its impact on the urban ecosystem.

Turfgrasses dominate a significant part of the urban landscape and it continues to expand, yet, carbon (C) exchange from these systems is poorly understood. Specifically, the C exchange from warm season turfgrasses like bermudagrass, that cover a significant part of urban lawns in southern United States (Duble, 1996), are understudied (Fissore et al., 2012; Wu and Bauer, 2012). Much of the previous turf related research were focused on cool season grasses (Bremer and Ham, 2005; Wu and Bauer, 2012) and only a few studies were related to warm season grasses (Dugas et al., 1999). In addition to their growing acreage in tropical, subtropical and warm temperate urban areas, their long growing season and highly efficient C_4 photosynthetic pathway make warm season turfgrasses an ideal system to study C behavior. In addition, they are characterized by dense canopy and extensive root system, making them one of the potentially effective C assimilating systems.

Turfgrasses offer a great advantage to the urban environment by

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sequestering atmospheric C in addition to making the urban landscape green (Conant et al., 2001; Gebhart et al., 1994; Golubiewski, 2006; Huh et al., 2008; Post and Kwon, 2000; Qian and Follett, 2002; Qian et al., 2010; Selhorst and Lal, 2013; Wu and Bauer, 2012). Urban lawns are potential assimilators of atmospheric C and owing to their dominant presence, they can sequester a significant amount of C in these urban soils.

With global warming being a growing concern worldwide, concerns over global climate change has intrigued an interest in quantifying the role of agricultural and non-agricultural soils as source or sink of atmospheric CO_2. While the public welcomes and views golf courses, soccer fields and home lawns as most desirable, the perception that turf is an environmental foe lingers because of the public perception that large amount of greenhouse gases from the turf system are released to the atmosphere. The veracity of this perception warrants robust, scientific evaluations. Thus, rigorous, scientifically robust and credible studies related to the carbon behavior of turfgrass systems are thus called for to endorse or dispel this negative public bias.

While most of the C related studies in turfgrasses are based on the analysis of soil organic C pools, the validation of these data is limited by meteorological and soil factors. Results from such studies are often affected by the vertical distribution of organic carbon (SOC) in the soil profile (Jobbagy and Jackson, 2000), its differential decomposition rate (Jenny, 1941; Schlesinger, 1977) and the accuracy by which they are measured (Wander et al., 1998). In recent years, the eddy-covariance method has emerged as a state-of-art technology providing spatially- and temporally-integrated flux measurements from a system (Leclerc and Foken, 2014; Leclerc and Thurtell, 1990; Rannik et al., 2012; Vesala et al., 2008). This method is more efficient than conventional soil sampling methods and provides uninterrupted flux data for the system.

This study makes use of the highly efficient eddy-covariance system in warm season turfgrass, making it one of the first of its kind turf research. Through our study, we have quantified the CO_2 fluxes from a highly managed commercial sod farm, differentiating this study from usually researched golf courses, home lawns and natural grasslands. The present study delves into the spatial and temporal dynamics in CO_2 fluxes over a warm season turfgrass cultivar and gained insight on its source-sink potential. In addition, we have used two eddy-covariance systems in this study. Two eddy-flux systems on each side of the field offer more advantages than one in the middle, given the relatively small area of the experimental site. First, only one eddy-flux system in the middle of the field would not allow sufficient spatial extension. Two systems on each side of the field offer sufficient fetch, albeit only in some directions. Combining data from the two towers would provide full fetch coverage of the experimental site. Second, this set up would be able to capture the upwind source coming all flow directions of the field during different seasons of the year.

This study addresses 1) the diurnal, seasonal and annual variations in C fluxes in warm season turfgrass, 2) C budgets of a managed commercial sod farm.

2. Methods

2.1. Site description

The experimental site is a twenty-seven-acre (0.1 km^2) section of a commercial sod farm (Super Sod, Middle Georgia) located in south-central part of Georgia near Fort Valley. The site is an ideally flat terrain with homogeneous vegetation (Tifway 419 bermudagrass) meeting the quasi-ideal conditions for eddy-covariance measurements. The general field layout and instrument locations at the experimental site are shown in Fig. 1. A stretch of non-experimental turf separates the site 450 m from Highway 96 in the north and 1000 m from Interstate 75 in the west. A thin strip of land (about 10 m) separates the experimental site from a pecan orchard to the south, while abandoned lots lay on the east side. There is a small lake west-north west (WNW) of the site.

This area is subject to warm temperate continental climate with a mean annual air temperature (hereafter referred to as T_{air}) of 17.7 °C and annual rainfall amounts averaging to 1877 mm (http://en.climatedata.org/location/135830/). This area consists primarily of sandy loam soil (http://websoilsurvey.nrcs.usda.gov). The dominating wind for the site during the study was easterly and westerly (Fig. 2). During the study, the average T_{air} was 18.08 °C, which coincides with the historical average T_{air} of the area. The highest recorded T_{air} during this period was 36.15 °C in July of 2015 and the lowest was −12.30 °C in January of 2015. The field received a total of 2,433.06 mm of rainfall during the 31-months study.

2.2. Instrumentation

The instrumental setup consisted of two eddy-flux systems installed on opposite corners of the field. Tower 1 (T1) was installed in the east corner (32°32′29" N, 83°43′46" W) of the field facing west (240° from north) at an elevation of ~121 m, while Tower 2 (T2) was installed in the west corner (32°32′21" N, 83°43′52" W) of the field facing east (20° from north in 2013 and 28° from north from 2014 onwards) at an elevation of ~119 m. Each eddy-flux system consists of a three-axis sonic anemometer (CSAT3, Campbell Scientific, Logan, UT) and a fast-response open-path infrared gas analyzer (LI7500, Li-COR Inc., Lincoln, NE) mounted at the height of 1.5 m above the ground. Both systems were powered by two 12 V DC deep cycle batteries that were charged using a 120 W solar panel. These systems measure three-dimensional wind components, air temperature, and concentration of water vapor and CO_2. The height and location of the two towers were chosen to minimize any outsource fluxes and to ensure that the CO_2 fluxes measured by these systems are directly influenced by the specific cultivar selected for the study.

Belowground measurements, consisting of soil temperature (hereafter referred to as T_{soil}) and soil water content (hereafter referred to as SWC) profiles, were made at the base of Tower 2. T_{soil} was measured by custom-built chromel-constantan thermocouples placed at depths of 0.02, 0.05, 0.1, and 0.2 m. Soil water content (SWC) was measured using time domain reflectometry sensor (CS616, Campbell. Scientific, Logan, UT) placed at the depths of 0.02, 0.05, 0.1, and 0.2 m. Soil heat flux was measured using two heat plates (HFT-3, Campbell Scientific, Logan, UT) placed 0.9 m apart at depths of 0.08. The average temperature of the soil layer above the plate was measured using four parallel thermocouples (TCAV, Campbell Scientific, Logan, UT) placed at depths of 0.02 m and 0.06 m above each heat plate. Soil water content was measured using CS616 reflectometer placed at a depth of 0.025 m.

An automatic weather station (ET106, Campbell Scientific, Logan, UT) was installed 2 m above the ground (32°32′24" N, 83°43′51" W, at an elevation of 121 m) to measure standard meteorological parameters such as precipitation, wind speed and direction, air temperature and relative humidity. The weather station was powered by a 7 AHr sealed-rechargeable battery that was charged by a 12 W solar panel. A motion camera (Simmons Whitetail Trail Camera – 4 MegaPixel) was also mounted on each eddy-flux tower to document any unattended management activities carried out in the field. A light box was used to take digital pictures of the turfgrass canopy (Haselbauer et al., 2012) during regular field visits. To ensure consistency of the images, all the images were taken using the same camera settings as well as the same locations (5, 13, 21 and 29 m from the eddy-flux systems in the direction of the sonic anemometer).

2.3. Meteorological and eddy-covariance measurements

The flux measurements were taken at a sampling rate of 20 Hz for June–September 2013 and 10 Hz for the rest of the measurement period; and were stored in high performance CR1000 dataloggers