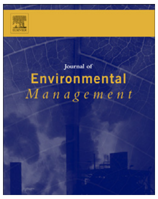
Journal of Environmental Management 151 (2015) 233–242

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman



The effects of household management practices on the global warming potential of urban lawns

Chuanhui Gu [a, *], John Crane II [b], George Hornberger [b], Amanda Carrico [c]

[a] *Department of Geology, Appalachian State University, Boone, NC 28607, USA*
[b] *Vanderbilt Institute for Energy and Environment, Vanderbilt University, PMB 407702, 2301 Vanderbilt Place, Nashville, TN 37240-7702, USA*
[c] *Environmental Studies Program, University of Colorado Boulder, UCB 215, Boulder, CO 80309, USA*

ARTICLE INFO

Article history:
Received 13 September 2014
Received in revised form
31 December 2014
Accepted 4 January 2015
Available online 9 January 2015

Keywords:
Greenhouse gases
Global warming potentials
Soil organic carbon
Lawn management
Nitrous oxide

ABSTRACT

Nitrous oxide (N_2O) emissions are an important component of the greenhouse gas (GHG) budget for urban turfgrasses. A biogeochemical model DNDC successfully captured the magnitudes and patterns of N_2O emissions observed at an urban turfgrass system at the Richland Creek Watershed in Nashville, TN. The model was then used to study the long-term (i.e. 75 years) impacts of lawn management practice (LMP) on soil organic carbon sequestration rate (dSOC), soil N_2O emissions, and net Global Warming Potentials (net GWPs). The model simulated N_2O emissions and net GWP from the three management intensity levels over 75 years ranged from 0.75 to 3.57 kg N ha^{-1} yr^{-1} and 697 to 2443 kg CO_2-eq ha^{-1} yr^{-1}, respectively, which suggested that turfgrasses act as a net carbon emitter. Reduction of fertilization is most effective to mitigate the global warming potentials of turfgrasses. Compared to the baseline scenario, halving fertilization rate and clipping recycle as an alternative to synthetic fertilizer can reduce net GWPs by 17% and 12%, respectively. In addition, reducing irrigation and mowing are also effective in lowering net GWPs. The minimum-maintenance LMP without irrigation and fertilization can reduce annual N_2O emissions and net GWPs by approximately 53% and 70%, respectively, with the price of gradual depletion of soil organic carbon, when compared to the intensive-maintenance LMP. A lawn age-dependent best management practice is recommended: a high dose fertilizer input at the initial stage of lawn establishment to enhance SOC sequestration, followed by decreasing fertilization rate when the lawn ages to minimize N_2O emissions. A minimum-maintained LMP with clipping recycling, and minimum irrigation and mowing, is recommended to mitigate global warming effects from urban turfgrass systems. Among all practices, clipping recycle may be a relatively malleable behavior and, therefore, a good target for interventions seeking to reduce the environmental impacts of lawn management through public education. Our results suggest that a long-term or a chronosequence study of turfgrasses with varying ages is warranted to capture the complete dynamics of contribution of turfgrasses to global warming.

1. Introduction

Urban residential lawns comprise the majority of intensely managed turfgrass systems, covering 1.9% of land in the continental United States (Milesi et al., 2005) and increasing at an annual rate of 800,000 ha (U.S. Depart. of Housing and Urban Development, 2000). Typical lawn maintenance involves mowing, management of lawn clippings, fertilization, irrigation, etc. Maintaining an aesthetically appealing lawn is a common driver for lawn irrigation and fertilization (Nielson and Smith, 2005). Currently, turfgrass is the most irrigated crop in the U.S. (Milesi et al., 2005) and fertilization rates are close to agronomic row crops and golf courses (Barthe, 1995). Between 50 and 70% of homeowners throughout the U.S. fertilize their lawns regularly, but only a few homeowners base their application rates on soil test recommendations (Barthe, 1995; Fissore et al., 2011; Law et al., 2004; Robbins et al., 2001).

Urban lawn management practices such as no-till, irrigation and fertilization enhance net primary production and soil organic carbon (SOC) storage in turfgrass systems (Bandaranayake et al., 2003; Qian and Follett, 2002; Selhorst and Lal, 2013). Furthermore, turfgrasses are a perennial plant and have capability of long-term SOC

---

* Corresponding author.
E-mail address: guc@appstate.edu (C. Gu).

http://dx.doi.org/10.1016/j.jenvman.2015.01.008
0301-4797/© 2015 Elsevier Ltd. All rights reserved.

storage (Pouyat et al., 2006). Turfgrass soils have a 2-fold higher SOC density than rural forest soils in southeast US (Pouyat et al., 2006). The carbon sequestration rates in golf fairways in Colorado can sequester SOC at a rate of 1.0 Mg ha^{-1} yr^{-1} during the first 25 years after conversion from crop land or native grassland (Qian and Follett, 2002). Conversion of arable lands to perennial grasses sequestered 1.1 Mg C ha yr^{-1} with fertilizer and irrigation (Post and Kwon, 2000). Increased fertilizer and irrigation management in a golf courses converted from farmlands sequesters an average of 3.1 Mg C ha^{-1} yr^{-1} (Selhorst and Lal, 2011).

Lawn management can also increase soil emissions of other greenhouse gases (GHGs), such as nitrous oxide (N_2O) (Groffman et al., 2009; Kaye et al., 2004; Townsend-Small and Czimczik, 2010). Lawn care practices can provide optimum conditions for N gaseous losses as N_2O, especially lawns receiving sufficient N and water. N_2O is a GHG with 310 times greater global warming potential (GWP) than CO_2 on a per molecular basis over a 100-yr time frame (IPCC, 2007). Rainfall or irrigation, especially right after fertilizer N applications, enhances N_2O emission, because the water inputs provide soil moisture contents essential for enhancing the nitrification and denitrification processes (Horgan et al., 2002). In addition, soil N_2O emission in turfgrass ecosystems might be enhanced by the increased SOC pools, thus increased supply of substrates for nitrification and denitrificaiton (Bouwman et al., 2002). N_2O emission has been found to overcompensate for carbon sequestration in arable lands (Robertson et al., 2000) and urban turfgrass (Townsend-Small and Czimczik, 2010). Nevertheless, the impacts of turfgrass management practices of mowing, irrigating, fertilizing, and clipping placement on N_2O emissions and carbon sequestration in turfgrass ecosystems remain unclear. A complete turfgrass carbon and nitrogen cycle must be understood to develop best management practices (BMPs) for turfgrass to promote healthy turfgrass ecosystem and mitigate greenhouse gases emissions. In addition to the biogeochemical processes, it is important to understand typical lawn management practices and the motivations for these practices. This information will provide a baseline against which to estimate GHG emissions reductions if lawn management practices were changed. In addition, this information can help decision makers select behaviors to target in outreach effort as well as strategies for changing those behaviors (Carrico et al., 2011; Dietz et al., 2009). Together this information can help inform the development of more effective BMP guidelines and communications.

To understand global warming contributions of turfgrass ecosystems, a full budget of all greenhouse gases and SOC sequestration, as well as CO_2 emitted from energy use in lawn management is warranted. Nevertheless, it is impractical to make multi-decadal simultaneous measurements of SOC, N_2O, and CH_4 emissions. To address this issue, a process-based model was adopted io assess the impacts of turfgrass management practices on SOC sequestration, N_2O and CH_4 emissions, and net global warming potentials (GWP). The objectives of this study were: 1) to measure the impacts of common lawn care management regimes on N_2O fluxes at residential lawn sites at Nashville, TN; 2) to investigate the N_2O and net GWP mitigation measures including variations of fertilizer application, irrigation, clipping placement, and mowing; and 3) to determine the net GWP of turfgrasses over time for three levels of lawn management intensity; 4) to examine the relation between lawn management practices and lawn appearance concerns and environmental concerns. The results can provide crucial insights into the potential role turfgrasses play in climate change and help develop BMPs for minimizing the global warming potential of turfgrasses.

2. Materials and methods

2.1. Study sites

Much of the data used in these analyses were collected as part of the Nashville Yard Project, an interdisciplinary project examining the environmental impacts of lawn care, as well as the psychological, social, and legal influences on lawn management behavior. The study site is the Richland Creek Watershed (RCW), which encompasses an area of 73.8 square kilometers in Metropolitan Nashville, Tennessee. The RCW is comprised mostly of private residences, but also contains several municipal parks, four golf courses, and some industrial sites near the Cumberland River. The Tennessee Department of Environment and Conservation lists the RCW as impaired due to excessive nutrient pollution and *Escherichia coli*.

2.2. N_2O measurements

Nitrous oxide emissions were monitored using the closed chamber method (Crane II and Hornberger, 2012) between Jan 1 2012 and Dec 31 2012. For each measurement, the chamber was fitted to a PVC collar permanently installed into the lawn soil to form a tight seal. During non-sample collection periods, the area of the landscape within the collars remained open to the atmosphere. The static chamber tops were tightly fitted on the collars for 30 min to allow the N_2O gas to accumulate under the chamber, and samples were taken 0, 15, and 30 min after chamber top placement. N_2O samples were analyzed $\leq$48 h after sample collection using a Shimadzu GC-2010 Plus (Shimadzu Scientific Instruments, Kyoto, Japan).

2.3. The DNDC model

In this study, we applied the DNDC (DeNitrification–DeComposition) model to simulate turfgrass growth, soil carbon and nitrogen cycles, and trace gas emissions under a wide range of turfgrass management conditions. DNDC is a process-based model that simulates carbon and nitrogen cycling processes in soil-plant-atmosphere system (Li et al., 1992). The detailed description of the DNDC model has been presented by Li, (2000) and Zhang et al., (2002).

The DNDC perennial grass crop parameter set gave the closest match to turfgrass in this study. We modified the default parameterization for perennial grasses to reflect the characteristics of turfgrass ecosystems. Adjustments of the following default DNDC settings: Leaf and stem C:N ratio was assigned to 20 and root C:N ratio was assigned to 40 to account for the lower C:N ratio of leaf, litter, and fine roots of fertilized and irrigated turfgrass (Qian et al., 2003).

We simulated mowing activities as numerous biomass cutting events. 8% of aboveground standing biomass was cut off during each mowing (Qian et al., 2003). We then simulated clipping recycle as green manure application. Green manure is equivalent to fresh plant residue.

2.4. Model input data

Site specific soil texture was obtained from the USDA web soil survey. We collected soil samples using a tube sampler. We took a sample in conjunction with the household survey so we have up to 348 samples, and sent the soil to the University of Tennessee Agricultural Extension (UTAE) for analysis of soil bulk density, porosity, pH, and organic carbon content. The soil sampling and analysis followed the protocol of the UTAE. Meteorological data