TEMPORAL COMPARISON OF GREENHOUSE GAS EMISSIONS BETWEEN FOUR DIFFERENT RIPARIAN LAND-USE TYPES IN SOUTHERN ONTARIO, CANADA

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Abstract

Soils are one of the largest contributors of greenhouse gas (GHG) emissions, particularly CO_2, but the emissions from riparian buffer soils are largely un-accounted for. It is important to quantify and compare land-use types in order to find the best way to potentially mitigate or offset GHG emissions, while protecting stream quality. The goals of the study are to determine and compare GHG (CO_2, CH_4, N_2O) emissions between a grassed buffer, an undisturbed natural forest, a 32-year old rehabilitated forested riparian buffer, and an agricultural field (corn-soybean rotation) found along Washington Creek, Oxford County, Ontario. Highest seasonal CO_2 emissions were observed from the grassed buffer and highest seasonal N_2O emissions were found at the AGR site. Neither of these were found to be statistically significant. However, the UNF site had significantly higher seasonal CH_4 emissions than all other land-use types. Further comparisons of soil characteristics were conducted to determine influences on emissions between land-use types.

Keywords: greenhouse gas; riparian buffer; soil; carbon dioxide; nitrous oxide, methane; land-use type

Introduction

When managed as an agroforestry land-use system, riparian buffers (RBs) are defined as a tree-based vegetative strip between agricultural fields and water courses that intercept indirect sources of pollution from upland agricultural runoff (Tufekcioglu et al. 1999). The role of RBs is to provide various environmental services, such as reducing streambank erosion and sedimentation, creating wildlife habitat, enhancing carbon sequestration, enhancing streamside microclimate, and filtering contaminants and pollutants from surface agricultural runoff (Gregory et al. 1991; Montagnini and Nair 2004; Verhoeven et al. 2006). These services result in increased water quality and habitat. However, there are potential environmental disservices as a result of RBs being efficient at filtering nitrogen (N) runoff and the high carbon (C) availability, working together to make RBs potential hot spots for soil greenhouse gas (GHG) emissions (Shrestha et al. 2009). Despite this concern of RBs as a GHG source, there is a lack of studies [illegible] ation is crucial [illegible] ssions, as this has future implications for contributions to climate change. Therefore, the goal of this study is to quantify and compare GHG emissions from four different land-use systems on a temporal scale. The specific objectives of the study are (1) to determine and compare GHG (CO_2, CH_4, N_2O) emissions between a grassed buffer (GRS), an undisturbed natural forest (UNF), a 32-year old rehabilitated riparian forest buffer (RH), and an agricultural field (corn-soybean rotation) (AGR); and (2) to quantify and compare the relationship between temporal GHG emissions, soil moisture, soil temperature, soil organic C, and ammonium and nitrate in the GRS, UNF, RH and AGR land-uses.

Materials and methods

This study will be conducted at sites found along Washington Creek, a spring-fed first-order tributary, in the Township of Blandford-Blenheim in Oxford County (43”18’N, 80”33’W). Simple random sampling was used to distribute four (n=4) GHG chambers in each land-use type. Chambers consist of white, non-reflective PVC piping (25 cm height, 10 cm radius), and ventilated PVC caps, covered in an insulated reflective coating (Lutes et al. 2016). Deployed chambers were permanently sit 10 cm into the soil, with 15 cm of headspace above the soil surface (Lutes et al. 2016). Gas samples will be taken bi-weekly and at the time of sampling, gas samples were extracted from the headspace using a syringe for each chamber at 0, 10, 20 and 30 minutes. All gas samples will be analyzed on a Gas Chromatograph. At the same time as GHG sampling, soil temperature and moisture were quantified using a W. E. T. sensor, and soil samples were collected to a 10cm depth within a 1m radius of each GHG chamber (Estefan et al. 2013). These soil samples were analyzed for ammonium and nitrate using a UV-Vis Spectrophotometer (Doane and Horwath 2003).

Linear mixed models were used to make comparisons where there were within- and between-sample variation, due the observations not being independent (i.e. repeated measures). Linear mixed models were run on both GHG data and soil characteristic data. Tukey’s post hoc test was used to find significant differences between land-use type.

Results

Mean soil temperature in the summer and the fall were 18.89°C and 10.71°C, respectively. Throughout the sampling period, the highest soil temperature was 26.90°C recorded at the AGR site and the lowest was 4.00°C recorded at the UNF site. The AGR experienced the highest mean soil temperature in the summer, while the GRS experienced the highest in the fall; though, this was quite similar to the AGR (0.11°C difference) (Table 1). However, the soil temperature at the AGR site was found to be significantly higher than all other land-use types. The lowest mean soil temperature for both summer and fall was recorded at the UNF site. Variation between land-use types is most apparent between the AGR and UNF sites, with a mean temperature difference of 3.91°C. For all land-use types, the temperature significantly decreased in the fall. Mean volumetric moisture content in the summer and fall were 37.97% and 40.04% respectively, with the highest recording being 63.50% at the UNF site and the lowest recording being 13.40% at the AGR site. In the summer, the RH has a significantly higher soil moisture than the AGR site, and the UNF site was significantly higher than all the other land-use types (Table 1). In the fall, the UNF site was once again significantly higher than all the other land-use types. There appears to be no significant difference in moisture content between seasons.

Table 1: Mean seasonal soil temperature (°C) and soil moisture content (% volume) for an agricultural field (AGR), grassed buffer (GRS), rehabilitated riparian forest buffer (RH) and an undisturbed natural forest (UNF) along Washington Creek, southern Ontario, Canada during 2017. Standard errors are shown in brackets.

	Season	AGR	GRS	RH	UNF
Soil Temperature (°C)	Summer	**21.43 (0.46)^{AX}**	18.67 (0.35)^{BX}	18.04 (0.30)^{BX}	17.52 (0.20)^{BX}
	Fall	11.68 (1.21)^{AY}	11.79 (1.27)^{AY}	10.49 (1.09)^{AY}	**9.33 (1.07)^{AY}**
Soil Moisture (% vol)	Summer	**25.64 (2.04)^{AX}**	32.42 (1.22)^{ABX}	38.33 (1.15)^{BX}	55.00 (1.10)^{CX}
	Fall	28.93 (1.23)^{AX}	37.41 (1.18)^{AX}	35.79 (2.20)^{AX}	**55.26 (1.11)^{BX}**

*Significant differences between land use type is detonated by ABCD, while significant differences between seasons are shown with XY.

Mean seasonal GHG emissions for the summer were 43.65, 211.23 and 179.89 measured in μg GHG m^{-2} h^{-1} for N_2O, CO_2 and CH_4, respectively. For the fall, mean GHG emissions were 24.94, 161.88 and 239.31. The GRS site had the highest mean summer and fall CO_2 emissions, while the other 3 land-use types had similar mean emissions (Table 2). The GRS site did not have much seasonal variation in CO_2 emissions, but all other land-use types decreased in the fall. However, there were no significant differences between land-use types for CO_2 emissions in the summer or the fall. The RH site had the lowest mean summer N_2O emissions. The RH site was significantly lower in CO_2 emissions than all the other land-use types. The AGR site had the highest mean summer and fall N_2O emissions, with the GRS and UNF sites producing similar emissions. The AGR site and GRS site didn't vary substantially between seasons, but the UNF site roughly doubled its mean N_2O emissions between the summer and fall. These differences between seasons were not found to be statistically significant. Finally, the highest mean seasonal CH_4 emissions for both the summer and fall were observed at the UNF site, with emissions almost doubling in the fall (Table 2). CH_4 emissions were significantly higher at the UNF site compared to all the other land-use types, with the next highest at the RH site. Both the AGR and GRS sites were on average not emitting CH_4 in the summer and fall, while the RH site had positive mean CH_4 emissions for the summer but not for the fall. Seasonal differences in CH_4 emissions were not found to be statistically significant.

Table 2: Mean seasonal CO_2-C emissions (μg CO_2-C m^{-2} h^{-1}), N_2O-N emissions (μg N_2O-N m^{-2} h^{-1}), and CH_4-C emissions (μg CH_4-C m^{-2} h^{-1}) for an agricultural field (AGR), grassed buffer (GRS), rehabilitated riparian forest buffer (RH) and an undisturbed natural forest (UNF) along Washington Creek, southern Ontario, Canada during 2017. Standard errors are shown in brackets.

	Season	AGR	GRS	RH	UNF
CO_2-C	Summer	159.14 (18.90)^{AX}	**366.15 (86.06)^{AX}**	163.13 (21.13)^{AX}	154.34 (26.81)^{AX}
	Fall	**73.13 (18.41)**^{AX}	316.90 (88.31)^{AX}	93.82 (17.82)^{AX}	116.70 (35.77)^{AX}
N_2O-N	Summer	**64.03 (15.48)^{AX}**	21.98 (5.66)^{AX}	38.93 (12.22)^{AX}	21.33 (17.72)^{AX}
	Fall	62.27 (16.87)^{AX}	18.55 (3.33)^{AX}	**5.30 (2.96)^{BX}**	53.94 (28.23)^{AX}
CH_4-C	Summer	-13.14 (19.74)^{AX}	**-59.16 (26.91)^{AX}**	22.86 (30.59)^{AX}	760.97 (279.89)^{BX}
	Fall	-55.10 (39.33)^{AX}	-44.46 (13.88)^{AX}	-12.37 (11.46)^{AX}	**1272.05 (470.82)^{BX}**

*Significant differences between land use type is detonated by ABCD, while significant differences between seasons are shown with XY.

Discussion

The GRS site had substantially higher CO_2 emissions than all other land-use types in both the summer and fall. Gritsch et al. (2015) did a similar study and yielded similar results, for they also observed the grassland site having the highest CO_2 emissions, followed by forested and arable land, which had similar emissions. Schaufler at al. (2010) also found similar results, indicating that the high C and N contents, dense root systems and high C inputs from decaying matter result in grassed sites having high CO_2 emissions. Additionally, in higher latitudes emissions are highly effected by temperature increases (Schaufler et al. 2010). This likely explains the drop in CO_2 emissions across all land-use types in the fall, for moisture content remained similar but the temperature decreased for all land-use types. Soil needs some air-filled pore space in order for soil microbes to carry out decomposition and subsequent respiration (Gristch et al. 2015), which explains why there were little emissions from the UNF site as the soil was oversaturated.

The highest CH_4 emissions were observed at the UNF site. This is again consistent with Schaufler et al. (2010), as there is a positive relationship between CH_4 emissions and moisture content of soil. Additionally, CH_4 production requires anaerobic conditions, which indicates why both the AGR and GRS sites had no emissions (Smith et al. 2003). The RH site had very little CH_4 emissions on average in the summer, and then no emissions in the fall. This likely, again, can be attributed to the soil not being fully anaerobic (Smith et al. 2003). Temperature has been shown to have little effect on CH_4 emissions, therefore changes in emissions likely cannot be attributed to falling temperatures in the fall or differences between land-use type (Schaufler et al. 2010; Smith et al. 2003).

Seasonal precipitation will have the largest impact on N_2O emissions, and proportion of soil pores occupied by water will determine the magnitude (Rochette et al., 2018). Therefore, the low soil moisture content at all land-use types likely explains low N_2O emissions, except the UNF site where soil moisture was often above 50%. Since the soil at the UNF site was oversaturated, the lack of oxygenated pores for N_2O to escape likely resulted in denitrification leading to the release of N_2 (Smith et al. 2003). The slightly elevated emissions at the AGR site may be explained by synthetic inputs of N, though, it has been proven that in well-aerated soils or dry climates the impact of this input is masked, as soil environmental conditions are the main drivers of N_2O emissions and denitrification (Rochette et al. 2018; Pilegaard et al. 2006). Therefore, these higher emissions are more likely a result of increased soil temperature (Smith et al. 2003).

In the fall, the RH site had much higher emissions of N_2O. A study by Pilegaard et al. (2006) looked at regional differences in forest soil N_2O emissions and found that in deciduous forests N_2O emissions are higher due to a compact and moist litter layer. This likely explains higher rates in the RH and UNF sites in the fall, for both are predominantly deciduous.

Conclusion

GHG emissions do not appear to be higher at any one land-use type along Washington Creek, Ontario. Highest CO_2 emissions were seen at the grassed buffer site, which is in tune with other studies' findings, but they were not found to be statistically significant. Similarly, the seasonal N_2O emissions were highest at the AGR site, but this was not significant. However, the RH site produced significantly lower emissions than all other sites in the fall. This is very important, as the riparian buffer has the potential to be a hot spot for N_2O emissions due to the incoming plant available nitrogen from the neighbouring agricultural field. Temperature likely played a role in this result. The highest CH_4 emissions were at the UNF site, showing significantly higher emissions than all other land-use types. This is likely due to the soil being oversaturated. Another field season will be conducted to observe spring emissions to include the freeze-thaw emissions, as well as another summer and fall field season to strengthen comparisons. Further comparison studies will be conducted to see what soil characteristics are influencing emissions, as in accordance with the Agricultural Greenhouse Gas Project (AGGP).

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