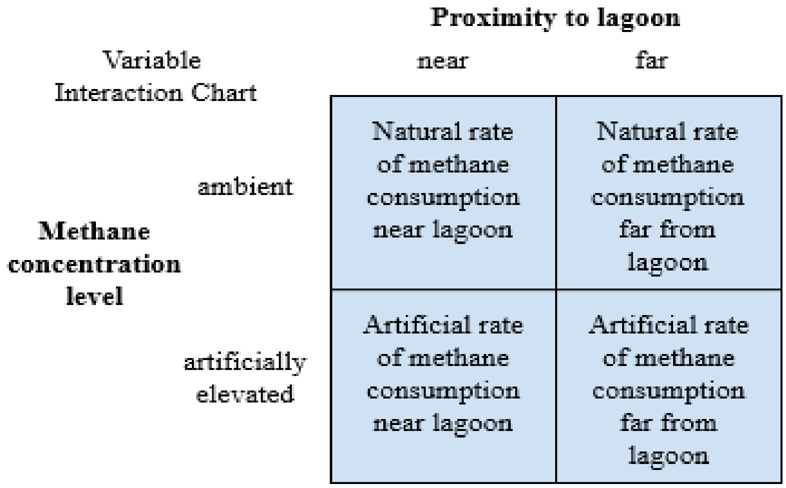
Quantifying the Effect of Methane Production on Surrounding Soil Atmospheric Gas Exchange

Abstract:

By observing the behavior of soil microorganisms with respect to proximity to a methane production site (dairy farm lagoon), the relationship between anthropogenically manipulated atmospheric methane levels and methane consumption was more thoroughly investigated than in previous studies. The purpose of this study is to understand how human activity affects soil microbial populations, which has potential to lead to better management practices in order to reduce net methane emissions. No significant was found between the distance from the methane production site and the level of methane consumption by the surrounding soil.

Introduction:

A rising standard of living combined with rising populations has a positive influence on greenhouse gas emissions. A greater demand for high protein foods calls for an expansion in the meat and dairy industry. This is under scrutiny from climatologists as greenhouse gas emissions threaten the stability of our climate and ecosystems. Approximately 13.7% of agricultural greenhouse gas emissions are manure management related, 50% of which comes from dairy production, though research has estimated that these reported numbers may be underestimated by up to 130% (Leytem et. al. 2017), and dairy cattle are just one form of methane emissions that are influencing atmospheric gas concentrations, such as fossil fuel combustion, irrigated rice cultiva- tion, enteric fermentation of domestic ruminants, biomass burning, which accumulates to 75% of total CH4 emissions (Kirschke et al., 2013). To understand and quantify the impact we have on our environment, it's necessary to understand the Earth's natural cycles of carbon and climate regulation, in which the soil plays a significant role as a reservoir of carbon. With proper understanding of methane cycling, it is possible to stabilize emissions with adapted management methods, potentially reducing global temperature increase by 25% (Thompson et al. 1992). The goal of this project is to better understand methane cycling specifically with respect to anthropogenic emissions and the role of soil microorganisms.



Variable Interaction Chart

		Proximity to lagoon	
		near	far
Methane concentration level	ambient	Natural rate of methane consumption near lagoon	Natural rate of methane consumption far from lagoon
	artificially elevated	Artificial rate of methane consumption near lagoon	Artificial rate of methane consumption far from lagoon

Carbon cycles through the soil in various forms depending on environmental conditions. Microbially mediated CH4 oxidation accounts for about 80% of global CH4 consumption (Reeburgh et al 1993). The highest consumption rates or potentials are observed in soils where methanogenesis is or has been effective and where CH4 concentration is or has been much higher than in the atmosphere including rice fields, swamps, landfills, etc. In the case of the OSU Dairy, methane conditions are raised due to decomposing manure in the lagoon and soil moisture conditions were mostly dry with scarce rainfall events and therefore minimal methanotrophic production in the soil. The raised atmospheric methane levels would likely lead to a rise in the activity of methanotrophic bacteria, as microbes are highly adaptable to their environments as well as highly sensitive to changes in soil conditions, allowing them to serve as indicators for changes in soil activity (Zhao et al 2015).

Based on previous studies, we can assume that limiting factors will include availability of organic matter, water, and oxygen, as found by Knightly & Nedwell in their study of laboratory scale microcosms in 1994. Similarly, their interest was with respect to landfill methane production and the decomposition of generated waste. The following measurements were taken during a mostly dry period throughout the months of June and July in Oklahoma in a temperate climate. The absence of water can slow methane consumption potentials as it inhibits all microbial activities, while the saturation of the soil can lead to a production of methane due to anaerobic conditions (Le Mer & Roger 2001). Microbes are known to be adaptable to their environments as well as sensitive to changes in soil conditions, allowing them to serve as indicators for changes in soil health (Zhao et al 2015). This project will assess the effect of anthropogenic methane production on the surrounding soil and the role soil microbes play in the methane cycle by comparing activities of soil microbes with respect to distance from a dairy lagoon.

Methods:

On the north eastern side of the most northern lagoon, a total of nine gas chambers were placed strategically, representing three distances from the lagoon and three reps at each distance, directly on top of the berm at the edge of the lagoon, 9.1 m from the berm and 48.7 m from the berm. Each chamber was placed approximately 3 m apart and parallel to the lagoons edge.

Beginning in June, samples were collected approximately every second day between the hours of 9 and 12 pm. Each chamber is placed on a matching metal frame with a water sealed edging to ensure there is no loss of gas. Measurements were taken through a rubber stopper with a syringe at 20 mL and injected into glass vials with 30 seconds in between each chamber. After the first round of sampling all 9 chambers, the second round began at 20 minutes after the initial start time, the third round at 40 minutes, and the final round at 60 minutes. This allows for the same twenty minute interval for each chamber all taken within less than five minutes of each other.

After samples were collected they were processed in the gas chromatography machine and analyzed for methane and carbon dioxide levels. Four twenty minute intervals allows for a linear progression of gas exchanges over a 60 minute time period. These linear progressions of methane were analyzed for significance and each rep was compared with respect to their carbon dioxide levels.

Results:

Table 1: the average CH4 and CO2 emissions measure between June 18 and Nov. 14th during 27 measurement events.

Location	CH4-C	CO2-C
	mg m-2 hr-1	
Berm	(-0.00248b)	118a
9.1 m	0.00087a	79b
48.7 m	0.00051a	81b

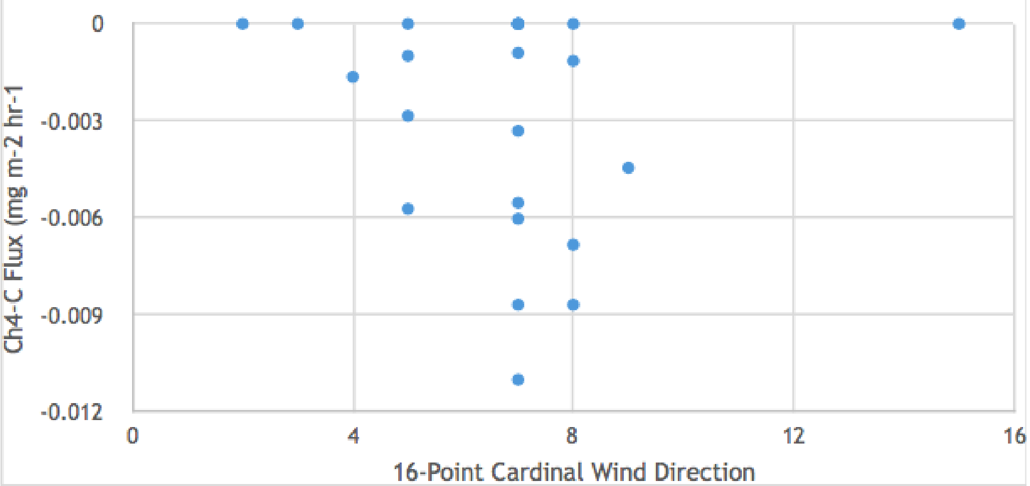


Figure XX: The CH4 flux from the chambers located on the berm as a function of the 16 point cardinal wind direction. The value 5 represents a wind direction of SEE, 6=SE, 7=SSE, 8=S and so on. Winds directions between 5 and 9 are from a southerly direction and would move air over the lagoon to the sample locations.

Figure XX shows that negative fluxes were measured at the berm when the daily average wind direction was from a southerly direction. The flux chambers were located on the North side of the lagoon so it is expected that a southerly wind would transport CH3 to the chamber locations where it could move into the soil by diffusion from the elevated concentration in the near surface atmosphere to a low concentration in the soil.

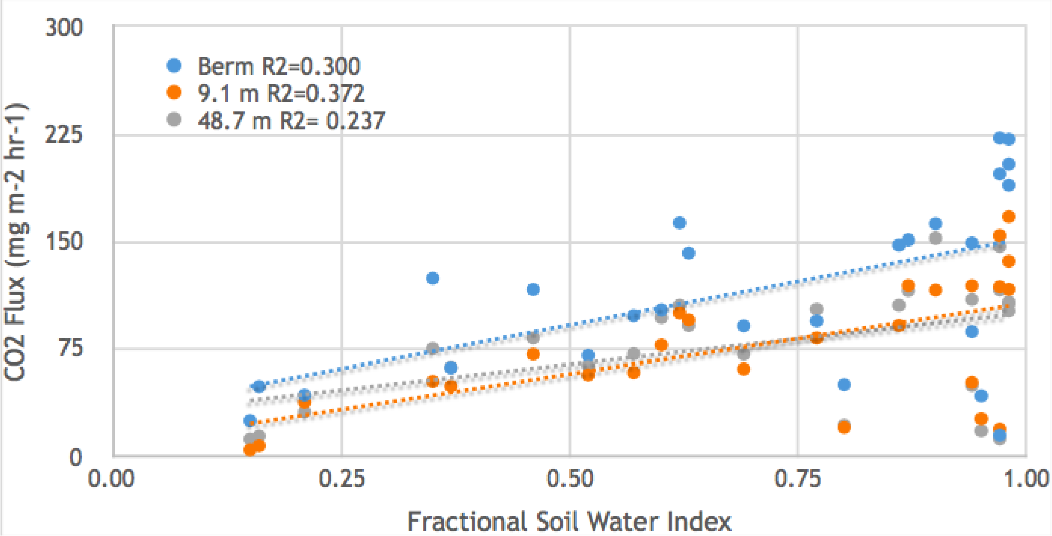


Figure XX: The CO2 flux at the lagoon berm, 9.1 and 48.7 m from the berm as a function of the fractional soil water index as measured at 5 cm at the Stillwater Mesonet.

Figure XX shows that the maximum CO2 flux increases with increasing soil moisture. The CO2 flux values below 50 mg m-2 hr-1 at fractional water indexes equal or greater than 0.80 were collected in the fall when soil temperatures had fallen or directly after a rain when near surface soil was saturated which limited diffusion of CO2 out of the soil. These measurements are responsible for the low R2 values for the linear regression

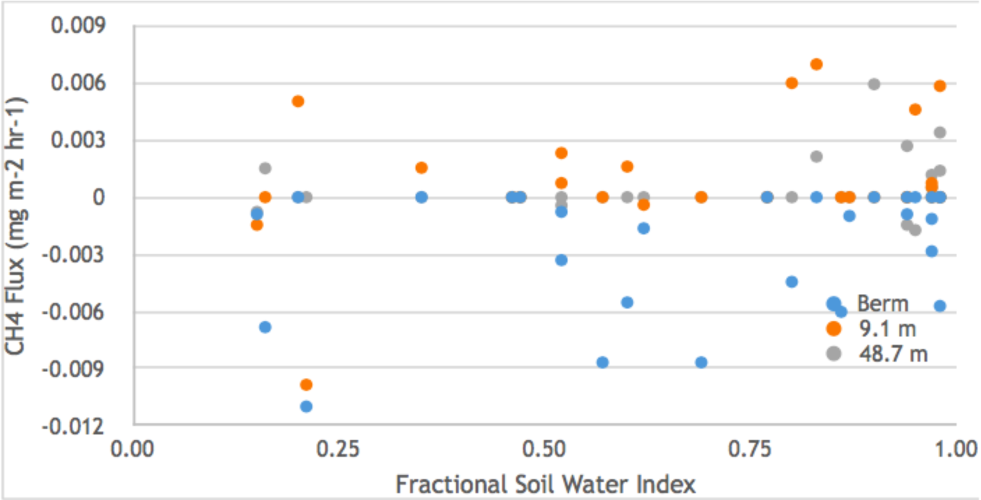


Figure XX: the CH4 flux at the lagoon berm, 9.1 and 48.7 m from the berm as a function of the fractional soil water index as measured at 5 cm at the Stillwater Mesonet.

Figure XX shows that there is no relationship between fractional soil water index and the CH4 Flux.

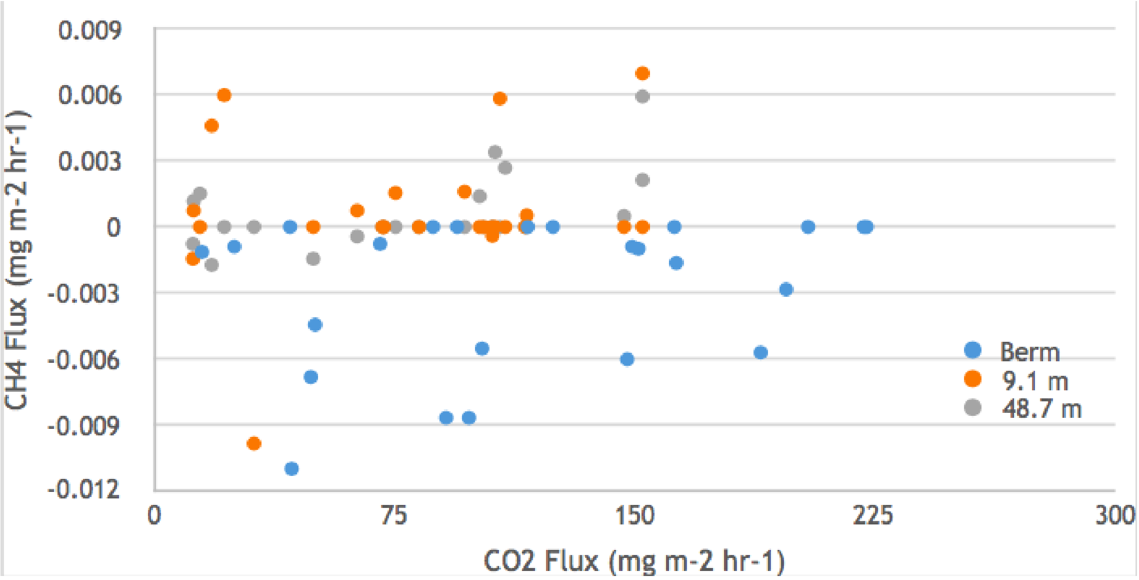


Figure XX: the CH4 flux at the lagoon berm, 9.1 and 48.7 m from the berm as a function of the CO2 flux.

Figure XX shows that there is no relationship between CO2 flux and the CH4 flux from chambers at the berm, 9.1 and 48.7 m from the berm.

Discussion:

Potential limitations to this project include the unknown microscopic conditions and genetic representation of microbial populations. Methanotrophic bacteria responsible for the consumption of atmospheric CH4 are largely unknown. Micro-organisms that have been isolated and most studied are not necessarily those that are the only or the most active in soil (Le Mar & Rogers 2001). This makes it difficult to know if lack of activity is due to low populations/absence of methanotrophs or due to environmental conditions. Methane concentrations can also vary due to the management of manure, depending on the schedule of the dairy farm to flush waste and certain anomalies, such as a dumped tank of milk adding to emissions. Additionally, the spontaneity of methane movement in the atmosphere can inhibit uptake due to high wind speeds and atmospheric pressure. The application of methane uptake by methanotrophs taken by Le Mer & Rogers has different conditions, as the methane is produced and consumed in situ, while in this case the methane travels more easily with only a fraction coming into contact with the surface. Of the known and cultured species of methanotrophs, none so far have the kinetic ability to oxidize methane at atmospheric levels, oxidation occurs during relatively high CH4 centrations that emerge in the vicinity of CH4 production zones, e.g., in wetlands (Reburgh et. al 1993). This would indicate that in order to initiate oxidation of methane, gas released by the lagoon would need to be forced through a soil barrier in order to create kinetic gradients high enough for oxidation.

Errors and external influences in data collection include the differences in soil characteristics between the three trials. The berm was a man made hill and chambers were placed at the peak of the rounded slope where the soil is likely to be drier from compaction and topography, while at 47.8 m from the berm there was a slight depression allowing for more moisture, taller grass, anda lower bulk density. These conditions influence the levels of atmospheric gas and water infiltration, therefore changing the circumstances for microbial activity. Additionally, although the morning hours are recognized as generally having the highest soil microbial activity, it is not known the rate at which the lagoon releases methane depending on the routine flushing of the dairy.

Conclusion:

In this small scale observational study on the behavior analysis of soil methane consumption by microbial organisms, no significant relationships were found between the methane consumption and the distance from a methane production site. With respect for future application of this theme of methanotrophic bacteria, it would be valuable to measure the potential oxidation of methane by soil in a controlled environment, as done by Knightly & Nedwell. Additionally, it would be beneficial to better understand the conditions in which methanotrophs thrive and how these circumstances can be manipulated anthropogenically.

References:

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