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**Greenhouse gas flux in Nebraska's saline marshes:
an analysis of Frank Shoemaker Marsh**

Thesis by:

Alicia Lenners

In partial fulfillment of the requirements

for the degree of

Bachelor of Science in Environmental Studies-Biology

University of Nebraska

Lincoln, Nebraska

Spring 2013

Introduction

For my thesis I will be studying the flux of greenhouse gases (CH_4 , CO_2 , and N_2O), focusing on methane production, released from wetlands, specifically the saline wetlands of Lincoln, NE. Methane is an important greenhouse gas (GHG), and wetlands are the biggest producers of the gas. With time most of the methane will be oxidized into the atmosphere as carbon dioxide (CO_2), but meth (Laing, Shreeve, & Pearce, 2008).

The greenhouse effect is what makes life on Earth possible by trapping energy from the Sun's rays to keep the Earth warm and from going through drastic temperature changes; however, with too much GHG, the overall temperature of the Earth will increase with it. CO_2 is the most well-known and studied GHG because it is the most abundant, but CH_4 is 25 times more potent than CO_2 over a 100 year time span (Jorgenson, 2006). This means that a smaller amount of methane will have a significant effect on the environment than carbon dioxide.

Another potent greenhouse gas is nitrous oxide (N_2O). N_2O is found in much lower concentrations in the Earth's atmosphere than CH_4 , but it is also more potent than methane, having 300 times the heat trapping capacity of CO_2 . N_2O is produced through the microbial process of nitrification and denitrification. The last step of this process is the conversion of N_2O to N_2 , which is currently the only known way terrestrial processes reduce N_2O concentration (Hénault & Revellin, 2011).

Plant-life has a huge influence on the amount of methane released from the wetlands. Methane is produced through the decomposition of organic matter (Figure 1). The gas is then released through the vascular tissue of plants in a gas exchange when plants pump oxygen into the anaerobic soils so their roots can function. Some of the methane will be converted into carbon dioxide as a byproduct of the gas exchange (Ström, Mastepanov, & Christensen, 2004).

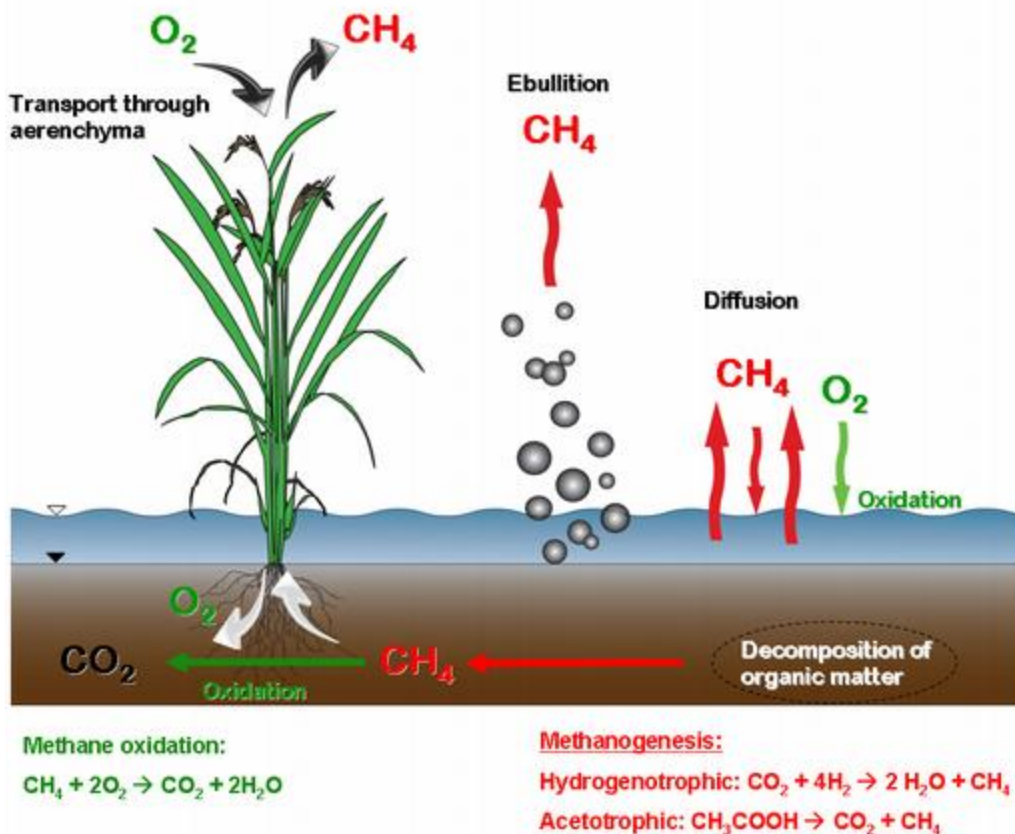


Figure 1. Shows how CH_4 is transported out of wetlands. The CH_4 produced when decomposers break down organic matter is transported through the vascular system of hydrophytes as oxygen is pumped into the roots.

The people who founded Lincoln were attracted to these wetlands and built the city on top of them. Since then, the majority of the wetlands have been drained away, but with increasing urbanization, Lincoln's saline wetlands are slowly declining even further. The saline wetlands provide a habitat for plant species such as saltgrass (*Distichlis spicata*), sea blite (*Suaeda depressa*), and saltwort (*Salicornia rubra*), the latter of which is endangered, and insect species like the endangered Salt Creek Tiger Beetle (Harvey, Ayers, & Gosselin, 2007). Even though these wetlands are unique in the Nebraska area, they have not been studied to a great extent. This is why it is important to study these habitats as much as possible.

My hypothesis is freshwater wetlands will produce more methane than saline wetlands because methane production is reliant on plant productivity. My broader research question is how do salinity and plant cover affect greenhouse gas fluxes in Shoemaker Marsh? In my study, my aim is to measure the amount of methane and other GHGs (CO₂ and N₂O) gas transmitted through different species of wetland plant life in both habitats. To do this, I will be taking gas samples from soil sites with different salinity levels and plant treatments at Shoemaker Marsh, located 1 mile north of Lincoln, NE and comparing the fluxes with the different salinity and plant treatments.

One of the limiting factors to this study is the location of the two collection sites. The first limitation is the type of soil might affect how well the plants transport the gases. The second limitation is the species of plants that grow in the different salinity areas. Because of this, it is important that I collect data from a wide variety of plant life. The third limitation is the climate and weather. Because biological activity is dependent on moisture and temperature, it will be important for me to study the weather conditions of all the areas and factor them into my data.

Literature Review

There have been many studies that have looked into how plants transport methane. In a study performed by Lena Ström, Mikhail Mastepanov, & Torben R. Christensen, the how role of vascular composition in plants in relation to methane emission was explored. They took three different species of plants, *Eriophorum vaginatum*, *Carex rostrata* and *Juncus effusus*, from the same wetland in southern Sweden. What the researchers found was *E. vaginatum* contributed over 90% of the plant-transported methane in the wetland observed. Because some plants are better at transporting methane than others, it is important to sample various types of plants in each type of system (Ström, Mastepanov, & Christensen, 2004).

Another study, by Albert Koelbener, Lena Ström, Peter J. Edwards, and Harry Olde Venterink, tested how the presence of vascular plants affect methane emissions in peatlands. They used eight different plant species to observe whether the root biomass had any effect on methane production. Out of the 8 species tested, 5 of them produced 5 times as much methane than the control peat soil with no plants. However, only one of the plant species showed a positive relationship of root biomass and methane production (Koelbener, Ström, Edwards, & Venterink, 2010).

An investigation carried out by Pantip Klomjeka and Suwanchai Nitisoravut explored plant growth in a saline wetland environment. 8 plant species were studied under artificially-created saline conditions, and 6 of the species were salt-tolerant. It was found that the plant species were less productive in the saline soils than in the freshwater soils, creating less methane (Klomjeka & Nitisoravut, 2005).

Methods and Materials

The main goal of this study was to observe if there was any noticeable difference in greenhouse gas production between saline and freshwater areas of a wetland. All samples were collected at Shoemaker Marsh, which is the largest protected saline wetland in Nebraska and is located 1 mile north outside Lincoln, NE. Saline areas were differentiated from freshwater areas based on the local plant-life. The freshwater areas will be high in cattail (*Typha capensis*) and marsh elder (*Iva annua*) growth, and saline areas are higher in saltwort (*Salicornia rubra*) and sea blite (*Suaeda depressa*).

Before collecting any samples, permission was needed due to the many endangered species, including the Salt Creek Tiger Beetle (*Cicindela nevadica lincolniana*) and *S. rubra*, which occupy Frank Shoemaker Marsh. Permission was granted by Tom Malmstrom of the

Lower Platte South Natural Resources District on the condition that any results gathered would be shared with the City of Lincoln, NE.

8 PVC chambers were divided into 4 overlapping treatments: saline soil with plant (*S. rubra* and *S. depressa*), saline soil with no plant, freshwater soil with plant (*I. annua*), and freshwater soil with no plant. Due to the size, *T. capensis* could not be used in the chambers, so *I. annua* was used in both duplicates. Figure 2 shows images of the chamber set up of the two collection sites. The idea was to compare the different rates of GHG production of plants growing in different salinity conditions while also comparing GHG flux produced by plants against bare soil. The chambers were evenly spread out approximately 20-m from each other to prevent the soil activity in one chamber from interfering with the soil activity in a nearby chamber and were grouped into two different sites (figure 3).



Figure 2a. Chambers from site 1 (read clockwise starting from the top-left): saline/bare, saline/plant (*S. rubra*), fresh/plant (*I. annua*), and fresh/bare.



Figure 2b. Chambers from site 2 (read clockwise starting from the top-left): saline/bare, saline/plant (*S. depressa*), fresh/plant (*I. annua*), and fresh/bare.

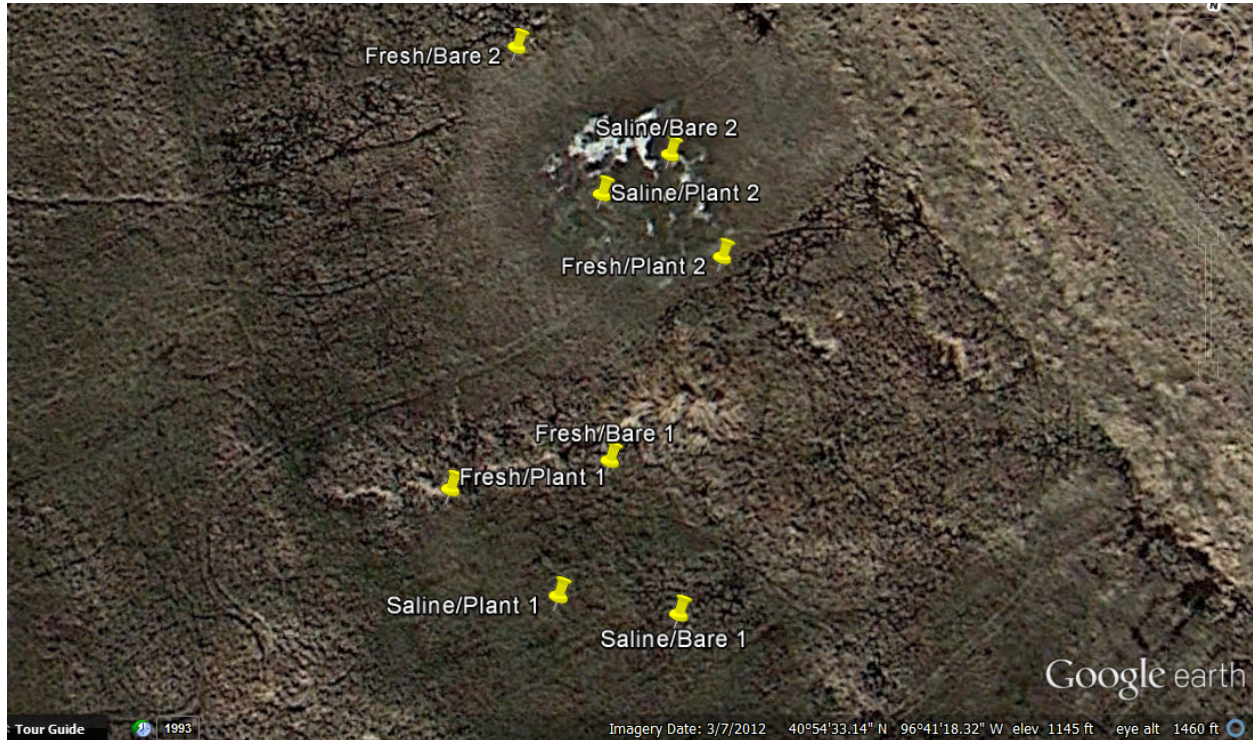


Figure 3. The locations of the chambers in sites 1 and 2.

Saline/Bare1 (40°54'32.43"N, 96°41'18.00"W); Saline/Plant1 (40°54'32.44"N, 96°41'18.45"W);
Fresh/Bare1 (40°54'32.83"N, 96°41'18.33"W); Fresh/Plant1 (40°54'32.69"N, 96°41'18.90"W);
Saline/Bare2 (40°54'33.72"N, 96°41'18.26"W); Saline/Plant2 (40°54'33.58"N, 96°41'18.50"W);
Fresh/Bare2 (40°54'33.98"N, 96°41'18.90"W); Fresh/Plant2 (40°54'33.44"N, 96°41'18.01"W).

Samples were taken approximately every two weeks from mid-August to the end of September 2012. During each trip 4 air samples were taken from each chamber every 15 minutes, making a total of 32 samples. To do this, the chambers were forced 1 inch into the soil and were covered with a PVC lid. The chamber lids were then sealed with a large latex band. The lid was then connected to PVC plastic tubing, which would lead to a 20-ml syringe. During each round, the syringe would be aerated and pull 20-ml of air from the chamber. The air would then be injected into the appropriately labeled sample glass vial. Additional measurements taken on site included soil temperature and chamber volume. The soil temperature was taken with a digital meat thermometer, and the chamber volume was calculated by averaging the height measurements taken from four sides of the chamber and calculating it with the diameter of the chamber.

After the samples were collected, they were taken to the Aquatic Ecology and Water Chemistry Lab at the University of Nebraska-Lincoln. The samples were injected into a Gerstel MultiPurpose Sampler to be analyzed for CH₄, CO₂, and N₂O content. All of the results were compiled into an Excel spread sheet, which were compared against the standard curve of the local ambient air levels.

Results

Neither soil salinity nor plant cover had a significant effect of CH₄ flux (figure 4a). All of the flux averages had a high amount of variation between chamber site and date of collection. Even though the saline/plant category had the lowest CH₄ flux average, the graph below shows

that it also had the highest amount of variation. Conversely, even though the fresh/plant category had the highest average of CH₄ flux, it had the lowest amount of variation. The differences between the saline and freshwater soil types in the no plant category were negligible.

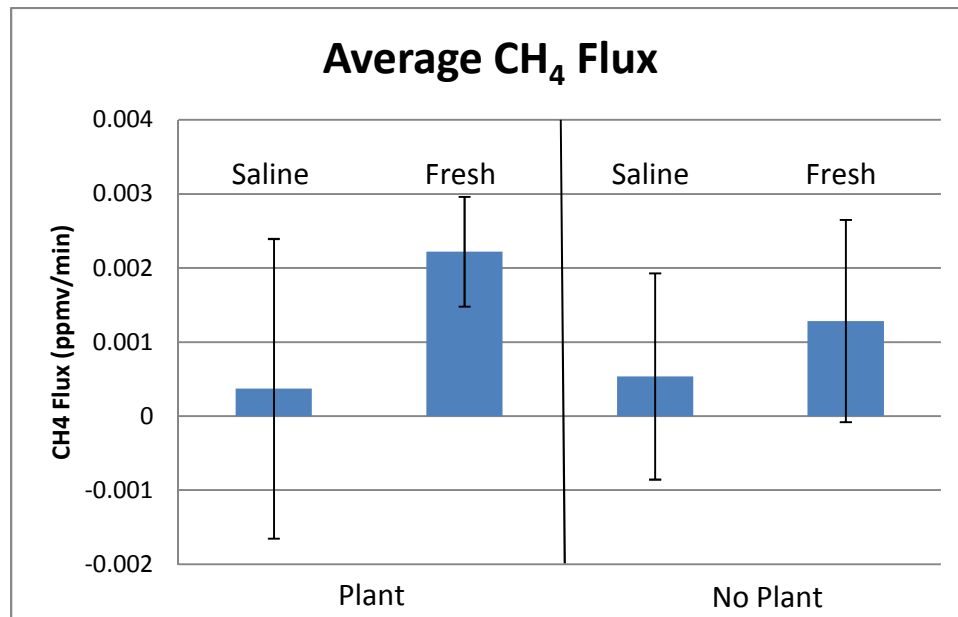


Figure 4a. The average CH₄ flux of each of the four soil types. Df=14; p-value (saline/plant vs. fresh/plant)=0.47; p-value (saline/plant vs. saline/no plant)=0.20; p-value (saline/plant vs. fresh/no plant)=0.35; p-value (fresh/plant vs. saline/no plant)=0.15; p-value (fresh/plant vs. fresh/no plant)=0.35; p-value (saline/no plant vs. fresh/no plant)=0.28.

CO₂ flux is higher in chambers with saline soil than in freshwater soil (figure 4b). The presence of plants seems to have minimal effect on CO₂ flux, but soil salinity had a greater effect on flux. The most drastic difference in CO₂ flux occurred between the fresh/plant and the saline/no plant groups, where the flux in the fresh/plant chambers averaged to 9 ppmv/min and the flux in the saline/no plant chamber averaged to 40 ppmv/min.

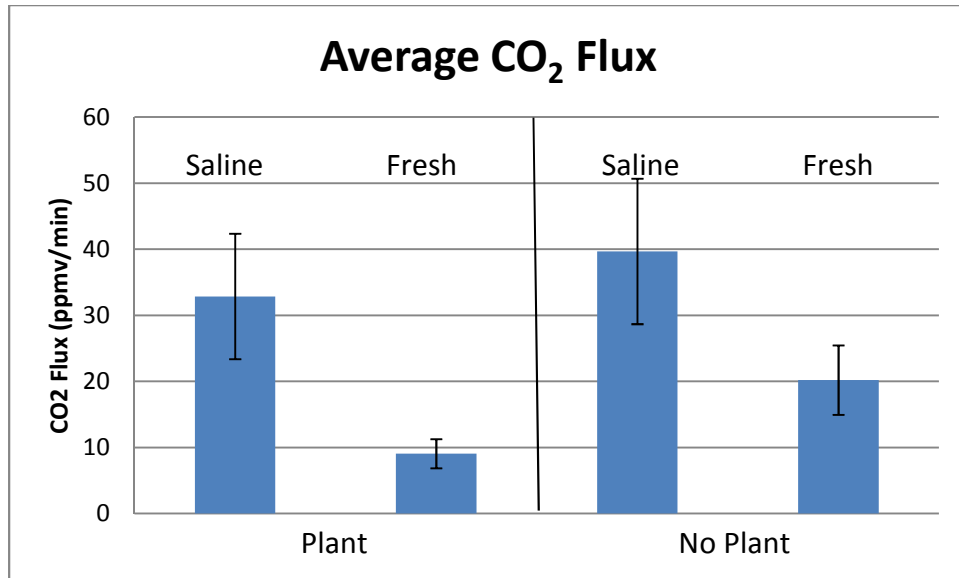


Figure 4b. The average CH_4 flux of each of the four soil types. Df=14; p-value (saline/plant vs. fresh/plant)=0.32; p-value (saline/plant vs. saline/no plant)=0.014; p-value (saline/plant vs. fresh/no plant)=0.13; p-value (fresh/plant vs. saline/no plant)=0.0082; p-value (fresh/plant vs. fresh/no plant)=0.066; p-value (saline/no plant vs. fresh/no plant)=0.035.

Freshwater soils with low plant cover were the biggest producers of N_2O flux out of all of the chamber collection sites (figure 4c). N_2O flux from the fresh/no plant sites had an average rate of 0.16 mmv/min and were on average 3 times as much as any of the other three categories. The saline/plant chamber sites produced the least amount of N_2O , with a flux rate of 0.001 ppmv/min.

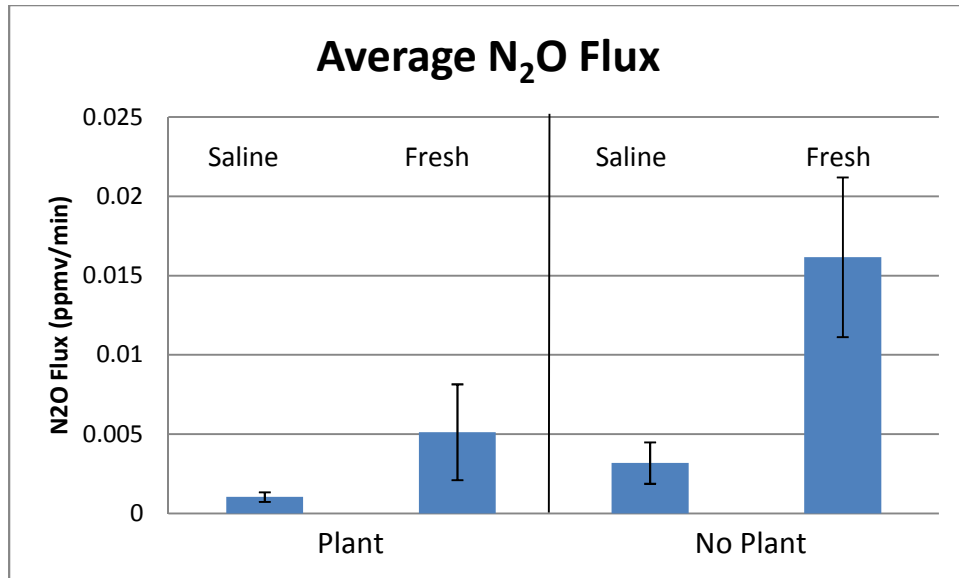


Figure 4c. The average CH₄ flux of each of the four soil types. Df=16; p-value (saline/plant vs. fresh/plant)=0.064; p-value (saline/plant vs. saline/no plant)=0.098; p-value (saline/plant vs. fresh/no plant)=0.0057; p-value (fresh/plant vs. saline/no plant)=0.28; p-value (fresh/plant vs. fresh/no plant)=0.015; p-value (saline/no plant vs. fresh/no plant)=0.044.

Discussion

With any type of field study, there are going to be limitations. One of the major limitations with this study was the limited amount of time and equipment to produce enough Also, because the rate of GHG emissions from saline wetlands has not been studied that much, there was no means of comparing the data collected at Shoemaker Marsh with other wetlands. Because of the drought in the summer of 2012, there was very little variation in weather and moisture, which would have given deeper insight to how GHGs would fluctuate while the marsh was saturated.

When running the t-test between the different soil and plant categories, there appeared to be little statistical significance between the average flux in methane emissions; however, the chambers located in the saline sites showed a higher level of variation than in the freshwater sites (figure 4a). While methane flux tended to constantly stay positive in the freshwater sites, the

saline sites showed both positive and negative fluxes. An interesting point was the presence of plants had a seemingly minimal effect on methane flux. This is interesting because the presence of plants usually act as a bio-conductor for methane emission in wetlands (Potter, et al, 2006).

CH₄ is normally produced by microbes and released into the atmosphere through hydrophytes vascular tissue when O₂ is directed to their roots when soils are saturated; this process is referred to as methanogenesis (Koelbener et al, 2005). While the methane emissions from the fresh/plant chamber was higher on average, the similarity among the other three chamber groups does not support this principle.

Another possibility is the presence of methanotrophs. Because negative flux indicates that a gas is being consumed, figure 4a indicates that there are methane-consuming bacteria inhabiting the saline soils. These microbes often inhibit aerobic soils and will consume methane as their source of carbon and energy (Hanson & Hanson, 1996). Wetlands are typically anaerobic due to saturated soils, but because the summer of 2012 in Nebraska was particularly dry, aerobic organisms were allowed to flourish. The main difference between the saline groups and the freshwater groups may have been the fact that the freshwater areas had a higher concentration of dead plant matter, thus trapping in more moisture and preventing aerobic bacteria populations from growing.

Concerning CO₂ emissions, figure 4b demonstrates that soil salinity has higher effect on CO₂ flux than plant cover. Because there is little literature on how gas flux is influenced by soil salinity, a proper comparison cannot be made, but it is known that CO₂ is released in relation to organic matter decomposition (Potter et al, 2006). Along with the flux differences between salinity states, the areas with plant cover also showed a small decrease in CO₂ flux compared

with the areas with no plant cover. Because plants use CO_2 as a part of their photosynthesis process (Rasse et al, 2003), the decrease in CO_2 flux makes sense when put in this context.

Fresh, bare soils have the highest N_2O flux (figure 4c), and saline soils with plants have the lowest flux. In the nitrogen cycle, N_2O is a byproduct of nitrification and denitrification processes carried out by bacteria in soils (Johansson et al, 2002). The lower salinity in the soil and nitrogen competition with the local plant may have led to the increased N_2O production. Microbes will convert inorganic Ammonium (NH_4^+) into Nitrite (NO_2^-) and Nitrate (NO_3^-) through nitrification. When plants are within the area, they will take up the Nitrate nutrients; however, when there is little plant cover, some of the nitrogen is lost as nitrogen gas (N_2) and N_2O through denitrification (Jiang et al, 2013).

This study shows that there are many factors into what determines GHG production. An appropriate continuation to this study would be to determine how soil moisture affects methane consumption by methanotrophs. This would need to be performed in a more controlled environment, but it would give more insight into the results figure 4a gives.

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References

- Hanson, Richard S. & Thomas E. Hanson. (1996). "Methanotrophic bacteria." *Microbiological Reviews*, 60(2). DOI: 0146-0749/96/\$04.0010
- Harvey, F.E., J.F. Ayers, & D.C. Gosselin. (2007). "Ground water dependence of endangered ecosystems: Nebraska's eastern saline wetlands." *Papers in Natural Resources*. Paper 131. Retrieved from Academic Search Primer. DOI: 10.1111/j.1745-6584.2007.00371.x.
- Hénault, C. & C. Revellin. (2011). "Inoculants of leguminous crops for mitigating soil emissions of the greenhouse gas nitrous oxide." *Plant Soil*, 346. DOI: 10.1007/s11104-011-0820-0
- Johansson, A.E., Å.K. Klemetsson, L. Klemetsson, & B.H. Svensson. (2002). "Nitrous oxide exchanges with the atmosphere of a constructed wetland treating wastewater." *Tellus*, 55B.
- Jorgenson, A.K. (2006). "Global warming and the neglected greenhouse gas: a cross-national study of the social causes of methane emissions intensity, 1995." *Social Forces*, 84(3): 1779-1798. Retrieved from Academic Search Primer.
- Klomjeka, P. & S. Nitisoravut. (2005). "Constructed treatment wetland: a study of eight plant species under saline conditions." *Chemosphere*, 58 (5): 585–593. Retrieved from Google Scholar. doi: 10.1016/j.chemosphere.2004.08.073
- Koelbener, A., L. Ström, P.J. Edwards, & H.O. Venterink. (2010). "Plant species from mesotrophic wetlands cause relatively high methane emissions from peat soil." *Plant Soil* 326:147–158. doi:10.1007/s11104-009-9989-x
- Laing, C.G., T.G. Shreeve, & D.M.E. Pearce (2008). "Methane bubbles in surface peat cores: in situ measurements." *Global Change Biology*, 14: 916–924. Retrieved from Academic Search Primer. DOI: 10.1111/j.1365-2486.2007.01534.x

- Ornes, H, & C.M. Hogan. (2012). "Wetland." *Encyclopedia of Earth*.
<<http://www.eoearth.org/article/Wetland>>
- Potter, C., S. Klooster, S. Hiatt, M. Fladeland, V. Genvese, & P. Gross. (2006). "Methane Emissions from natural wetlands in the United States: satellite-derived estimation based on ecosystem carbon cycling." *Earth Interactions*, 10.
- Rabalais, N.N., R.E. Turner, & W.J. Wiseman. (2002). "Gulf of Mexico hypoxia, a.k.a 'the Dead Zone.'" *Annual Review of Ecology & Systematics*, 33: p235. Retrieved from Academic Search Primer.
- Rasse, D.P., J.-H. Li, & B.G. Drake. (2003). "Carbon dioxide assimilation by a wetland sedge canopy exposed to ambient and elevated CO₂ : measurements and model analysis." *Functional Ecology*, 17.
- Ström, L., M. Mastepanov, & T.R. Christensen. (2004). "Species-specific effects of vascular plants on carbon turnover and methane emissions from wetlands." *Biogeochemistry*, 75: 65-82. Retrieved from Academic Search Primer. doi:10.1007/s10533-004-6124-1.
- Tanaka, N., K. B. S. N. Jinadasa, D. R. I. B. Werellagama, M. I. M. Mowjood, & W. J. Ng. (2006). "Constructed tropical wetlands with integrated submergent-emergent plants for sustainable water quality management." *Journal of Environmental Science and Health Part A*, 41:2221–2236. Retrieved from Academic Search Primer. DOI: 10.1080/10934520600867581.
- Jiang, Xianjun, Wei Liu, Qiu Liu, Zhongjun Jia, Alan Wright, & Zhihong Cao. (2013). "Soil N mineralization, nitrification and dynamic changes in abundance of ammonia-oxidizing bacteria and archaea along a 2000 year chronosequence of rice cultivation." *Plant & Soil*, 365(1/2). DOI: 10.1007/s11104-012-1377-2