The Influence of Eutrophication Status on the Kinetics of Methane Oxidation in Soils from a Subtropical Freshwater Wetland

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Introduction

- Microbial mediated methane (CH_4) oxidation is a significant determinant of net soil CH_4 emissions and may reduce these emissions by up to 90%.
- By examining the Michaelis-Menton kinetics of CH_4 oxidation, an increased understanding of the regulators of CH_4 oxidation may be gained.
- Determining the impact of factors which affect soil CH_4 flux is essential to improve strategies to reduce CH_4 emissions from wetland systems.
- Increased knowledge of this process may allow for greater accuracy when estimating soil CH_4 emissions, improve the ability to model CH_4 emissions, and potentially allow for more informed policy decisions regarding the mitigation of climate change to be achieved.

Objectives and Hypotheses

- Determine how the interaction of nutrient status and carbon (C) quality affect the Michaelis-Menton kinetics of CH_4 oxidation. *Increased nutrient availability and C quality in eutrophic soils will result in higher potential maximal rates of CH_4 oxidation (V_{max}) and lower enzymatic affinity (K_m) for CH_4 due to increased substrate availability.*
- Determine the potential of CH_4 oxidation along the soil depth. *Changes in C quality, microbial biomass, and the availability of nutrients, oxygen (O_2), and CH_4 along the soil depth will alter the kinetics of CH_4 oxidation.*

Methods

- A laboratory study was performed to determine the potential rates of aerobic CH_4 oxidation for soils from differing trophic status at three depths (0-5 cm, 5-10 cm, and 10-20 cm).
- Enriched 99% atom ^{13}C-CH_4 was added to the microcosms at varying concentrations (~300 to 2000 ppm).
- CH_4 and carbon dioxide (CO_2) concentrations were measured periodically over a three day period using gas chromatography to determine the potential rates of CH_4 oxidation.
- Michaelis-Menton kinetics were calculated from the rates of CH_4 oxidation using the Lineweaver-Burk equation to determine V_{max} and K_m of CH_4 oxidation.

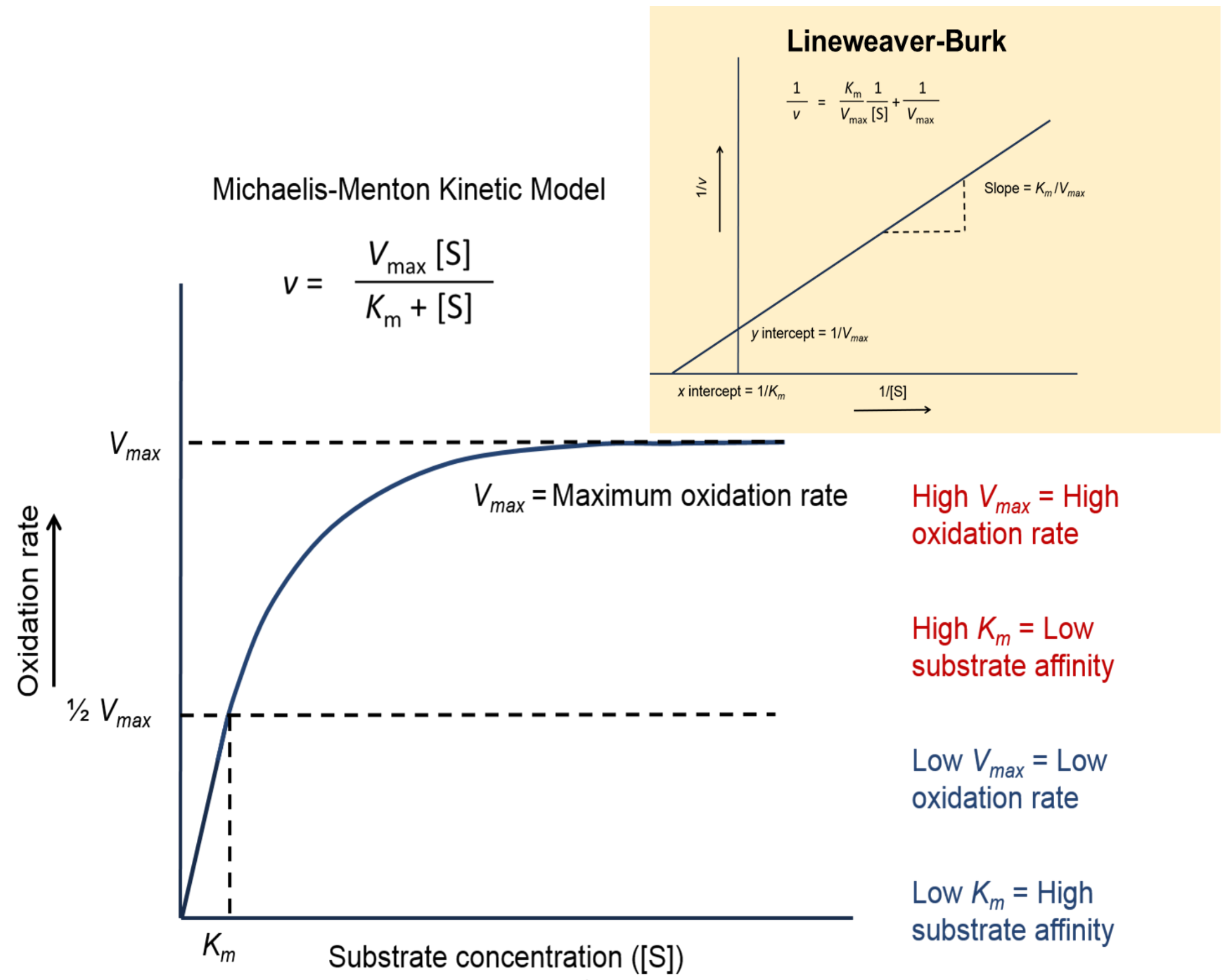
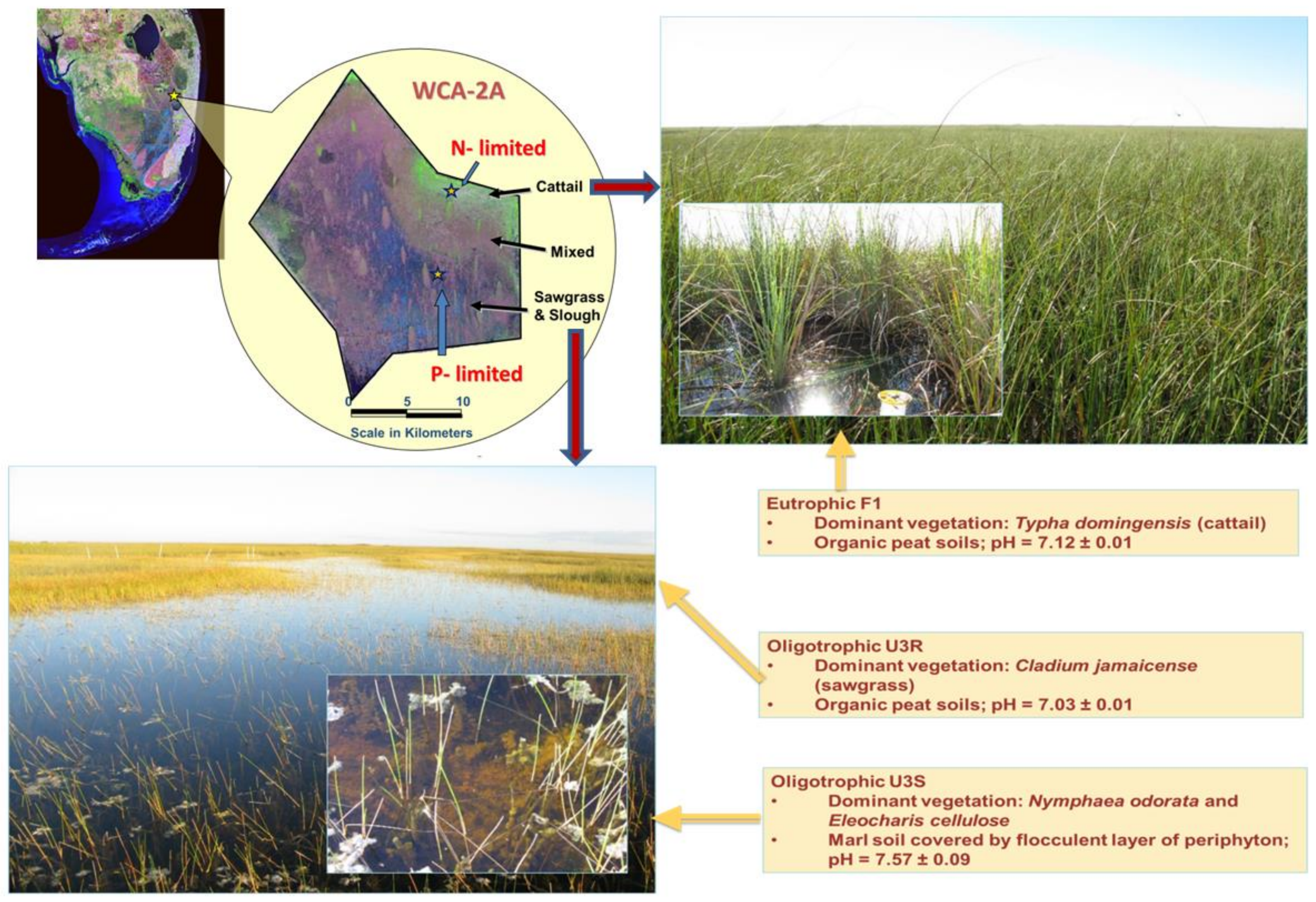


Figure 1. The Michaelis-Menton Kinetic model and Lineweaver-Burk equation.

WCA-2A Florida Everglades



Eutrophic F1
- Dominant vegetation: *Typha domingensis* (cattail)
- Organic peat soils; pH = 7.12 ± 0.01

Oligotrophic U3R
- Dominant vegetation: *Cladium jamaicense* (sawgrass)
- Organic peat soils; pH = 7.03 ± 0.01

Oligotrophic U3S
- Dominant vegetation: *Nymphaea odorata* and *Eleocharis cellulose*
- Marl soil covered by flocculent layer of periphyton; pH = 7.57 ± 0.09

Figure 2. WCA-2A: a 54,700 ha subtropical freshwater wetland with an established phosphorous (P) gradient which spans the marsh.

Figure 3. Soil cores collected from F1, U3R, and U3S showing soil composition.

Results

Table 1. Physio-chemical and biogeochemical soil characteristics.

Site	Depth (cm)	BD (g cm^{-3})	LOI (%)	TP (mg kg^{-1})	Ext NO_3-N (mg N kg^{-1})
Eutrophic F1	0-5	0.05 ± 0.000^a	89.8 ± 0.5^a	1094 ± 30^a	120.4 ± 7.5^{†,a}
	5-10	0.063 ± 0.006^a	89.7 ± 0.2^a	1111 ± 54^a	7.8 ± 5.4^b
	10-20	0.067 ± 0.012^a	86.0 ± 1.2^a	1008 ± 279^a	9.7 ± 3.0^b
Oligotrophic U3S	0-5	0.117 ± 0.015^a	43.3 ± 15.8^b	191 ± 14b^a	17.6 ± 3.4^a
	5-10	0.110 ± 0.010b^a	48.0 ± 13.6^b	196 ± 17^a	19.6 ± 8.7^a
	10-20	0.093 ± 0.012^a	74.4 ± 9.3^a	186 ± 28^a	7.8 ± 6.0^a
Oligotrophic U3R	0-5	0.043 ± 0.006^b	87.5 ± 0.4^a	459 ± 28^a	63.2 ± 11.2^a
	5-10	0.067 ± 0.012^{ab}	85.7 ± 0.3^a	560 ± 59^{†,a}	7.2 ± 4.4^{†,b}
	10-20	0.077 ± 0.006^a	86.5 ± 1.0^a	308 ± 49^a	1.2 ± 0.6^b

Data represent mean (n=3; when † n=2). Letters represent significant differences for each site along the depth profile among the mean values according to Tukey's test (α = 0.05). BD: bulk density; LOI: loss on ignition; TP: total phosphorous; NO_3-N: extractable nitrate.

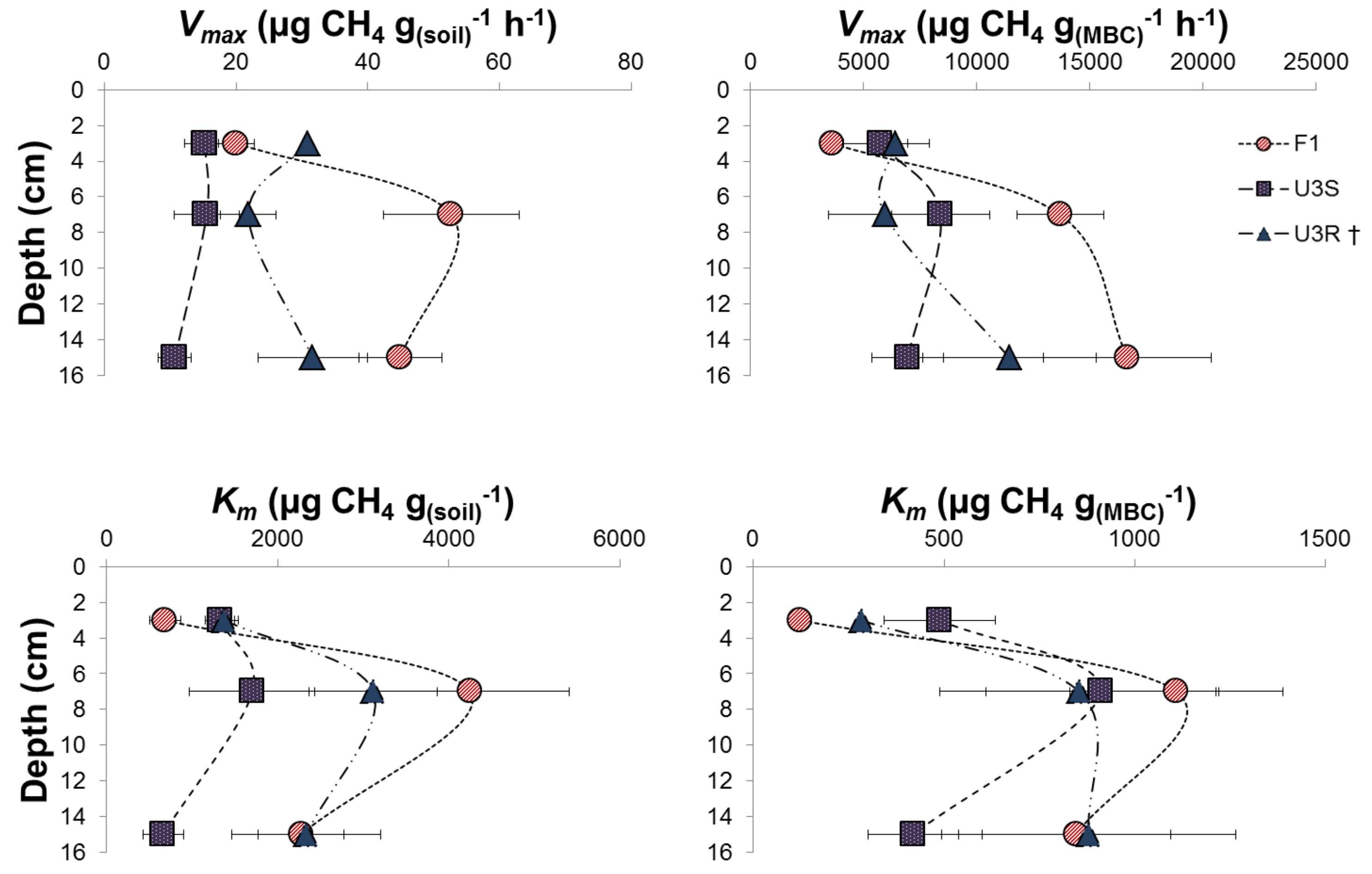


Figure 4. V_{max} and K_m along the soil depth.

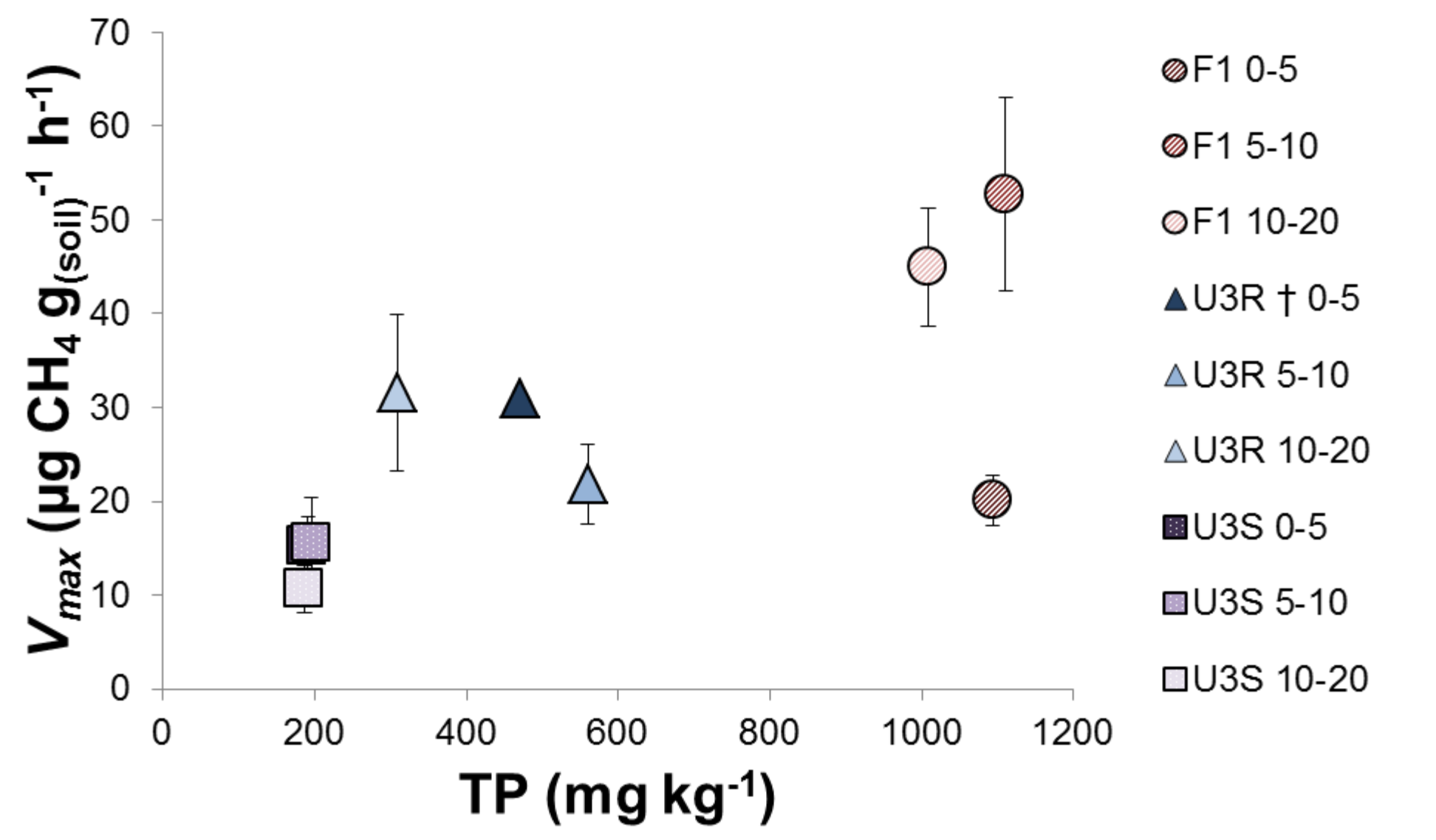


Figure 5. Significant positive correlations were determined between V_{max} and TP; $p = 0.0002$.

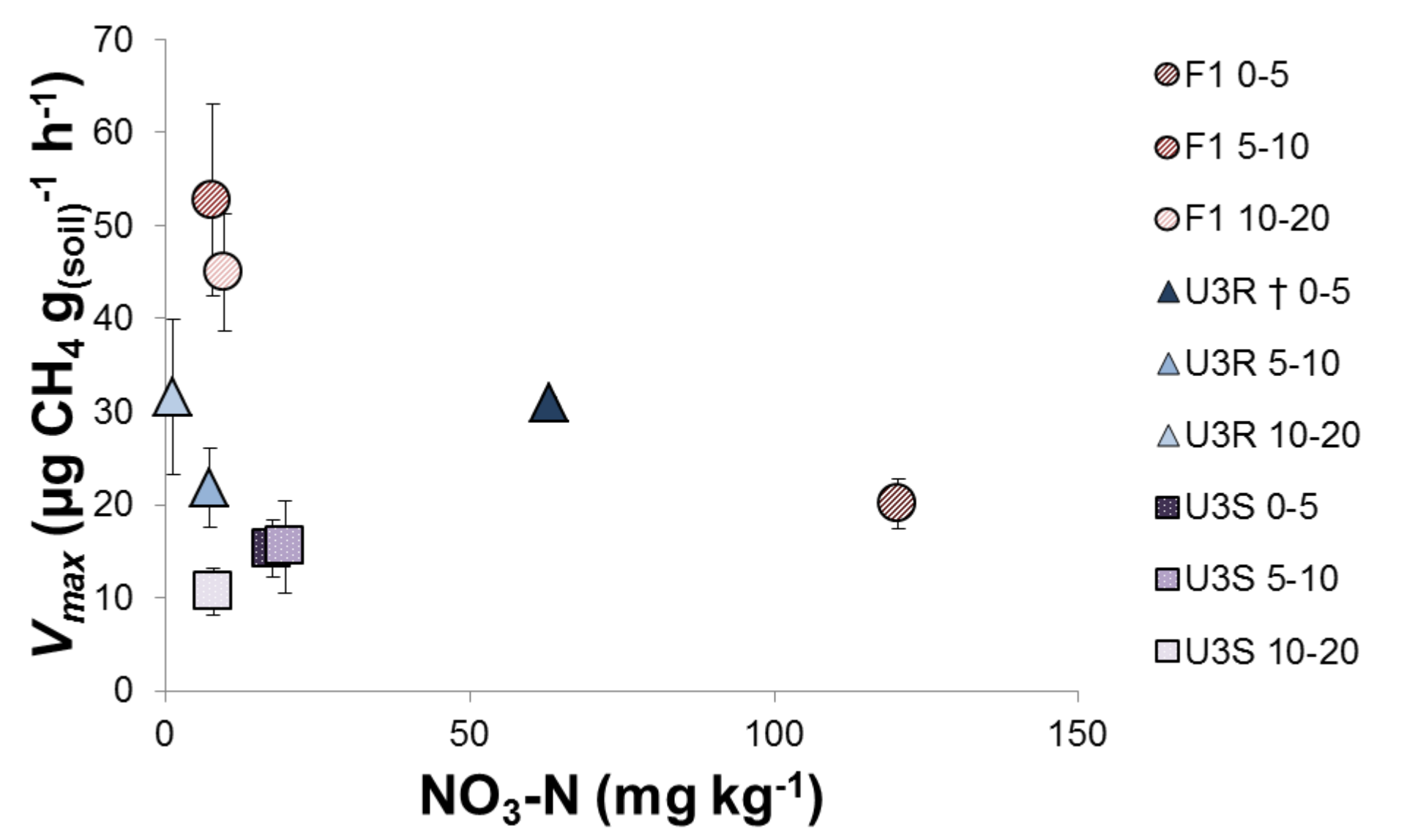


Figure 6. Significant negative correlations were determined between V_{max} and NO_3-N; $p = 0.0126$.

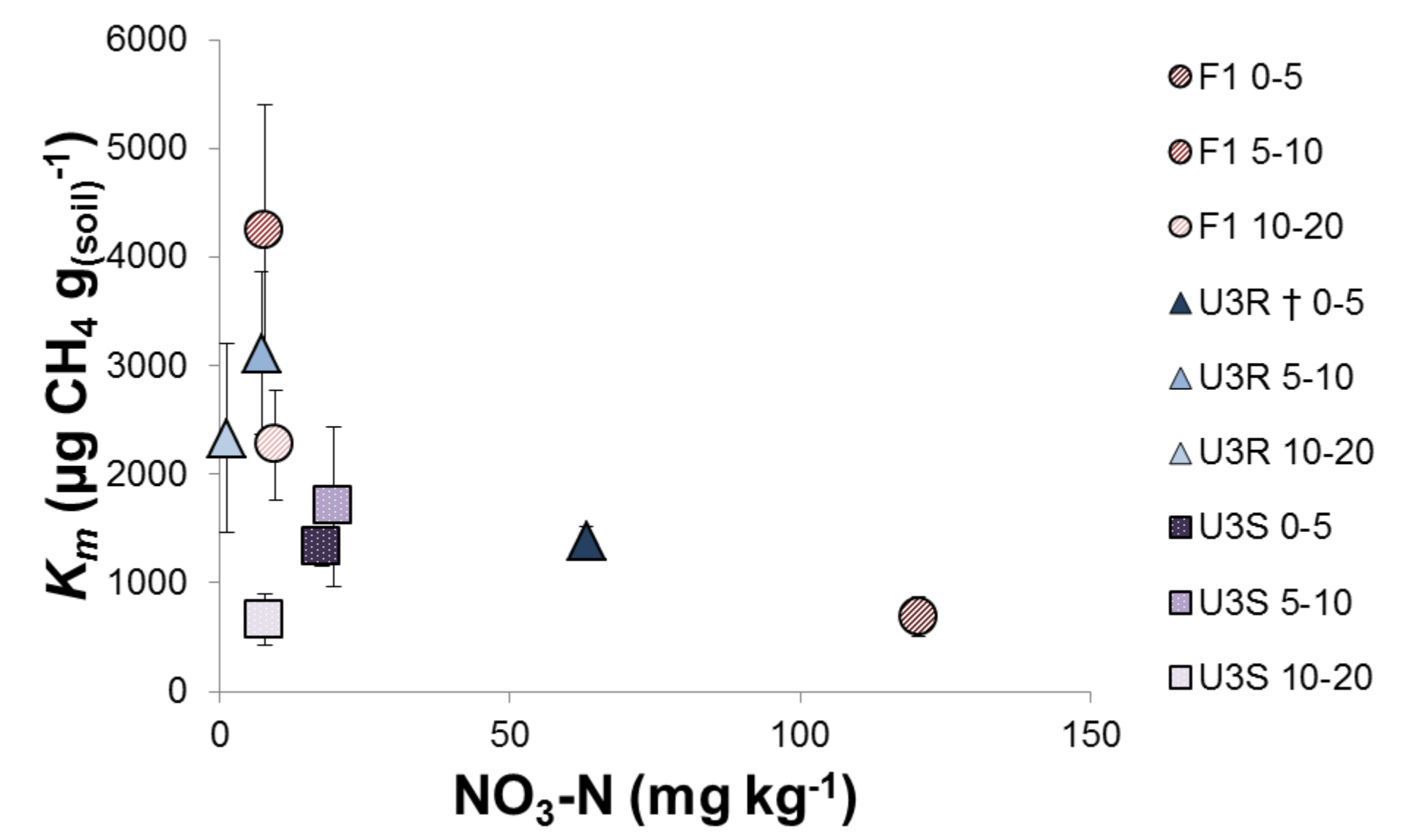


Figure 7. Significant negative correlations were determined between K_m and NO_3-N; $p = 0.0045$.

Conclusions

- Increased eutrophication status appears to result in higher rates of CH_4 oxidation and lowered affinity for CH_4.
- Significant positive correlations with TP suggest increased TP may influence the rates of CH_4 oxidation directly and indirectly. Increased TP is known to result in greater ecosystem productivity. This may lead to higher rates of CH_4 production resulting in an increase of substrate availability. The increase in substrate availability may allow for greater CH_4 oxidation potential.
- Overall negative correlations with NO_3-N suggest the presence of inorganic N may be inhibitory to CH_4 oxidation. Further research is needed to determine the effect of N limitation and N concentration on CH_4 oxidation activity.
- Differences in the kinetics of CH_4 oxidation calculated against soil vs. MBC suggest the composition of the microbial community influences the oxidation activity.

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