Impact of Change in Soil Thermal Gradient on the Fate of Soil Nitrogen

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ABSTRACT

Warming climate trend will shift the soil thermal gradient and thus impact the soil-nutrient dynamics. This impact will be more pronounced in areas where air temperatures have been significantly less than those of the vadose zone. It has been observed that the soil nitrogen content in form of nitrate (NO_3^-) and ammonium (NH_4^+) have increased in water bodies with increase in temperature. This observation can be owed to the reason that the denitrification process is significantly affected by warm temperatures. Nitrogen content in the soil thus can be affected by warm temperatures. Nitrogen content in the soil thus can be expected to change due to increasing temperatures. The present study attempts to find the effect of air temperature on soil root zone properties (viz. soil temperature and soil moisture content at root zone depth) consequently affecting soil-nutrient status. A support vector regression (SVR) model was trained to develop a regression between air temperature and soil nitrogen status at different soil moisture contents. The model was applied to simulate future (i.e. years 2030 and 2050) soil nitrogen status and moisture contents. Effect of increasing temperature on the fate of soil nitrogen was predicted based on the optimal temperature range required for the chemical reactions. The model used the data from experimental watershed Bear Brook Watershed, Maine and soft data from Global Land Data Assimilation System (GLDAS) for training and validation purposes.

Keywords:
Soil Temperature, Air Temperature, Soil Nitrogen

HYPOTHESIS

Soil nitrogen migration occurs in the direction of soil thermal gradient.

OBJECTIVES

1. To study the patterns of change in concentrations of nitrogen compounds released to nearby water bodies with change in air temperature, soil moisture and soil temperature at different depths; and
2. To simulate the trend of concentrations of nitrogen compounds till 2050.

MATERIALS & METHODS

Method Used

Regression analysis using Support Vector Regression (SVR) method to identify the trend in the time-series data of air temperature, soil moisture at root zone depth, soil temperature (10cm and 25cm) and its effect on concentrations of NO_3^- and NH_4^+ compounds of the water body in its vicinity.

Data Used

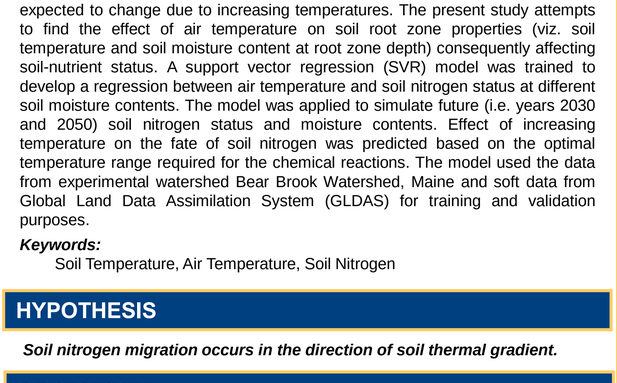

Figure1: Bear Brook Watershed in Maine (BBWM) (adapted from Patel et al. 2018).

Two models were prepared –

1. Model 1 for predicting soil temperatures at 10cm and 25cm depths, and
2. Model 2 for predicting concentrations of NO_3^- and NH_4^+ in the stream in the BBWM

Data used and sources (cf. Figure 1)

Attribute	Period	Source	Usage
Air Temperature	Jul 2001 – Sep 2013	BBWM	Training and Testing
Soil Moisture		GLDAS	
Soil Temperature (10cm)		BBWM	
Soil Temperature (25cm)		BBWM	
NO_3^-		BBWM	
NH_4^+		BBWM	
Air Temperature	Oct 2013 – Dec 2050	Ensemble GCM product	Prediction
Soil Moisture		Ensemble GCM product	

RESULTS

The results obtained from Model 1 show the annual change and the trend till the year 2050 (Figures 2 – 5).

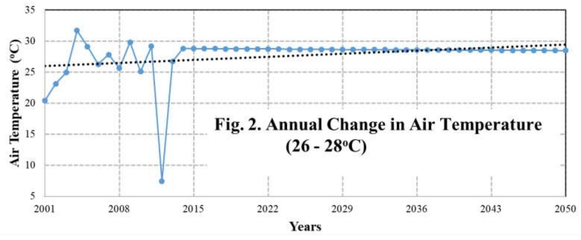

Fig. 2. Annual Change in Air Temperature (26 - 28°C)

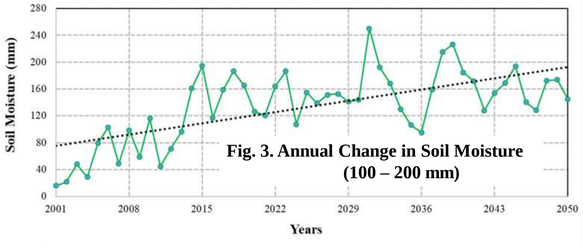

Fig. 3. Annual Change in Soil Moisture (100 – 200 mm)

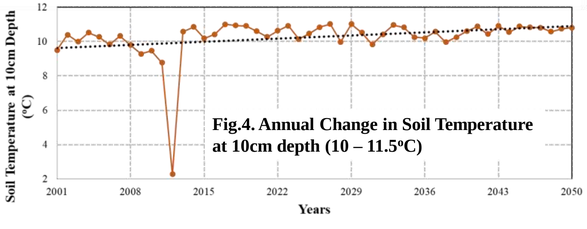

Fig.4. Annual Change in Soil Temperature at 10cm depth (10 – 11.5°C)

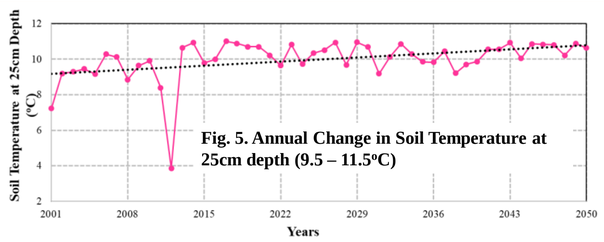

Fig. 5. Annual Change in Soil Temperature at 25cm depth (9.5 – 11.5°C)

Model 2 showed the changes in release of nitrogen compounds w.r.t. changes in soil temperature at 10cm and 25cm depths (Figures 6 – 9).

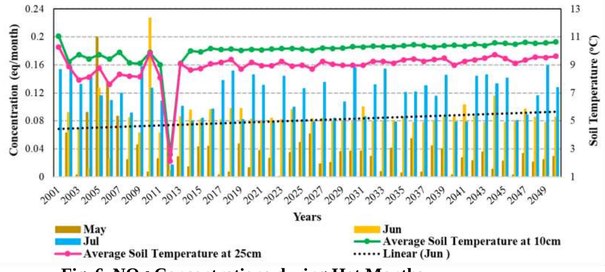

Fig. 6. NO_3^- Concentrations during Hot Months.

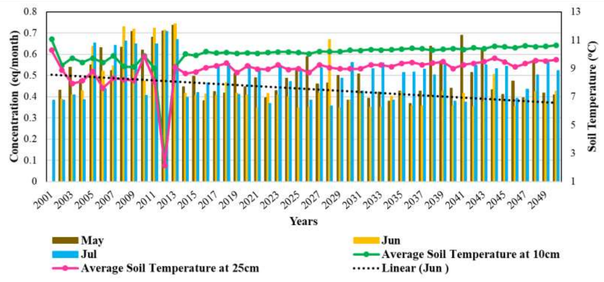

Fig. 7. NH_4^+ Concentrations during Hot Months.

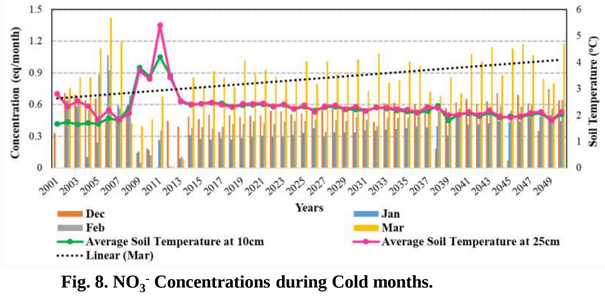

Fig. 8. NO_3^- Concentrations during Cold months.

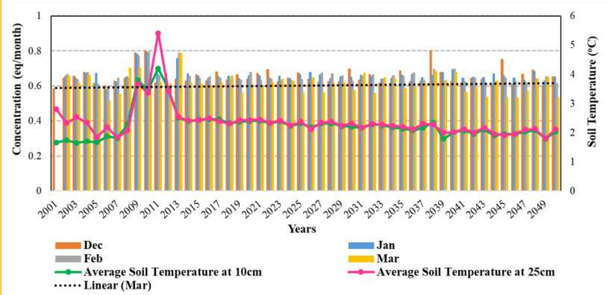

Fig. 9. NH_4^+ Concentrations during Cold months.

Model 2 showed when the temperature at 25cm depth is higher than at 10cm, there is higher release of nitrogen compounds to the water body.

DISCUSSION

Findings of the Models –

- The variations in air temperature and the soil temperatures at 10cm and 25cm depths is found to be directly proportional.
- There is an increasing trend of air temperature by 2050 and an increasing trend in the release of nitrate to water bodies.
- Concentrations of nitrogen compounds released to water bodies is high towards the end of cold months and low during hot months.
- For any temperature above or below the optimum range for the denitrification reaction (12 – 27°C), the concentrations of nitrogen compounds in water body are found to be high.
- The concentration of NO_3^- and NH_4^+ in the water body is high when the temperature at 25cm depth is higher than at 10cm depth, thus creating a positive soil thermal gradient, and vice versa.

CONCLUSIONS

1. Soil moisture, air temperature and soil temperature gradient can affect the release of soil nitrogen to water bodies, significantly.
2. The movement of NO_3^- and NH_4^+ is upward when soil temperature at deeper depth is higher than at the shallower depth (cf. Figs. 6 – 9).
3. The movement of NO_3^- and NH_4^+ is downward when the temperature at shallower depth is more than the bottom profile of the soil (cf. Figs. 6 – 9).
4. The models predicted an increase in nitrogen compounds by the year 2050 in BBWM.

REFERENCE

- Patel K. F., Nelson, S. J., Spencer, C. J. and Fernandez, I. J. (2018) Fifteen–year record of soil temperature at the Bear Brook Watershed in Maine, *Scientific Data*, 5, 180153 (2018) doi:10.1038/sdata.2018.153.

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