Assessing Factor Contribution to Nitrogen Concentration Levels in the Raccoon River Watershed in Iowa

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Introduction

The Raccoon River Watershed (RRW) in Iowa has received considerable attention in recent years due to concerns regarding excessive nitrate-nitrogen (N) concentrations in the Raccoon River (RR).

Source: Jha, Gassman, and Arnold, (2007).

Frequent detections of N concentrations above the federal drinking water standard of 10 *mg L*$^{-1}$ have raised questions about the sources of N in the RR.

Intensive agricultural production is a predominant use of a significant portion of the land in the RRW and is a primary driver of the local economy within the watershed. The increase in livestock production is also a concern within the watershed.

Objective

The purpose of this study is to assess the factors affecting the monthly N concentrations in the RRW. What determines the variation of N concentrations among a list of presumed relevant factors (fertilizer application rate, rainfall, temperature, livestock, crop-N-removal, and population), and what are their relative importance?

Method

This study employs the GARCH(1,1) process to model the distribution of nitrate concentrations in the Raccoon River. The GARCH model is an extension of the Autoregressive Conditional Heteroscedastic (ARCH) model originally developed by Eagle (1982).

GARCH is a time series technique used to model the serial dependence of volatility. The GARCH model allows current and lagged conditional variances, as well as past realization of the disturbance term, to affect the sample data generating process.

1) **Mean Equation**:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} +$$

$$\beta_3 FLOW_t + \sum_{i=0}^{2} \gamma_i RF_{t-i} + \sum_{i=0}^{2} \delta_i TEM_{t-i} +$$

$$\sum_{i=0}^{6} \theta_i FER_{t-i} + \tau_1 NRE_t + \tau_2 POP_t + \tau_3 T_t + \varepsilon_t$$

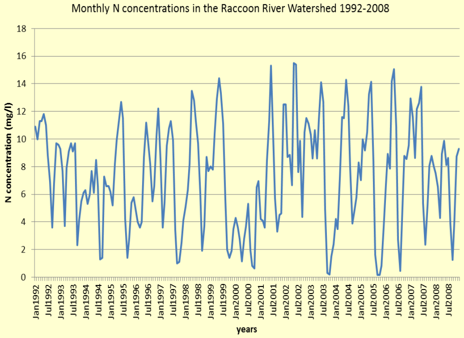
Y_t = Average N Concentration;
$FLOW_t$ = Average water flow rate;
RF_t = Average rainfall;
TEM_t = Average Temperature;
FER_t = Total Nitrogen fertilizer application;
NRE_t = Total N update
POP_t = Total population;
T_t = months;
ε_t = error term.

2) **Variance Equation**:

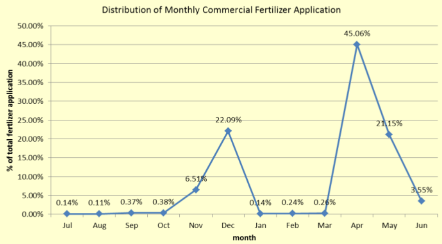
$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2$$

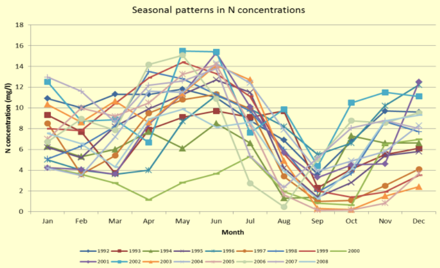
Data Description

Study period: 1992-2008
Monthly N concentration data: Des-Moines Water Works at Van Meter
Water flow rate: Des Moines Water Works



Rainfall and Temperature: National Climate Data Center
Corn planted acreage and yield: NASS/USDA
Livestock numbers: NASS/USDA
Commercial fertilizer sales: Commercial Feed and Fertilizer Bureau
Plant N uptake: calculated by assuming that corn grain contains, on average,7% crude protein and that the protein is comprised of 16% nitrogen (Morrison,1961).





Results

Variable	Lag	Parameter Estimate	Short Run Implied Elasticities[1]	Long Run Implied Elasticities[1]
		Mean Equation		
Constant		3.2270 (32.8058)		
N-Concentration	-1	0.7370** (0.0129)		
	-2	-0.0729 (0.0838)		
Water Flow Rate (t)		-0.0031 (0.0035)		
Precipitation (t)		0.0124* (0.0051)	0.1333	0.1333
	-1	0.0163** (0.0038)	0.1727	0.2695
	-2	-0.0045 (0.0032)		
Temperature (t)		0.0058 (0.0453)		
	-1	0.0706* (0.0249)	0.6110	0.6484
	-2	-0.0498 (0.0259)		
Total N Fertilizer Application (t)		1.75e-08 (1.39e-08)		
	-1	3.05e-08 (2.09e-0.8)		
	-2	4.49e-08* (2.15e-08)	0.0863	0.1454
	-3	5.38e-08* (2.02-e08)	0.0997	0.1841
	-4	4.40e-08* (2.61e-08)	0.0815	0.2070
	-5	3.72e-08* (1.23e-08)	0.0688	0.2079
	-6	2.38e-08 (1.27e-08)		
Plant N Uptake (t)		-1.28e-08 (4e-08)		
Population (t)		-6.19e-05 (2.98e-04)		
Time (t)		0.0021 (0.0255)		
R^2		0.5091		
Log-likelihood		-426.9810		

Note: *, ** denotes statistical significance level at 0.05 and 0.01 respectively; and standard errors are in parentheses (Heteroskedasticity consistent standard errors according to Bollerslev and Wooldridge,1992); [1] calculated at their mean values.

Estimated mean equation is explicitly constructed by lags of N concentration and current and lagged values of a number of independent variables. Hence, the model estimated has an interesting separation of short- and long-run effects.

There is no statistically significant, observed increasing trend in N concentrations. There are very significant intra-annual variations in N concentrations and the existence of a very strong seasonal pattern.

Variations in rainfall and temperature contribute more to the monthly variation in N concentration than do the changes in nitrogen application rates. Practices such as strategically-placed wetlands designed for nitrogen removal could prove very beneficial in mitigating the effects of seasonal climatic variables such as rainfall and temperature on in-stream nitrogen levels.

Estimated parameters in the variance equation are not statistically significant except the intercept term.

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