# HYDROLOGIC NUTRIENT CYCLE RELATIONS IN THE OZARKS

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## ABSTRACT

A study was conducted on an Oak-Hickory forested experimental watershed in the southeast Missouri Ozarks to determine the relationship between precipitation input of certain cations, the variation in their concentration in throughfall and litter leachate, and the seasonal changes in streamflow output. During the year of study, with below normal precipitation, the nutrient flux was mostly positive. The nutrient concentrations in precipitation, throughfall and litter leachate tended to vary with season of the year and the amount and sequential timing of precipitation events.

## INTRODUCTION

Over the past ten years or more America has become increasingly concerned with all aspects of environmental preservation. A principal focus, the protection and restoration of high quality water in our streams and lakes, has been demanded by the public. With Public Law 92-500, water quality has been made a national committment. The greatest volume of high quality water originates in our forests and other wildlands. Today, wildland managers face the dilemma of trying to meet the ever-expanding demands being placed on the resource while at the same time protecting the source areas for clean water yield. Moreover, is spite of a backlog of research on other aspects of watershed management and forest hydrology spanning several decades, relatively little is known about the impact of various forest land use practices on water quality.

Earlier research was directed at determining the effects of clearcutting and other forms of devegetation on forest nutrient yields. In general, the yield of most nutrients to streamflow tends to increase following timber harvest at rates dependent on factors, among others, related to the method and duration of devegetation (Borman et al., 1969; Aubertin and Patric, 1972; Swank and Douglas, 1975).

In order to better understand these responses, more recent researchers, working in undistrubed watersheds, have been attempting to identify the pathways and mechanisms binding the nutrient and hydrologic cycles. Nutrient flux studies, quantifying basin ion inflows through precipitation and outflows by way of streamflow, have been reported by Swank and Douglas (1975), Elwood and Henderson (1975) and Settergren et al. (1976). However, the magnitude of intrasystem cycling has been reported to be significantly greater than input and loss components (Cole et al., 1967; Woodwell and Whittaker, 1967). Moreover, it is these intrasystem processes which are most likely to be disrupted by the various forest management activities. Winters (1976) and Akhtar et al. (1976) provide summaries of a number of studies on other nutrient budgets associated with throughfall, stemflow, litterfall and litter leachate. In general, these sources contribute calcium, magnesium, potassium, sodium, phosphorous and nitrogen. The additions of phosphorous and nitrogen tend not to be reflected in streamwater concentrations because of other sinks including soil and plant uptake.

## RESEARCH IN MISSOURI

Settergren et al. (1976) reported on a nutrient flux study involving 4 small undistrubed forested watersheds at University Forest in the southeast Missouri Ozarks. These catchments annually lose calcium, magnesium and silica. During years of above normal precipitation there was also a small net loss of potassium and sodium. Ammonium, nitrate and total phosphate showed a positive flux.

Variations in yields of specific ions were attributed to internal watershed process including annual plant-soil nutrient cycling and geochemical weathering. High yields of ammonium, phosphorous, potassium and calcium occur most frequently in the summer and early fall as these nutrients are picked up by rainfall from the tree foliage and decomposing leaf litter. The relative concentrations also appeared to be related to the storm magnitude and the time since the previous flushing event.

## THE STUDY

The present study, carried out on one of the four watersheds at University Forest, was conducted to quantify the contributions from several of these internal sources to the nutrient flux. Specifically, the objectives of this research were to examine the magnitude and variability in the nutrient content of precipitation, throughfall and forest floor leachate, and to discuss these pathways in relation to streamflow quality. In addition, a number of independent variables were examined to determine their relationship to the nutrient concentration.

### Study Area and Methods

The study was conducted on a 7.29 hectar (18 acres) gauged watershed at University Forest (figure 1). The catchment has an even-aged, predominantly oak and hickory forest cover which has been undisturbed since establishment 50 to 70 years ago.

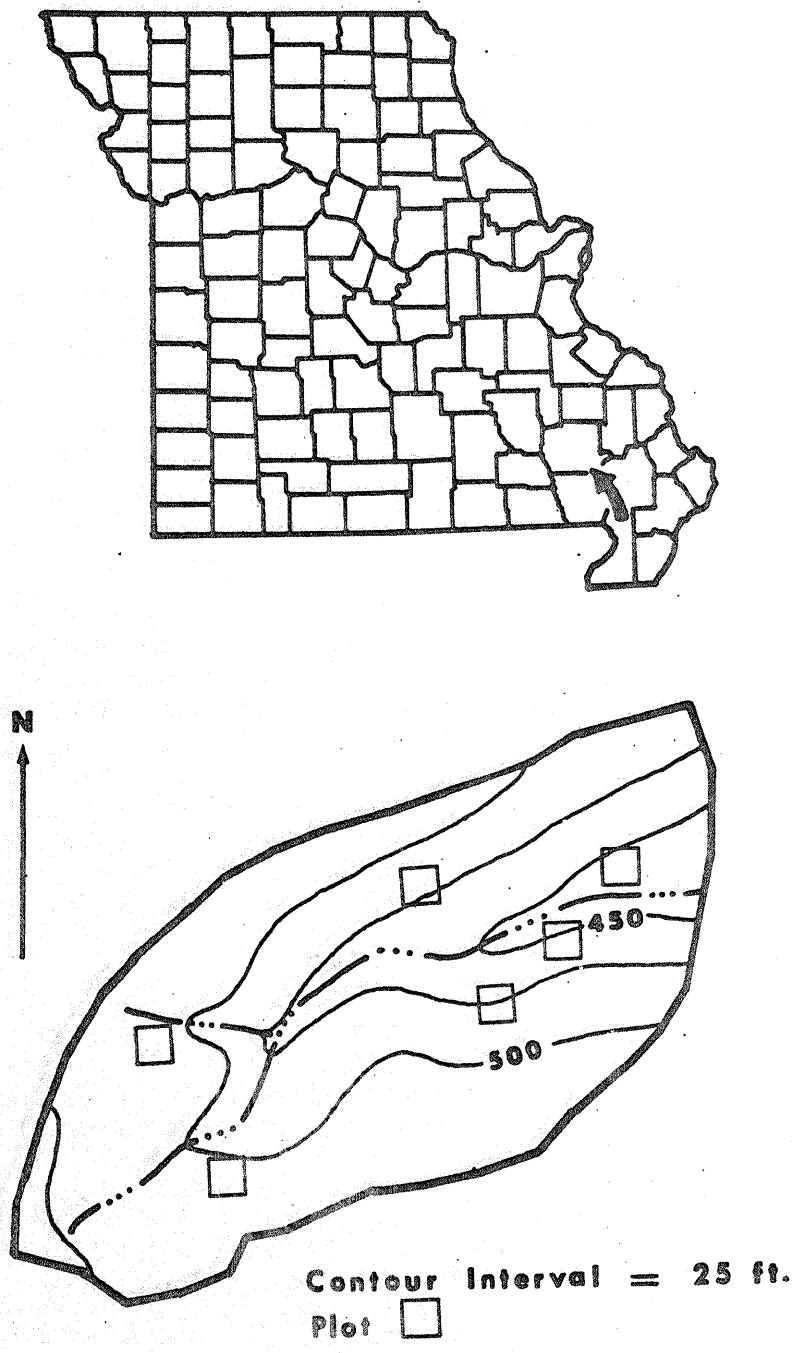


Figure 1. Watershed and plot location at University Forest.

The watershed overlies carbonate bedrock and the potential for periodic losses to deep seepage has already been demonstrated (Settergren and Boehm, 1972). The soils are derived from the weathered residuum of the underlying dolomitic limestone and sandstone, primarily of the Roubidoux formation series. The soils are classified as Clarksville stony loam, a member of the loamy-skeletal, seliceous mesic family of Typic Paleudults. These soils are strongly acid at the surface, tend to increase in density, percent clay and chert with depth but, in spite of their density, tend to be relatively well drained (at least in comparison with other Ozark soils). They are frequently droughty during the late summer.

Six plots were selected within the watershed for the collection of throughfall and leachate samples. The collectors were randomly located within each plot (figure 1). The plots were located to enable the sampling of different slope positions, aspects and elevations. Throughfall was sampled using simple funnel collectors. Litter patches were cut, lifted and relocated in pan collectors to sample the litter leachate. Five replications of throughfall and two replications of litter leachate were established for each plot. Subsamples were combined for analysis. Precipitation samples were obtained at the nearby weather station using throughfall collectors. Stream discharge was gauged and water quality samples were obtained automatically for all storm events using a gang of single-stage collectors similar to those designed by Sartz and Curtis (1967). Grab samples were also taken to augment the streamflow quality data.

During the almost year-long study period, which extended from July 15, 1975 to June 15, 1976, 26 storms were sampled. However, not all storms during the period were inventoried. In both July and August as many storms as possible were sampled. After September 1, however, only events during the first 15 days of each month were inventoried. The 1975-1976 water year produced well below normal precipitation and only three of the sampled storms yielded measurable streamflow from the intermittant drainage. The sampled storms ranged from 0.04 to 1.87 inches and totaled, for the year, 14.59 inches. Total precipitation for the year of study was 41.61 inches, 6.15 inches less that normal for the area.

Several statistical analyses were employed on the storm nutrient data. An analysis of variance was performed, classifying samples by date, aspect, elevation and an aspect-elevation interaction. Multiple linear regression analyses were used to describe nutrient concentration relationships, as well as the total amounts of collected throughfall and leachate. A number of additional variables were generated for use in the analysis including total storm precipitation, mean monthly temperature, an indicator variable for dormant or growing season and several anticedent moisture parameters.

## Sample Preparation and Nutrient Analysis

All samples were collected and frozen within 24 hours of each storm event. The samples were transported to the laboratory at the University in Columbia for analysis, usually on a monthly basis. Standard methods were employed for the analysis of calcium, magnesium, potassium and sodium. Calcium and magnesium concentrations were determined by atomic absorption spectroscopy using a Perkin-Elmer 290-B unit. Sodium and potassium were determined by flame emission.

# RESULTS AND DISCUSSION

The nutrient concentrations for the storms sampled are presented below. No attmept will be made here to present more that a summary of the significant results of the several multivariate analyses run. This information is available elsewhere (Winters, 1976).

## Nutrient Content of Sampled Components

The relative importance of precipitation, throughfall and forest floor leachate in contributing to streamflow concentration varies with each nutrient (table 1). Quantities of sodium are least influenced by the forest canopy and the forest floor. On the other hand, the bulk of the calcium and magnesium deposition appears to come from the mineralization of leaf litter at the forest floor, even though considerable quantities of calcium and magnesium also originate as throughfall. Potassium is contributed in great quantities in throughfall. Of the three combined pathways, throughfall accounts for 46 percent of the total potassium reaching the surface of the mineral soil.

Table 1. Nutrient concentrations in precipitation, throughfall and forest floor leachate for 26 sampled storms during 1975 and 1976.

| Source | K | Na | Ca | Mg |
|---|---|---|---|---|
| | - - - - - - - kg/ha - - - - - - - | | | |
| Precipitation | 0.76 | 1.46 | 3.61 | 0.29 |
| Throughfall | 6.86 | 1.85 | 6.94 | 1.33 |
| Forest Floor Leachate | 13.15 | 1.97 | 15.02 | 3.05 |

With the paucity of streamflow nutrient concentration data, samples available from only three storms, it is difficult to make any definitive statement with respect to the possible contributions from the three input sources. In fact, in contrast to the annual nutrient budget calculated by Settergren et al. (1976) for this basin, which shows a small (negative flux) loss of all four ions examined in this study, there is a positive flux for these three storms combined for calcium, potassium and sodium (table 2). Apparently, a portion of the nutrients added by stemflow, throughfall and litter leachate are being diverted elsewhere. Possibly, during this year of high soil moisture deficit, the nutrients may have a greater opportunity to be adsorbed in the surface soil. And, with a greater proportion of the water going into replenishing depleted soil storage, there is less of a chance for nutrient flushing to streamflow. Furthermore, the small net streamflow loss of magnesium can more than be accounted for by the additions of throughfall and litter leachate for the combined storm data. The annual flux (table 3) shows the same trend.

## Factors Influencing Nutrient Concentrations

The models developed for determining the relative significance of the several independent variables studied revealed some interesting relationships. For example, significantly higher concentrations of calcium and magnesium were found in the forest floor leachate from plots on a north aspect as compared to the south. These north sites normally have a deeper litter accumulation and, therefore, a greater nutrient pool.

A number of variables related to season of the year were found to be significant in determining the concentration of various nutrients in throughfall. The concentration of calcium and magnesium in the forest floor leachate, for instance, increases with higher temperature during the summer months. Higher temperatures bring on higher rates of litter decomposition and mineralization of nutrients. Higher temperatures may also bring about higher rates of solubility for calcium compounds.

Table 2. Nutrient cycling and flux for three selected storms (12/5/75, 12/15/75, and 3/4/76).

| Source | K | Na | Ca | Mg |
|---|---|---|---|---|
| | kg/ha | | | |
| Precipitation | 0.206 | 0.610 | 0.882 | 0.088 |
| Throughfall | 0.701 | 0.834 | 1.316 | 0.212 |
| Forest Floor Leachate | 2.839 | 0.827 | 1.956 | 0.416 |
| Runoff | 0.203 | 0.058 | 0.268 | 0.242 |
| Flux | +0.003 | +0.552 | +0.614 | -0.154 |

Table 3. Nutrient flux for the period July 15, 1975 to June 15, 1976.

| Source | K | Na | Ca | Mg |
|---|---|---|---|---|
| | kg/ha | | | |
| Precipitation | 2.611 | 1.824 | 5.438 | 1.194 |
| Runoff | 0.915 | 0.798 | 2.486 | 1.244 |
| Flux | +1.696 | +1.026 | +2.952 | -0.050 |

The throughfall potassium concentration increased during the growing season, again, because of the increased availability of this nutrient in leaf tissue to leaching. In addition, the effect of frontal versus convective precipitation in controlling the concentration of sodium in throughfall may be responsible for its inverse relationship to mean monthly temperature. Winter cyclonic storms may import greater quantities of sodium. The high magnesium concentration in throughfall in the spring coincides with the emergence of young leaves and reproductive structures.

The amount and timing of precipitation inputs was, as anticipated, strongly related to nutrient concentrations. The amount of storm precipitation was inversely related to all nutrient concentrations in the precipitation, throughfall and forest floor leachate. The statistical importance of the sequential timing of precipitation events, however, may be a reflection of some coincidental occurrences between precipitation events. The observed increase in throughfall potassium and calcium concentration, for instance, may be due to an import of atmospheric calcium between storm events, or to a build-up of excess nutrient material in leaf tissue as transpiration progresses.

A relationship between anticedent moisture and calcium and magnesium leachate concentrations may also be due to timing of storm events. With deficient quantities of precipitation, the forest floor produces less calcium and magnesium in the leachate. This may be due to decreased biological decomposition when the forest floor moisture is depleted. Concentrations of magnesium and calcium may be further reduced if there has been some anticedent precipitation event only one day prior. In this case, decomposition of the litter may not have proceeded far enough to replenish the pool of soluble mineral nutrients.

## CONCLUSIONS

Nutrients are in a delicate balance within a watershed. The annual flux of some ions may be positive or negative depending on the precipitation and runoff regime and the magnitude and timing of inputs from several internal processes. A more comprehensive study of these processes on a storm by storm basis would be useful.

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