People and the Temperate Region

A Summary of Research from the United States Man and the Biosphere Program 1991
The Southern Appalachian Biosphere Reserve Cluster was established to provide a basis for research on the structure, function, and dynamics of selected forest ecosystems and to enhance the understanding of natural processes and people’s impacts upon them, with subsequent applications toward the formulation of better land management policies. Coweeta Hydrologic Laboratory and the Great Smoky Mountains National Park, two biosphere reserves, are the sites for the development of this program.

Objectives

Watershed studies at both biosphere reserve sites have shown that concentrations of nitrate-nitrogen (NO$_3$-N) are highly variable in streamflows from old-growth, aggrading, and disturbed deciduous forest ecosystems. At the Coweeta Hydrologic Laboratory, for example, logging and other disturbances produce elevated NO$_3$-N concentrations compared to aggrading forests; while in the Great Smoky Mountains National Park, NO$_3$-N concentrations are higher in streams of old-growth compared to aggrading forests. Other studies at the Coweeta Hydrologic Laboratory indicate enhanced microbial activity in the forest floor and soil following disturbances, increasing soil NO$_3$ available for leaching to streams. However, similar nitrogen transformation data have been unavailable for the Great Smoky Mountains National Park and, consequently, this study was designed to address the following objectives:

- Quantify the rates of free-living nitrogen fixation, potential mineralization, and potential nitrification in the forest floor and soil compartments of old-growth and aggrading forest stands in the Great Smoky Mountains National Park.
- Compare the rates of these nitrogen transformation processes in forests disturbed by wild pig rooting (Figure 1) with the rates from undisturbed forests, and measure the impacts of NO$_3$ concentrations in the soil and stream water draining these forests.

**FIGURE 1.** Intensive wild pig rooting alters the nitrogen transformation processes in the deciduous forests of the Great Smoky Mountains National Park.
Approach

Four existing experimental sites located in the Great Smoky Mountains National Park were utilized in this study.

- The old-growth forest site, located on the Camel Hump Creek watershed, is dominated by a virgin stand of Tsuga, Aesculus, Tilia, and Betula species. Husky Branch watershed, selected as the aggrading forest, is dominated by an 80-year-old Liriodendron stand in association with Betula and Prunus species. These two watersheds are each about 650 hectares in size, oriented toward the northeast, and underlain by sandstone bedrock.

- The two sites selected to study the disturbance by wild pig rooting were the Double Spring Gap watershed, an area that has been rooted intensively for 15 years, and the Garretts Gap watershed, which had not been occupied by wild pigs. Each watershed, 0.2-hectare in size, is drained by intermittent streams. The forest cover, which is similar on both study sites, is comprised primarily of Fagus with Acer and Betula the predominant associated taxa.

Samples of partially decomposed forest floor litter (the O layer), and A horizon (0-10 centimeter depth) and B horizon (20-30 centimeter depth) soil compartments were collected seasonally in six sample periods for assays of nitrogen transformation.

- For the old-growth and aggrading forest sites, on each sample date, six samples were taken for each soil horizon from plots located at approximately the same elevation and exposure on each watershed. For the two sites used to study wild pig rooting, five samples were obtained in the same manner.

- Nitrogen mineralization and nitrification potentials were measured as changes in total mineral nitrogen and NO₃, respectively, during 33-day aerobic incubations in the laboratory. Uniform temperature and moisture conditions were maintained throughout the incubation period. Nitrogen fixation potentials of free-living bacteria in the sampled horizons were measured on field-moist samples in the laboratory with the C₂H₂-reduction assay.

- Streams draining the rooted and unrooted sites were gauged with H-flumes. Samples of runoff were collected proportionally to the flow with a Coshocton wheel. Four pairs of porous cup lysimeters were installed on each watershed site at depths of 30 and 100 centimeters to collect soil water for chemical analyses.

Major Findings

Among the major findings of this study were:

- Potential nitrogen mineralization rates were highest in the forest floors on all study sites and declined with an increase in soil depth (Figure 2). In the comparison of old-growth and aggrading forests, potential mineralization was 20 to 30 percent higher in the forest floor and soil layers in the old-growth forest, although the differences were not statistically significant.

- For the rooted and unrooted comparison, the mineralization potential was lower in the O layer of the sites rooted by wild pigs (Figure 2). Percent of nitrogen also was significantly lower in this layer in comparison to the unrooted site. Conversely, the mineralization rates were about 20 percent higher in the A and B soil horizons on the rooted sites, but these differences were not statistically different.
Potential Mineralization

![Graph showing potential mineralization rates on the forest floor of all study sites declined in relation to soil depth.]

FIGURE 2. Potential nitrogen mineralization rates on the forest floor of all study sites declined in relation to soil depth.

Potential Nitrification

![Graph showing potential nitrification rates on the forest floors in all study sites declined in relation to soil depth.]

FIGURE 3. Potential nitrification rates on the forest floors in all study sites declined in relation to soil depth.

- Potential nitrification rates (that is, the oxidation of ammonium to nitrate) also were highest in the forest floor on all study sites and declined with soil depth (Figure 3). These rates were not statistically different on the old-growth and aggrading forest sites, but they tended to be higher in several compartments of the old-growth stand. Rates of nitrification were significantly lower in the O$_2$ layer on the rooted site, although they tended to be higher in the soil horizons in comparison to the unrooted site.

- Nitrogen fixation potentials were higher in the O layer in the aggrading forest, but lower than the rates for the two soil compartments in the old-growth forest. There were no significant differences in nitrogen fixation between the rooted and unrooted stands.

- Soil water concentrations of NO$_3$-N at 30 and 100 centimeters were higher in the rooted forest. Nitrate-nitrogen concentrations in the stream water of the rooted sites were greater than those that were found at the unrooted site. These concentrations showed a trend that was parallel to that of the soil water.

**Implications**

The results of this initial study of nitrogen transformations in selected forest ecosystems of the Great Smoky Mountains National Park generally parallel the findings at the Coweeta Hydrologic Laboratory and other eastern temperate forest ecosystems. Specifically, these results indicate the following:

- Higher rates of nitrogen mineralization and nitrification in old-growth forests in comparison to aggrading forests appear to contribute to higher NO$_3$ concentrations in the streams draining the old-growth forests. Other processes of nitrogen cycling not measured in this study, such as vegetative uptake and incorporation of nitrogen into the old-growth stands, are thought to account for part of the observed differences in the levels of NO$_3$ in the streams. The high NO$_3$ losses from old-growth forest stands, therefore, should be interpreted as a natural consequence of stand maturation rather than an external influence of people.
Disturbance, as represented by the intensive wild pig rooting of deciduous forests in the Great Smoky Mountains National Park, alters the nitrogen transformation processes in the forest floor and soil compartments. Observed increases in $\text{NO}_3^-$ concentrations in the soil and stream water of the rooted forest could be partly the net effect of nitrogen microbial processes, and partly a response to reduced nitrogen uptake and recycling due to the elimination of the herbaceous vegetative layer by the rooting activity. In combination with other studies of wild pig rooting in the Great Smoky Mountains National Park, such a disturbance is considered to have negative impacts on the deciduous forest.