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Spatial variation in soil physical properties and effects on soil NO3– production on forest hillslopes

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Ammonium (NH_4^+) and nitrate (NO_3^-) concentrations and production rates in forest soil vary by hillslope position due to variation in ammonia-oxidizing microorganism concentrations, soil chemistry, and surface soil moisture. These spatial distributions have a significant effect on nutrient cycles and streamwater chemistry. Soil moisture conditions significantly restrict microbial activity, influencing the spatial distribution of NO_3^- concentrations on forest hillslopes. However, studies linking forest hydrological processes to nitrogen cycling are limited. Therefore, we investigated the determinants of spatial variation in soil moisture and evaluated the effects of soil moisture fluctuations on spatial variation in NO_3^- concentration and production rate.

The study sites were the Fukuroyamasawa Experimental Watershed (FEW) and Oyasan Experimental Watershed (OEW) in Japan. The two have similar topographies, climates, and tree species. In each watershed, a 100 m transect was set up from the ridge to the base of the slope, and soil moisture sensors were installed at soil depths of 10 cm and 30 cm at both the top and bottom of the slope. We collected surface soil samples at a depth of 10 cm at the top, middle, and bottom of the slopes using 100 cm^3 cores, and measured soil physical properties, particle size distribution, volcanic ash content, chemical properties (pH, NO_3^-, NH_4^+, nitrification rate, and mineralization rate), and microbial content (archaeal content). Spatial and temporal changes in soil moisture on the hillslope were calculated using HYDRUS-2D to examine contributing factors of soil moisture.

At FEW, high NO_3^- concentrations and nitrification rates were observed only at the slope bottom and middle, and no NO_3^- concentrations were detected at up slope. By contrast, at OEW, high NO_3^- concentrations and nitrification rates were observed at all points. NH_4^+ concentrations were similar at all points in both watersheds. At FEW, 10 cm surface soil moisture fluctuated within 25–40% at the slope top but was within 40–50% at the slope bottom. At OEW, surface soil moisture was 30–40% at both the slope top and bottom, with no significant differences according to slope position. It was confirmed that soil moisture was significantly involved in NO_3^- concentration and nitrification rates. Model simulations showed that the difference in soil moisture fluctuations between FEW and OEW was mainly explained by the spatial variation in soil physical properties. In particular, volcanic ash influenced soil moisture along the entire slope at OEW, resulting in high water retention, but only influenced soil moisture at the slope bottom at FEW. These findings indicate that spatial variability in soil physical properties has a significant effect on soil moisture fluctuation and leads to a spatial distribution of NO_3^- production.