Atmospheric depositions on forest ecosystems in areas along the Sea of Japan

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In recent years, concerns about the effects of excess-nitrogen usage by human activities on terrestrial environment, including forest ecosystems, have been increasing at a global scale. The phenomenon of high-nitrate efflux from several forest watersheds has already been reported in the surroundings of metropolitan areas in Japan. Furthermore, concerns regarding the effects of transboundary air pollution on areas along the Sea of Japan with expanding economic activities have been increasing in Asian countries. However, on-site monitoring throughout the year is difficult in most of these areas because of heavy snow, especially in the mountainous area. Therefore, the behaviors of elements within forest ecosystems throughout a year have primarily not yet been elucidated in this district. This study was conducted to determine the influxes and effluxes of elements in this heavy snowy region and to understand the contribution of transboundary air pollution to the quantity of atmospheric deposition. We also carried out rainfall and stream water investigations from the headwater area to the lower stream area in the Tedori River Basin and an inland mountainous area to understand the geographical distribution of the actual conditions of elements' influxes and effluxes in this region. We started monitoring the major and minor elements in a small forested watershed in the middle part of the Tedori River Basin, Ishikawa prefecture, Japan, in 2013. In this study site, we observed a large amount of precipitation throughout the year. Regarding the annual snowfall amount, there were extensive variations among the years. Seasonal fluctuations were observed in the influx of atmospheric deposition; in particular, the distribution of most of the elements increased during winter. The annual deposition average of inorganic nitrogen (NH_4-N + NO_3-N) in this site was 15.8 kg ha^{-1}. The contribution of winter season deposition to the annual inputs was high. The influx of nitrogen by bulk precipitation during winter season was 2.3 times that of summer, and that of sulfur sulfate was 3.7 times. The nitrogen influx quantity was similar to or more than that reported in nitrogen-saturated forested areas of the Kanto district. Therefore, similar to that in the Kanto district, higher nitrogen deposition loads from the atmosphere could also be influenced on the effect of nitrogen dynamics and the increase in nitrogen efflux at these forest watersheds. However, the efflux concentrations of most of the dissolved elements in stream water did not show clear seasonal fluctuations. Stream water nitrate concentration was stable and low. In addition to the seasonal fluctuation of nitrogen and sulfur, the ratios among some trace elements, which are anthropogenic substances (Pb, V, As, etc.), and sea salts and yellow sand could be useful indicators to elucidate the contribution of transboundary air pollution to these regions. We compared the element inputs associated with precipitation during the non-snowy season (July–November) at six locations in the Tedori River Basin and one location in the inland area. The inorganic nitrogen and sulfuric acid sulfur influxes were the largest at the middle reaches of the Tedori River Basin. The inflow amount of inorganic nitrogen and sulfuric acid sulfur at two points in the mountainous area was approximately half or less than that at the middle region and was approximately the same as the inflow amount at the inland mountainous area. Furthermore, we investigated stream water, spring water, and ground water samples from the headwater area to the lower stream area in the Tedori River Basin. The nitrate concentrations in all the samples ranged from 0.00 to 2.93 mgL^{-1} (median value: 0.69 mgL^{-1}). In contrast, the nitrate concentrations of stream water in the Tsukuba experimental forest watershed, which has been reported as a nitrogen-saturated forested area of the Kanto district, were much higher (average value: 7.56 mgL^{-1}) than those in the Tedori River Basin. Compared with the influx, the efflux concentrations of nitrate in the water

samples were generally very low around this basin. Therefore, higher nitrogen depositions have not yet distinctly influenced the nitrate concentrations of stream water in this area. To elucidate the influence of transboundary air pollutant influx on the entire Tedori River Basin, it is necessary to evaluate the inflow amount during the snowy season in the mountainous area. Therefore, it is important to establish a method that can be used to observe the influx and efflux of elements throughout the year even in mountainous areas with heavy snow.

