Long-term dynamics and future perspective of streamwater chemistry in forested headwater catchments

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In Japan, rainfall patterns have been changing and extreme storm events are increasing as the effects of climate change. These events will cause some kinds of changes of hydrological and hydrochemical responses of the catchments. However, the responses may different depending on the attributes and/or background conditions of each catchment. In this study, we discuss about past, current, and future hydro-biogeochemical responses in a forested headwater catchment in Japan.

The observation was conducted in Kiryu Experimental Watershed (KEW). The area of KEW is 5.99 ha. The bedrock material is weathered granite, and the vegetation is Japanese Cypress planted about 60 years ago. Now, the forest is unmanaged, and it is the typical of Japanese artificial forest. We set up the nested catchments, K and M. The K catchment correspond to the whole of KEW, and the M catchment (0.68 ha) is one of a subcatchment of K. The observation have been conducting since 1972 for precipitation and discharge rate at K, and since 1990 for discharge rate at M and for streamwater chemistry at both catchments, respectively.

The number of rainy days is decreasing but days with larger rainfall intensity is increasing in KEW. The annual baseflow ratio is decreasing and annual direct runoff ratio is increasing at the K catchment as the result of the changing pattern of rainfall. The sediment transport at the K catchment was constrained by the erosion control dams, however, it abruptly increased since 2010 because overaged dams were damaged and destroyed by recent large precipitations.

The effects of rainfall patterns are unclear in the monthly streamwater chemistry. However, the chloride concentration is decreasing for decadal periods at both catchments. At the M catchment, the vegetation was disturbed at about 20% of catchment area around 1990, and the nitrate concentration was highest around 1997-1999, then gradually decreased till 2005. However, it is increasing again in recent 10 years. At the K catchment, the effects of disturbance occurred at the M catchment was not so clear, but it is also increasing in recent 10 years. The dynamics of the streamwater chemistry in recent 10 years may be a result of the forest degradation, that is, chloride shows the decrease of evapotranspiration and nitrate shows the decrease of nutrient uptake.

The direct runoff rate and nitrate load at dormant (Oct. to Mar.) and glowing (Apr. to Sep.) seasons were estimated and considered the relationship to the precipitation in each season for K catchment. The nitrate load was estimated using the power-law relationship of concentration (C) and discharge rate (Q). The direct runoff rate is larger in the glowing season, that is, in rainy season in Japan, and consequently the nitrate load also larger in the season. This fact means that the nitrate load is mainly controlled by the hydrological processes. Moreover, it is suggested that the increase of extreme storm events especially in summer may cause the explosion of nitrate export from the headwater catchment to the downstream.

For the future perspective under the climate change, forested headwater catchments will respond both hydrologically and biogeochemically. In our site, the solute transport mainly controlled by the hydrological responses. However, the forest degradation can cause the change of the biogeochemical condition, and it will be the base of the streamwater chemistry. Therefore, we need to keep on monitoring to detect these changes with the state-of-the-art techniques.

Keywords: long-term monitoring, streamwater chemistry, forested headwater catchment, hydrological processes, forest dynamics