The Twenty-second Session of the Scientific Advisory Committee
on the Acid Deposition Monitoring Network in East Asia
18-20 October 2022, Virtual Meeting

**Progress of the studies on effects of acid deposition on ecosystems**
**(Project Activity 2 in 2022)**

Network Center for the EANET

## I. Introduction

1. Forest ecosystems provide various ecological services, such as provision of nature resources, groundwater recharge, carbon sequestration, and prevention of disasters. Long-term atmospheric deposition of acidifying species and related chemical substances may have disturbed the functions and resilience of forest ecosystems. According to the experience in Europe and North America, a recovery of forest ecosystems from acidification did not progress as expected and problems remained even after enough reduction of $SO_2$ and $NO_X$ emissions. Meteorological variabilities and extreme weather, such as changing precipitation patterns, high temperature and sudden heavy rains, may also affect the recovery process.

2. A field observation on a catchment scale is a useful approach to evaluate effects of atmospheric deposition on forest ecosystems, quantitatively and qualitatively, as suggested by previous studies in Europe and the United States[1]. In the EANET, the Scientific Advisory Committee (SAC) and its Task Force on Soil and Vegetation Monitoring (TFSV) recommended to promote catchment analysis and develop the monitoring methods for the EANET in the strategy papers[2], which were drafted by TFSV and adopted by SAC.

3. Besides the on-site catchment analysis, impact assessments on the regional scale have been contributing to reduction of the emissions historically, as shown in the experience in Europe (adoption of relevant protocols under the Convention on Long-Range Transboundary Air Pollution, UNECE). Therefore, the strategy papers above suggested that regional impact assessments be promoted in EANET to create common understanding of the current ecological impacts and provide useful inputs for policy makers.

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[1] Such as, the Hubbard Brook Experimental Forest (USDA Forest Service) and the network for ICP Integrated Monitoring under CLRTAP since 1960s and 1990s, respectively. In particular, the former is famous for the first observational evidence of acid deposition effects on forest ecosystems in the United States.

[2] The current version is ***"Strategy Paper for Future Direction of EANET on Monitoring of Effects on Agricultural Crops, Forest and Inland Water by Acidifying Species and Related Chemical Substances"***, which was adopted at the 20th Session of SAC.

4. The Asia Center for Air Pollution Research (ACAP) as the Network Center for EANET (NC), has been promoting studies on acid deposition effects on ecosystems from the catchment scale to the regional scale, according to recommendations in the technical documents and strategy papers. Since 2022, the studies have been conducted as one of the Project Fund Activities (Activity 2 in 2022).

5. In this report, the progress is overviewed with major outputs, such as scientific journal papers.

## II. Project scheme

6. The current active catchment sites relevant to the EANET are shown in Fig. 1. The field surveys at the Kajikawa catchment (KJK) have been continued since 2002 as one of the NC's research activities to assess the response of forest ecosystems to changing atmospheric deposition. Simultaneously, assessments of the regular EANET monitoring data have been promoted for the Lake Ijira catchment (IJR) and Komarovka River catchment (KMR) since 2005 and 2016, respectively, because acidification phenomena in these sites were suggested in previous reports. The data at the La Mesa Watershed (LMW), the new site launched in 2019, are expected to be accumulated gradually.

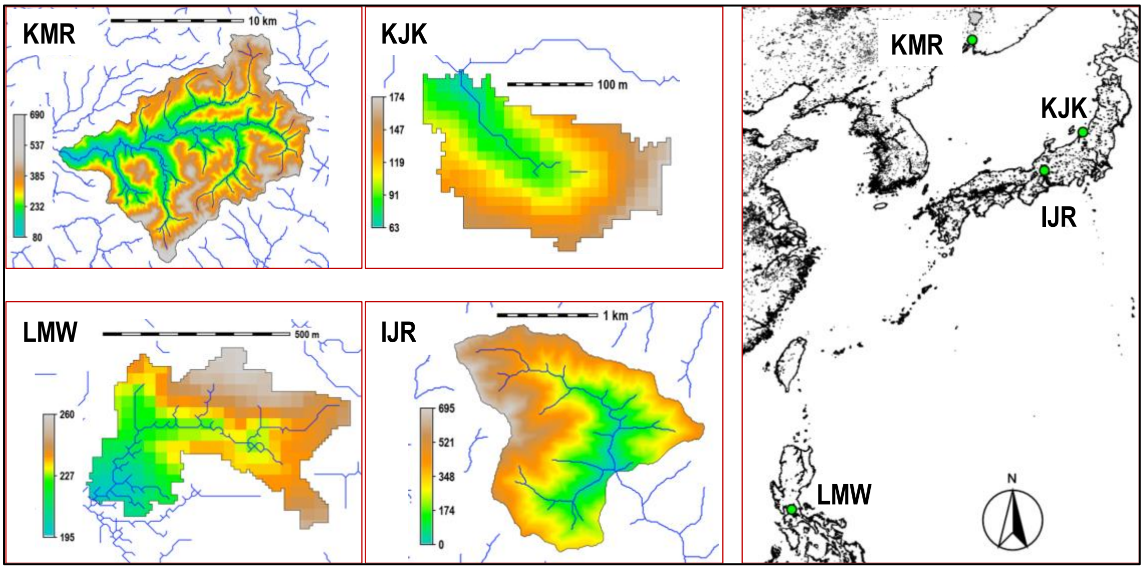


**Fig. 1 Locations of the EANET relevant catchment study sites (EANET 2021, Fourth Periodic Report of the State of Acid Deposition in East Asia, PRSAD4). KMR, Komarovka River catchment; KJK, Kajikawa catchment; IJR, Lake Ijira catchment; LMW, La Mesa Watershed.**

7. It should be pointed out that the external research budgets/grants have been supporting the research activities above in addition to the EANET Project Fund. Currently, the Grant-in-

Aid for Scientific Research (KAKENHI) from Japan Society of the Promotion for Sciences (JSPS) and the Ph.D. Program in Niigata University support intensive surveys at KJK and data assessment at KMR, respectively. The intensive surveys on isotopic analysis at KJK and IJR are collaborating with the national monitoring in Japan, too. They are considered as the in-kind contributions to the Project Activities (Fig. 2). Cooperation with modeling communities, such as MICS-Asia, will also contribute to methodological studies on impact assessments of the EANET region. Scientific knowledges, in particular scientific journal papers, which were outputs from the Project Activities, will contribute to preparation of the EANET Periodic Report as well as the national reports. In order *"to create common understanding on state of acid deposition in East Asia"*, which is one of the EANET objectives, these scientific knowledges will be shared through the EANET meetings, such as SAC sessions, and thematic workshops and seminars.

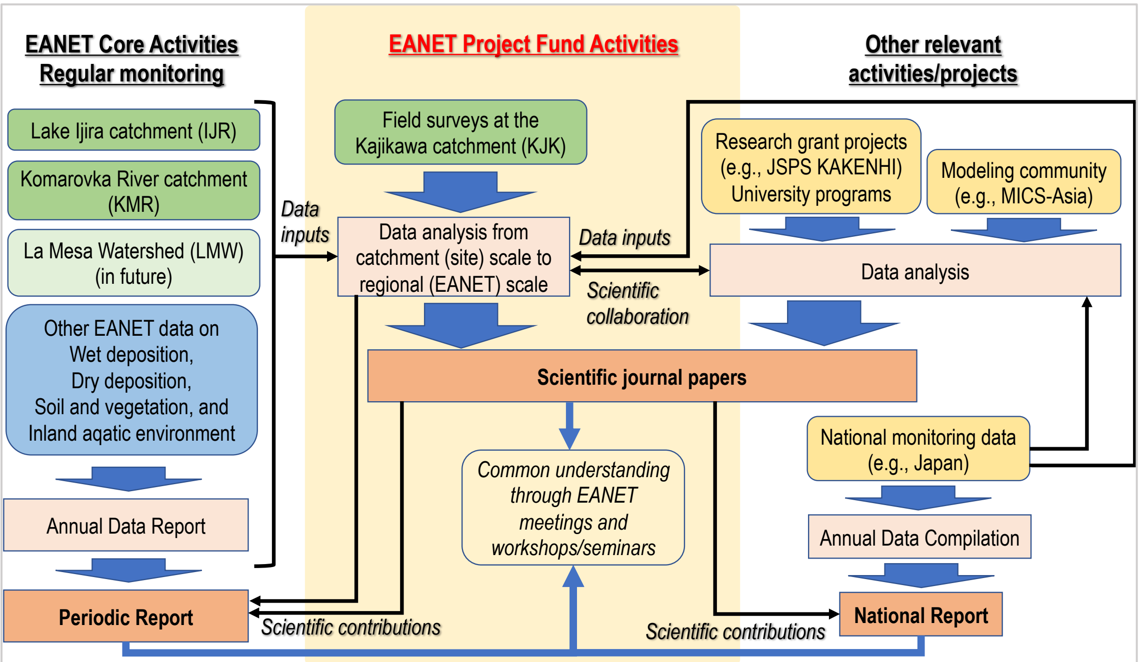


**Fig. 2. Overall scheme of the project activities for assessment of ecological effects.**

## III. Major progress

### A) <u>Findings at KJK, IJR and KMR</u>

8. Major findings highlighted in the latest publications from KJK and IJR include:

   - Compared to similar type soils in Japan, IJR accumulated more various S compounds (Tanikawa et al. 2022). As suggested by previous studies (Nakahara et al. 2010; Sase et al. 2021), in IJR, where S deposition was the highest level in Japan, sulfur (S) derived from the atmospheric deposition has been accumulated in forest soil (Fig. 3).

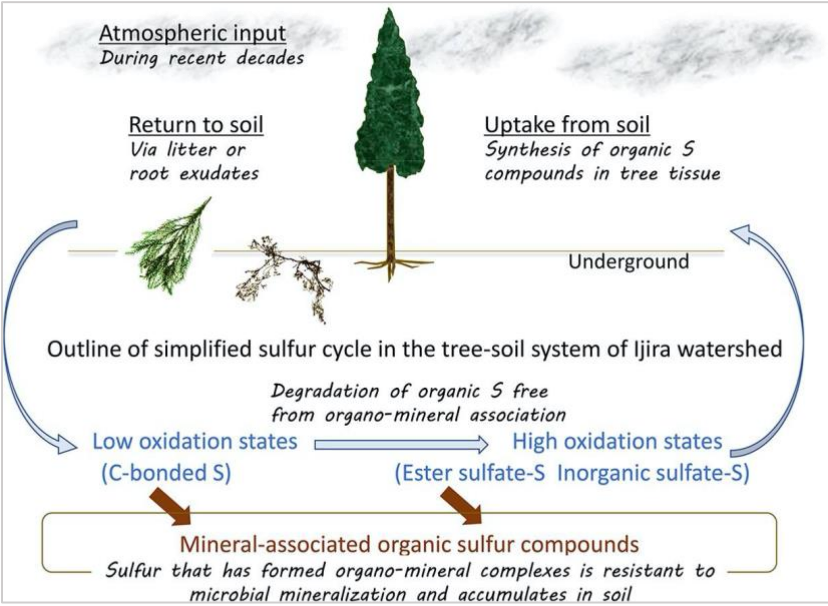


**Fig. 3. A mechanism of sulfur accumulation in the forest ecosystem of the Lake Ijira catchment (IJR) (Graphical abstract from Tanikawa et al. 2022)**

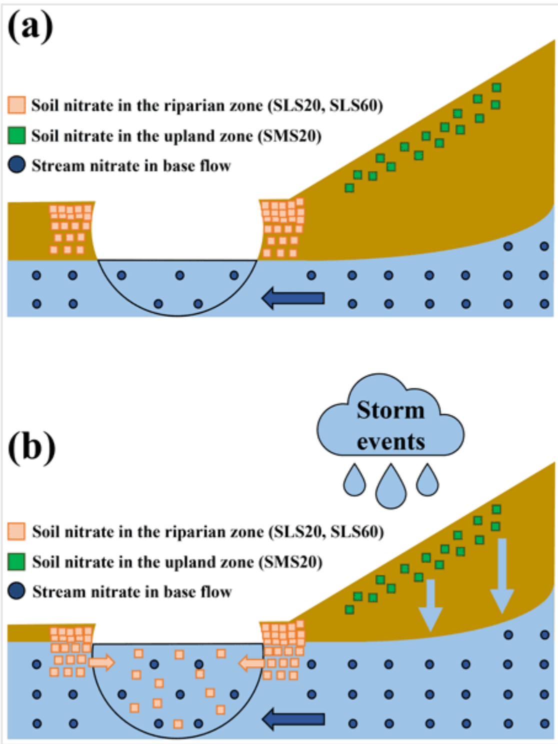


**Fig. 4. A mechanism of $NO_3^-$ leaching during storm events at the Kajikawa catchment (KJK) (Graphical abstract from Ding et al. 2022)**

- Long-term excess nitrogen (N) deposition causes an increase in $NO_3^-$ concentration in stream water. The $NO_3^-$ concentrations are also known to increase with increasing stream flow during storm events (e.g., Kamisako et al. 2008). Using the stable isotopes ($\delta^{15}N$, $\delta^{18}O$, and $\Delta^{17}O$) of the stream water at KJK during storm events, it was concluded that soil $NO_3^-$ in the riparian zone was a primary source for the stream $NO_3^-$ increase during storm events (Ding et al. 2022; Fig. 4).
- Vertical changes in S isotopic ratio ($\delta^{34}S$) in waters flowing in the KJK forest ecosystem have been studied to clarify a buffering system of seasonal large acid deposition. Seasonal variations of both $\delta^{34}S$ values and the reciprocal of $SO_4^{2-}$ concentrations became smaller vertically from rainwater through soil solutions to stream water (Fig. 5). It is suggested that no large internal S source was identified and atmospheric S deposition was the main source of $SO_4^{2-}$ in stream water. Because no clear biological fractionation was found, $SO_4^{2-}$ adsorption – desorption process in soil was considered as the main buffering mechanism (Saito et al. submitted).

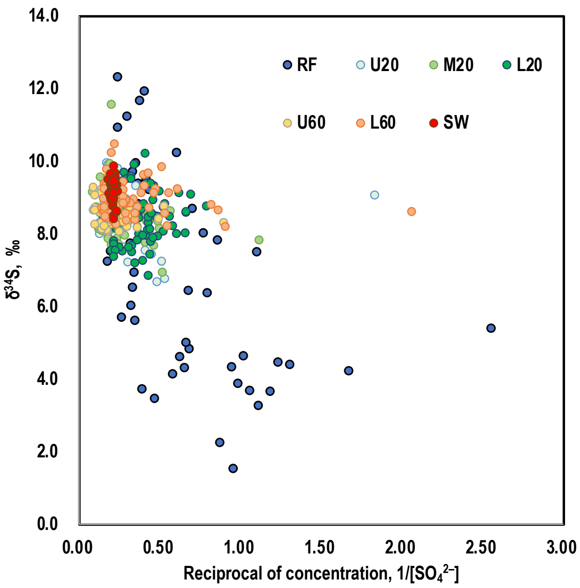


**Fig. 5. Relationship between reciprocals of $SO_4^{2-}$ concentrations and $\delta^{34}S$ values in rainwater (RF), soil solutions (U20, M20, L20, U60, and L60), and stream water (SW) at the Kajikawa catchment (KJK).** For soil solution, U, M, L indicate upper, middle, and lower slope positions, respectively and 20 and 60 indicate depths in cm. (Saito et al. submitted)

- At KMR, since 2010/2011, since stream water pH has decreased with increasing concentrations of $SO_4^{2-}$ and $NO_3^-$, whereas rainwater pH has been increasing (Fig. 6). The NC scientist as the Visiting Professor of Niigata University supervised the PhD student, who was dispatched from the Institute of Global Climate and Ecology (IGCE), Russia, to study the acidification mechanism. It was suggested that the recent increase in warm-season precipitation contributed to increase in S and N deposition and discharge of $SO_4^{2-}$ and $NO_3^-$ to the stream water, resulting in stream water acidification (Zhigacheva et al. 2022).

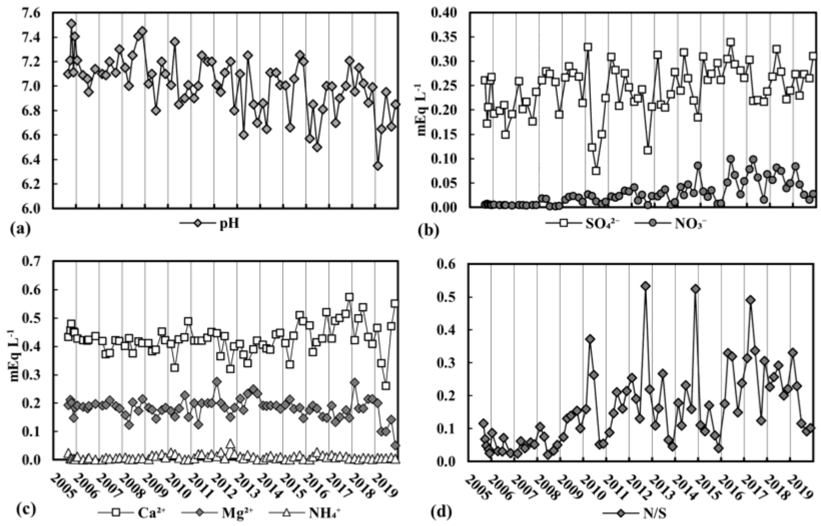


**Fig. 6. Variations in the stream water chemistry at Komarovka River (KMR)**

- Scientific journals containing the above findings:
  1) Tanikawa T, Sase H, Fukushima S, Ito Y, Yamashita M, Yamashita N, Kamisako M, Sugiyama A, Imaya A, Ishida T, Takenaka C, Takahashi M. 2022. Sulfur accumulation in soil in a forested watershed historically exposed to air pollution in central Japan. Geoderma 407: 115544. https://doi.org/10.1016/j.geoderma.2021.115544
  2) Ding, W, Tsunogai, U, Nakagawa, F, Sambuichi, T, Sase, H, Morohashi, M, Yotsuyanagi, H. 2022. Tracing the source of nitrate in a forested stream showing elevated concentrations during storm events. Biogeosciences, 19, 3247–3261, https://doi.org/10.5194/bg-19-3247-2022.
  3) Zhigacheva, E.S., Sase, H., Nakata, M. Ohizumi T., Gromov S.A., Takahashi M. 2022. Stream water acidification in the Far East of Russia under changing atmospheric deposition and precipitation patterns. Limnology https://doi.org/10.1007/s10201-022-00696-0

## B) Impact assessment on the regional scale

- It is crucial to identify areas susceptible to acid deposition for common understanding among the region, which contributes to regional cooperation for technological and scientific solutions and relevant policy making from national to regional levels. Critical load assessments have been utilized for this purpose in other regions, such as Europe.

The critical load map in Asia has been updated based on the latest scientific data. The high-risk areas for eutrophication coincided well with the EANET sites, in which $NO_3^-$ concentration in the inland water significantly increased over the last 20 years (Yamashita et al. 2022; Fig. 6). This study is considered as methodological research for impact assessments applicable to the EANET region.

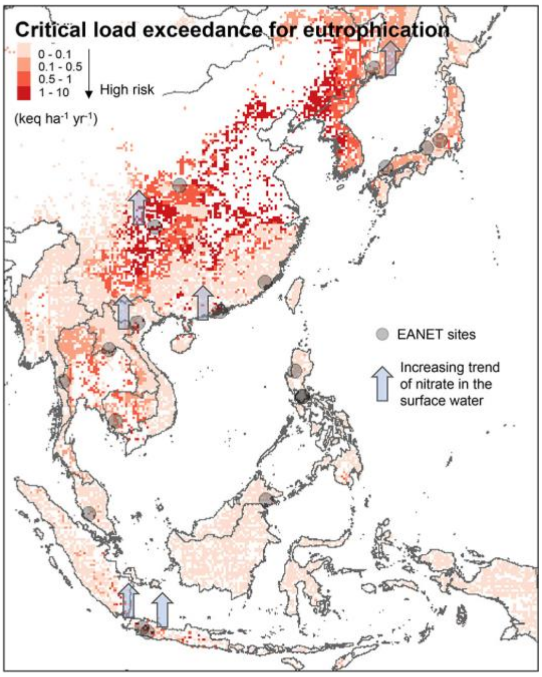


**Fig. 6 Critical load exceedance for eutrophication and comparison with the EANET data (Graphical Abstract from Yamashita et al. 2022)**

Scientific journals containing the above findings:

4) Yamashita N, Sase H, Kurokawa J. 2022. Assessing critical loads and exceedances for acidification and eutrophication in the forests of East and Southeast Asia: a comparison with EANET monitoring data. Science of the Total Environment 851, 158054. http://dx.doi.org/10.1016/j.scitotenv.2022.158054

## IV. Actions required at SAC22

9. SAC22 is invited to review the progress of the studies on effects of acid deposition on ecosystems.