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Acidification and recovery of forest ecosystems in central Japan during the past few decades

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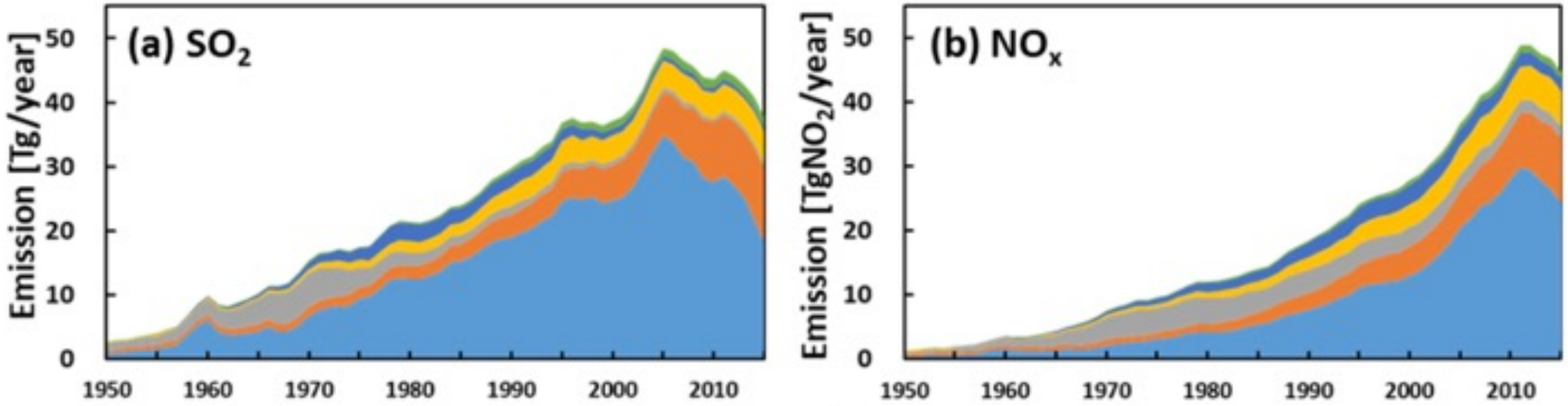
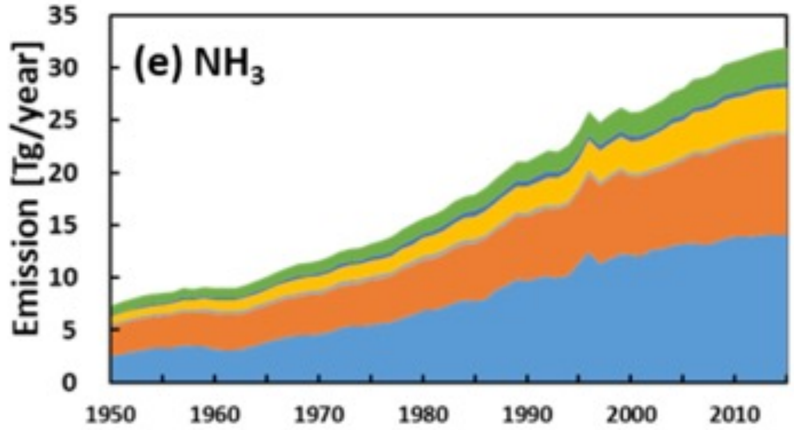
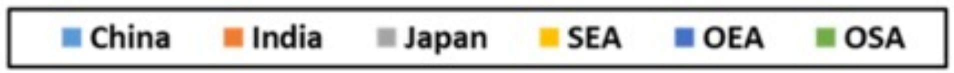
Emission trends of S and N species in Asia

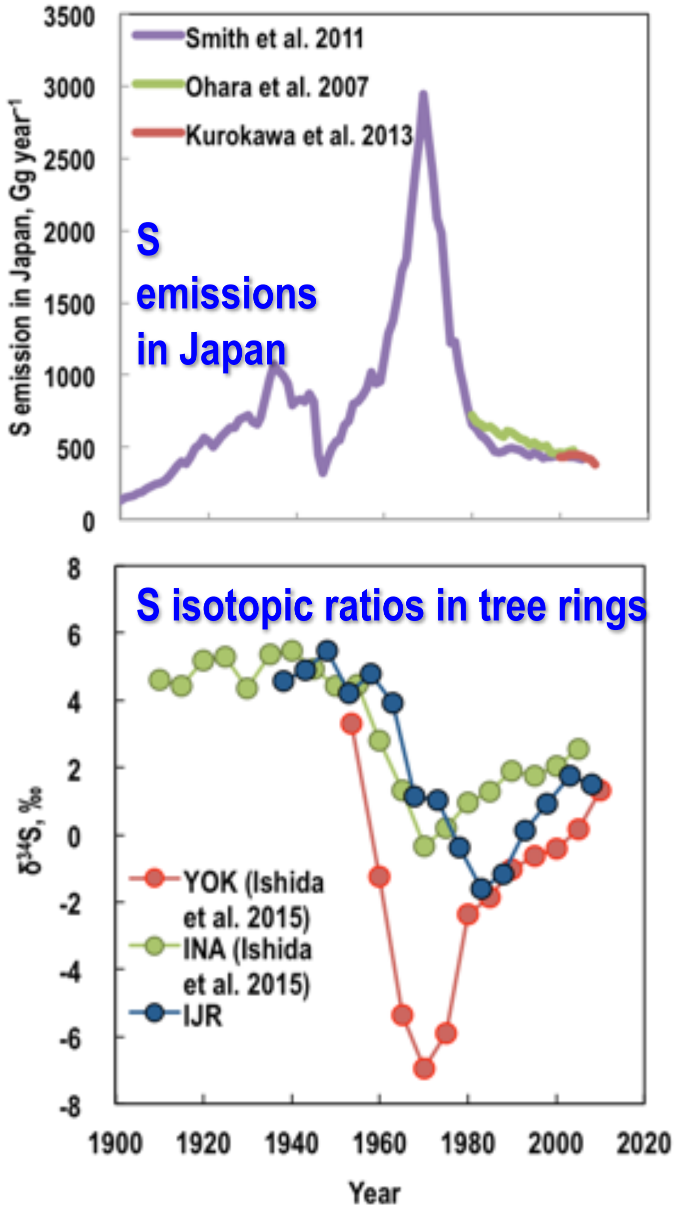
(Kurokawa and Ohara 2020, *ACP*)







Emissions of SO_2 and NO_X have just started declining in the mid-2000s/early-2010s, those of NH_3 have not shown the declining trends.



Air pollution effects recorded in tree rings (Sase et al. 2019, *Biogeochemistry*)

- S emissions in Japan peaked in 1969/1970 and steeply decreased thereafter.
- S isotopic ratios in tree rings of Japanese cedar (*Cryptomeria japonica*) in central Japan showed similar profiles (but opposite!).
- Oils imported from the Middle East showed negative isotopic values (≥ - 10‰).
- It is suggested that higher S deposition in the 1960s/1970s were circulated in the plan-soil systems and finally recorded in the tree rings.

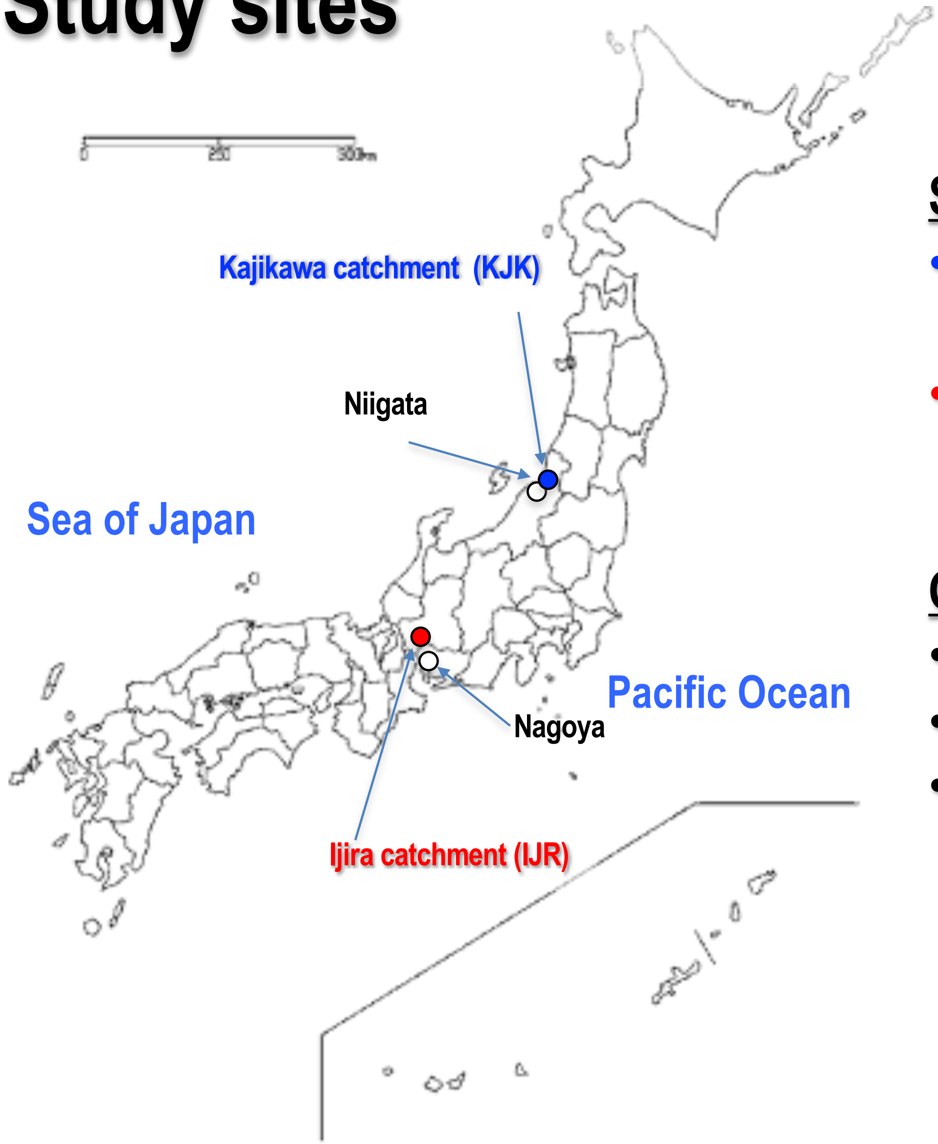
Objectives of the study

- To understand recovery process from acidification in Asia
  - ✓ To clarify sulfur dynamics in terrestrial ecosystems in Asia, where recovery from acidification has just started in accordance with reduction of air pollution.
  - ✓ To clarify whether N leaching processes response to the declining deposition smoothly and/or what additional factors influence the processes.
- In this presentation, outputs from two catchment sites in Japan will be presented based on the recent publications (Sase et al. 2019, 2021) and the latest available dataset.

Sase et al. 2019, *Biogeochemistry*

Sase et al. 2021, *Atmospheric Environment*

Study sites



Study sites:

- Kajikawa catchment (KJK): Sea of Japan side, 2002 –
- Ijira catchment (IJR): Pacific side, (1988) – 2005 –

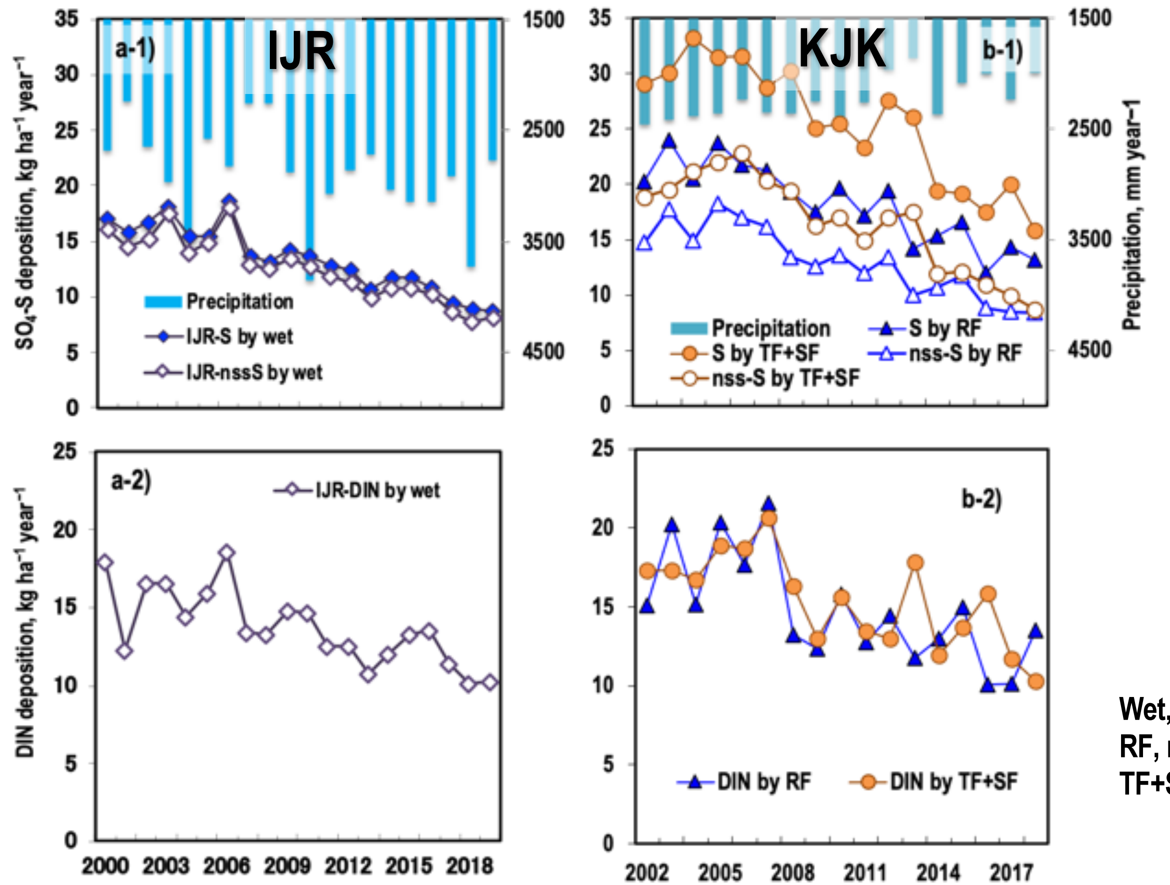
Observations:

- Rainfall (RF)
- Soil solution (SS)
- Stream/river water (SW)
  - ✓ Ion concentrations
  - ✓ Isotopic ratios (2014 –): S, Sr, Pb, H and O in H_2O, N and O in NO_3^-

Atmospheric deposition

SO_4-S

DIN as $NO_3^- + NH_4^+$

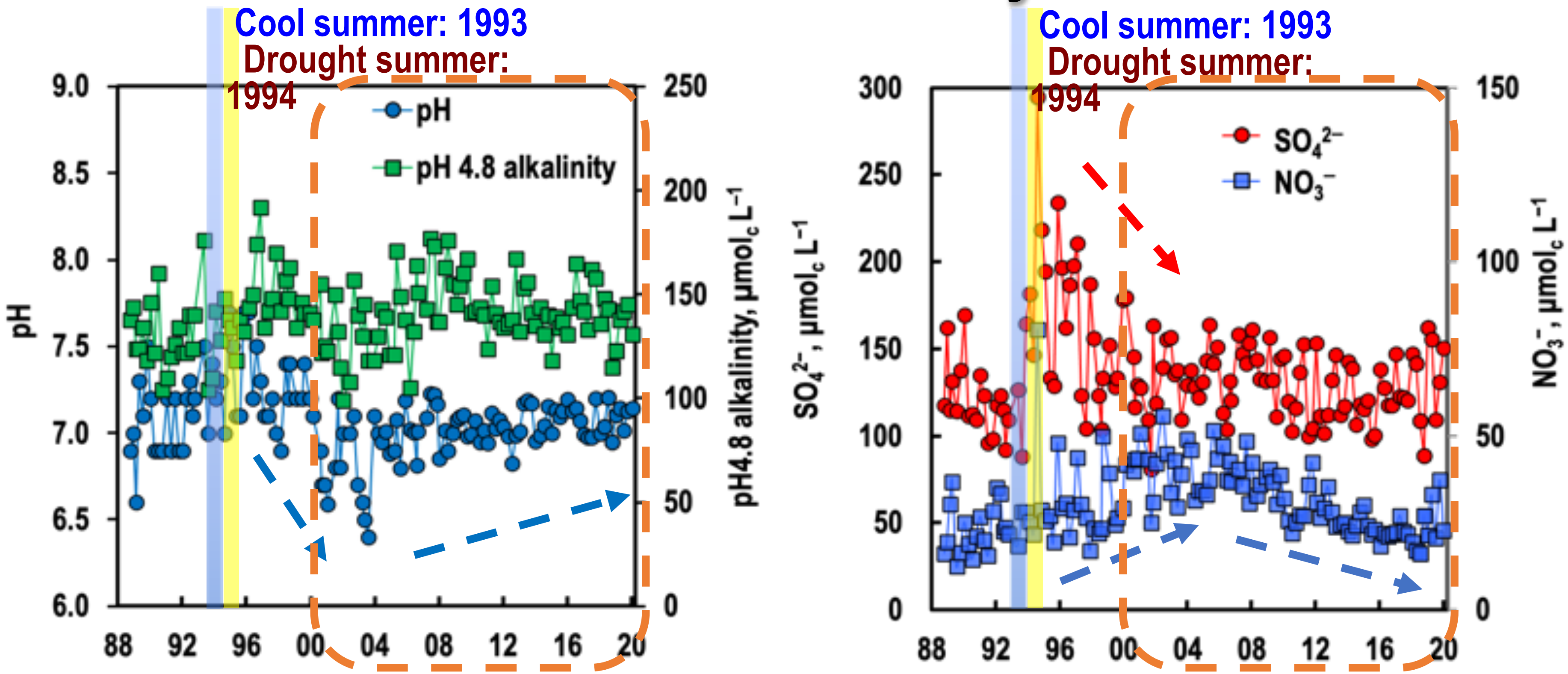


Wet, wet deposition;
RF, rainfall outside canopy;
TF+SF, throughfall and stemflow

- The peak of nss-S deposition was observed in 2006/2007 at both sites!
- DIN deposition has also bee declining at both sites

(Updated after EANET 2020; Sase et al. 2021)

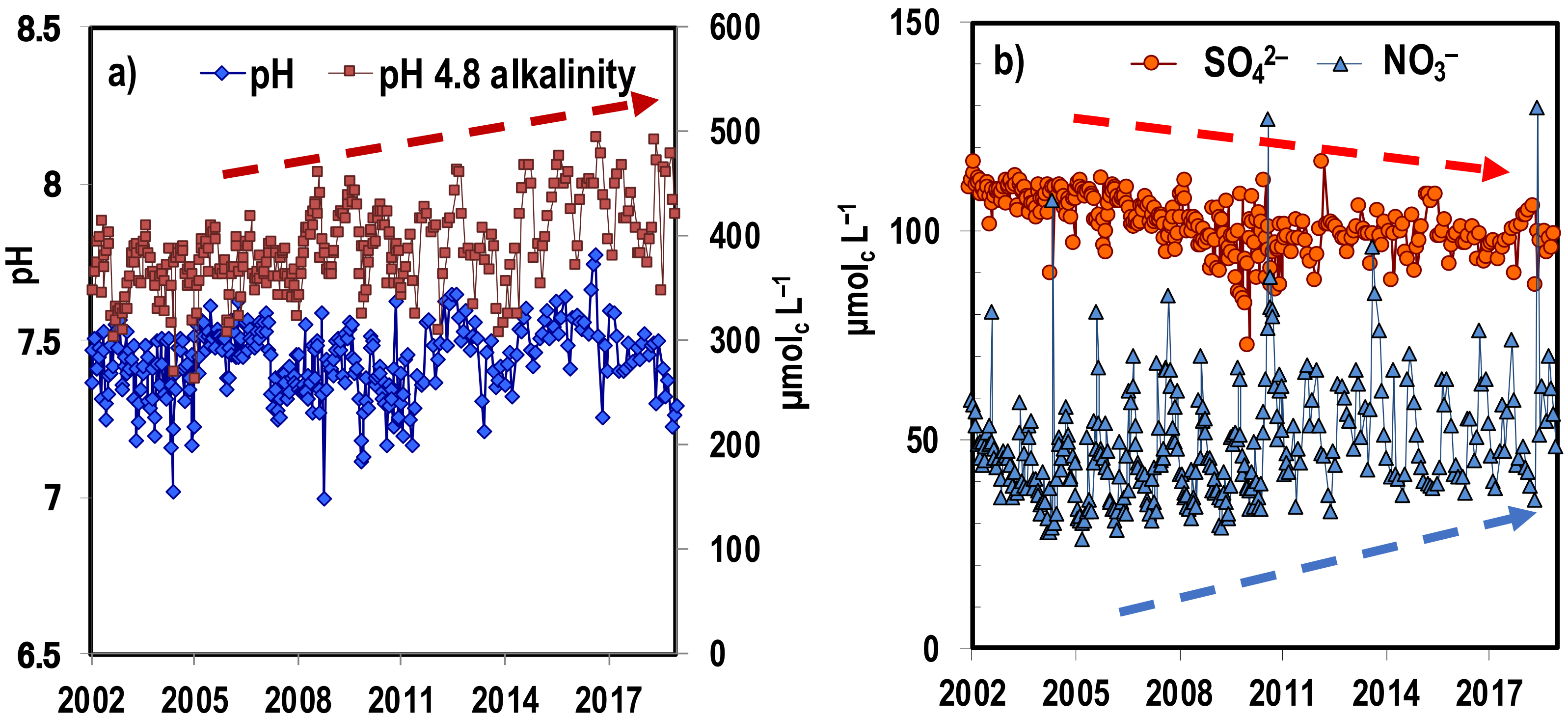
Stream water chemistry at IJR



- Climatic anomalies in 1993/1994 triggered changes in biogeochemical cycles and caused acidification and N saturation (Nakahara et al. 2010, *Biogeochemistry*).
- Recovery from acidification/ N saturation has been observed over the last decades.

(Updated after Nakahara et al. 2010; EANET 2020; Sase et al. 2019)

Stream water chemistry at KJK

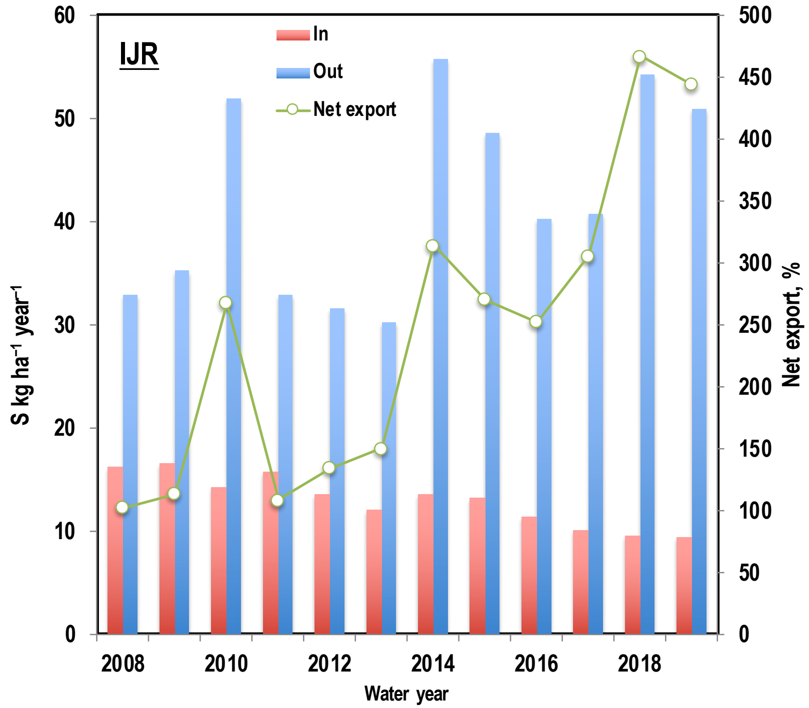


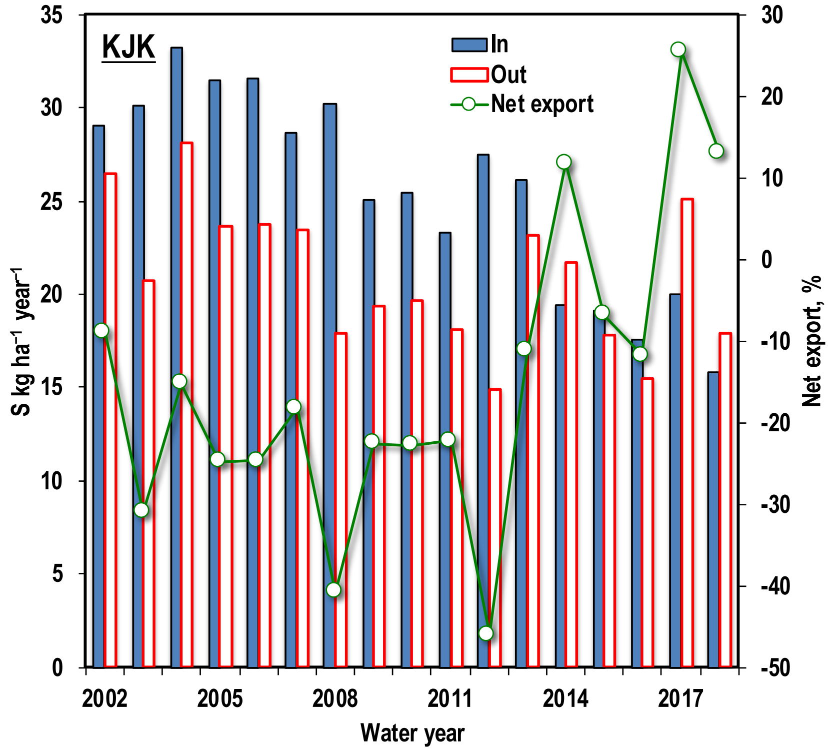
- The pH and alkalinity increased with decrease of SO_4^{2-} concentration, in particular since 2006/2007, suggesting recovery from acidification.
- The NO_3^- concentration increased gradually.

(Updated after Sase et al. 2021)

Input-output budget of sulfur

Input: atmospheric deposition
Output: stream water discharge



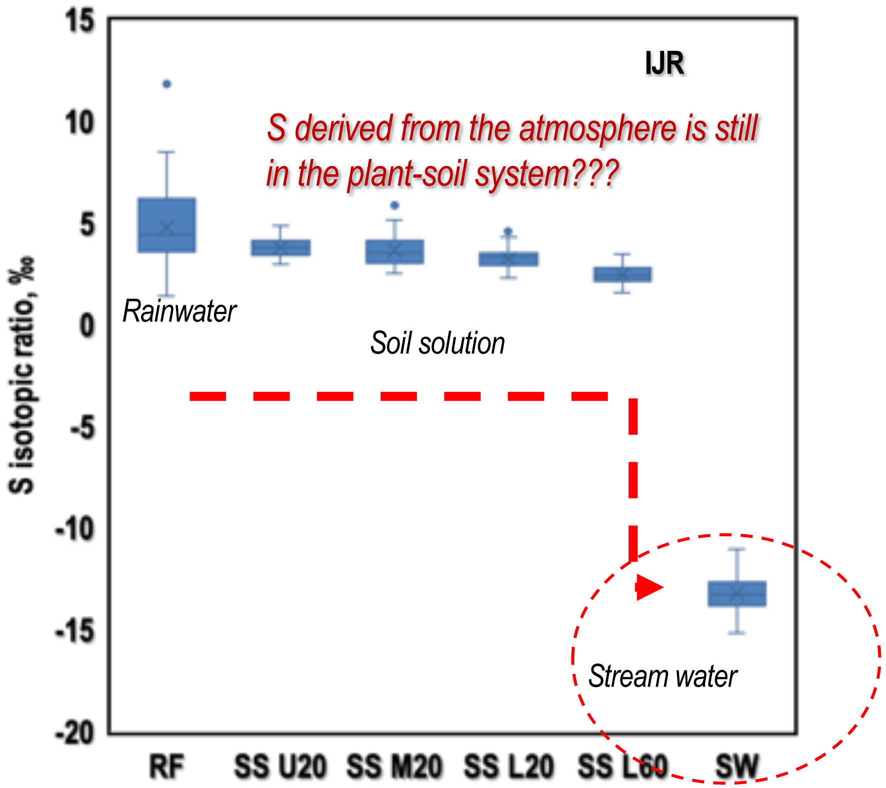


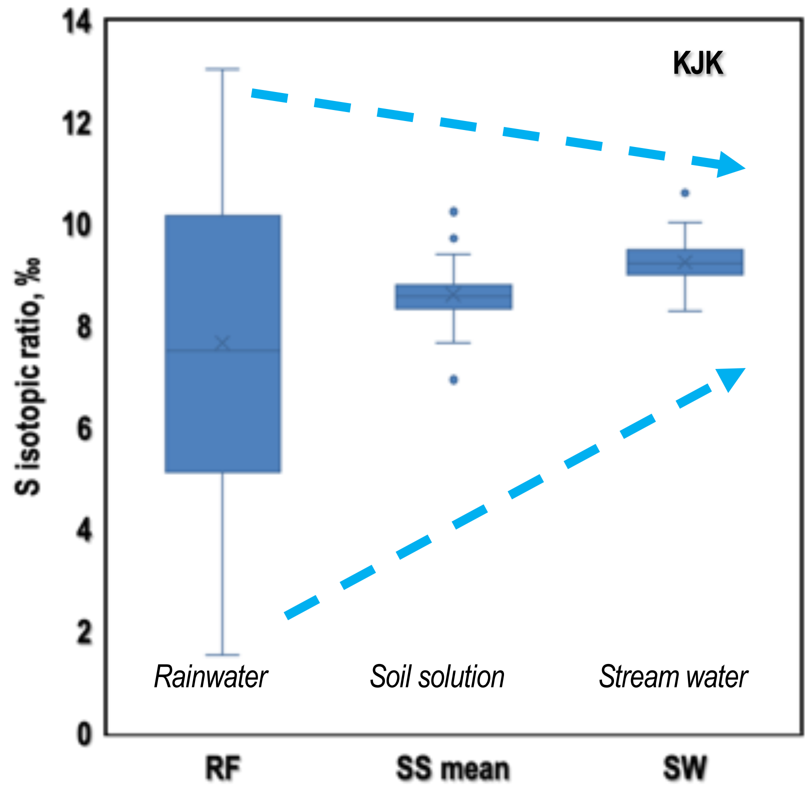
Input <<< Output
Suggesting other S sources than atmospheric deposition
Effects of geological S (+ climate)?

Input ≥ Output (sometimes, opposite)
Effects of internal S
Recovery is slower than the atmospheric input.

(Updated after EANET 2020; Sase et al. 2021)

Vertical changes in S isotopic ratios



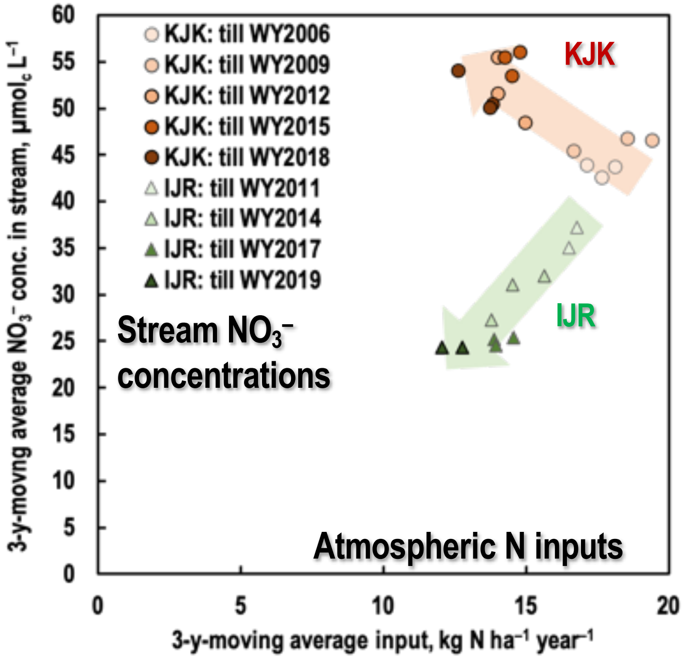


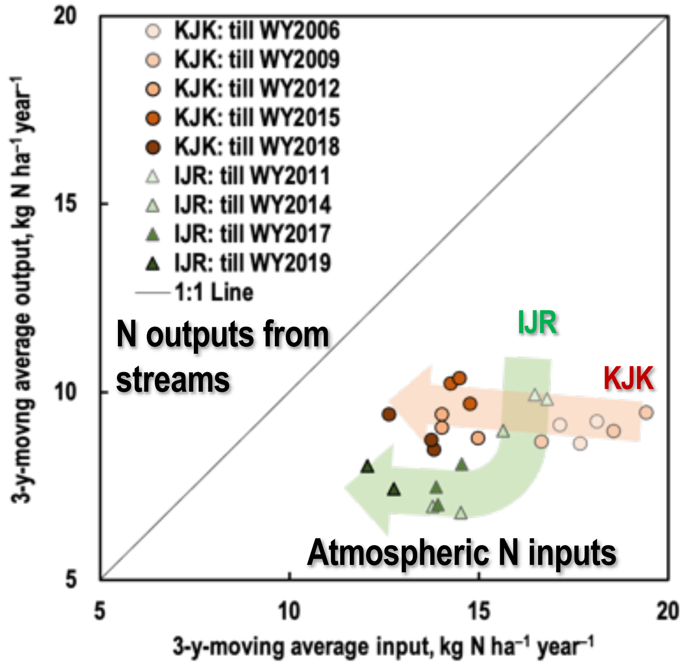
Indicating a different S source
Estimate of the mixing model:
Ground water (geological S), 75 %

Suggesting homogenization
in the internal S cycle

(Updated after EANET 2020; Sase et al. 2019, 2021)

Changes in NO_3^- concentration and N outputs with N inputs





- The recent $\Delta^{17}O$ analysis of NO_3^- estimated that 6.5 % ± 1.8 % and 9.4 % ± 2.6 % of the annual atmospheric NO_3^- inputs flowed into stream water as the output without biological processes in plant-soil systems in IJR and KJK, respectively (Nakagawa et al. 2018, *Biogeosciences*).
- N outputs from the streams are approaching the 1:1 line. In IJR, recent higher precipitations contributed to the higher N outputs.
- Anyway, the current atmospheric N inputs, > 10 kg ha^{-1} y^{-1}, are still high…

Summary

- Two forest catchments in central Japan, IJR and KJK, have been recovering from acidification with decline of atmospheric S deposition.
- In IJR, geological S appears to contribute to river water chemistry, while most of S derived from atmospheric inputs has been accumulated in the plant-soil system. The NO_3^- concentration in stream water has been declining with N deposition but the N output is increasing due to increase of water discharge.
- In KJK, the internal S cycle appears to have sensitively responded to changes in the atmospheric S input. However, N leaching is still increasing, possibly due to lowering N uptake by Japanese cedar trees under relatively high N deposition.
- The climate change, such as increase of precipitation amounts, appears to influence S and N leaching (and recovery processes?), especially in IJR.

Acknowledgements

- The study in IJR was conducted based on monitoring data from the Ministry of the Environment of Japan and their related research outputs.
- The study in KJK was conducted as one of the Network Center's research activities for Acid Deposition Monitoring Network in East Asia (EANET).
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