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Editorial

Recovery Processes of Acidic Soils Experiencing Decreased Acidic Deposition

Gregory B. Lawrence [1,*] **and Scott W. Bailey** [2]

[1] New York Water Science Center, United States Geological Survey, 425 Jordan Road, Troy, NY 12052, USA
[2] Northern Research Station, United States Department of Agriculture Forest Service, 234 Mirror Lake Road, North Woodstock, NH 03262, USA; scott.bailey@usda.gov
* Correspondence: glawrenc@usgs.gov

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Citation: Lawrence, G.B.; Bailey, S.W. Recovery Processes of Acidic Soils Experiencing Decreased Acidic Deposition. *Soil Syst.* **2021**, *5*, 36. https://doi.org/10.3390/soilsystems5020036

Received: 8 June 2021
Accepted: 9 June 2021
Published: 21 June 2021

Reductions in acidic deposition rates through legislative actions in North America and Europe have stemmed further environmental degradation and shifted the focus to potential recovery [1,2]. In the early 2000s, it had become clear that recovery of surface waters was being slowed by the long-term effects of acidic deposition on soils, which were only then becoming well documented [3]. As a result, recovery of soils from acidic deposition has drawn considerable attention with respect to both aquatic and terrestrial ecosystems, particularly in the most recent decade. Recovery of surface waters is proceeding, but soil recovery appears to be in an early stage [4] and impacts on water chemistry and aquatic biota remain in the most affected regions even though acidic deposition has decreased to levels approaching those of the early 1900s [5]. Some indications of recovery in terrestrial ecosystems have been documented [6,7], but linkages between soil conditions and the health of recovering tree species, such as red spruce, have not been determined. Many questions remain concerning the recovery of soils as they adjust to the new chemical climate while continuing to be affected by numerous other ambient factors. Therefore, ongoing research is being conducted to document the rates and magnitudes of soil recovery to improve our understanding of how soil recovery processes are linked to surface water chemistry and forest health. In this regard, a Special Issue in the journal Soil Systems has been developed, entitled: "Recovery Processes of Acidic Soils Experiencing Decreased Acidic Deposition". In this Special Issue, six original research papers are presented that provide documentation of recent long-term soil responses to lowered acidic deposition, assessment of factors influencing pathways of soil recovery, analysis of ongoing surface water changes with respect to soil recovery, and information on the use of lime additions of lime may to help accelerate the recovery of soils. Summaries of the major findings of each paper immediately follow.

In Bailey et al. [8], soil sampling and resampling spanned a 50-year period in western Pennsylvania (PA), USA, marking this study as one of the longest running soil monitoring efforts in North America. The initial sampling in 1967 occurred prior to the acidic deposition peak in North America, which occurred in the 1970s [9] to early 1980s [10]. By 1997, decreases in pH and exchangeable calcium and magnesium were observed along with increases in exchangeable aluminum (Al) throughout the soil profile; all changes that were likely related to acidic deposition. Between 1997 and 2017, the uppermost organic horizons became thicker, concentrations of organic carbon, exchangeable calcium, and magnesium increased, and concentrations of exchangeable Al decreased. These results suggest that decreased acidic deposition levels led to recovery of the base cation–Al balance in the primary rooting zone, which may have increased the efficiency of vegetative recycling of nutrients. The long duration of this study provides unique data that document both acidic deposition effects and the subsequent response of these soils to the large decreases in acidic deposition that have been achieved in recent decades.

In Lawrence et al. [11], results are presented from a resampling study of seven sites in the western Adirondack region of New York, one of the regions most impacted by acidic deposition in the USA. This study found pronounced increases in exchangeable calcium concentrations and decreases in exchangeable Al in Oe horizons between the late 1990s and 2010–2014. These changes were interpreted as an increase in vegetative recycling of calcium due to a large increase in the calcium–aluminum ratios, similar to the results observed by Bailey et al. [8] in PA. A small, but statistically significant increase was also observed in exchangeable calcium concentrations in the upper B horizon between the late 1990s and 2010–2017 for this group of seven sites. The increase in upper B horizon calcium suggests that the rate at which calcium is becoming available for cation exchange reactions and nutrient cycling within the soil profile through weathering, vegetative processes, and hydrologic transport may now be exceeding the rate at which calcium is being leached out of the soil profile. This result is significant because inputs to the available soil pool of calcium must exceed leaching losses to reverse soil calcium depletion.

In Hazlett et al. [12], a large data set from sites distributed throughout the northeastern USA and eastern Canada was analyzed to determine the roles of site characteristics and inherent soil properties in controlling soil recovery. Recovery responses in upper profile pH and exchangeable Al were similar to those found by Bailey et al. [8]. The results show that O and B horizons that were initially acidified to a greater degree showed greater recovery, which was unexpected. However, B horizon recovery was found to be positively related to the number of recovery years and negatively related to sulfate deposition around the time of initial sampling, which was consistent with conventional views of soil recovery processes.

In Watmough et al. [13], long-term chemical monitoring of seven Canadian lakes showed that increases in acid-neutralizing capacity (ANC) were modest from 1982 through 2005 because the large decreases in sulfate concentrations over this period were matched by decreases in calcium concentrations, a relationship tied to soil acidification. However, from 2005 through 2015, the rates of decrease in calcium concentrations slowed relative to the rates of decreases in sulfate concentrations, resulting in an increase in ANC. The marked change in the sulfate–calcium relationship after 2005 suggests an increase in calcium export from the watersheds of these lakes, which could be an indication of recovery of exchangeable calcium concentrations in soils. However, the paper concludes that increases in exchangeable calcium alone may not have been sufficient to explain the lake trends. A number of other factors that may play a role in the recovery of lake chemistry are discussed and further study is called for to unravel the mechanisms that could increase calcium availability in the watershed.

In LoRusso et al. [14], sources and processing of dissolved organic matter (DOM) are investigated in a watershed–lake system. Like many other surface waters in regions where acidic deposition is decreasing, dissolved organic carbon concentrations have been increasing in the study lake, largely through changes in soil and wetland-related processes. Through analysis of DOM quality using optical measurements and statistical modeling, watershed sources of DOM components were identified. An increase in aromaticity of dissolved organic carbon in the lake over the past decade was documented. These changes in organic chemistry of the lake, which are tied to acidic deposition recovery of soils, have implications for thermal stratification, nutrient cycling, and food web dynamics in lake ecosystems.

In Jansone et al. [15], results of repeated measurements of plots receiving lime in 1983 and 2003, and untreated adjacent control plots are presented. This experiment, conducted in southwest Germany, produced a valuable data set that enabled changes in soils responding to decreased acidic deposition to be compared to changes in soils that had received lime over a period of 30 years. Some indications of soil recovery were measured in the untreated plots, but changes were limited, and soils remained highly acidic in the final sampling in 2015. Liming substantially reduced soil acidity in both the organic and mineral horizons; this effect was more pronounced in coarser textured soils that were more acidic at the start of the experiment. The liming had a strong positive effect in aiding natural soil recovery under decreasing acidic deposition levels, which lasted more than a decade after treatment.

In Lawrence et al. [11], results were also presented for the first 5 years after liming of an acidified 30 ha watershed. The goal of this experiment was to boost ecosystem calcium availability to accelerate recovery of both the forest and stream ecosystems, which remained severely acidified 23 years after passage of the 1990 U.S. Clean Air Act Amendments. By the fifth year after treatment, liming increased exchangeable calcium concentrations down into the upper B soil horizon, and stream calcium concentrations were approximately three times that of the stream in the reference watershed. The low rate of acidic deposition during the experiment was viewed as a key factor in the relatively rapid response of the treatment.

Author Contributions: Both authors contributed to the writing, review, and editing of the original draft of this special issue summary. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded through NYSERDA agreement 122529.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Donald Ross and Douglas Burns provided helpful reviews of the original manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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