

ABSTRACT

Atmospheric deposition of sulfur (S) and nitrogen (N) as a result of fossil fuel combustion is known to impact ecosystem structure and function. Potential impact includes acidification of soil and surface water and mobilisation of metal ions, with the resultant loss of plant productivity, changes in plant species diversity and changes in biotic communities in aquatic ecosystems. Rates of S ($\sim 8 \text{ kg S ha}^{-1} \text{ year}^{-1}$) and N ($> 6 \text{ kg S ha}^{-1} \text{ year}^{-1}$) deposition to the grasslands of the South African Highveld are comparable to other industrialised areas where ecosystem impacts have been observed. As part of a larger project, this work investigated four aspects of ecosystem impact: changes in soil and river water chemistry as well as S and N mineralisation rates.

Reassessment of the soil chemistry at 18 sites on the South African Highveld after a 16-year period showed increases in both acidic and basic ion concentrations for individual sites and when the values for these sites were averaged to represent the study region. Grouping the soils by clay content showed that all sites with less than 25% clay (16 of 18 sites) showed significantly reduced $\text{pH}(\text{H}_2\text{O})$ values. Sites with less than 4% clay showed increased exchangeable acidity and decreased acid neutralising capacity. Spatial scaling and mapping from site to soil form and land type, showed that across 92% of the study area the $\text{pH}(\text{H}_2\text{O})$ values had been reduced. This method identified the sandier soils, near the southern and eastern boundaries of the study area where rainfall is higher, as sensitive to additional acidic inputs via atmospheric deposition. Clay-rich soils occur in the drier central part of the study area, close to emission sources. It is suggested that this proximity to emission sources results in the co-deposition of basic and acidic ions, adding to the buffering capacity of the soils, resulting in small but significant increases in soil acidity status over the 16 years.

Sulfur and N mineralisation rates, using the *in situ* incubation method at 11 sites, were found to range between -0.66 and $1.09 \mu\text{g SO}_4^{2-} \text{ g}^{-1} \text{ soil day}^{-1}$ and -0.97 and $1.21 \mu\text{g N g}^{-1} \text{ soil day}^{-1}$. This translated into an annual flux of between -40 and 9.9 kg S ha^{-1} and between 27 and 81 kg N ha^{-1} from the soil organic pools. The use of the *in situ* incubation technique to determine S mineralisation is a new

development and is proposed for in-field studies where S and N cycling are of interest as the method allows for concurrent mineralisation rate determination. It was found that from a biogeochemical perspective the Highveld grasslands are under researched with respect to S and N and complete assessments of the S and N cycles are proposed. The S budget proposes accretion of S in the soil organic pool due to continued inputs via deposition and low losses to the atmosphere or deeper soil horizons. Nitrogen, however, appears to limit productivity in these grasslands because atmospheric inputs and mineralisation rates are approximately equal to plant uptake.

In the assessment of river water quality it was hypothesised that between 1991 and 2008 concentrations of dissolved salts, sulfate, nitrate and ammonium would increase in surface waters at five sites draining the Highveld grasslands. The Department of Water Affairs water quality monitoring database was accessed to assess for spatial and temporal differences in water quality. Significant spatial differences were found; however, over time few significant increases were found to support the hypothesis: sulfate, nitrate-plus-nitrite, and ammonium were observed to increase at one site each. In addition, the export of nitrogen, as mass load, from natural grasslands was found to be negligible at $<2 \text{ kg N ha}^{-1}\text{year}^{-1}$.

A conceptual framework proposes that soil texture, distance from emissions and land use are key drivers in the response of the grassland soils and surface waters to atmospheric S and N deposition. Although the study identified the soils most sensitive to deposition, it is proposed that processes in the Highveld grasslands are not yet negatively affected by the additional sulfur and nitrogen inputs. Continued monitoring for impacts on ecosystem structure and function is advocated.