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Nitrogen loss from deserts in the southwestern United States

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Abstract. A lower limit for nitrogen loss from desert ecosystems in the southwestern United States was estimated by comparing nitrogen inputs to the amount of nitrogen stored in desert soils and vegetation. Atmospheric input of nitrogen for the last 10 000 years was conservatively estimated to be 2.99 kg N/m^2. The amount of nitrogen stored in desert soils was calculated to be 0.604 kg N/m^3 using extant data from 212 profiles located in Arizona, California, Nevada, and Utah. The average amount of nitrogen stored in desert vegetation is approximately 0.036 kg N/m^2.

Desert conditions have existed in the southwestern United States throughout the last 10 000 years. Under such conditions, vertical leaching of nitrogen below a depth of 1 m is small (ca. 0.028 kg N/m^2 over 10 000 years) and streamflow losses of nitrogen from the desert landscape are negligible. Thus, the discrepancy found between nitrogen input and storage represents the amount of nitrogen lost to the atmosphere during the last 10 000 years. Loss of nitrogen to the atmosphere was calculated to be 2.32 kg N/m^2, which is 77% of the atmospheric inputs.

Processes resulting in nitrogen loss to the atmosphere from desert ecosystems include wind erosion, ammonia volatilization, nitrification, and denitrification. Our analysis cannot assess the relative importance of these processes, but each is worthy of future research efforts.

Introduction

Losses of nitrogen from arid lands may be important to the global atmosphere and to native desert vegetation. In desert ecosystems volatile losses of nitrogen are considered to be especially significant (West & Skujins 1978; West & Skujins 1977; Bowden 1986; Skujins 1981). Volatile losses of nitrogen include nitric oxide (NO), nitrous oxide (N_2O), ammonia (NH_3), and dinitrogen (N_2) gas. Of these compounds nitric oxide, nitrous oxide, and ammonia are of particular consequence to the atmosphere. Nitric oxide has a short turnover time and is important in regulating atmospheric hydroxyl and ozone levels (Logan et al. 1981). Nitrous oxide has a long atmospheric lifetime and can undergo photochemical reactions in the stratosphere that are linked to the destruction of ozone (Cicerone 1987; Mooney et al. 1987). Nitrous oxide is also a 'greenhouse' gas that is contributing to the global warming of the Earth's surface (Dickinson & Cicerone 1986; Bolle et al. 1986; Ramanathan et al. 1985). Ammonia has a short atmospheric lifetime but is the only trace gas capable of increasing the alkalinity of precipitation (Warneck 1988; Charlson & Rodhe 1982; Quinn et al. 1987). Thus, ammonia is involved in the regulation of rainfall acidity.

In addition to its possible atmospheric effects, nitrogen loss in any form represents a loss of soil fertility to desert vegetation. Several studies have shown that nitrogen limits plant growth in deserts (Ettershank et al. 1978; Fisher et al. 1988; Nobel et al. 1988; James & Jurinak 1978; Romney et al. 1978), and nitrogen is commonly thought to be second only to water as a major limiting factor in arid regions.

The magnitude of nitrogen loss from arid lands is poorly known despite its possible regional and global significance. Therefore, in this paper we use available data to estimate a lower limit for the magnitude of nitrogen loss from deserts in the southwestern USA.

Methods and results

Conceptual model

The conceptual model used to estimate nitrogen loss from deserts is a simple comparison between nitrogen inputs and the amount of nitrogen stored in the system. The difference between nitrogen inputs and storage represents the quantity of nitrogen lost from the ecosystem. To make this estimate conservative (i.e. a lower limit), whenever necessary the values used were weighted to either overestimate the storage component or underestimate the input component of the model. In either case, the amount of nitrogen lost from the ecosystem is underestimated. Each component of the conceptual model (time, input, storage, and deep seepage) will now be discussed and the methods used to quantify them described.

Time

The northward displacement of the jet stream at the end of the last glacial period has allowed desert conditions to exist in the southwestern United States throughout the last 10 000 years (COHMAP 1988). As a result evapotranspiration has greatly exceeded precipitation causing lakes to dry and resulting in the range expansion of xeric plant species (Street & Grove 1977; Thorne 1986; Van Devender & Spaulding 1979). Under arid conditions vertical leaching of nitrogen below a depth of 1 m, and streamflow losses of nitrogen from the desert landscape are negligible. Thus, by confining our calculation to the last 10 000 years any discrepancy between nitrogen input and storage should represent the amount of nitrogen lost to the atmosphere.

Inputs

Nitrogen input into desert ecosystems can occur by wetfall and dryfall deposition, and by nitrogen fixation. The annual deposition of nitrogen in wetfall was determined by averaging over 50 measurements made during a 4-year period in the western United States after excluding values identified as being influenced by pollution (Young et al. 1988). Nitrogen deposition measured in that study