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Estimating global nitrous oxide emissions by lichens and bryophytes with a process-based productivity model

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Lichens and bryophytes have been shown to release significant amounts of nitrous oxide (N_2O), which is a strong greenhouse gas and atmospheric ozone - depleting agent. Relative contributions of lichens and bryophytes to nitrous oxide emissions are largest in dryland and tundra regions, with potential implications for the nitrogen balance of these ecosystems. So far, this estimate is based on large-scale values of net primary productivity of lichens and bryophytes, which are derived from empirical upscaling of field measurements. Productivity is then converted to nitrous oxide emissions by empirical relationships between productivity and respiration, as well as respiration and nitrous oxide release.

Alternatively, we quantify nitrous oxide emissions using a global process-based non-vascular vegetation model of lichens and bryophytes. The model simulates photosynthesis and respiration of lichens and bryophytes directly as a function of climatic conditions, such as light and temperature. Nitrous oxide emissions are then derived from simulated respiration, assuming a fixed relationship between the two fluxes, which is based on laboratory experiments under varying environmental conditions. Our approach yields a global estimate of 0.27 (0.19 - 0.35) $Tg\,N_2O\,yr^{-1}$ released by lichens and bryophytes. This is at the lower end of the range of a previous, empirical estimate, but corresponds to about 50 % of the atmospheric deposition of nitrous oxide into the oceans or 25 % of the atmospheric deposition on land. We conclude that, while productivity of lichens and bryophytes at large scale is relatively well constrained, improved estimates of their respiration may help to reduce uncertainty of predicted N_2O emissions. This is particularly important for quantifying the spatial distribution of N_2O emissions by lichens and bryophytes, since simulated respiration shows a different global pattern than productivity. We find that both physiological variation among species as well as variation in climatic conditions are relevant for variation in respiration and, consequently, N_2O emissions simulated by LiBry. To constrain our predictions, field observations of respiration in combination with a more process-based approach for relating nitrous oxide emissions to respiration may be helpful.