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Inverse modeling of gas diffusion coefficients and CO_2 production rates from steady state gas profiles in a tropical lowland forest soil

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Soil respiration is the second largest flux in the global carbon (C) cycle but the underlying below-ground process, soil carbon dioxide (CO_2) production, can not be measured in the field. Mathematical models may be a useful tool to calculate soil CO_2 production rates. Under the assumptions that gaseous diffusion is the only relevant transport pathway for CO_2 in soils and that measured soil CO_2 profiles are at steady state, soil CO_2 production has frequently been calculated from the vertical change in CO_2 flux. The flux was determined using gas diffusion coefficients calculated based on established relationships with soil properties like porosity. Large uncertainties remain regarding the calculated soil CO_2 production rates. Encountered problems were that the calculated production strongly depended on the chosen function to calculate the diffusion coefficients; production rates were sometimes negative and a depth-resolution of soil CO_2 production was not achieved but rather production was reported as sum per soil horizon and top soil production was often calculated from mass balance with the measured soil CO_2 efflux. Instead of using a relationship with soil properties to calculate diffusion coefficients we calculated diffusion coefficients based on fitting parameters of a steady state function describing the measured CO_2 profiles. We assessed the validity of these diffusion coefficients using radon as a tracer, tested the model assumptions and demonstrate the model approach using CO_2 data from a seasonal tropical lowland forest. Our calculations produced valid results in that calculated production profiles decrease monotonically from the top to the deep soil and production is largest at the end of wet season and smallest at the end of dry season. Calculated mineral soil production rates agree with measured soil CO_2 effluxes during dry season and the annual difference between wet season measured CO_2 efflux and modeled mineral soil CO_2 production is in the same order of magnitude as the litterfall-C input, and thus attributable to a missing description of litter layer decomposition/CO_2 production. We show that the assumption of steady state should not a priori be considered valid for all data sets but be tested, that diffusion coefficients calculated based on soil properties may not be of sufficient accuracy to reliably calculate soil CO_2 production, and that the calculation results depend critically on the method chosen to interpolate between the measured CO_2 concentrations.