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Greenhouse gas emissions from shifting cultivation in the tropics, including uncertainty and sensitivity analysis

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The burning of secondary vegetation in shifting cultivation releases CO_2 and other trace gases to the atmosphere. Part of the carbon dioxide released by fire will be reincorporated into the vegetation biomass regrowing in the fallow areas that make up the system and may not therefore contribute to large variations in the atmospheric CO_2 concentration on longer time scales, while the other trace gas emissions will represent a net addition to the atmosphere.

Annual emissions of CO_2, CH_4, CO, N_2O and NO_x from biomass burning in shifting cultivation systems in tropical Asia, Africa and America were estimated at national and continental level, as the product of area burned, aboveground biomass, combustion completeness and emission factor. The classical equation of Seilor and Crutzen (1980) for pyrogenic emissions estimation was adapted to the special case of shifting cultivation emissions, given that there are no direct estimates of the area of forest cleared and burned annually in this type of agricultural system, and that the biomass present at the time of clearing depends on how many years natural vegetation is allowed to recover, i.e., the length of the fallow period.

The total area of shifting cultivation in each country was derived from the Global Land Cover 2000 map, while the area cleared and burnt annually was obtained by multiplying the total area by the rotation cycle of shifting cultivation, calculated using cropping and fallow lengths reported in the literature. We conducted an extensive literature review about shifting cultivation systems in the tropical countries of Asia, Africa and America. The GLC2000 product was selected because is the only available global land cover with regionally optimized maps whose legends include classes explicitly concerning shifting cultivation. Aboveground biomass accumulation was estimated as a function of the duration and mean temperature of the growing season, soil texture type and length of the fallow period, using equations that relate biomass accumulation following disturbance with the growing season temperature and the duration of the growing season, in sandy and non-sandy soils. Combustion completeness values were collected from studies describing tropical forest clearing experiments conducted in Brazil and India. Concerning the emission factors, we used an updated version of published data provided by M. O. Andreae.

The uncertainty associated with each model variable was estimated and an uncertainty and sensitivity analysis of greenhouse gas estimates was performed with Monte Carlo and variance decomposition techniques. Uncertainty analysis quantifies the overall uncertainty associated with the model response as a result of uncertainties in the model inputs, while sensitivity analysis allows the quantification of the contribution of each variable to the model output total variance.

Our results reveal large uncertainty in emission estimates for all five gases. In the case of CO_2,mean (standard deviation) emissions from shifting cultivation in Asia, Africa and America, were estimated at 315 (176), 534 (379) and 996 (736) Tg year^{-1}, respectively. According to the sensitivity analysis performed, combustion completeness and emission factors were the model inputs that contributed the most to the uncertainty of estimates. The equation to estimate biomass accumulation on sandy soils (derived with fewer data than that for non-sandy soils) is another factor with some contribution to the model uncertainty. Our mean estimates are within the range of literature values for atmospheric emission from biomass burning in shifting cultivation systems. Only mean values can be compared to the estimates of other studies, since they do not provide any measure of uncertainty.