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Modelling the biogeochemical cycle of silicon in soils: application to a temperate forest ecosystem

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Silicon (Si) plays an important role in numerous biogeochemical processes occurring in terrestrial environments including chemical weathering, soil sustainability, and biotoxicity. Si is ubiquitous in plants and represents one of the most abundant elements in the tissues of many species. Closely coupled interactions have been reported between biology and geochemistry, which control Si dynamics in soils covered by various types of vegetation. This is well documented in tropical soils but not in temperate soils. The development and application of a numerical model that allows solving mass transfers coupled to biogeochemical processes is beneficial independent of the climatic regime. A comprehensive model would enable us to simulate geochemical weathering processes controlling the concentrations of dissolved Si in soil solutions, including biological cycling (i.e. plant uptake + restitution with litter fall/decomposition). Our objectives are to present: (a) a model that we developed for simulating the biogeochemical cycling of Si in the vadose zone (b) results of its application to a forested (Douglas fir) field site in a temperate regime (Beaujolais mountains, France).

The conceptual model development was guided by preliminary site specific studies focusing on geochemical processes that control dissolved Si and unsaturated flow modelling. These studies and additional data enabled us to develop a conceptual model. A version of the computer code MIN3P was developed that is specifically designed for applications in the soil zone and allows for solving multicomponent reactive transport problems in a one-dimensional unsaturated soil profile accounting for evapotranspiration processes (Mayer et al., 2002; Gérard et al., 2004). Richard's equation including two different preferential flow schemes, unsaturated zone solute transport, aqueous speciation, dissolution/precipitation kinetics, both passive (i.e. mass flow) and active plant uptake, and provisions to account for the influence of temperature on geochem-

ical processes and transient boundary conditions are incorporated.

The application of MIN3P to the Vauxrenard field site shows that the model is capable of reasonably well simulating about four years of dissolved Si data collected from a soil profile at various depths by means of suction-cups lysimeters. The calibration of important model parameters such as longitudinal dispersion, mineral reactive surface and active uptake flux has been performed on the first two years of measurements. We validated the model over the rest of the measurement period, which yielded good results. Interestingly, the modelling of the Vauxrenard field site indicates that the annual flux of Si released by silicate weathering was slightly less than the uptake by the Douglas fir forest. Also, only about 10% of the total uptake of Si occurred actively and about 90% was passive uptake. The flux of Si brought to the soil by the decomposition of the forest litter was about 35% of the weathering flux, which makes the biological cycle of Si approximately 60% of the biogeochemical cycle in this ecosystem. This is less than that determined by other means in tropical ecosystems, but fairly large compared with other data from forest ecosystems under a temperate climatic regime. By allowing the coupled modelling of the major processes involved in the biogeochemical cycles of elements in soils, the MIN3P model, though still in development, is a promising tool.

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