SOIL ACIDIFICATION PREDICTION AND QUANTIFICATION USING APSIM-SWIM.

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Abstract

The background and development is presented for a model that can quantify soil acidification, and thus be useful for analysing management options aimed at its control or amelioration. It is proposed that such a model needs a geochemical basis if it is to cope explicitly with the mineral nutrition aspects (*eg.* Al toxicity) that are a consequence of soil acidification.

Key words: soil acidification, modelling, soil pH, pH buffering, geochemistry, aluminium, weathering

Large areas of agricultural land in Australia are affected by accelerated soil acidification due to an imbalance between inputs and outputs (3). For example, leaching of nitrate that was originally applied in the form of an ammonium-based fertiliser is acidifying, as is the removal of alkalinity in produce. To quantify acidification and to analyse alternative management options aimed at its control, requires consideration of many complex and interactive above- and below-ground processes. A comprehensive model of the soil-plant-atmosphere continuum would provide a framework within which the complexity and variability of the agricultural system could be analysed. To this end, we are currently building an acidification module into the systems model APSIM (Agricultural Production Systems Simulator, (5)). Here we present the background and development of this module.

Modelling soil acidification

The processes involved in soil acidification have been described by Helyar and Porter (3). They developed a proton budget framework, which tracks the production and consumption of protons and determines the relative importance of the various acidifying processes. The change in protons in the system is based on the measured change in soil pH and the pH buffer capacity. The model has been used in several Australian studies and the major acidifying processes were found to be nitrate leaching, accumulation of organic anions in soil organic matter and removal of organic anions in produce or animal products (6).

In applications of the Helyar and Porter model, changes in pH buffer capacity are usually ignored due to lack of data. This can lead to under- or over-predictions of proton production, especially in situations where the levels of organic matter have changed dramatically over the period of study. Another limitation of the model is that nitrate leaching is calculated by difference, which assumes that all acidification that cannot be accounted for by other processes is due to nitrate leaching (6). This can lead to large uncertainties or even erroneous results.

To quantify the distribution of acidity within the profile a multi-layer model SPAM (Soil Profile Acidification Model, (2)) was developed. It is based on the Helyar and Porter approach, but includes movement of alkalis and acids within the profile and ion intake balances for the roots in each layer. Nitrate leaching is, however, still treated as an unknown and fitting against actual pH data is required.

The agricultural systems model APSIM simulates all the major processes which contribute to soil acidification, including nitrate leaching. For example, the soil residue module simulates decomposition of residues and the effect of various tillage practices, and the soil nitrogen module describes urea hydrolysis, mineralisation, immobilisation, nitrification and denitrification (7). Uptake of nitrogen is part of the crop modules, and transport and leaching of nitrogen is simulated by the water balance modules Soilwat (7) or SWIM (Soil Water Infiltration Movement, (8)). Development of a soil acidification module in APSIM should not only quantify soil acidification, but also predict changes in pH.

Acidification module for APSIM

A first attempt to build an acidification module into APSIM has been based on the SPAM model. Proton budget equations have been coded into a module (called SoilpH) that makes use of the output of other APSIM modules. It uses a pH buffer capacity calculated from the soil pH, carbon content, exchangeable cations and aluminium. At the moment the effect of soil acidification on crop or pasture performance is not included, but it is hoped that this feedback will be incorporated into the various crop modules of APSIM in the near future. SoilpH is described in more detail elsewhere in these proceedings (4).

A key component of further developments of the acidification module will be the geochemical description of the buffer capacity. This will include dynamic simulation of the chemical processes such as weathering, cation exchange, aluminium complexation and dissolution, that are responsible for the pH buffering and determine the composition of the soil solution. Prediction of the latter is particularly useful as it is often not the low pH in itself, but high aluminium concentrations or low base cation concentrations that cause poor plant growth. In addition, this geochemical approach will allow study of the movement of various ameliorants and their effect on aluminium speciation in the soil solution.

The module will be able to take advantage of the detailed description of water and nutrient transport of the APSIM-SWIM module (8), which already includes cation exchange and adsorption. The development of the geochemical equations will draw on existing models in Europe and North America (*eg.* (1) and (9)). While these models were developed for soil acidification resulting from acid deposition in forest ecosystems, many of the principles should hold, even though the relative importance of the various acidifying and pH buffering processes will differ. Most of these models have a geochemical basis and are based on a charge balance equation:
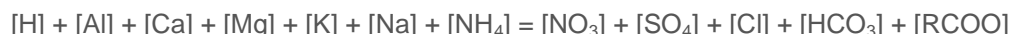
$[H] + [Al] + [Ca] + [Mg] + [K] + [Na] + [NH_4] = [NO_3] + [SO_4] + [Cl] + [HCO_3] + [RCOO]$
where the brackets indicate equivalent charge concentrations, Al represents the charged soluble aluminium compounds and RCOO the organic anions. The pH is obtained by combining this equation with equations that describe the reactions involving the various compounds. This calculation is generally part of a separate chemical equilibrium submodule. It is envisaged that such a submodule could be linked to the acidification module in APSIM. The advantage of this approach is that the model simultaneously obtains the concentrations of other cations such as free aluminium and basic cations, so that significant opportunities are created for the analysis of alternative management options not only aimed at increasing the pH, but also alleviating aluminium toxicity or nutrient deficiencies.

Acknowledgments

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