THE SIPEAA SWCN SOIL COMPONENT FOR SIMULATING WATER, CARBON AND NITROGEN DYNAMICS IN SOIL

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Processes occurring in the soil are of fundamental importance for ecosystems and agroecosystems functions. Despite that in the past decades algorithms and theories related to the dynamics of water, carbon (C) and nitrogen (N) in the soil have greatly evolved, a reusable software component which properly describes soils and simulates soil processes is still missing. Such a component would be particularly useful to the research community given the complexity of the processes to be simulated and the difficulties in their software implementation (e.g. for the numerical solution of the Richards' equation which describes water infiltration and redistribution in soils). With the purpose of developing a modular framework for the simulation of farming system, a research project started in 2002 in Italy (SIPEAA project; Donatelli et al., 2004). The objective of this paper is to describe the structure and functionalities of the soil component developed in the SIPEAA project, named SWCN (Soil Water Carbon Nitrogen).
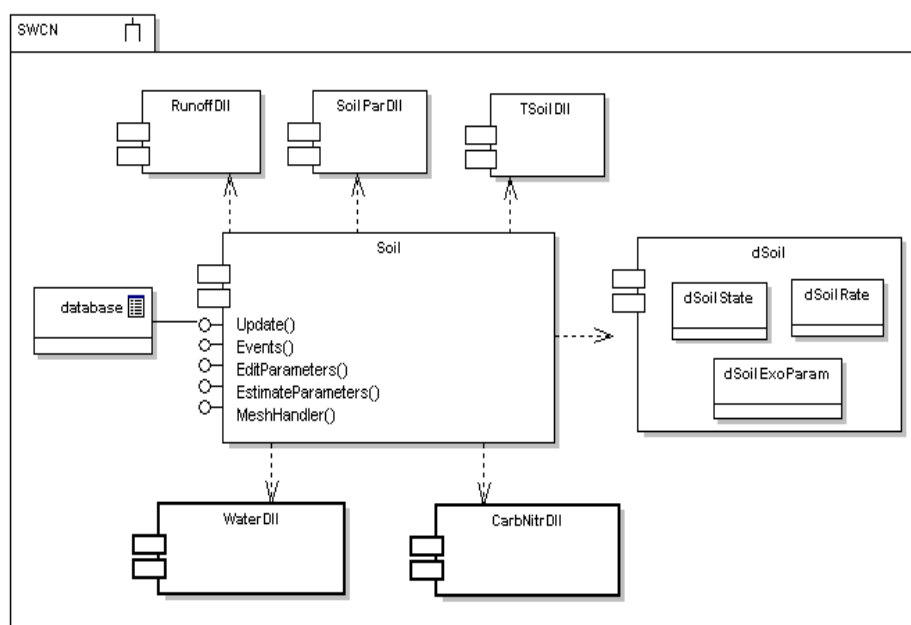
Methods
Requisites of the soil component: 1) describe the soil in the vertical dimension or in 2 dimensions (under development) using: a) upper and lower boundary conditions; b) soil layers data (soil particles distribution and initial hydrological properties, soil water content and potential, and different forms of soil C and N); c) pipe drains data, if present; 2) describe soil moisture retention and unsaturated conductivity with different equations; 3) use a daily time step in the interface to the system; 4) simulate soil temperature; 5) simulate processes of the soil water balance (drainage, runoff, evaporation, crop water uptake), by using different approaches (cascade model, numerical solution of the Richards' equation); 6) simulate soil water preferential flow (under development); 7) simulate dynamics of hydrological properties, depending on tillage and residue incorporations; 8) simulate carbon dynamics (mineralization and humification); 9) simulate nitrogen dynamics (mineralization-immobilization, nitrification, denitrification, leaching, volatilization, crop uptake, runoff) by using different approaches, each characterized by different number and types of Soil Organic Matter (SOM) pools.

Structure of the soil component
SWCN is a component designed using the Unified Modeling Language (UML) notation to describe the products of an object-oriented analysis. The figure shows the component diagram. Standard interfaces (Update(), Events(), EditParameters()) are implemented to communicate within the SIPEAA system (Donatelli et al., 2004) or within another simulation framework; other interfaces allow to estimate

hydrological properties as a function of measured soil properties (PTFs: SoilParDll sub-component, Acutis and Donatelli, 2003) and to split or aggregate soil states and parameters for different meshes. According to the architecture chosen for the project, SIPEAA model components compute rate variables only. For this reason, the method Update() of the SWCN component updates the properties of the object of type dSoilRate, by using the simulation models described below, and on the basis of the values of the state variables (dSoilState, which contains the result of integration carried out externally), the exogenous variables and the parameters (dSoilExoParam).

Simulation models contained in the soil components: 1) cascade model: when water reaches the soil surface, the first soil layer is filled with water up to field capacity; excess water is drained to lower layer or, when last layer is reached, is lost from profile as drainage; water is immobile at water contents lower than field capacity, with the exception of evaporation and transpiration; option to increase water travel time that approximates the reduction of hydraulic conductivity with decreasing soil water content and to empirically estimate the capillary raise from water table are available; 3) finite difference numerical solution of the Richards' equation, (the water flow between 2 points is proportional to the potential gradient between the points and to hydraulic conductivity) with the algorithm of van Dam and Feddes (2000) which allows for the formation of perched water table in the profile; it is possible to use Campbell or vanGenuchten-Mualem soil water retention and hydraulic conductivity functions; 4) numerical solution of the Richards' equation, by considering also a gravitational flow in the macroporous domain, with an approach based on the MACRO model (Jarvis, 1994); 5) runoff is simulated with the simplified Curve Number approach if only daily rainfall data are available or on the basis of the Green-Ampt infiltration law and the kinematic wave for water routing if hourly rainfall are recorded; 6) evaporation is simulated by using the simplified relationship between soil water content of the evaporation layer and evaporation rate (Campbell and Norman, 1998); 7) crop water uptake is simulated on the basis of relative root mass in each layer and the potential crop water uptake. Three approaches are available, taken from CropSyst, CERES and EPIC (e.g. Stockle and Jara, 1999), implementing different concepts about the root system ability to compensate water deficit in a soil layer when more water is available in others; 8) C and N dynamics can be simulated with two different approaches, one of high complexity, similar to DAISY (Hansen et al., 1993) including 2 pools of stable SOM, 2 pools of Soil Microbial Biomass (SMB), and 2 typologies of added organic materials (AOM), and one of relatively lower complex structure (CERES, including 1 pool of SOM and 3 typologies of AOM; SMB not explicitly simulated). Each new application of organic matter creates a new pool, with its humification and mineralization history. First order kinetics are used for computing the rates of transformation of C and N pools, influenced by soil temperature and soil water content/potential, and in case of the nitrification process, also by the NO_3/NH_4 ratio. To handle the solute movement, convection-dispersion equation, solved in stationary condition, is also implemented. Approaches updating soil parameters depending on tillage, residues incorporation and soil shrinking-swelling are under development, using the Braudeau et al. (2004) approach.

References
Acutis M., Donatelli M., 2003. Eur. J. of Agron., 18, 3-4, 373-377.
Braudeau et al., 2004. Soil Sci. Soc. Am. J., 68, 359-370.
Campbell G.S., Norman J.M., 1998. An introd. to environ. biophysics. Springer, New York, 286 p.
van Dam J.C., Feddes R.A., 2000. J. of Hydrol., 233, 72-85.
Donatelli M. et al., 2004. These proceedings.
Hansen S. et al., 1993. Royal Veterinary and Agricultural University, Copenhagen, 272 p.
Jarvis N.J., 1994. Rep. and Diss. n. 19, Dept of Soil Science, Uppsala, 51 p.
Jones J. et al., 1986. College Station, TX: Texas A&M Press, 105 p.
Stockle C.O., Jara J., 1999. Agron. J., 91, 256-265.