Nitrogen turnover in the soil-crop system; comparison of fourteen simulation models

P. de Willigen
Institute for Soil Fertility Research, P.O. Box 30003, 9750 RA Haren (Gn.), The Netherlands

Abstract

Fourteen models of the nitrogen turnover in the soil-crop system were compared. The comparison comprised the processes included in the models, the methods of process description, as well as the results of simulations carried out with the same data set. It is concluded that simulation of the aboveground processes was less problematic than that of the belowground processes. None of the models could account for the loss of mineral nitrogen occurring shortly after application of fertilizer in late spring and early summer.

Introduction

It has long been known that nitrogen is one of the elements of which supply is most often limiting growth. Traditionally agricultural research has focussed on how to provide the crop with sufficient nitrogen to guarantee optimum yields. If efficiency was taken into account, the reason was usually to maximize financial returns rather than to minimize the danger of leaching. Nowadays agriculture is faced with a growing popular demand for a higher priority to prevention of minimization of pollution. The challenge for agricultural research is to devise production methods which hold no risk of losses causing pollution but which at the same time lead to economically acceptable yield levels. Simulation models, which describe in sufficient detail the turnover of nitrogen in the soil-crop system, can be of great assistance in understanding the interactions between the different processes involved. Also, they can point to gaps in our knowledge, and in doing so, can help in designing experiments that aim at clarification of poorly understood parts of the problem.

To celebrate its centennial the Institute for Soil Fertility Research organized a workshop on 5–6 June 1990. The purpose was to compare various simulation models of nitrogen turnover in the soil-crop system. The participants were requested to run their model with data provided by the Institute prior to the workshop. The main purpose of the workshop was to bring together scientists working in the same field, and to provide them with an opportunity to present their work in some detail and get acquainted with that of others. The data furnished were used to demonstrate the performance of the respective models.

This paper surveys the models presented, and summarizes the results. We will compare the models in terms of the processes they represent and of their description of these processes. Further we will point out for what purposes they seem best suited.

Description of models

In all, 18 papers were presented. Fourteen dealt with the data supplied. Table 1 gives the list of these 14 models, together with the names of the

Table 1. List of participating models

Code	Name of first author	Pages where model is discussed (Fert Res)	References for further information
[A]	Cabon	161–169	(1), (2), (3)
[B]	Ramos	171–180	(4)
[C]	Bergström	181–188	(5), (6)
[D]	Rijtema	189–198	(7)
[E]	Grant	199–213	(8), (9), (10), (11), (12)
[F]	Lafolie	215–231	—
[G]	Vereecken	233–243	(6), (13), (14)
[H]	Hansen	245–259	(15)
[I]	Groot	261–272/349–383	(16)
[J]	Kersebaum	273–281	(17)
[K]	Whitmore	283–291	(18), (19)
[L]	Mirschel	293–304	(20), (21)
[M]	Addiscott	305–312	(18)
[N]	Eckersten	313–329	(22), (15), (16)

References for further information, corresponding with Table 1.

(1) Geng QZ (1988) Modélisation conjointe du cycle de l'eau et du transfert des nitrates dans un système hydrologique. Thèse de doctorat, Ecole Normale Supérieure des Mines de Paris, Paris

(2) Girard G (1975) Modèle global ORSTROM 1974. Première application de modèle à discrétisation spatiale sur le bassin versant de la crique Grégoire en Guyanne. Atelier hydrologique sur les modèles mathématiques, ORSTROM

(3) Ledoux E (1980) Modélisation intégrée des écoulements de surface et des écoulements souterrains sur un bassin hydrologique. Thèse de Docteur-Ingenieur, Ecole Nationale Supérieure des Mines de Paris, Paris

(4) Wagenet RJ and Hutson JL (1989) LEACHM: Leaching Estimation and Chemistry Model: A process based model of water and solute movement transformations, plant uptake and chemical reactions in the unsaturated zone. Continuum Vol 2 Version 2 Water Resources Inst, Cornell Univ, Ithaca, NY

(5) Jansson PE and Halldin S (1979) Model for annual water and energy flow in layered soil. In: Halldin S (ed) Comparison of Forest Water and Energy Exchange Models, pp 145–163. Copenhagen: International Society for Ecological Modelling

(6) Johnsson H, Bergström L, Jansson PE and Paustian K (1987) Simulated nitrogen dynamics and losses in a layered agricultural soil. Agric Ecosystems Environ 18: 333–356

(7) Rijtema PE, Roest CWJ and Kroes JG (1990) Formulation of the nitrogen and phosphate behaviour in agricultural soils, the ANIMO model. Report 30 (in press), Wageningen, The Netherlands: The Winand Staring Centre

(8) Grant RF (1989) Simulation of carbon accumulation and partitioning in maize. Agron J 81: 563–571

(9) Grant RF (1989) Test of a simple biochemical model for photosynthesis of maize and soybean leaves. Agric For Meteorol 48: 59–74

(10) Grant RF (1989) Simulation of maize phenology. Agron J 81: 451–457

(11) Grant RF, Peters DB, Larson EM and Huck MG (1989) Simulation of canopy photosynthesis in maize and soybean. Agric For Meteorol 48: 75–91

(12) Grant RF (1990) Dynamic simulation of water deficit effects upon maize yield. Agric Systems (in press)

(13) Keulen H van, Penning de Vries FWT and Drees EM (1982) A summary model for crop growth. In: Penning de Vries FWT and van Laar HH (eds) Simulation of Crop Growth and Crop Production, pp 87–97. PUDOC Wageningen

(14) Vereecken H, Vanclooster M and Swerts M (1989) A model for the estimation of nitrogen leaching with regional applicability. Presented at the Int Congress 'Fertilizer and the Environment', pp 13. August 27–30, 1989, Leuven, Belgium

(15) Hansen S, Jensen HE, Nielsen NE and Svendsen H (1990) DAISY: A soil plant system model. Danish simulation model for transformation and transport of energy and matter in the soil plant atmosphere system, 350 pp (in press)

(16) Groot JJR (1987) Simulation of nitrogen balance in a system of winter wheat and soil. Simulation Reports CABO-TT no. 13, Centre for Agrobiological Research and Department of Theoretical Production Ecology, Wageningen, 69 pp

(17) Kersebaum KC (1989) Die Simulation der Stickstoff-Dynamik von Ackerböden. Ph. D. Thesis University Hannover

(18) Addiscott TM and Whitmore AP (1987) Computer simulation of changes in soil mineral nitrogen and crop nitrogen during autumn, winter and spring. J Agric Sci, Camb 109: 141–157

(19) Whitmore AP and Parry LC (1988) Computer simulation of the behaviour of nitrogen in soil and crop in the Broadbalk continuous wheat experiment. In : Jenkinson DS and Smith KA (eds) Nitrogen Efficiency in Agricultural Soils, pp 418–432. Elsevier, London

(20) Matthäus E, Mirschel W, Kretschmer H, Künkel K and Klank I (1986) The winter wheat crop model TRITSIM of the agroecosystem AGROSIM-W. In: Tag.-Ber. der ADL der DDR (Computer Aided Modelling and Simulation of the Winter Wheat Agroecosystem (AGROSIM-W) for Integrated Pest Management) (242), pp 43–74