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Quickscan of simulations models

A. Verhagen, S. Conijn & A.H.C.M. Schapendonk

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Introduction

Dynamic simulation models, quantifying bio-physical process, are the most appropriate tools to quantify the water, carbon and nitrogen cycle in soil-crop ecosystems. It is Plant Research International mandate in the NRP sponsored project on the relation of climate and land to quantify these cycles and provide estimates of GHG fluxes at various scales for arable land.

As not all of the project partners are acquainted with the scope and nature of available models it was decided that an inventory of simulation model should be made available to the project partners.

This overview of well-known models ranges from comprehensive models (e.g. WAVE) to models only focussing on a part of the system (e.g. LINTUL). A checklist with requirements for the different models is also included.

The information presented in this report is derived from the Register of Agro-ecosystems Models (CAMASE; http://www.bib.wau.nl/camase/cam-proj.html) and the www server for Ecological modelling (http://dino.wiz.uni-kassel.de/ecobas.html).

ANIMO

Agricultural NItrogen MOdel

Keywords
carbon, nitrogen cycle, phosphorus cycle, leaching, runoff, mineralisation, immobilization, crop uptake, denitrification, nitrification, desorption, adsorption, soil complex

Abstract

Dynamic simulation of carbon, nitrogen and phosphorus cycles in an unsaturated and saturated soil system. The model was developed to analyse the leaching of nitrogen from the soil surface to ground water and surface waters. The phosphorus cycle was added to, hydrological data must be supplied by another model. Model system is a multi-layer one-dimensional soil column. The upper boundary is the soil surface, the lower boundary is the depth of the local ground water flow and the lateral boundary is defined by the surface water system(s). Main processes included in the model are: mineralisation and immobilization, crop uptake, denitrification related to (partial and temporal) anaerobiosis and decomposing organic materials, oxygen and temperature distribution in the soil, nitrification, desorption and adsorption of ammonium and phosphorus to the soil complex, runoff, discharge to different surface water systems and leaching to ground water.

Technical Information

Operating System(s):	VAX, IBM compatible PC with coprocessor
Programming Language(s):	FORTRAN-77

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CENTURY

Grassland and agroecosystem dynamics model

Keywords
grassland, agroecosystem, dynamics, nitrogen, carbon, phosphor, sulfur, nutrient cycle, capacity cascade model

Abstract

Century is a simulation and process model used to understand grassland and agroecosystem dynamics. Other versions exist for savannas and forests. The purpose of the model is to analyze soil organic matter dynamics in response to changes in management and climate. The model uses monthly time steps for simulations of up to several thousand years to examine the flows of carbon, nitrogen and phosphorus.

Data required for input are:
- monthly mean maximum and minimum temperatures;
- mean precipitation;
- soil texture and soils depth;
- vegetation types and CO2 levels.

The output contains information on carbon and nitrogen fluxes, net primary production and soil organic matter. The spatial extent of the model is regional with most executions at the 1m2 resolution.

Global change implications: The model has been used extensively for global change research. The model has been executed in over 22 different areas in the world (Bill Parton, personal communication). It can be used to assess the impacts of regional climate change on a variety of important grassland ecosystems. It has also been coupled to vegetation growth models (Laurenroth et al., 1993) such as STEPPE.

Technical Information

Operating System(s):	DOS, Unix
Programming Language(s):	Fortran

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CNGRASxFUSSIM

A Simulation Model for Grassland Management

The grassland management model is a dynamic model that calculates daily changes in the major state variables of a managed soil-grass system at the field scale. It simulates grass production, water, carbon and nitrogen flows as a function of management, climate, soil and plant characteristics. The purpose for developing a grassland management model was to offer a mathematical framework in which all relevant processes are described according to the state-of-the-art knowledge and to develop new management options for optimization of grass production with minimal adverse environmental side effects. The functionality of the model is given below by describing its four main sections.

Management

Via a model input file, information on grassland management can be supplied by the model user. This includes data on harvesting, fertilization, supplemental feeding, animal production and irrigation. Most input data are organised in the management calendar, which enables the user to specify a different set of input data for each growing period or harvesting event within a growing season. F.i. cutting and grazing can be applied alternatively during a growing season and the fertilization can be adjusted for each growing period to supply the adequate amount of nitrogen for the desired yields . Data on supplemental feeding and animal production are used to calculate the excretion of nitrogen by animals in the field, which has potentially a large impact on the nitrogen balance.

Grass growth

Total grass dry matter production, carbon fixation and nitrogen uptake are calculated as a function of absorbed radiation, temperatures, water and nitrogen status in plant and soil. Growth of roots, leaves and stems is computed by partitioning the total increase in dry matter, carbon and nitrogen among these plant compartments and a reserve pool. The reserve pool is used as a buffer, from which relocation may take place to accelerate grass growth. Nitrogen concentrations are expressed as total actual (protein-N and nitrate-N) and total optimum (mainly protein-N) amount of nitrogen per unit dry matter. During spring generative development may be simulated with increased growth of stems. The turnover rates of roots, leaves and stems due to senescence and harvesting activities are calculated and the amounts of dry matter, carbon and nitrogen in the dead plant material are transferred to the pools of organic matter, carbon and nitrogen in the soil.

Soil water

Water movement in a soil profile can be simulated in 1 or 2 dimensions. Processes taken care of are: water movement (Richards equation), root water uptake, infiltration, evaporation, drainage. Based on atmospheric conditions and leaf area index potential demands for transpiration and evaporation are computed. Based on these potential demands, on the current water status and on the root distribution, it is determined what the actual transpiration and evaporation will be. Similarly, it is checked whether the infiltration capacity allows infiltration of the amounts of rain and irrigation water. If not, ponding and/or runoff will occur. Two-dimensional water movement in grassland soils is particular of interest in studies concerning outflow to drains or ditches, and in studies with different management options within a field, e.g., areas without or with less fertilization.

Soil nitrogen

Nitrogen (N) transport through the soil profile (1 or 2 dimensions) is described by the classic convection-dispersion equation. Based on known water fluxes and water contents, the solute fluxes are computed and from that the new solute distribution. N is divided over NO3 and NH4. For NH4 linear adsorption to soil particles is considered. The demand for N uptake is divided as demand for NO3 and for NH4. As for water, based on current N distribution and on the root distribution, it is determined if these demands can be achieved, or, otherwise, it is determined what the actual N uptake will be. N input comes from atmospheric deposition (as NH4), fertilization, plant residues, and from animal excreta (if present). Mineralization is computed from total organic N and is influenced by soil type, soil temperature and water content. Other processes considered are: ammonia volatilization, nitrification of NH4 and denitrification of NO3 into N20 and N2. Thus, it is possible to compute losses of N from the soil-grass system, as loss of NH4, N2O and N2 and as loss of N from the root zone by leaching to drains, groundwater and/or open water systems.

Technical Information

Platform:	MSDOS
Language:	FORTRAN 90, FSE4

Daisy

Daisy

Keywords
Crop science, soil science, and environmental science. Cropping system/animal husbandry system.

Abstract

Model for the simulation of soil water and nitrogen dynamics in the crop-soil system. The main modules simulate: 1) water dynamics, including snow accumulation and melting, evaporation from open water surfaces and soil, transpiration and water uptake by plants (based on the single root uptake and root density), infiltration, percolation and soil water dynamics (Richards' equation); 2) soil heat, including freezing and melting and soil temperature; 3) nitrogen dynamics, including turnover of organic matter (based on carbon pools, microbial biomass, and first order kinetics), mineralization/ immobilization (a consequence of the carbon turnover), nitrification, denitrification, nitrogen uptake by plants (based on single root uptake and root density), and nitrogen transport (convection-dispersion equation) and leaching; 4) crop growth, i.e. crop development, dry matter production, crop nitrogen demand, crop nitrogen content, photosynthesis, water stress, nitrogen stress, assimilate partitioning, maintenance and growth respiration, leaf area development, root penetration and root density distribution. The model allows for the simulation of different management strategies and crop rotations.

Technical information

Hardware:	PC or Workstation.
Programming language:	Microsoft FORTRAN-77.
Other software required:	MS-DOS or UNIX.

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DNDC

DeNitrification and DeComposition model

Keywords
nutrient dynamics, CO2, denitrification, decomposition

Abstract

DNDC is a process-oriented simulation model of soil C and N biogeochemistry. The model contains 4 interacting submodels: soil climate, crop growth, decomposition, and denitrification. The soil climate submodel uses soil texture, air temperature, and precipitation data to calculate soil temperature and moisture profiles and soil water fluxes through time. The crop submodel simulates N-uptake and crop biomass growth. The decomposition submodel calculates daily decomposition, nitrification, ammonia volatization processes, and CO2 production. The denitrification submodel calculates hourly denitrification processes and N2O and N2 production during wet periods. Effects of tillage, fertilization, manure amendment, and irrigation are incorporated into the model. The model requires input data on weather, agricultural practices, soil N2O and CO2 pools. Output from the model includes daily emissions of N2O and CO2, and daily and seasonal fluxes to soil carbon pools. The model operates on a hourly to daily time step.

This model could be used to study the effects of elevated CO2 on denitrification and decomposition. It may also provide some insights into the ability of soils to act as carbon sinks.

Technical Information

Operating System(s):	DOS
Programming Language(s):	BASIC (C-version ?)

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DSSAT

Decision Support System for Agrotechnology Transfer Version 3.5

Keywords
environment, agriculture, agroecosystem, agricultural management effects, rotation, yield, crop growth, corn, bean, soybean, peanut, decision support system, modellling system, multiple growth models, Ceres, Cropgro, database

Abstract

The goal of the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) Project is to accelerate the flow of agrotechnology and increase the success rate of technology transfer from agricultural research centers to farmers' fields. To do this, IBSNAT has developed computer software which helps match crop requirements to land characteristics using crop simulation models, data bases, and strategy evaluation programs. The resulting system is called the Decision Support System for Agrotechnology Transfer (DSSAT). DSSAT provides easy access to data bases and crop models so that the user may "test" on screen the performance of new cultivars, sites, or manag ement practices. This system allows user to screen new technology packages, such as a new cultivar or fertilizer management strategy, whithout spending excess time on expensive, time consuming field trials. By simulating outcomes of strategies on the computer screen, user can ask "what if" questions and explore the options on screen. Sustainable agriculture requires tools that enable decision makers to explore the future. A decsion support system must help users make choices today that result in desired outcomes, not only next year, but 10, 25, and 50 or more years into the future.

DSSAT was designed primarily for user groups in agriculture, but owing to its break with traditionaly ways of diagnosing and prescribing solutions, it has been adopted by other types of users. The emergence of issues which require assessment of conditions not in the past or present, but in the future calls for the systems approach to problem solving encompassed by DSSAT, which includes:

- Global climate studies,
- Use with geographic information systems,
- Whole-farm system models,
- Pest-crop interaction models,
- Fertilizer strategies,
- Plant breeding.

DSSAT is comprised of the following components:

1. a data Base Management System (DBMS) to enter, store, and retrieve the "minimum data set" needed to validate, list and use the crop models to provide outcomes to alternative management input
2. a set of validated crop models
3. an application program for analyzing and displaying outcomes of long-term simulated agronomic experiments.

The following **crop models** are currently accessible under the DSSAT shell. They include:

- the CERES family of models:
  CERES-maize, CERES-wheat, CERES-rice, CERES-barley, CERES-sorghum, and CERES-millet;
- the CROPGRO series of models for legumes:
  CROPGRO-soybean, CROPGRO-peanut, CROPGRO-dry bean (Phaseolus)

- the CROPSIM model series for root crops: CROPSIM-cassava and SUBSTOR-potato
- and for other crops: CROPGRO-Tomato, CROPGRO-Chickpea, Sugarcane, Sunflower
- (Taro, tanier and pineapple will be added in the near future.)

All crops share a common input-output format, and are similar in level of detail. They operate on a daily time step, and are based on an understanding of biophysical processes.

These models are process oriented, designed to have global applications, and work independent of location, season, crop cultivar, and management system. The models simulate the effects of weather, soil water, genotype, and soil and crop nitrogene dynamics on crop growth and yield.

The Data Base Management System (DBMS) in DSSAT is used to organize and store the Minimum Data Set (MDS). The MDS is the minimum data required to run DSSAT's crop models, and has become an international standard data set for model calibration and validation. The DBMS provides easy access to four data bases.

- **The Weather Data Base**
  This data base contains daily weather data from the Minimum Data Set experiments, and allows easy editing, and printing of data.
- **The Soil Data Base**
  This data base is comprised principally of the 600 pedons in the USDA Soil Conservation Service (SCS) International Benchmark Soil Data base.
- **User's Input Data Base**
  This database allows the user to enter soil data collected by their own national soil survey organization. Data is entered into the User's Input program using a standardized format, so that the user can retrieve their own soil profiles and combine them with the Weather and Experiment data bases.
- **The Management and Experimental Data Base**
  Management information includes planting date, planting density, row spacing, planting depth, crop variety, and irrigation and fertilizer practices. The experimental data base includes the minimum data set required for validating the crop models.
- **Utilities and Summary Reports**
  The utility programs allow users to input data in ASCII format (i.e., a spread-sheet) and the program converts it into the correct input/output file format used by the crop models. The Summary Reports allow:
  1. chronological listing of activities and events for an experiment;
  2. summary of preplant soil fertility and preplant soil water content for each layer;
  3. date and fertilizer inputs by plot; and
  4. tables and/or graphs of weather data on a 10-day or monthly basis.

The Strategie Evaluation Program in DSSAT allows users to evaluate the merits of simulated strategies and identify the best one. The program uses cumulative probabilty functions to develop and select the strategy with the preferred mean and variability characteristics. With this program users can determine the effectiveness of crop management stragegies, the economic return of a new cultivar, or the suitability of a site for a specific crop. Using weather generators programs which generate coefficients from historical weather data, DSSAT can simulate the growth and development of a crop for up to 50 consecutive years. DSSAT allows up to 15 combinations of options to be simulated in a single experiment, generating in a few hours, amounts of data that have traditionally required an agronomist's lifetime of work.

Technical Information

Operating System(s): DSSAT v3.5:
Any 486 or better IBM Personal Computer or compatible microcomputer with:

- 640K of random access memory (RAM); minimum free RAM required is 590K
- a hard disk (required); complete installation requires 25 MB disk space
- DOS version 3.3 or later
- an VGA graphic adapter or better
- a math coprocessor (recommended)

DSSAT v3.5 is distributed by the International Consortium for Agricultural Systems Applications (ICASA), University of Hawaii.
Complete DSSAT v3.5 PACKAGE includes (7 - 3.5" DS/HD Installation disks):
Management System for new DSSAT v3.5 files,

- Crop models and User's Guides for:
- Cereals - Maize, Wheat, Rice, Sorghum, Barley, and Millet models,
- Grain Legumes - Soybean, Peanut, Dry Bean, and Chickpea models,
- Root Crops - Cassava and Potato models, and
- Sugarcane, Tomato, Sunflower and Pasture.
- Seasonal, Sequence and Spatial (AEGIS/WIN) Analysis programs, and
- 4 Volume set of DSSAT v3.5 User's Guides.

Technical Information

Programming Language(s): Components of software are written in FORTRAN (crop models), C (shell), Pascal (graphics), DBase (database), and Basic (strategy and risk management programs)

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EPIC

Erosion-Productivity Impact Calculator

Keywords
non-point source pollution, soil erosion, crop production, management, hydrology, soil temperature, event based, process based

Abstract

EPIC (Erosion-Productivity Impact Calculator) is a mechanistic simulation model used to examine long-term effects of various components of soil erosion on crop production (Williams et al., 1983). EPIC is a public domain model that has been used to examine the effects of soil erosion on crop production in over 60 different countries in Asia, South America and Europe.

The model has several components:
- soil erosion,
- economic,
- hydrologic,
- weather,
- nutrient,
- plant growth dynamics and
- crop management.

The model requires input from GIS layers. These include soil series and weather data, although the model can generate the necessary weather parameters. The model also requires management information that can be input from a text file. Currently, there are many management files that exist for EPIC and an effort is underway to catalogue these files and provide them to users. The model provides output on crop yields, economics of fertilizer use and crop values.

EPIC has been used widely forthe study of global change. The most noteworthy example is the MINK (Missouri-Iowa-Nebraska-Kansas) study conducted by Rosenbergand Crosson (Rosenberg and Crosson, 1991). This study examinedthe effects of elevated CO2 (EPIC had to be modified to incorporatesensitivity to CO2) and temperature on crop yields, soil erosion andeconomics in this four state region. The MINK study also provides generalinsights about the use of models for global change research.

Technical Information

Executables:

Operating System(s)
DOS - Ver 5300
Solaris - Ver 5300
Europe: DOS ver 5125
SUN/Unix ver 5125

Source-code:
Programming Language(s)
Fortran ver 5125 Europe: Fortran ver 5125

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FUSSIM2

Flow in Unsaturated Soil SImulation Model in 2 dimensions

Keywords
soil, unsaturated, flow, water transport, richards equation, finite elements

Abstract

Solves the non-linear Richards' equation in 2 dimensions (x,z). Soil hydraulic properties described by Van Genuchten-Mualem functions. Richards' equation is left in mixed 0-h form. Method proposed by Celia *et al.* (1990; WRR 26: 1483-96) is used to assure perfect mass balance. Solution is obtained numerically using the control volume finite element method. The resulting matrix problem is solved via an iterative alternating direction implicit method. Top and bottom boundary conditions can be of prescribed pressure head or prescribed flux density type; left and right boundaries are no flow boundaries.

Technical Information

Operating System(s):	IBM compatible, VAX, ALPHA. Contract necessary: Costs: : Dfl. 110,=.
Programming Language(s):	Microsoft FORTRAN-77.

References

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FUSSIM2: a simulation model for two-dimensional flow of water in unsaturated soil.
DLO-Instituut voor Bodemvruchtbaarheid Nota 260. 146 pp.

LINTUL

Light INTerception and UtiLization simulator.

Keywords
crop, growth, light interception, light utilization, temperature-sum based

Abstract

LINTUL is a simple general crop model, which simulates dry matter production as the result of light interception and utilization with a constant light use efficiency. Leaf area increase during the exponential phase is temperature-determined, and thereafter follows from dry matter allocation to leaves. Allocation functions depend on the temperature-sum. Leaf senescence also depends on the temperature-sum but is accelerated at overly high leaf area index. LINTUL simulates potential crop growth but extensions of the model dealing with drought, potato late blight and potato cyst nematodes have been developed already. The model is geared towards analyzing deviations of actual crop growth from potential growth. Its simplicity allows easy addition of user-defined modules simulating abiotic or biotic stress. LINTUL is expanded with a CO_2 dependent photsynthesis routine.

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Simulated effects of elevated carbon dioxide concentration and temperature on the productivity of potato. Interaction with cultivar differences for earliness. In: Ecology and modeling of potato crops under conditions limiting growth. A.J. Haverkort and D.K.L. Mac Kerron, eds. Kluwer Academic Publishers pp 101-117.

Schapendonk, A.H.C.M., M. van Oijen, Riki van den Boogaard & Jeremy Harbinson, 1999.
Nitrogen shortage in a tomato crop; scaling up from effects on electron-transport rate to plant productivity. Z. Naturforsch. 54C 9-10: 840-848.

LINtul GRAss

Light interception grass

A sink/source model to simulate grassland productivity in Europe

Keywords
grass, leaf area, Lolium perenne L., modelling, phenology, productivity, sink-source.

Abstract

A simulation model for the prediction of the productivity of Lolium perenne L. grasslands is described and validated. Simulated key processes are light utilization, leaf formation, leaf elongation, tillering, and carbon partitioning (storage, shoot, root). Source- and sink-limited growth are simulated independently. Sink-limited growth is characterized by temperature-dependent leaf expansion and tiller development whereas source-limited growth is determined by photosynthetic light-use-efficiency of the canopy and the remobilization of stored carbohydrates in the stubble. At each integration step, commonly 1 day, the available amount of carbon from the source is compared with the carbon required by the sink. Actual growth is determined by minimum value of either sink or source. If the source is in excess of the sink, the surplus is allocated to storage carbohydrates in the stubble. This storage carbon is available for remobilization at times that the sink requires more carbohydrates than available from photosynthesis. In contrast to previous grassland models, LINGRA describes regrowth after defoliation in a mechanistic way, balanced by temperature-driven remobilization of stored carbohydrates.

For validation of LINGRA, an extensive set of experimental data was used, derived from measurements at 35 sites in Europe. The average error between observed and predicted yields was 14% at the level of irrigated, and 19% at the level of non-irrigated treatments for the whole of Europe.

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LINGRA_CC

Sink/source model to simulate the impact of climate change and management on grassland productivity.

Keywords
Carbon dioxide, climate change, grassland productivity, *Lollium perenne* L., sink-source relationships

Abstract

A simulation model for the prediction of grassland (Lolium perenne L.) productivity under conditions of climate change is described and validated. In this work the validated model was used to study the impact of different management strategies on the productivity of the grassland under present and increased atmospheric CO_2 concentrations.

In LINGRA_CC simulated key processes are light utilisation, leaf formation, leaf elongation, tillering, and carbon partitioning. The daily growth rate is determined by the minimum of a sink and a source term. As in a previous model (LINGRA), the potential growth of the sink depends on the mean daily temperature, and can be modified by the effects of the availability of assimilates on tillering. The growth of roots is calculated from the amount of carbohydrates the shoot is unable to utilise when the number or activity of the sinks is small (overflow hypothesis). Main differences between LINGRA and LINGRA-CC are with respect to the way the source of assimilates for growth is calculated. Assimilate production depends on intercepted radiation, and a photosynthetic light-use efficiency (LUE) calculated as a function of CO_2, temperature, light intensity and the Rubisco concentration of upper leaves. Other differences with LINGRA are that in LINGRA_CC, the specific shoot leaf area for the newly growth depends on the level of reserves. The model predicted well the observed amounts of harvested biomass, and the dynamics of the leaf area index, tiller number and specific shoot area. In this work LINGRA_CC was used to study the effects of different combinations of cutting intervals and cutting height on biomass production, at ambient and double CO_2 conditions.

References

Rodrigues, D., M. van Oijen & A.H.C.M. Schapendonk, 1999.
LINGRA_CC: a sink/source model to simulate the impact of climate change and management on grassland productivity. The New Phytologist, 144: 359-368.

MOTOR

Modular description of Organic matter TurnOveR.

Keywords
organic matter, soil, decomposition, carbon dynamics, nitrogen dynamics

Abstract

MOTOR is a MOdular system describing the Turnover of Organic matteR. It derives from the model of Jenkinson and Rayner (1997) in that it allows the manipulation of vectors and matrices containing the rate constants, the quality, nitrogen (and other nutrient) content and labelled nitrogen (and carbon) content of each pool describing the transformation of organic matter in soil. However MOTOR goes one step further in that the number of pools or compartments of organic matter can easily be changed. The flexibility of this system has already been used in dynamic description of the protection of organic matter in soil (Hassink and Whitmore, 1997). Furthermore MOTOR also allows continuous variation of carbon:nitrogen ratios and the efficiencies with which micro-organisms in soil use substrate.
Model parentage: Bradbury et. al., Jenkinson and Rayner model.

Technical Information

Programming Language(s): Microsoft FORTRAN.

References

Hassink, J. & A.P. Whitmore, 1997.
A model of the physical protection of organic matter in soils. Soil Science Society of America 61:131-139.
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The turnover of soil organic matter in soil in some of the Rothamsted classical experiments Soil Science 123:298-305.
Whitmore, A.P., H.K. Gunnewiek, G.J. Crocker, J. Klír, M. Körschens & P.R. Poulton, 1997.
Modelling the turnover of carbon in soil using the Verberne/MOTOR model.
Geoderma 81, 137-151.

SUCROS2

Simple and Universal CRop growth Simulator

Keywords
water balances, drought stress, crop growth, dry matter production,assimilation, CO2, teaching

Abstract

Crop growth model for water-limited conditions. SUCROS2 describes crop growth (as applied to spring wheat) under water-limited conditions by including water balances of crop and soil in the SUCROS1 model. Conditions of other growth factors are supposed to be optimal, i.e. ample nutrients and a pest-, disease- and weed-free environment. With the SUCROS2 model, options for soil and water conservation can be studied. The crop/soil water balances in SUCROS2 are based on earlier versions documented by Stroosnijder (1982) and Penning de Vries et al. (1989). SUCROS2 can only be understood on the basis of SUCROS1, the crop growth model for potential production. The effect drought-stress is transmitted through two variables, one acting on daily gross CO2 assimilation and the other one acting on root-shoot partitioning.

Technical information

Operating System(s):	VAX computer, IBM compatible PC/AT
Programming Language(s):	FORTRAN

References

Laar, H.H. van, J. Goudriaan & H. van Keulen (editors), 1992.
Simulation of crop growth for potentialand water-limited production situations, as applied to spring wheat. Simulation Reports 27, 72 pp.

SUNDIAL

SUNDIAL

Keywords
soil, decomposition, plant, plant debris, animal debris, organic matter

Abstract

The model simulates the decomposition of soil organic matter.

a) *Description of the decomposition of plant and animal debris*
Decomposition of plant and animal debris described by a single pool obtained by fitting

b) *Description of the decomposition of soil organic matter*
Decomposition of soil organic matter described by multiple pools as follows:

1. **BIO** defined by Rate of decomposition, Ratio BIO+HUM retained:CO2 evolved, Ratio BIO:HUM obtained by fitting
2. **HUM** defined by Rate of decompostion, Ratio of BIO+HUM retained: CO2 evolved, Ratio of BIO:HUM obtained by fitting

c) *Factors assumed to affect organic matter decomposition*

- Soil moisture
- Clay content
- Air temperature

d) *Soil layers used in the model*
The model divides the soil into 12 layers as follows:

- 5 cm layers between 0-50cm; 50 cm layers between 50-100 and 100-150cm. Organic matter contained 80% in 0-25cm, 20% in 25-50cm.

Technical Information

Operating System(s): DOS 5

References

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Jenkinson, D.S., N.J. Bradbury & K. Coleman, 1994.
How theRothamsted Classical Experiments have been used to develop and testmodels for the turnover of carbon and nitrogen in soil. In: Long-termExperiments in Agricultural and Ecological Sciences (eds R.A. Leigh andA.E. Johnston), CAB International.

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SUNDIAL:Simulation of Nitrogen Dynamics in Arable Land. A user-friendly,PC-based version of the Rothamsted Nitrogen Turnover model.Agronomy J. (in press).

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Simulation of nitrogen in soil and winter wheat crops: modellingnitrogen turnover through organic matter. Fertilizer Research 27,283-291.

WAVE

WAVE

Keywords
water transport, unsaturated, richards equation, crop growth, soil, decomposition, plant debris, animal debris

Abstract

The WAVE model is a process based, deterministic, mathematical model simulating the movement of water and the transfer and fate of (agro-)chemicals in the soil-crop continuum. The model describes the one-dimensional transport of matter and energy in agricultural soils. It is a unique ad-hoc simulation tool that can be used as basis for improving management practices, controlling the transport of water and chemicals in soils, evaluating experimental data, designing laboratory and field experiments, predicting short- and long-term effects of farming and other land-uses on the quality of soils and aquifers and developing environmental oriented policies regarding the use of fertilizers, pesticides and herbicides. Structure of the model. The WAVE model is an open modular software tool, and whenever new knowledge becomes available, modules can be added or existing modules can be replaced by new modules. The modules available in the present version of the WAVE model simulate the following soil processes: the energy balance, the flow of water, the transport of non-reactive and reactive solutes, and the movement and transformations of nitrogen. In addition, the WAVE model simulates crop growth for several field crops. The modular structure enables the user to start only the modules required to analyze his problem. The model distinguishes different soil horizons that are divided in soil compartments with equal thickness. A water, heat and solute mass balance is developed for each compartment allowed for different sink/source terms. Flow equations are implemented which are solved numerically using finite difference schemes. A dynamic time step is used to reduce numerical errors. Description of the model. Water movement is described using the Richards' equation, driven by parametric models for the moisture retention characteristic and the hydraulic conductivity soil water content relation. Both non-hysteretic and hysteretic moisture retention models are available. Distinction is made between non-modal and multi-porosity retention curves. The hydraulic conductivity soil water content relation is modelled using empirical, semi-empirical and theoretical statistical pore size distribution conductivity models. Water extraction by the crop is mimicked in a macroscopic way, with the water sink term corrected for anaerobiosis and wilting in wet and dry soils, respectively. Solute transport is modelled with a non-equilibrium two-site/two-region convection dispersion model. The exchange rate between an immobile and mobile soil region is diffusion based. Sorption on the mobile and immobile sorption sites is described with a linear equilibrium isotherm. Decay of the solute is characterized with a first order reaction kinetic. The heat flow equation combines Fourier's heat flux law and the heat conservation equation. Soil thermal conductivity is calculated based on the geometry, the soil density, the volume of water and air. Soil thermal capacity and conductivity are updated as the moisture content of the soil changes. For the description of the mineral N-transformation processes (urea hydrolysis, ammonia nitrification, nitrate denitrification) first-order kinetics are used. The rate constants are reduced for temperature and soil water content, to mimic reduced microbial activity in extreme wet and/or dry conditions, or extreme warm and cold conditions. The soil organic N pool is subdivided into three sub-pools (the litter, humus and manure pool) and the transfer between these sub-pools is controlled by first-order rate constants. These constants vary with depth and are adjusted for extreme moisture and temperature conditions. The mineralization/ immobilization is driven by a constant C/N ratio of the biomass in the soil. Crop growth is simulated using a universal crop growth model, describing the dry matter accumulation in different plant parts as a function of the development stage, air temperature, incident radiation and crop physiological parameters. The daily gross photosynthetic assimilation rate is

reduced when water and/or nitrogen content is limited in the root zone. The potential nitrogen content in the crop organs determines the target nitrogen demand of the crop in the root system. Both convective and diffusive uptake of nitrogen are calculated and their sum defines the actual plant nitrogen uptake.

Model parentage: SWATRER, LEACH and SWATNIT.

Technical information

Operating System(s):	DOS 5, versions of the model can be compiled for Macintosh, Workstations or Supercomputer
Programming Language(s):	Microsoft FORTRAN.

References

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Simulating nitrogen behaviour in soil cropped with winter wheat.Fertilizer Research 27:233-243.

CHECKLIST

General Info

	Temporal scale	Spatial scale	Language	Platform
ANIMO	Daily/ Weekly	Plot/field	FORTRAN77	MSDOS/UNIX
CENTURY	Monthly	Regional	FORTRAN77 / C	MSDOS/UNIX
CNGRASxFUSSIM	Daily	Plot/field	FORTRAN90	MSDOS/UNIX
DAISY	Daily	Field	FORTRAN77	MSDOS/UNIX
DNDC	Daily/ Monthly	Plot	BASIC (C?)	MSDOS (UNIX?)
DSSAT	Daily	Plot/field	FORTRAN/C/Pascal/BASIC	MSDOS
EPIC	Daily/ Monthly	Regional	FORTRAN	MSDOS/UNIX
FUSSIM2	Daily	Plot/field	FORTRAN77	MSDOS (UNIX?)
LINTUL	Daily	Plot/field	FORTRAN77	MSDOS/UNIX
MOTOR	User specified	Plot	FORTRAN77	MSDOS
SUCROS2	Daily	Plot/field	FORTRAN77	MSDOS/UNIX
SUNDAIL	Weekly	Plot/field	(FORTRAN77?)	MSDOS
WAVE	Daily	Plot/field	FORTRAN77	MSDOS

Input data

Weather Info

	Temperature	Precipitation	Irradiation	Wind speed	Evapotranspiration over grass
ANIMO	+	+	+	+	+
CENTURY	+	+	-	-	+
CNGRASxFUSSIM	+	+	+	-	+
DAISY	+	+	+	-	-
DNDC	+	+	-	-	-
DSSAT	+	+	+	-	-
EPIC	+	+	+	+	-
FUSSIM2	+	+	-	-	+?
LINTUL	+	+	+	-	+?
MOTOR	+	+	+	-	+
SUCROS2	+	+	+	-	+?
SUNDAIL	+	+	+	-	+
WAVE	+	+	+	-	+

Soil

	Texture	% Clay	Bulk density	Organic matter	pH	Retention curve	Hydraulic conductivity curve
ANIMO	+	+	-	+	+	-	-
CENTURY	+	+	-	+	+	-	-
CNGRASxFUSSIM	+	+	+	+	+	+	+
DAISY	-	+	-	+	-	-	-
DNDC	-	+	+	+?	+	-	-
DSSAT	+	+	-	+	+	-	-
EPIC	-	+	+	+	+	-	-
FUSSIM2	+	+	+	+	+	+	+
LINTUL	-	-	-	-	-	-	-
MOTOR	+	+	-	+	+	-	-
SUCROS2	-	-	-	-	-	-	-
SUNDAIL	-	+	-	+	-	-	-
WAVE	-	+	+	+	-	+	+

Crop

	Crop parameters	Crop yield
ANIMO	-	-
CENTURY	+	-
CNGRASxFUSSIM	+	-
DAISY	+	-
DNDC	-	+
DSSAT	+	-
EPIC	+	-
FUSSIM2	-	-
LINTUL	+	-
MOTOR	-	-
SUCROS2	+	-
SUNDAIL	-	+
WAVE	+	-

Management

	Grazing	Inorganic fertiliser	Organic fertilizer	Irrigation
ANIMO	-	+	+	+
CENTURY	-	+	+	+
CNGRASxFUSSIM	+	+	+	
DAISY	-	+	+	+
DNDC	-	+	+	+
DSSAT	-	+	+	+
EPIC	-	+	+	+
FUSSIM2	-	-	-	+
LINTUL	-	-	-	-
MOTOR	-	+	+	-
SUCROS2	-	-	-	-
SUNDAIL	-	+	+	+
WAVE	-	+	+	+

Output

Soil

	Total C	Total N	NO_3	NH_4	Soil water dynamics	CO_2
ANIMO	+	+	+	+	+	-
CENTURY	+	+	-	-	+	+
CNGRASxFUSSIM	+	+	+	+	+	+
DAISY	+	+	+	+	-	+
DNDC	+	+	-	+	+	+
DSSAT	+	+	+	+	+	-
EPIC	+	+	+	+	+	-
FUSSIM2	-	-	+	+	+	-
LINTUL	-	-	-	-	-	-
MOTOR	+	+	+	+	-	+
SUCROS2	-	-	-	-	+	-
SUNDAIL	+	+	+	+	+	+
WAVE	+	+	+	+	+	+

Crop

	N-uptake	C input to soil in plant debris	N input to soil in plant debris	Dry matter production	C removed	N removed	Gaseous losses
ANIMO	+	-	-	-	-	-	-
CENTURY	+	+	-	+	+	+	+
CNGRASxFUSSIM	+	+	+	+	+	+	+
DAISY	+	+	+	+	-	+	-
DNDC	+	+	+	+	+	+	-
DSSAT	+	+	-	+	+	+	+
EPIC	+	+	+	+	+	+	+
FUSSIM2	-	-	-	-	-	-	-
LINTUL	-	-	-	+	-	-	+
MOTOR	-	-	-	-	-	-	-
SUCROS2	-	-	-	+	-	-	-
SUNDAIL	+	+	+	-	-	+	+
WAVE	+	+	+	+	-	-	+