COST ACTION 718 “Meteorological Applications for Agriculture”

Report of WG2 group

Summary on the Swap model

Joop G. Kroes, April 2001

General

Swap (Soil-Water-Atmosphere-Plant) is the successor of the agrohydrological model Swatr (Feddes et al., 1978) and some of its numerous derivatives. The experiences gained with the existing Swatr versions were combined into Swap, which integrates water flow, solute transport and crop growth according to current modelling concepts and simulation techniques. The model offers a wide range of possibilities to address both research and practical questions in the field of agriculture, water management and environmental protection. Alterra and Wageningen Agricultural University have developed the computer model Swap in close co-operation. The theory of the processes simulated by the model is extensively described by Van Dam et al. (1997) and Van Dam (2000). User manuals are written by Kroes et al (1999) and Huygen et al (2000).

System definition

Swap is a computer model that simulates transport of water, solutes and heat in variably saturated top soils. The program is designed for integrated modelling of the Soil-Atmosphere-Plant System (figure 1). Transport processes at field scale level and during whole growing seasons are considered. System boundaries at the top are defined by the soil surface with or without a crop and the atmospheric conditions. The lateral boundary can be used to simulate interaction with surface water systems. The bottom boundary is located in the unsaturated zone or in the upper part of the groundwater and describes the interaction with regional groundwater.

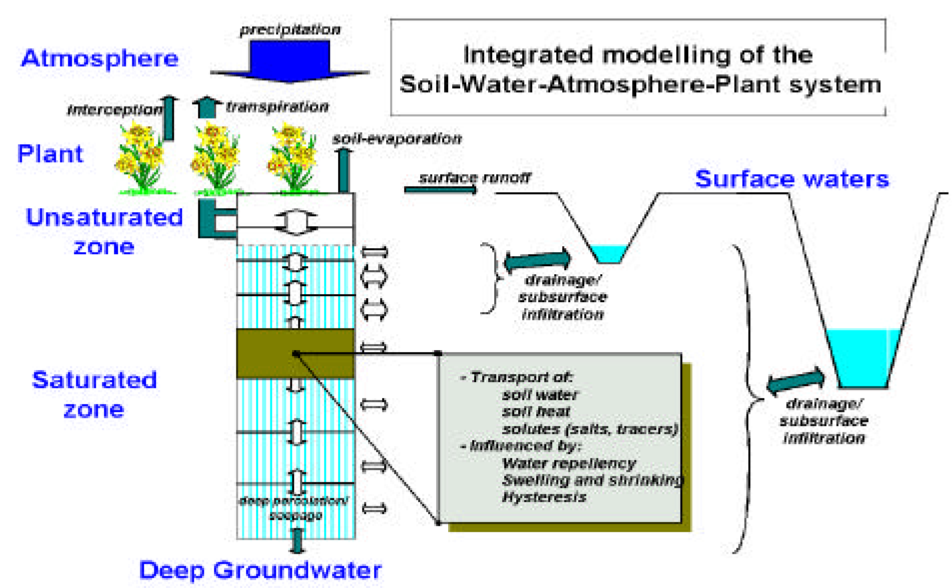

Fig 1. A schematised overview of the modelled system

Model Input

An extensive description of the format of input and output is given by Kroes et al (1999).
A summary of all input files the model can handle is given in table 1. Some files are required, other files are optional. A minimum dataset exists of 4 datafiles (see table 1). The model requires daily meteorological data as input. Soil hydraulic functions are required as well as boundary conditions regarding interaction with deeper soil layers and surface water systems. For irrigated conditions irrigation timing and depth criteria can be input or generated by the model. Detailed rules for the formats of all input data files are given by Kroes et al (1999).

Table 1 Summary of input file requirements

Kind of data	Description of file-content (kind of parameters)	Filename	Required	Optional
General	Simulation and I/O-options	**Swap.key**	+	
Meteo	Daily data	Hupsel.**yyy**	+	
	Detailed rainfall	Hupsel**ir.yyy**		+
Irrigation	Irrigation fixed	Hupsel.**irg**		+
	Irrigation calculated	Irrig.**cap**		+
Crop	Rotation	Year80.**cal**		+
	Detailed non-grass	Maize. **crp**		+
	Detailed grass	Grass.**crp**		+
	Simple crop model	MaizeS.**crp**		+
Soil related	Soil water	Hupsel.**swa**	+	
	Soil hydraulic functions	Sandt.**sol**	+	
	Drainage lateral: basic	Hupsel.**drb**		+
	Drainage extended: surface water	Hupsel.**dre**		+
	Bottom boundary conditions	Hupsel.**bbc**	+	
Heat	Heat flow	Hupsel.**hea**		+
Solute	Solute transport and transformation	Hupsel.**slt**		+

Model output

The model generates water and salt balance over a flexible time period ranging from days to several years. Balance terms include evaporation by intercepted rainfall, bare soil and crop, irrigated (computed) gifts, runoff, infiltration and drainage. Other examples of output are water contents, pressure heads, LAI, soil temperatures, which can be generated at time scales varying from one day to a maximum of one year. The program may optionally generate various ASCII output files:

- Water balance with cumulative data (*.wba)
- Water balance with data for time increments (*.inc)
- Water balance with data cumulative over time and vertical space (*.bal)
- Solute balance (*.sba)
- Soil temperature (*.tep)
- Soil moisture-, solute- and temperature- profiles (*.vap)
- waterfluxes to/from surface water (Extended Drainage) (*.drf, *.swb, *.man)
- simulated irrigation demands/gifts (*.sc1, *.sc2, *.sc3).
- crop growth state parameters (*.cr1, *.cr2, *.cr3).
- export files with data that cover the entire simulation period (*.afo, *.aun, *.ate, *.air).

The export files can be directly used as input for pesticide and nutrient models.

More information

General information about the Swap model is available on internet: http://www.alterra.nl/models/swap/. On this site you also find a detailed reference list with theoretical backgrounds and examples of applications. Through this site the model can be downloaded.

The Swap model has also been integrated with a pesticide model into the software package Pearl. This can be downloaded through the site: http://www.alterra.nl/models/pearl/. The Pearl software includes a database with parameters for many European countries.

References

Feddes, R.A., P.J. Kowalik and H. Zaradny, 1978. *Simulation of field water use and crop yield.* Simulation Monographs, Pudoc, Wageningen, 189 p.

Huygen, J., J.C. van Dam, J.G. Kroes, 2000. *Swap Graphical User Interface, User Manual, version January 2000*, Alterra, Wageningen

Kroes, J.G., J.C. van Dam, J. Huygen, R.W. Vervoort, 1999. *SWAP 2.0: User's Guide, Simulation of water flow, solute transport and plant growth in the Soil-Water-Atmosphere-Plant environment.* Technical Document 53. Alterra (DLO Winand Staring Centre), Wageningen Report 81, Department Water Resources, Wageningen Agricultural University, Wageningen

Van Dam, J.C., 2000. *Field-scale water flow and solute transport. SWAP model concepts, parameter estimation, and case studies.* PhD-thesis, Wageningen University, Wageningen, 167 p.

Van Dam, J.C., J. Huygen, J.G. Wesseling, R.A. Feddes, P. Kabat, P.E.V. van Walsum, P. Groenendijk, C.A. van Diepen, 1997. *SWAP version 2.0, Theory. Simulation of water flow, solute transport and plant growth in the Soil-Water-Atmosphere-Plant environment*. Technical Document 45, DLO Winand Staring Centre, Wageningen, 1997. Report 71, Department Water Resources, Wageningen Agricultural University, 1997

Input of the Swap model

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Heat	Heat flow	Hupsel.**hea**		+
Solute	Solute transport and transformation	Hupsel.**slt**		+

Detailed rules for the formats of all input data files are given by Kroes et al (1999).

An input parameter inventory for the Swap model is given in table on the next pages for a situation with irrigation, a deep groundwater level and the simplified approach for crop modeling.
For situations with shallow groundwater levels additional information about the interaction between groundwater and surface water will be required and can be found in Kroes et al (1999).

References

Kroes, J.G., J.C. van Dam, J. Huygen, R.W. Vervoort, 1999. *SWAP 2.0: User's Guide, Simulation of water flow, solute transport and plant growth in the Soil-Water-Atmosphere-Plant environment.* Technical Document 53. DLO Winand Staring Centre, Wageningen Report 81, Department Water Resources, Wageningen Agricultural University, Wageningen. (see also internet http://www.alterra.nl/models/swap)

MODEL: .... filled in by **COUNTRY / PERSON:** ...... / ....

model input variables	**measured** (+) not measured (-) calculated (c)	**available** (+) not available (-)	**temporal resolution** (h-hour, d-day, m-month)	**spatial resolution** (no of stat. / 100km²)	**comments**		
					type of station (A – automat. S- synoptic)	**quality** (1-bad, 2-middle, 3-good)	other comments
Meteorological data							
Global Radiation							
Minimum temperature							
Maximum temperature							
Average vapour pressure							
Average windspeed							
Rainfall							
Irrigation data							
Irrigation timing							
Irrigation Depth							
Concentration of salts in irrigated water							
Crop data							
Crop emergence date Crop harvest date							
Crop development							
Light extension							
leaf area index							
soil cover fraction							
crop height							
rooting depth							
Soil profile							
maximum rooting depth							
vertical distribution of soil horizons							
texture analysis of each soil horizon							
soil organic matter content of each soil horizon							
groundwater level							
pressure heads							
soil moisture content							

Further comments:

MODEL: SWAP........ filled in by **COUNTRY / PERSON:** NL.. / ..Kroes.......

model input variables	**measured** (+) not measured (-) calculated (c)	**available** (+) not available (-)	**temporal resolution** (h-hour, d-day, m-month)	**spatial resolution** (no of stat. / 100km²)	**comments**		
					type of station (A – automat. S- synoptic)	**quality** (1-bad, 2-middle, 3-good)	other comments
Meteorological data							
Global Radiation	+	+	1 d	0.02	A	3	Evaporation data also available as ET_Makkink (mm/d)
Minimum temperature	+	+	1 d	0.02	A	3	
Maximum temperature	+	+	1 d	0.02	A	3	
Average vapour pressure	+	+	1 d	0.02	A	3	
Average windspeed	+	+	1 d	0.02	A	3	
Rainfall	+	+	1 d	0.2	A + S	3	
Irrigation data							
Irrigation timing	+	+	m	0.01	S	2	
Irrigation Depth	+	+	d	0.01	S	2	
Concentration of salts in irrigated water	-	-	-	-			
Crop data							
Crop emergence date	+	+	m	0.01	S	2	
Crop harvest date	+	+	m	0.01	S	2	
Crop development	+	+	m	0.01	S	2	
Light extension	-	-	-	-	-	-	
leaf area index	-	-	-	-	-	-	
soil cover fraction	+	+	m	0.01	S	2	
crop height	-	-	-	-	-	-	
rooting depth	-	-	-	-	-	-	
Soil profile							
maximum rooting depth	+	+	-	1	S	2	for regional applications default values can ve taken from National databases
vertical distribution of soil horizons	+	+	-	1	S	3	
texture analysis of each soil horizon	+	+	-	1	S	2	
soil orga nic matter content of each soil horizon	+	+	-	1	S	2	
groundwater level	+	+	d	1	A, S	3	
pressure heads	-	-	h	0.01	A, S	3	
soil moisture content	+	+	h	0.01	A, S	3	

Further comments:

Output of the Swap model

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The program may optionally generate various ASCII output files:

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- crop growth state parameters (*.cr1, *.cr2, *.cr3).
- export files (formatted and unformatted/binary) can be generated with data that cover the entire simulation period (*.afo, *.aun, *.ate, *.air).

The export files can be directly used as input for pesticide and nutrient models.

Specific output

Use of the model and its results depends on the kind of user and the scale of the application. One may distinguish different users and different scales of application (table 1).

Table 1 . Relation between users and scale of application

User	Scale of application	
	Local	regional
Farmer	X	
Extension officer	X	
Researcher	X	X
Policy makers		X

Examples of minimum use of output is given for each combination in table 2.

Table 2. Minimum output for each combination

User	Scale of application	Minimum output	Output files
Farmer	Local	Irrigation demand	*.sc1, *.sc2, *.sc3
Extension officer	Local	Irrigation potentials	*.sc1, *.sc2, *.sc3
Researcher	Local	Irrigation strategies	*.sc1,*.sc2, *.sc3, *.wba
Researcher	Regional	Distribution of irrigation potentials	through postprocessing (Gis/Dbase)
Policy makers	Regional	Spatial and sectoral Irrigation strategies	through postprocessing (Gis/Dbase)

Alternative use of the model is given for each combination in table 3.

Table 3. Examples of alternative use of model results, given for each combination

User	Scale of application	Model use	Model result
Farmer	Local	3-day prediction of water demand	Irrigation as part of waterbalance
Extension officer	Local	Demonstrate impact of different soils on irrigation demand	
Researcher	Local	Analyse field measurements Compare methods to determine transpiration (e.g. FAO59 vs others) Generate input for leaching models	Detailed results (*.vap), Integrated output (*.aun)
Researcher	Regional	Analyse leaching potentials	Postprocessing
Policy makers	Regional	Reduction of recharge of aquifers Minimize evapotranspiration excess Optimize Irrigation strategies Reduce leaching of pesticides and/or nutrients	Postprocessing

References

Kroes, J.G., J.C. van Dam, J. Huygen, R.W. Vervoort, 1999. *SWAP 2.0: User's Guide, Simulation of water flow, solute transport and plant growth in the Soil-Water-Atmosphere-Plant environment.* Technical Document 53. DLO Winand Staring Centre, Wageningen Report 81, Department Water Resources, Wageningen Agricultural University, Wageningen (see also internet http://www.alterra.nl/models/swap)