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SPAC-GROWTH
User's Manual

Input files | Switches | Parameters | Outputs | Execute

Technical
Model specific

Henrik Eckersten

Institutionen för markvetenskap
Avdelningen för lantbrukets hydroteknik

Swedish University of Agricultural Sciences
Department of Soil Sciences
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Table of Contents

1 Background

(911029)

The SPAC-GROWTH model is a combined transpiration-growth model based on the soil-plant-atmosphere-continuum concept and simulates the flow of water from soil trough plant to the atmosphere. The basic version of the model, which simulates the transpiration of a fixed plant that does not change in size, was described by Turner & Kowalik (1983) and Kowalik & Eckersten (1984). The plant has a reservoir of water that regulates the transpiration rate which affect the total growth rate (cf. Eckersten, 1986). The total growth is allocated to root, leaf+stem and grain, respectively (Eckersten & Jansson, 1990). The size of the plant in its turn, affect the evaporation of intercepted water and the transpiration through the leaf area index and root development (Fig. 1). The grain development can be cancelled for species that have only vegetative growth. For woody plants like willow the size of the plant water reservoir can be regulated with the special parameters. For plants more than one year old the biomass compartments represent the accumulated growth of the current year.

Most of the input variables to the model needs to be given at a time scale of minutes. However, in many cases only synoptic or daily values are present. There is a special subroutine of the model that can estimate minute values of the input variables from the daily values (Eckersten, 1986a). See further the parameter groups named Analytic and Analytic_Start and the output variable groups named Auxiliaries and Drivings.

The source code of the model is written in FORTRAN 77 and the exe-file is created making use of the PSIM simulation modelling support programmes for PC (made by Per-Erik Jansson and Jan Clareus, Uppsala). The input variables as well as the outputs from the model are aimed to be created and presented and further evaluated using the PG-program. This program also enables the conversion between SPAC-GROWTH specific files and ordinary DOS-files with ASCII-format.

The aim of this manual is to be a complete technical description of all inputs and outputs of the model so that the model can be used in all its context by the person running the model. The manual is available in the program under the help option. Just press [F1]! The section on switches, parameters and outputs are placed at the end of the manual because they are so frequently used.

The theoretical description of the model is given by Eckersten (1991). This manual for the software is directly linked to that report through the symbols given for each parameter and variable. Observe that the units may differ between the manual and the model description.

The SPAC-GROWTH model is in the following only named SPAC.

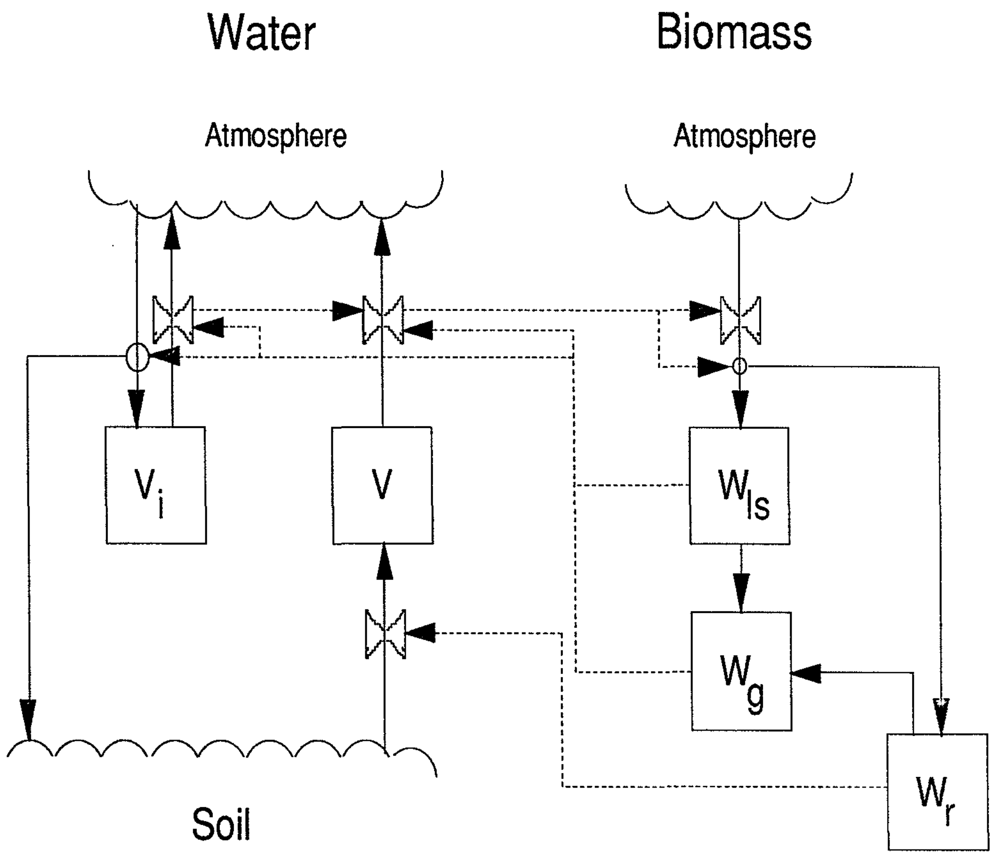

Fig. 1: Schematic description of the SPAC-GROWTH model. V and V_i are storage of water in the plant and on the leaf surface, respectively. W_{ls}, W_r and W_g are accumulated biomass during the current year of leaf+stem, roots and grain, respectively. Solid lines are flow of water or biomass whilst dotted lines represent flow of information.

2 Getting started

2.1 Installation

The model is normally distributed on a floppy diskette for IBM PC together with a demonstration example (sse below). You just put all files in the same directory. However, keep a copy somewhere else.

2.2 Files

If you want to distribute the files among different directories the following order is recommended (PATH should be available to directories other than the working (application) directory. Setting this PATH most conveniently is done in the AUTOEXEC.BAT file. Check also addresses given in parameter files):

Directory	Files	Description
GENERAL PROGRAMS	PG.EXE	Executable file, PGraph program. A special version that is freely available is named PGDEMO.EXE
	PREP.EXE	Executable file, PREP program
	PG.HLP	Help file, Pgraph program
MODEL PROGRAMS	SPAC.EXE	Executable file, SPAC model
	SPAC.DEF	Definition file
	SPAC.HLP	Help file
	SPAC.TRA	Variable name translation file
APPLICATION FILES	DEMO.BIN	PG-file with input variables for running the model.
	DEMO.PAR	Parameter file for the SPAC model

2.3 Demonstration example

Usually a demonstration example is delivered together with the model. This example draws pictures of selected inputs and outputs of the model and give a short verbal description. Files belonging to this example are named DEMO..., those named SPAC_.... are outputs, those named SPAC... are model general files and those named P.... are general programs. For further information just type:

DEMO info

2.4 Running the model

For running the program interactively use commands as specified in the section on COMMANDS in the manual. An example is as follows:

PREP SPAC FILE1 — This means that PREP-program starts the SPAC model making use of the information in the FILE1.PAR-file. In PREP then, you can modify the prerequisites of the simulation (if you want) and then start the simulation.

2.5 Evaluating your simulation

An successful simulation will result in two different output files numbered as NNN :

SPAC_NNN.SUM — A summary file with a list of output variables. The variables to be stored in the output files are selected by the PREP-program.

SPAC_NNN.BIN A file including output variables from the simulation.

The presentation of data is made by use the PGraph-program: PG SPAC_NNN. This program can convert the results to ASCCII if wanted. For details on how to use Pgraph see the Pgraph manual or use the help utility in the program (F1 key).

3 Program structure

The preparation of the model prior to a run follows an interactive dialogue where the user has the possibility to design the simulation.

The different menus can be reached in any order after moving the cursor to the subject using arrow keys and pressing "return" at the chosen subject. "RETURN" takes the cursor down in the menus and "ESC" moves the cursor up one level. Normally a user will start with the subjects to the left in the main menu and move to the right. It is a good rule to modify the settings of switches and input files before moving to the other menus since the content of the other menus are influenced by the setting of the two first sub menus. The main menu is as follows:

1 INPUT FILES
2 SWITCHES
3 PARAMETERS
4 OUTPUTS
5 RUN OPTIONS
6 EXECUTION.

4 Input files

4.1 Driving variable file

XXXX.BIN: A driving variable file is always a PG-file. The variables in the PG-file can be organized in different ways depending on how different parameters are specified. (See parameters in the group Driving variables)

4.2 Parameter file

XXXX.PAR: The parameter file is an ordinary DOS-file with ASCII- characters. All parameters and their actual numerical values should be included in the file. If any parameter is missing in the file a message is displayed on the screen and a default value is selected from the SPAC.DEF-file. New parameter files may be created prior the execution of the model using the EXECUTION-WRITE command.

4.3 Translation file

SPAC.TRA: A translation that must exist if the variables in the output PG-file should get their correct identification. Only if the switch OUTFORN is ON this file is unnecessary.

4.4 Initial states file

The file contains the initial values of all state variables (Not used).

4.5 Final states file

This file contains the final values of all state variables.

4.6 Output file

SPAC_NNN.bin: PG-structured file with output variables where NNN is the current run number. The file contains all the outputs that where selected in the PREP program. In case of having the ADDSIM switch ON you have to specify the name of the output file which is the same as used by the previous run with the model. The file is a binary file to be used by the PGraph program for plotting results from the simulation.

SPAC_NNN.SUM: Contains a summary of all instructions used for the simulation and a summary of simulated results. The first part of this file corresponds with a parameter file. This means that you can always rename or copy this file to a file named for instance MYRUN.PAR which could be used as a parameter file for future simulations. If you do not modify the instruction by editing this file or modifying anything by using the PREP program you will reproduce your old run.

4.7 Validation file

A validation file is a file with variables that should be compared with simulated variables. The result of the comparison will be found in the SPAC_NNN.SUM file. The first variable in the validation file will be compared with the first variable in the output PG-file, the second with the second and so on.

4.8 General file description

File	Description	Type
Files used for the simulation (xxxx are names given by the user):		
SPAC.exe	Program	
SPAC.tra	Labels of output variables	ASCII
xxxx.BIN	Input variables (data-file) (the DRIVPGRA switch must be ON)	PGRA
xxxx.PAR	Parameter names and values	ASCII
xxxx.cmd	Instructions to MR-program about multiple runs with different parameter values. Type: mr xxxx.cmd. (not used)	
SPAC.hlp	File containing help information which is identical to what is written in this paper (not necessary). This file is created in the following way (for programming): (i) >ms SPAC_hlp.doc, make new section for every symbol name (alt-h for every name plus alt-g for the first nameof each section) (ii) Retrieve help.set, global settings only (alt-j), (iii) Export ASCII-file (help.txt), unfold the document and write a screen image (alt-k), (iv) DOS> mhelp SPAC.txt (=help.txt).	
Output files:		
SPAC_nnn.bin	Output variables (data file), nnn is number of run.	PGRA
SPAC_nnn.sum	A summary of both inputs and outputs	ASCII
SPAC.sta	Information to SPAC about the current run number. Delete this file if you want to restart from run number 1.	

Files used for handling output files:

plotc.bat	Compares two simulations by plotting the variables on the same graph (e.g. Type: plotc xx 8 2)	ASCII
plotc_xx.pg	PG-instruction file in which the variables that shall be compared can be chosen.	ASCII

Files used when making name modifications:

For SPAC-parameters should be given (for programming only):

xxxx.PAR:	Names, Groups and Values
SPAC.DEF:	Numbers, Names, Groups and Values
PVAL.INC:	Numbers
PNAME.INC:	Names
PNAMEANA.INC:	Names
SPAC.HLP:	Names and Descriptions

For X-, T-, G- and D-variables should be given:

PVAL.INC:	Numbers
SPAC.DEF:	Numbers
SPAC.TRA:	Names
xxxx.BIN:	Variables
SPAC.HLP:	Names, Numbers(D...) and Descriptions

5 Run options

Are used to specify the timestep, the temporal representation of output variables and the period for the simulation.

5.1 Run no.:

You can restart from run number 1 by deleting the file: SPAC.STA

5.2 Start date:

The simulation period must be specified with a start and a termination date. The dates will be used when reading the driving variable file and when writing output variables to the PGRA-structured result file. The time is fully represented by a string like f.i. 198711030000. The simulation-start-time must always be at midnight.

5.3 End date:

5.4 Output interval:

The output interval determines how frequent the output variables will be given to the output file. The requested output variable can either be a mean value of the whole time interval or, the actual value at the time of output (see the switches, AVERAGEX, ..T, ..G and ..D). The output interval is given in units of minutes.

5.5 No of iterations:

The time step of the model is one minute. With the start parameter WSTDT longer time steps can be selected.

5.6 Run id:

Any string of characters may be specified as the identification of your simulation in addition to the run number. The identification given will be written in the variable identification field used by the Pgraph-program. Be careful when using long strings of characters since the default information stored in the identification field may be overwritten in some cases.

5.7 Comment:

6 Execute

6.1 Exit

The exit command will terminate the interactive session and quit the program without starting a simulation. By creating a parameter file before exit the program the input will be saved.

6.2 Run

The run command will terminate the interactive session and start a simulation using the instructions entered. All the instructions are also written to the SPAC_NNN.SUM-file which may be used as a parameter file if you would like to reproduce the simulation.

6.3 Write a parameter file

This will create a new parameter file which includes all the instructions specified. The new parameter file can be used as an input file.

7 Warnings and Errors of parameter values

If you specify your input files or your parameter values in a strange way you may get informations about this before you start executing the model. There are two levels of information: Warnings and Errors.

Normally you will be informed about warning or errors after you have modify a parameter value and moved to the new sub-menu. Some errors are the results of combinations of different parameters values and they may not occur before you try to run the model. In this situation a final check of all input files and all relevant parameter values are made. If the final check results in any warning or error messages you can always return to the PREP program and continue to modify your instructions so they will be within valid ranges of accepted intervals. The list of messages is found in a window under the execute menu.

In case of error messages the model can not run. In case of warnings only, however, you are allowed to run the model.

8 Commands

You start the preparation of a simulation by pressing
PREP SPAC
on the command line of the DOS system. This will be the starting point for adding any type of new instructions for your simulation. Parameter values from SPAC.PAR will be used if the file is present at the current directory default. Otherwise the original default values of the model will be used (SPAC.DEF).

You can also start the interactive session with default values taken from another parameter file by entering that parameter file name at the command line:
PREP SPAC FILE1
will result in default values from the parameter file FILE1.PAR.

You can run the SPAC model in batch mode, which means that you will not make use of the interactive session at all. Instead you will run the model from default values. Type:

PREP -b SPAC FILE1

This will result in a run with the model that use information from the FILE1.PAR file. If information is missing in the FILE1.PAR file values from the original model definition file will be used. A parameter file does not need to be complete. It may be restricted to only instructions that need to be changed compared to what is found in the original model definition file (SPAC.DEF). There are also a possibility to specify a number of parameter files on the command line:

PREP -b SPAC FILE1 FILE2 FILE3

This means that the PREP program will first read the instructions of FILE1.PAR then of FILE2.PAR and finally of the FILE3.PAR file. If information is repeated the latest given will be used. But remember that the parameter files not necessarily are complete. They can be organized with only information about for instance evaporation in the FILE2.PAR file information about run options like time periods in the FILE3.PAR file.

9 Problems

If you get problems, find bugs or just want to report an interesting phenomena please let us know about it. Write to:

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Swedish University of Agricultural Sciences
P.O. Box 7014
S-750 07 Uppsala
Sweden

Please remember to send a copy of your input data files and the commands used when you get any problems.

10 Help

Help is available (almost) everywhere.

Just press the F1 key and you are transferred to help.

In help, typing a single "RETURN" takes you one level down and by pressing "ESC" you move up again.

The <END> key brings you back to SPAC.

11 References

Papers and reports published with relevance for the SPAC model and publications referred to in the text.

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Kowalik, P.J. & Turner, N.C., 1983. Diurnal changes in the water relations and transpiration of a soybean crop simulated during the development of water deficits. Irrig. Sci., 4:225-238.

12 SWITCHES

The purpose of switches is to chose the simulation mode. Most switches could either be OFF or ON. Others can achieve different values.

12.1 Technical

■*ADDSIM*

OFF	The simulation results will be stored in a separate result file with a name according to the run number.
ON	The simulation results are automatically added to the result file of a previous simulation, run for an earlier time period. Note that the selected output variables must be exactly the same for the present and the previous simulation. The name of the former result file is given by the user as "output file" name. By default the start date of the present simulation is put identical as the terminate date of the previous simulation. The final values of state variables from the previous simulation must be selected as the initial values of state variables for the present run (see INSTATE and OUTSTATE switches). Note that the OUTSTATE switch must be on for any simulation to which a result of a later simulation will be added. No a new output data file ".BIN" will be created but a separate summary file ".SUM" will be created just like for an ordinary simulation.

■*AVERAGED*

OFF	the actual value at each time point is stored in the output file.
ON	all requested driving (=D) variables will be mean values representing the whole time period between adjacent time points in the output file. The time period is represented with the date in the middle of each period.

■*AVERAGEG*

OFF	the actual value at each time point is stored in the output file.
ON	all requested auxiliary (=G) variables will be mean values representing the whole time period between adjacent time points in the output file. The time period is represented with the date in the middle of each period.

■*AVERAGET*

OFF	the actual value at each time point is stored in the output file.
ON	all requested flow (=T) variables will be mean values representing the whole time period between adjacent time points in the output file. The time period is represented with the date in the middle of each period.

■AVERAGEX

OFF	the actual value at each time point is stored in the output file.
ON	all requested state (=X) variables will be mean values representing the whole time period between adjacent time points in the output file. The time period is represented with the date in the middle of each period.

■CHAPAR

OFF	Parameter values are constant for the whole simulation period.
ON	Parameter values may now be changed at different dates during the simulation period. The new parameter values and the dates from which they should be valid are specified after the other parameter values (valid from the start of the simulation). A maximum of 20 dates can be specified.

■DRIVPG

0	No variables are read from the input file. Allowed only when the ANALYTICR switch is ON and all the others are OFF. OBS! DRIVANA must be = 2.
1	Driving variables will be read from a PGraph file. The name of the file is specified by the user. Model parameters and switches are used to define the arrangement of variables in the file (see Driving variables under the heading OUTPUTS)

■INSTATE

OFF	initial state variables will be put to zero if not otherwise specified by model parameters.
ON	NOT USED (initial values of state variables will be read from a file. The name of the file is specified by the user, the format should be exactly the same as in the file for final values of state variables, created by the model when the OUTSTATE switch is on.)

■LISALLV

OFF	only the subset of output variables selected by the user will be found in the summary file.
ON	all output variables will be found in the summary file after the simulation.

■OUTFORN

OFF	the variables will be named according to the information stored in the file SPAC.TRA.
ON	all variables in the output Pgraph-file will be named according to their FORTRAN names.

■*OUTSTATE*

OFF	no action.
ON	final values of state variables will be written on a file at the end of a simulation. The name of the file is specified by the user and the format is the same as used in the file for initial state variables (see the INSTATE switch).

■*VALIDPG*

OFF	No validation.
ON	Validation variables will be read from a PGraph file. The name of the file is specified by the user. The values in the validation file will be compared with variables from the output file.

12.2 Model Specific

SWITCH-TREE

```
DRIVPG ON ---   DRIVANA < 2 -   -------------       TRANSP ----   TRANSPPOT
                                                    |             GROWTH
                                                    |             SPECIAL
                DRIVANA = 2 -   ANALYTICH ---       |
                                ANALYTICT ---       |
                                ANALYTICP ---       |
                                ANALYTICR ---       |
                                ANALYTICU ---       |

DRIVPG OFF --   DRIVANA = 2 -   ANALYTICR
```

■*TRANSP*

OFF	No water flow simulations are made.
ON	Water flow simulations are made.

■*TRANSPPOT*

OFF	No calculation of potential transpiration (F_{Tp}). OBS! That F_{Tp} is used in the calculations of allocation of biomass to roots. The ratio F_T/F_{Tp} is put equal to 1.
ON	The potential transpiration (F_{Tp}), defined as the transpiration being independent of the plants internal water status (i.e. $V=V_{Max}$), is calculated.

■GROWTH

0	The plant is fixed and stand characteristics are not given explicitly.
1	The plant has a fixed size determined by start parameters (ZSTTOT or ZSTALI, ZSTWLS, ZSTWR and ZSTWG).
2	The GROWTH submodel simulates the plant development.

■DRIVANA

0	Driving variables are minute values
1	Some of the minute driving variables in the input file are not available, or wanted to be modified. This option allow you then to make simple modifications of the following driving variables: Precipitation (DPR). Change start parameter WSTPSW. Soil water potential (DPS). Change sensitivity parameters WSPSR and WSPSD. Net radiation (DRN). Change start parameters WSTRNA, WSTRNB and WSTRNC.
2	Weather driving variables are daily synoptic values. This option calculates analytical minute values. By setting the switch TRANSP OFF you can use this routine separately.

■ANALYTICH

OFF	No action
ON	Activates the analytical calculations of humidity. OBS! DRIVANA must be = 2 and ANALYTICT must be ON.

■ANALYTICP

OFF	No action
ON	Activates the analytical calculations of precipitation. OBS! DRIVANA must be = 2.

■ANALYTICR

OFF	No action
ON	Activates the analytical calculations of global radiation. OBS! DRIVANA must be = 2.

■ANALYTICT

OFF	No action
ON	Activates the analytical calculations of temperature. OBS! DRIVANA must be = 2.

■ANALYTICU

OFF	No action
ON	Activates the analytical calculations of wind speed. OBS! DRIVANA must be = 2.

■SPECIAL

OFF	Parameters in the group Special are NOT available.
ON	Parameters in the group Special are available. These parameters enables modifications or introduction of special functions normally kept fixed or not used.

13 PARAMETERS

General rules for parameter names are as follows:

.ST..	= Start parameter
W..	= Water
Z..	= Growth
A..	= Analytic
.S..	= Sensitivity parameter
...	= Special

Note that the units sometimes are multiples of the basic SI-system.

13.1 Start

These parameters are of special concern prior each simulation. Note that the energy balance iterations are limited to 50 and the water balance iterations to 25. Information will be displayed on the screen when these limits are reached, if the parameter STXTGD=0. For small values (< about 50 g m^{-2}) of the water reservoir (V) problems in solving the water balance iterations appear. The lower limit of the water reservoir can be selected with the ZSTDL parameter which sets the minimum leaf area index.

Some special options are possible to chose with the start parameters:

(i) The potential transpiration (F_{Tp}), defined as the transpiration being independent of the plants internal water status (i.e. $V=V_{Max}$), can be calculated by setting TRANSPPOT-switch ON. OBS! That F_{Tp} is used in the calculations of allocation of biomass to roots. If TRANSPPOT-switch is OFF then the ratio $F_T/F_{Tp} = 1$ and the simulation time decreases.

(ii) Driving variables for simulating the evaporation of intercepted water on the canopy can be chosen in two ways:
a) WSTPSW > -9999: DPR is within day registrations of precipitation. Observe that interpolation is made between values.
b) WSTPSW <= -9999: DPR is the registration of wet or dry canopy.

(iii) Net radiation can either be read from the input file (WSTRNA=WSTRNB=0 and WSTRNC=1) or derived from the input data on global radiation (WSTRNA<>0, WSTRNB<>0 and WSTRNC=0)

(iv) The growth calculations needs an initial amount of assimilates (ZSTTOT, ZSTALI, ZSTWLS, ZSTWR).

(v) If the canopy nitrogen concentration (n_l) changes during the simulation then make use of the CHAPAR-switch on ZSTNL. By setting ZSTNL=0 you cancel the effect of n_l on all calculations.

(vi) Analytical driving variables can be calculated if DRIVANA-switch = 2. See further the Driving variables under heading of OUTPUTS.

[] is the value normally used.

Variable	Symbol ; Explanation	(Unit)
WSTDEN	Δ_{Max} [0.1] ; Maximum allowed deviation in the canopy energy balance	(W m^{-2})
WSTDPC	$\delta\psi_{cMax}$ [0.04] ; Maximum allowed change in the canopy water potential during a timestep of δt minutes.	(MPa)

WSTDT δt [1] ; Integration time (t_2-t_1) for the water balance calculations. High values (above 4) implies problems in solving the water balance calculations, especially when the canopy is small (see WSTDPC). A high value decreases the simulation time. The driving variables at the beginning of the period is used. (min)

If ANADRIV-switch = 2 and TRANSP-switch OFF: Then the value should be the wanted interval between the calculations. Errors in precipitation values appear if WSTDT > duration of precipitation (APRECD)

WSTDTS δT_{so} [25] ; δT_s at start of iteration of the canopy energy balance. (°C)

WSTPSW switch [0] ; Switch for precipitation input variable.
>-9999 --> DPR= is within day registrations of radiation. (-)
<=-9999 --> DPR= registration of wet or dry canopy. Wet canopy --> TFT=0, dry canopy --> TFI=0. (-)

WSTRNA a_R [-23.0] ; see WSTRNC below (W m^{-2})

WSTRNB b_R [0.649] ; see WSTRNC below (-)

WSTRNC c_R [0] (-)

a_R, b_R, c_R: Coefficients in: $R_{no}=a_R+b_RR_s+c_RR_{no}$, determining net radiation above canopy (R_{no}) as a function of DRS or DRN. OBS! If c_R<>0 then should be: $a_R=b_R=0$, and vice versa.

WSTTS0 T_{so} [-10] ; Canopy surface temperature at start of the iterations for solving the canopy energy balance. (°C)

ZSTALI If GROWTH-switch = 1: (-)
A_{li}(fixed) [1] ; Constant canopy leaf area index.
If GROWTH-switch = 2:
$A_{li}(t_o)$; Leaf area index at simulation start. Not used if ZSTTOT>0.

ZSTDL δA_{li} [0.5] ; Leaf area index of canopy internal layers used for calculating stomatal resistance ($r_s(R_s)$). Only used if GROWTH-switch > 0. This parameter also sets the minimum allowed leaf area index. (-)

ZSTGRA $\Sigma_{Acc}i_g(t_o)$; Accumulated sum of the grain index at start of simulation. Only used if GROWTH-switch = 2 and growth parameter ZGRA1<>0. (-)

ZSTLAT Latitude ; OBS! Minutes are given as decimals. Only used if GROWTH-switch = 2. (°)

ZSTNL n_l ; Leaf nitrogen concentration. =0 implies no calculations with n_l. (-)

ZSTTOT $W_t(t_o)$; Total plant biomass at start of simulation. Only used if GROWTH-switch = 2. (gDW m^{-2})

ZSTWG W_g(fixed) [0] ; Constant grain biomass. Only used if GROWTH-switch = 1. (gDW m^{-2})

ZSTWLS If GROWTH-switch = 1: (gDW m^{-2})
W_{ls}(fixed) [100] ; Constant leaf + stem biomass.
If GROWTH-switch = 2:
$W_{ls}(t_o)$; Leaf + stem biomass at simulation start. Not used if ZSTTOT>0.

ZSTWR If GROWTH-switch = 1: W_r(fixed) [100] ; Constant root biomass. Only used If GROWTH-switch = 2: $W_r(t_o)$; Root biomass at simulation start. Not used if ZSTTOT>0. (gDW m^{-2})

13.2 Plant_water

These parameters concern the plant water status.

WPCMAX ψ_{cMax} ; Canopy water potential when plant water content is at maximum. (MPa)

WPCMIN ψ_{cMin} ; Canopy water potential when the plant is out of water easily available for transpiration. (MPa)

WPSA ψ_{sp} ; ψ_s for the potential transpiration. Only used if TRANSPPOT is ON. (MPa)

WV0 V_o ; Maximum available plant water per unit of leaf surface. (g m^{-2})

13.3 Resistance_stomata

Parameters related to the resistance for water flow through stomata. (RESIST_STOMA)

WRSPA a_c ; see WRSPE below (m s^{-1})

WRSPB b_c ; see WRSPE below ()

WRSPC c_c ; see WRSPE below ()

WRSPD d_c ; see WRSPE below ()

WRSPE e_c ()

a_c, b_c, c_c, d_c, e_c are coefficients in: $r_s(\psi_c)=1/(a_c+b_c\psi_c+c_c\psi_c^2+d_c\psi_c^3+e_c\psi_c^4)$, determining the stomatal resistance as a function of canopy water potential (OBS! ψ_c is here in units of 0.1MPa)

WRSRA a_r ; see WRSRC below (m s^{-1})

WRSRB b_{rr} ; see WRSRC below ()

WRSRC c_r ()

a_r, b_r, c_r are coefficients in: $r_s(R_s)=1/(a_r+b_rR_s+c_rR_s^2)$, determining the stomatal resistance as a function of incident shortwave radiation.

WRSN r_{sMin} ; Minimum value of stomatal resistance. (s m^{-1})

WRSX r_{sMax} ; Maximum value of stomatal resistance. It equals the resistance through cuticular. (s m^{-1})

WRSRR R_{sMin} ; $R_s<R_{sMin}$ --> $r_s(R_s)= r_{sMax}$ (W m^{-2})

13.4 Resistance_other

Parameters related to the resistance for water flow from soil to the atmosphere (except of stomatal resistance). (subroutine RESIST_OTHER)

WRAA a_{Li} or a_h ; For alternative aerodynamic functions (differs)

If WRASW<>1:
a_{Li} ; in: $r_a=(a_{Li}+b_{Li}A_{li})/u$ (Lindroth equation for aerodynamic resistance). (s m^{-1})

If special parameter WRASW=1:
a_h ; in $z_h=a_h(W_{ls}+W_g)$. The height of the reference (measurement) level above the canopy as a function of above ground biomass. (m^3 g^{-1})

WRAB b_{Li} or a_d ; For alternative aerodynamic functions (-)

If WRASW<>1:
b_{Li} ; in: $r_a=(a_{Li}+b_{Li}A_{li})/u$ (Lindroth equation for aerodynamic resistance)

If special parameter WRASW=1:
a_d ; in $z_d=a_dz_h$. The displacement height proportional to the height of the reference (measurement) level above the canopy.

WRAC a_o ; in $z_o=a_oz_h$. The roughness height proportional to the height of the reference (measurement) level above the canopy. Only used if WRASW=1 (-)

WRP r_{po} ; Plant resistance from root surface to the mesophyll of leaves. (MPa s m^2 g^{-1})

WRPG a_{rp} ; Coefficient giving plant resistance as proportional to grain biomass (W_g). (MPa s m^4 g^{-2})

WRRA a ; Hydraulic conductivity of saturated soil (g m^{-2} s^{-1})

WRRB b ; Factor related to the root density. (MPa)

WRRN n ; Coefficient related to soil pore size distribution. (-)

13.5 Interception

Parameters related to the interception of precipitation (and/or irrigation) on the canopy.

WINTK k_P ; Rain interception coefficient related to leaf area. (-)

WINTKG k_{Pg} ; Rain interception coefficient related to grain biomass. (m^2 gDW^{-1})

WINTX V_{Io} ; Maximum amount of water intercepted per unit of leaf area index. (g m^{-2})

13.6 Growth

Parameters used for calculating the growth of plant. These parameters are used only if GROWTH-switch = 2.

ZBG b_g ; Fraction of biomass in plant tissues translocated to grain. (d^{-1})

ZBI0 b_{io} ; The leaf area to above ground biomass ratio at unity above ground biomass. (m^2 gDW^{-1})

ZBI1 b_{i1} ; Parameter related to the decrease in the leaf area to above ground biomass ratio as the above ground biomass increases. (gDW m^{-2})

ZBR0 b_{rMin} ; Minimum fraction of the total daily growth that is allocated to roots. (-)

ZGRA1	a_g ; The asymptote. The inverse of ZGRA1 gives the shortest possible duration of the vegetation phase in days and is therefore related to the basal vegetative period. (see ZGRA5 below)	(d^{-1})
ZGRA2	b_{gg} ; Temperature function ($b_{gg}>0$). (see ZGRA5 below)	($°C^{-1}$)
ZGRA3	c_g ; Threshold temperature. (see ZGRA5 below)	(°C)
ZGRA4	d_g ; Day-length function ($d_g>0$).(see ZGRA5 below)	(h^{-1})
ZGRA5	e_g ; Critical (threshold) photoperiod.	(h)
	a_g, b_{gg}, c_g, d_g, e_g: Coefficients for determining the index that switch on the grain development. ZGRA1=0 implies no grain development.	
ZEXTC	k ; Radiation (300 - 3000 nm) extinction coefficient related to leaf area.	(-)
ZNLX	n_{lMax} ; Maximum leaf nitrogen concentration. Only used if start parameter ZSTNL <> 0.	(-)
ZWUEN0	a_τ ; in: $\tau=a_\tau-b_\tau n_l/n_{lMax}$. Maximum water use efficiency in the nitrogen-equation.	($gDW\ gH_2O^{-1}$)
ZWUEN1	b_τ ; in: $\tau=a_\tau-b_\tau n_l/n_{lMax}$. Factor determining the decrease in water use efficiency as the leaf nitrogen concentration increases.	($gDW\ gH_2O^{-1}$)
ZWUEV	a_τ ; in: $\tau=a_\tau/\Delta e$. Factor determining the decrease in water use efficiency as the air vapour deficit increases.	($hPa\ gDW\ gH_2O^{-1}$)
ZWUEX	τ_{Max} ; Maximum water use efficiency.	($gDW\ gH_2O^{-1}$)

13.7 Analytic_Start

Parameters used for calculating analytical variables. Only used if DRIVANA-switch = 2.

General rules for parameter names are as follows:

AH..	= Air humidity
AP..	= Precipitation
AR..	= Radiation
AT..	= Air temperature
AU..	= Wind speed
AS..	= Sensitivity parameter

Using this routine you can either choose to make the water-growth simulations simultaneously using the estimated analytical driving variables (TRANSP-switch ON) or create an output file with the estimated analytical driving variables (TRANSP-switch OFF). In the latter case you create a file that is directly useful for a later water-growth simulations (i.e. when DRIVANA-switch = 2) by choosing the following variables in the following order, as output: GATA, GAHA, GARS, GAWS, GAPR, GAPS, GARN.

The start-parameters can be divided into the following groups:

(i) Time points for input data on humidity (AHT1, AHT2, AHT3).

(ii) Initial values of relative air humidity and a switch (AHH1, AHH2, AHH3, AHH3Y, AHSW).

(iii) Initial values of air temperature and a time point (ATTAN, ATTASY, ATTAX, ATTS).

(iv) Initial values of radiation and a switch and latitude (ARRAD, ARRSCL, ARSW, ARLATI).

(v) Initial value of precipitation (APPREC).

(vi) Initial value of wind speed and time of day (AUU, AUTIME).

(vii) Latitude of output variables (ATLATO).

(viii) Sensitivity parameters (ASTFAS and ASHA).

AHH1	$h_a(t_1)(t_o)$; Air relative humidity at first measurement time point on the first day of simulation.	(%)
AHH2	$h_a(t_2)(t_o)$; Air relative humidity at second measurement time point on the first day of simulation.	(%)
AHH3	$h_a(t_3)(t_o)$; Air relative humidity at third measurement time point on the first day of simulation.	(%)
AHH3Y	$h_a(t_3)(t_o\text{-}1)$; Air relative humidity at third measurement time point on the day before the first day of simulation.	(%)
AHSW	Switch [0]; <>0 implies the air temperature is taken as a driving variable from input file instead of from the analytically determined temperature. Not used at present.	(-)
AHT1	t_1 [7]; Time of the first humidity driving variable of the day.	(h)
AHT2	t_2 [13]; Time of the second humidity driving variable of the day.	(h)
AHT3	t_3 [19]; Time of the third humidity driving variable of the day.	(h)
APPREC	$F_P(t_o)$; Precipitation of the first day of simulation.	(mm d^{-1})
ARLATI	Latitude ; Latitude of the location for radiation input data. Not used if ARSW=3.	(°)
ARRAD	Rad(t) ; Radiation input variable for the first day of simulation. See further ARSW and DRADT.	(differs)
ARRSCL	$\Sigma_{Day}R_{sCl}(t_o)$; Daily sum of radiation (300-3000 nm) for clear sky conditions for the first day of simulation. This value should refer to the location of radiation input data (see ARLATI).	(W m^{-2} d^{-1})
ARSW	Switch [0]; =2 implies DRADT is the ratio between daily sums of actual global radiation and that of clear sky conditions. <>2 implies DRADT is daily sums of global radiation.	(-)
ASHA	w/w_o [1] ; Sensitivity parameter. The relative change of the absolute air humidity.	(-)
ASTFAS	δt_n [0] ; Sensitivity parameter. The absolute change of time for minimum temperature. Time is here normalized with respect to the night-length. =0 implies t_n equals the time for sunrise.	(-)

ATLATO	Latitude ; Latitude for the location of the output variables.	(°)
ATTAN	$T_n(t_o)$; Daily minimum air temperature on the first day of simulation.	(°C)
ATTASY	$T_{as}(t_o\text{-}1)$; Air temperature at sunset on the day before the first day of simulation.	(°C)
ATTAX	$T_x(t_o)$; Daily maximum air temperature on the first day of simulation.	(°C)
ATTS	$t_s(t_o)$; Time of sunset on the first day of simulation.	(h)
AUTIME	t_u ; Time from midnight for the input data on wind speed.	(min)
AUU	$u(t_u,t_o)$; Wind speed at time t_u of the first day of simulation (t_o).	(m s^{-1})

13.8 Analytic

Parameters for calculating analytical driving variables. Only used if DRIVANA-switch = 2. For general rules of names see the parameter group Analytic_Start.

APRECD	t_D ; Duration of precipitation.	(min)
APRECT	t_P ; Time from midnight for start of precipitation.	(min)
ARGD	g_d ; Parameter determining the amplitude of the oscillations of the analytical radiation around the curve of the "mean" radiation. The parameter is normalized with respect to the difference between the "mean" radiation (R_{sM}) and the closest of the clear and overcast radiation.	(-)
ARGF	g_f ; Parameter determining the frequency for oscillations of the analytical radiation around the curve of "mean" radiation (R_{sM}).	(h^{-1})
ARGO	g_o ; Radiation of overcast conditions as a fraction of radiation under the corresponding clear sky.	(-)
ARGS	g_s ; Parameter used for calculating the radiation for clear sky conditions and which is related to the air turbidity.	(-)
ATA	a_T ; Time lag of T_x from noon expressed as a fraction of the day-length.	(-)
ATB	b_T ; Parameter of the exponential decay of temperature during the night.	(-)
AUAMP	u_{Amp} ; Upper limit of daily mean wind speed for which daily variations occur.	(m s^{-1})

13.9 Plotting_on_line

Variables can be plotted on screen during the simulation by selecting appropriate values of STXTGD and STPMAX. This option consumes some time and can be put off by setting STXTGD<=0.

Variable	Symbol ; Explanation	(Unit)
STPMAX	plot maximum [1000] ; The expected maximum value among the variables selected by STPMAX =-99 activates a special trace option that shows which subroutine that has started.	(differs)

STXTGD variables plotted on screen [4000] ; Numbers of output variables to be presented on the screen during the simulation (e.g. 4200 means 4 X-, 2 T-, zero G- and zero D variables). =0 implies no plotting, but warnings are displayed if any iteration is not solved properly. <0 implies no plotting and no warnings. (numbers)

13.10 Sensitivity

These parameters are used for sensitivity test and to select some special options. The value for no test is given in brackets. The subscript $_o$ denotes the original value.
Where both the relative and the absolute values are possible to change a constant value of the variable concerned can be chosen by setting the relative change to 0. The soil water potential can either be an input variable (see DPS) (WSPSR=1 and WSPSD=0) or constant (WSPSR=0 and WSPSD=ψ_s).

[] is the value normally used.

WSPSD	ψ_s-ψ_{so} [0] ; Absolute change of soil water potential.	(MPa)
WSPSR	ψ_s/ψ_{so} [1] ; Relative change of soil water potential.	(-)
WSR	R_s/R_{so} [1] ; Relative change of solar radiation.	(-)
WSRSP	$r_s(\psi_c)/r_{so}(\psi_c)$ [1] ; Relative change of $r_s(\psi_c)$.	(-)
WSRSR	$r_s(R_s)/r_{so}(R_s)$ [1] ; Relative change of $r_s(R_s)$.	(-)
WSVD	c_V [0] ; Absolute change of the maximum available plant water (V_{Max}).	(g m^{-2})
WSVR	a_V [1] ; Relative change of the maximum available plant water (V_{Max}).	(-)

13.11 Special

These parameters regulates the use of special functions. The original value is given in brackets.

The special functions that can be chosen are as follows:

(i) Alternative functions for aerodynamic resistance can be chosen (WRASW, WSRAA, WSRAC)

(ii) The stomatal resistance function is taken the highest value of those proposed by different "sub functions". The sub functions that can be chosen to be involved are the following:
$r_s(R_s)$ and $r_s(\psi_c)$ and ($r_s(\Delta e, R_s)$ or Lohammar equation)
The choice is made by setting WSTSWR, WSTSWP and WSTSWV equal to 1 (it is involved in the calculations) or 0 (not involved). If WSTSWV = -1 the Lohammar equation is used for $r_s(\Delta e, R_s)$.

(iii) Alternative function for maximum exchangeable water (WSVW)

(iv) The relation between aerodynamic resistance for heat and water can be altered (ZSRAH).

(v) The stability factor (Richardson number) for the aerodynamic resistance can be cancelled by putting it equal to zero (ZSRARI).

(vi) The soil-root resistance can be put independent or dependent on the root biomass (ZSRR and ZSRRD).

(vii) The root allocation factor can be changed (ZSBRD and ZSBRR).

[] is the value normally used.

WRASW	Switch [0] ; Switch for chosing between two functions of the aerodynamic resistance (r_a). <>1: $r_a=f(A_{li})/u$. =1: $r_a=f(h,d,z_o)/u$	(-)
WRSVA	a_v or a_L ; see WRSVC below	()
WRSVB	b_v or b_L ; see WRSVC below	()
WRSVC	c_v ; a_v, b_v, c_v or a_L, b_L used for alternative stomatal functions: IF WSTSWV>0: $a_L(\mathrm{W\ m^{-2}})$, $b_L(\mathrm{hPa^{-1}})$ in Lohammar eq: $r_s(\Delta e,R_s)=r_{sMin}(R_s+a_L)(b_L\Delta e+1)/R_s$ IF WSTSWV<0: $a_v(\mathrm{s\ cm^{-1}})$, $b_v(\mathrm{s\ cm^{-1}\ hPa^{-1}})$, $c_v(\mathrm{cm\ s^{-1}\ (m^2/0.01W)^2})$ in: $r_s(\Delta e,R_s)=a_v+b_v\Delta e+c_v(R_s/100)^2$	()
WSRAA	z_h-z_{ho} [0] ; Absolute change of the height for measurements of the ambient air conditions. = x and ZRAH= 0 implies z_h is equal to x. = x and ZRAH> 0 implies z_h is equal to x plus the increase in z_h due to growth of plant. Only used if parameter WRASW=1.	(m)
WSRAC	z_o-z_{oo} [0] ; Absolute change of the roughness parameter. = x and ZRAH= 0 implies z_o is equal to x. = x and ZRAH> 0 implies z_o is equal to x plus the increase in z_o due to growth of plant. Only used if parameter WRASW=1.	(m)
WSTSWP	switch [1] ; (1/0 = Y/N) for $r_s=f(\psi_c)$	(-)
WSTSWR	switch [1] ; (1/0 = Y/N) for $r_s=f(R_s)$	(-)
WSTSWV	switch [0] ; (1/0/-1 = Y/N/Y) for $r_s=f(\Delta e,R_s)$ switches (1/0) for choosing arbitrary among different stomatal resistance functions. $r_s=f(R_s$ or/and ψ_c or/and $\Delta e,R_s)$ WSTSWV= -1 --> Lohammar eq. is used (see WRSVA,-B,-C)	(-)
WSVW	b_V [0] ; Coefficient giving the maximum available plant water (V_{Max}) as proportional to the leaf+stem biomass.	(-)
ZSBRD	br-bro [0] ; Absolute change of root allocation fraction.	(-)
ZSBRR	br/bro [1] ; Relative change of root allocation fraction.	(-)
ZSRAH	a_{ra} [1] ; $=r_{aH}/r_a$; The ratio between the aerodynamic resistance for heat and vapour.	(-)
ZSRARI	Ri-Ri_o [0] ; Relative change of the Richardson number.	(-)
ZSRR	a_{rr} [0] ; in $r_r(W_r)=r_r/(a_{rr}W_r)$. Root resistance inversely proportional to the root biomass.	($\mathrm{m^2\ gDW^{-1}}$)
ZSRRD	$a_{rr}W_r$-$(a_{rr}W_r)_o$ [1] ; Absolute change of the root factor that affects the soil-root resistance (r_r). =1 and ZSRR=0 implies that r_r is independent of the growth. =0 implies that r_r is divided by the growth factor.	(-)

14 OUTPUTS

The output variables are divided into four categories:
states (=X), flows (=T), auxiliaries (=G) and drivings (=D).
The variables are distributed among the groups not strictly following the meaning of the group name. Hence, XFIACC, XFTACC and XFTPAC are found among the state variables although they represent accumulation of a specific flow. The state and flow variables of biomass are found among auxiliaries, however named in the proper way. The flow variables are the net flows into the corresponding state variables.

General rules for names of variables are as follows (however not strictly followed):

X.. = State
T.. = Flow
D.. = Driving
G.. = Auxiliary variable used in more than one subroutine

All units expressed per unit of area refers to the ground surface. Note that units of output variables sometimes are multiples of the basic SI-system.

14.1 State variables

Variable	Symbol ; Explanation	(Unit)
XV	V ; Exchangeable water in canopy	(g m^{-2})
XFIACC	$\Sigma_{Acc}(F_I)$; Accumulated evaporation of intercepted water.	(g m^{-2} d^{-1})
XFTACC	$\Sigma_{Acc}(F_T)$; Accumulated transpiration	(g m^{-2} d^{-1})
XVP	V_p ; Exchangeable water for the potential transpiration	(g m^{-2})
XFTPAC	$\Sigma_{Acc}(F_{Tp})$; Accumulated potential transpiration	(g m^{-2} d^{-1})

14.2 Flow variables

Variable	Symbol ; Explanation	(Unit)
TV	δV ; Exchangeable water in canopy	(g m^{-2} s^{-1})
TFI	F_I ; Evaporation of intercepted water.	(g m^{-2} s^{-1})
TFT	F_T ; Transpiration	(g m^{-2} s^{-1})
TVP	δV_p ; Exchangeable water for the potential transpiration	(g m^{-2} s^{-1})
TFTP	F_{Tp} ; Potential transpiration	(g m^{-2} s^{-1})

14.3 Auxiliary variables

Variable	Symbol ; Explanation	(Unit)
GBOWEN	Bowen ratio ; $H/(\lambda(F_T$ or $F_I)$	(-)
GEA	e_a ; Vapour pressure in the ambient air.	(hPa)
GES	e_s ; Saturated vapour pressure in the stomata cavities.	(hPa)
GFTFTP	F_T/F_{Tp} ; Actual to potential transpiration ratio.	(-)
GFITP	F_I or F_T or F_{Tp} ; Evaporation. General used variable.	(g m^{-2} s^{-1})

GLFITP	$\lambda(F_I$ or F_T or $F_{Tp})$; Latent heat flux to the atmosphere.	($W\ m^{-2}$)
GPC	ψ_c ; Canopy water potential.	(MPa)
GRA	r_a ; Aerodynamic resistance.	($s\ m^{-1}$)
GRN	$R_n(A_{li})$; Net radiation of the canopy.	($W\ m^{-2}$)
GRR	r_r ; Soil-root resistance between soil and root surface.	($MPa\ s\ m^2\ g^{-1}$)
GRS	r_c ; Canopy stomatal resistance per unit of ground surface.	($s\ m^{-1}$)
GRSP	$r_s(\psi_c)/\delta A_{li}$; Leaf stomatal resistance for the lowest sublayer as a function of the canopy water potential (per unit leaf area of sublayer).	($s\ m^{-1}$)
GRSR	$r_s(R_s)/\delta A_{li}$; Leaf stomatal resistance for the lowest sublayer as a function of the incident shortwave radiation on the leaves (per unit leaf area of sublayer).	($s\ m^{-1}$)
GRSV	$r_s(\Delta e,R_s)/\delta A_{li}$; Leaf stomatal resistance for the lowest sublayer as a function of the vapour pressure deficit and the incident shortwave radiation above canopy (per unit leaf area of sublayer). Only if SPECIAL-switch is ON.	($s\ m^{-1}$)
GFG	F_G ; Amount of water from precipitation falling to the ground.	($g\ m^{-2}\ s^{-1}$)
GFP	F_P ; Precipitation above canopy.	($g\ m^{-2}\ s^{-1}$)
GTS	T_s ; Canopy surface temperature.	(°C)
GTSMTA	T_s-T_a ; Difference between canopy surface and ambient air temperature.	(°C)
GFU	F_U ; Water uptake by root.	($g\ m^{-2}\ s^{-1}$)
GVPD	Δe ; Vapour pressure deficit of the ambient air (e_d-e_a).	(hPa)
	************** Growth **************	()
GBI	b_i ; Leaf area to above-ground biomass ratio ($=A_{li}/(W_{ls}+W_g)$ (only for information).	($m^2\ gDW^{-1}$)
GBR	b_r ; Fraction of daily growth allocated to roots.	(-)
GWUE	τ ; Water use efficiency. Conversion of transpiration rate to growth rate.	($gDW\ gH_2O^{-1}$)
	*********** Other T- and X-variables ************	()
TWTWUE	W_t' ; Total plant growth	($gDW\ m^{-2}\ s^{-1}$)
XALI	A_{li} ; Leaf area per unit of ground surface (leaf area index).	($m^2\ m^{-2}$)
XVI	V_I ; Water intercepted on the canopy	($g\ m^{-2}$)
XWG	W_g ; Accumulated grain growth.	($gDW\ m^{-2}$)
XWLS	W_{ls} ; Accumulated growth of leaf and stem.	($gDW\ m^{-2}$)
XWR	W_r ; Accumulated root growth of the current year	($gDW\ m^{-2}$)
	*********** Analytical **************	()
GATA	T_a(analytic) ; Air temperature above the canopy.	(°C)
GAHA	h_a(analytic) ; Relative air humidity above the canopy.	(%)
GARS	R_s(analytic) ; Global radiation (300-3000 nm) above the canopy.	($W\ m^{-2}$)
GAWS	u(analytic) ; Wind speed above the canopy.	($m\ s^{-1}$)

GAPR	F_P(analytic) ; Precipitation above the canopy.	(mm min^{-1})
GAPS	ψ_s(analytic) ; Soil water potential. Is identical to the input variable DAPS, however interpolated for missing input values.	(MPa)
GARN	R_{no}(analytic) ; Net radiation above canopy. Is identical to the input variable DARN, however interpolated for missing input values.	(W m^{-2})
GA	w ; absolute air humidity.	(g m^{-3})
GDAYI	t ; Day-number since January 1	(number)
GDAYL	Y ; Day-length	(h)
GDEC	Dec ; Sun declination	(rad)
GHOUR	t ; Hours since 00:00	(h)
GMINUT	t ; Minutes since 00:00	(min)
GRSCL	R_{sCl} ; Global radiation (300-3000 nm) for clear sky conditions.	(W m^{-2})
GRSCLA	$\Sigma_{Day}R_{sCl}(t-1)$; Daily sum of radiation under the clear sky for the previous day. This variable refers to the location of input radiation data.	(W m^{-2} d^{-1})
GSEL	β ; Sun elevation.	(°)
GSOLAR	S_o ; Solar constant.	(W m^{-2})

14.4 Driving variables

The input variables, or driving variables as we call them, can be placed among the other variables in the output file.

Two different sets of driving variables are used depending on if analytical driving variables shall be calculated by the model or not. If not (i.e. DRIVANA-switch <> 2), variables D1-D7 are used. If analytical variables shall be calculated (DRIVANA-switch = 2), variables D1-D10 are used. See below.

********* For the normal (NON-analytical) case we have: ***************

Driving variables should be given every minute in the input file. The program is interpolating for minutes without input data. At the beginning and the end of the simulation period the program uses the first respectively the last value in the input file. The variables should be given in the same order in the input file as in the D-array (D1-D7).

************ For the ANALYTICAL case we have: ********************

These driving variables are used if DRIVANA-switch = 2. Using this routine you can either choose to make the water-growth simulations simultaneously using the estimated analytical driving variables (TRANSP-switch ON) or create an output file with the estimated analytical driving variables (TRANSP-switch OFF). In the latter case you create a file suitable for input to the model (when DRIVANA-switch <> 2) by choosing the following variables in the following order: GATA, GAHA, GARS, GAWS, GAPR, GAPS, GARN.

Driving variables should be given once a day at 00:00 in the input file. The program reads only the value at 00:00 and are neglecting the other time points. OBS! The variables should be given one day in advance. For instance, a variable of May 9 should be given at May 8 in the input file. The reason for this arrangement is to enable the program to have information about yesterday, today and tomorrow at the same time.

The variables DAPS and DARN are just transferred through the program without transformations (except of interpolation). Hence these variables are not following the rules given above. They should be given at their actual dates and are read every minute. Missing minutes of DAPS and DARN are interpolated. This latter rules can also be applied on any of the other variables by setting the switch of the variable concerned equal to zero. The variables only wanted to be transferred through the program without transformation should be given in the following positions in the input file:

If ANALYTICT=0	T_a=DTAXT
If ANALYTICH=0	h_a=DHA1T
If ANALYTICR=0	R_s=DRADT
If ANALYTICU=0	u =DWST
If ANALYTICP=0	F_P=DPRECT

At the beginning and end of the simulation period the program uses the first respectively the last value in the input file. The variables should be given in the same order in the input file as in the D-array (D1-D10).

Variable	Name ; Symbol ; Explanation	(Unit)
D1	**DTA** ; T_a ; Temperature of the ambient air. If DRIVANA-switch = 2: **DTAXT** ; $T_x(t+1)$; Daily maximum temperature of the next day.	(°C)
D2	**DHA** ; h_a ; Relative humidity of the ambient air. (%) If DRIVANA-switch = 2: **DTANT** ; $T_n(t+1)$; Daily minimum temperature of the next day. (°C)	(differs)
D3	**DRS** ; R_s ; Global radiation at the canopy top. (W m^{-2}) If DRIVANA-switch = 2: **DHA1T** ; $h_{a1}(t+1)$; Relative air humidity on the next day at time t_1 (see analytic start parameter AHT1). (%)	(differs)
D4	**DWS** ; u ; Wind speed in the ambient air. (m s^{-1}) If DRIVANA-switch = 2: **DHA2T** ; $h_{a2}(t+1)$; Relative air humidity on the next day at time t_2 (see analytic start parameter AHT2). (%)	(differs)
D5	**DPR** ; F_P or leaf wetness (i) Precipitation (if start parameter WSTPSW>-9999). To prevent interpolation between values of DPR the values of the adjacent minutes must be zero. (mm min^{-1}) (ii) Leaf Wetness (<0.9 is wet ; >=0.9 is dry) (if WSTPSW<=-9999). (-)	(differs)

	If DRIVANA-switch = 2: **DHA3T** ; $h_{a3}(t+1)$; Relative air humidity on the next day at time t_3 (see analytic start parameter AHT3). (%)	
D6	**DPS** ; ψ_s ; Soil water potential (see sensitivity parameters WSPSR and WSPSD). (MPa) If DRIVANA-switch = 2: **DRADT** ; Radiation factor = (i) $\Sigma_{Day}(R_s(t+1))$; Daily sum of global radiation of the next day. Analytic start parameter ARSW should be <>2. (W m^{-2} d^{-1}) (ii) $\Sigma_{Day}(R_s(t+1))/\Sigma_{Day}(R_{sCl}(t+1))$; Daily sum of global radiation of the next day divided by the corresponding value for clear sky conditions. ARSW should be equal to 2. (-)	(differs)
D7	**DRN** ; R_{no} ; Net radiation above the canopy (see start parameters WSTRNA, -B, -C). (W m^{-2}) If DRIVANA-switch = 2: **DWST** ; $u_D(t+1)$; Daily average wind speed of the next day. (m s^{-1})	(differs)
D8	If DRIVANA-switch = 2: **DPRECT** ; $F_P(t+1)$; Daily precipitation of the next day.	(mm d^{-1})
D9	If DRIVANA-switch = 2: **DAPS** ; $\psi_s(t)$; Soil water potential of the present day (OBS!). The time scale for this variable can be arbitrarily chosen.	(MPa)
D10	If DRIVANA-switch = 2: **DARN** ; $R_{no}(t)$; Net radiation above canopy of the present day (OBS!). The time scale for this variable can be arbitrarily.	(W m^{-2})

14.5 Other variables calculated

Here are presented some variables that are calculated by the program, however not available as output. Those denoted "General" can be put (by the programmer) among the output variables by replacing some of the old ones. This is done by changing the EQUIVALENCE statements in the DYNAMIC.FOR file and then making the corresponding changes of names in the SPAC.DEF and SPAC.TRA files. Those denoted "Local" must be extracted from the special subroutine to DYNAMIC.FOR before they can be picked out in the same way as the "General" variables. This list is not complete.

Variable	Symbol ; Explanation	(Unit)
	*********** General **************	
GCODT	$CO\delta t$; Counter of minutes from $-\delta t$ to 0	(min)
GCOMIN	t ; Minutes from 00:00	(min)
GCOTS	j ; Number of energy balance iterations	(number)
GCOV	i ; Number of water balance iterations.	(number)
GDAY	t ; Day-number from January 1	(d number)
GDAY0	t_o ; Day-number at simulation start	(d number)
GDAYY	t-1 ; Day-number of previous day	(d number)
GDEC	DEC ; Sun-declination	(rad)
GDTS	δT_s ; Temperature step at last iteration in the energy balance calculation.	(°C)
GED	e_d ; Saturated vapour pressure in the ambient air.	(hPa)
GGRASW	switch ; <>1 if non-grain period, =1 if grain period.	(-)
GH	H ; Sensible heat flux to the atmosphere.	(W m^{-2})

GPS	ψ_s ; Soil water potential.	(MPa)
GRA0	r_{ao} ; Aerodynamic resistance without considering Richardsons number.	$(s\ m^{-1})$
GRI	Ri ; Richardsons number.	$(s\ m^{-1})$
GRP	r_p ; Plant resistance from root surface to leaf mesophyll.	$(MPa\ s\ m^2\ g^{-1})$
GRPR	r_r+r_p ; The sum of plant resistance and soil-root resistance.	$(MPa\ s\ m^2\ g^{-1}$
GSW1	switch ; 1 --> F_{Tp} is calculated, 2 --> F_T is calculated.	(-)
GV	V(i) ; V at iteration i in the water balance calculation.	$(g\ m^{-2})$
GV0	$V_o(A_{li})$; Maximum amount of exchangeable water in the canopy.	$(g\ m^{-2})$
TWTWUE	W_t'' ; Minut total growth.	$(gDW\ m^{-2}\ min^{-1})$
XWTWUE	$W_t''(acc)$; Daily accumulation of minute total growth.	$(gDW\ m^{-2}\ d^{-1})$
	*********** Local **************	
GALIIN	$A_{li}'(in)$; Daily increase of leaf area index	(d^{-1})
GALIUT	$A_{li}'(ut)$; Daily leaf fall	(d^{-1})
GWGINL	$W_g'(inls)$; Daily allocation of assimilates from leaf and root to grain.	$(gDW\ m^{-2}\ d^{-1})$
GWGINR	$W_g'(inr)$; Daily allocation of assimilates from root to grain.	$(gDW\ m^{-2}\ d^{-1})$
GWLSIN	$W_{ls}'(in)$; Daily input of assimilates to leaf and stem.	$(gDW\ m^{-2}\ d^{-1})$
GWT	W_t' ; Total daily growth.	$(gDW\ m^{-2}\ d^{-1})$
TALI	A_{li}' ; Daily change of leaf area index.	$(gDW\ m^{-2}\ d^{-1})$
TWG	W_g' ; Daily growth of grain.	$(gDW\ m^{-2}\ d^{-1})$
TWLS	W_{ls}' ; Daily growth of leaf and stem.	$(gDW\ m^{-2}\ d^{-1})$
TWR	W_r' ; Daily growth of root.	$(gDW\ m^{-2}\ d^{-1})$

15 News

Important changes in new versions will be mentioned here.

Förteckning över utgivna häften i publikationsserien fr o m 1989

SVERIGES LANTBRUKSUNIVERSITET, UPPSALA. INSTITUTIONEN FÖR MARKVETENSKAP. AVDELNINGEN FÖR LANTBRUKETS HYDROTEKNIK. AVDELNINGSMEDDELANDE.

89:1 Linnér, H., Persson, R., Berglund, K. & Karlsson, S.-E. Resultat av 1988 års fältförsök avseende detaljavvattning, markvård och markförbättring samt bevattning.

89:2 Persson, L. & Jernlås, R. Apparat för kolonnexperiment under omättade förhållanden. Manuskript.

89:3 Berglund, K. Ytsänkning på mosstorvjord. Sammanställning av material från Lidhult, Jönköpings län. 18 s.

89:4 Messing, I. Saturated hydraulic conductivity as related to macroporosity in clay soils. 21 s.

89:5 Karlsson, I. M. Markbyggnad för bostads- och rekreationsområden. Prioritering av forskningsinsatser. 17 s.

89:6 Håkansson, A. Filtermaterial för dränering. Kommentarer till en serie demonstrationsprover av grus- och sågspånsmaterial. 11 s.

89:7 Persson, R. & Wredin, A. (red.). Vattningsbehov och näringstillförsel. Föredrag presenterade vid NJF-seminarium nr 151, Landskrona 1-3 aug 1989. 275 s.

89:8 Nitare, M. Rotutveckling i majs. Examensarbete i hydroteknik. 39 s.

89:9 Sandsborg, J. & Bjerketorp, A. Kompendium i elementär hydromekanik. 8: Hydraulisk likformighet samt dimensionsanalys. 30 s.

89:10 Karlsson, I. M. Effekten av jordkonditioneringsmedlet ammonium-lauretsulfat på den hydrauliska konduktiviteten i vattenmättat tillstånd i två svenska lerjordar. 16 s.

90:1 Linnér, H., Persson, R., Berglund, K. & Karlsson, S.-E. Resultat av 1989 års fältförsök avseende detaljavvattning, markvård och markförbättring samt bevattning. 73 s.

90:2 Jansson, P.-E. (ed.). The Skogaby Project. Project description. 77 s.

90:3 Berglund, K., Lindberg, K. & Peltomaa, R. Alternativa dräneringsmetoder på jordar med låg genomsläpplighet. 1. Ett nordiskt samarbetsprojekt inom Nordkalottområdet. 20 s.

91:1 Linnér, H., Persson, R., Berglund, K. & Karlsson, S.-E. Resultat av 1990 års fältförsök avseende detaljavvattning, markvård och markförbättring samt bevattning. Manuskript.

91:2 Persson, R. & Wesström, I. Markkemiska effekter av bevattning med Östersjövatten på Öland. 23 s + 5 bil.

91:3 Eckersten, H. WIGO model. User's manual. 30 s.

91:4 Eckersten, H. SPAC-GROWTH model. User's manual. 32 s.