Model SWAP-WOFOST for Flanders

User manual

December, 2022

This model is the first version of SWAP-WOFOST adapted to Flemish conditions. The model was developed and is maintained by Wageningen University & Research. This adjusted version was prepared by ILVO in the context of the project PEILIMPACT.

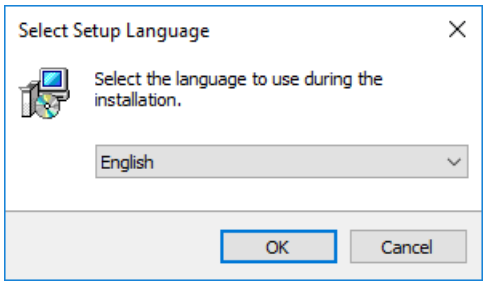
The SWAP manual can be downloaded from https://www.swap.alterra.nl/

Installation of R

1. Install R (only default settings)

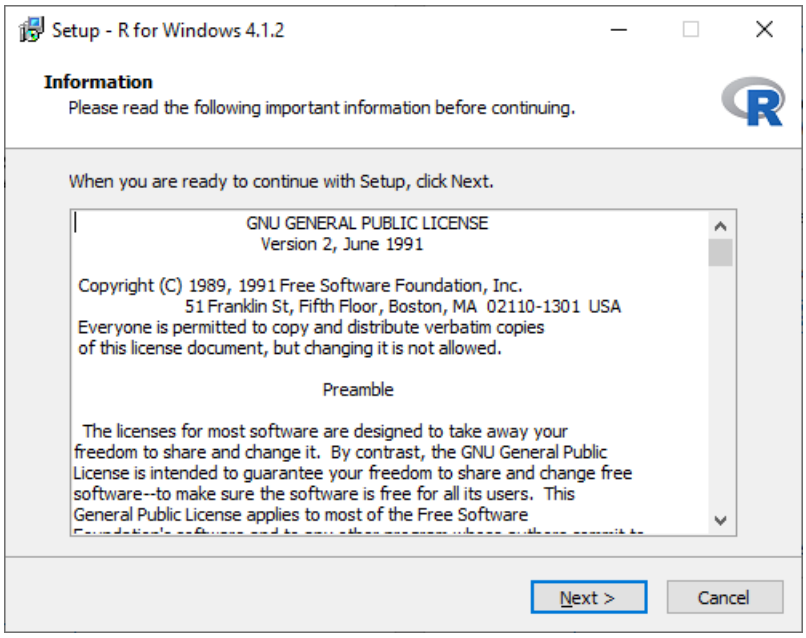
Installation program of R can be downloaded from https://www.r-project.org. Run the program *"R-4.x.x-win.exe"* and follow the steps given below (default settings). For analyzing SWAP-results, R version 4.2.x or later is required[1].

Step 1 Select setup Language: **English**



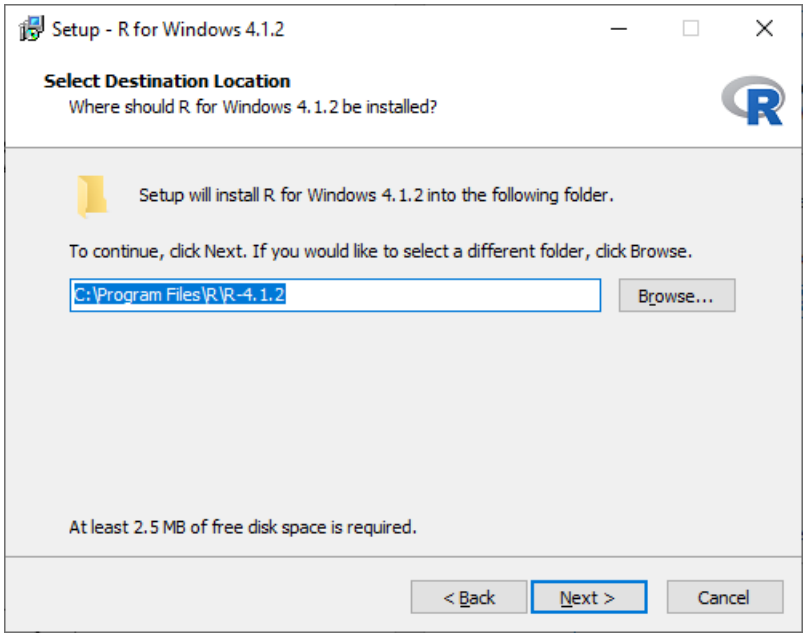
Step 2 Information: **Next**

[1] The screen dumps in this document shows an old version of R.

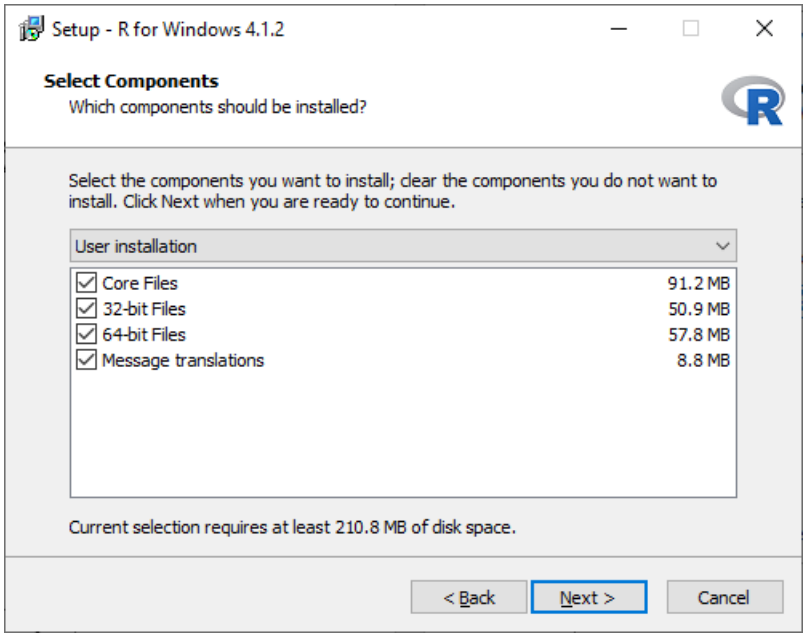

Setup - R for Windows 4.1.2
Information
Please read the following important information before continuing.
When you are ready to continue with Setup, click Next.
GNU GENERAL PUBLIC LICENSE
Version 2, June 1991
Copyright (C) 1989, 1991 Free Software Foundation, Inc.
51 Franklin St, Fifth Floor, Boston, MA 02110-1301 USA
Everyone is permitted to copy and distribute verbatim copies
of this license document, but changing it is not allowed.
Preamble
The licenses for most software are designed to take away your
freedom to share and change it. By contrast, the GNU General Public
License is intended to guarantee your freedom to share and change free
software--to make sure the software is free for all its users. This
General Public License applies to most of the Free Software
Next >
Cancel

Step 3: Select Destination Location: **Next**

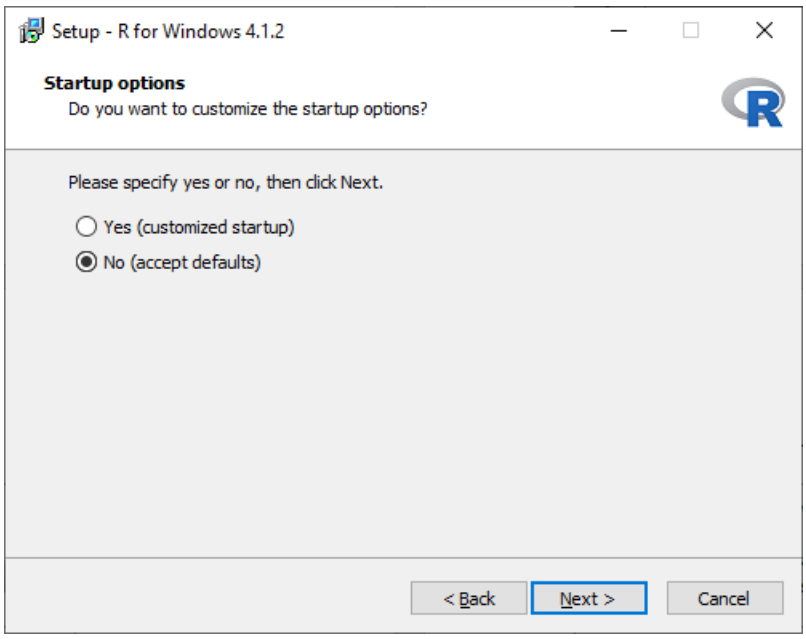
Note: Select a other location in case you don’t have writing permissions on the C-drive



Step 4 Select Components: **Next**

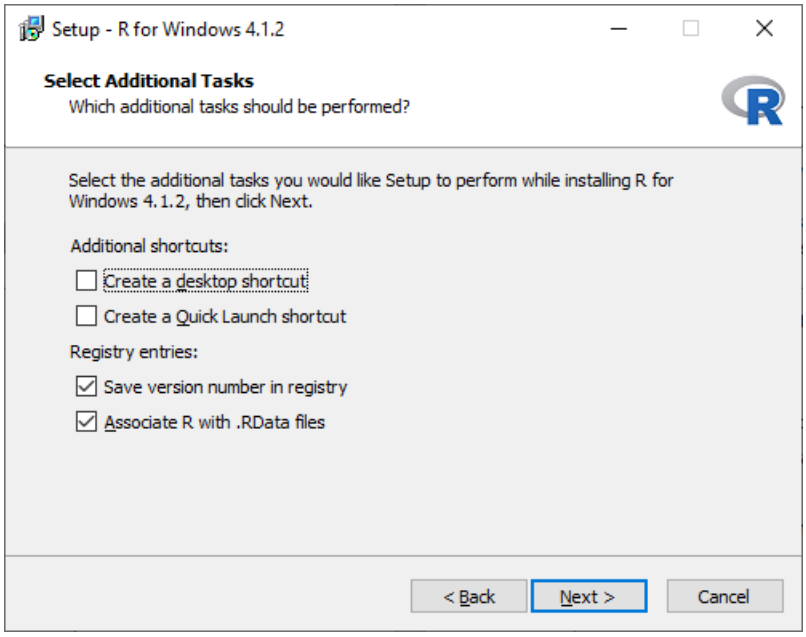


Step 5 Startup options: **Next**

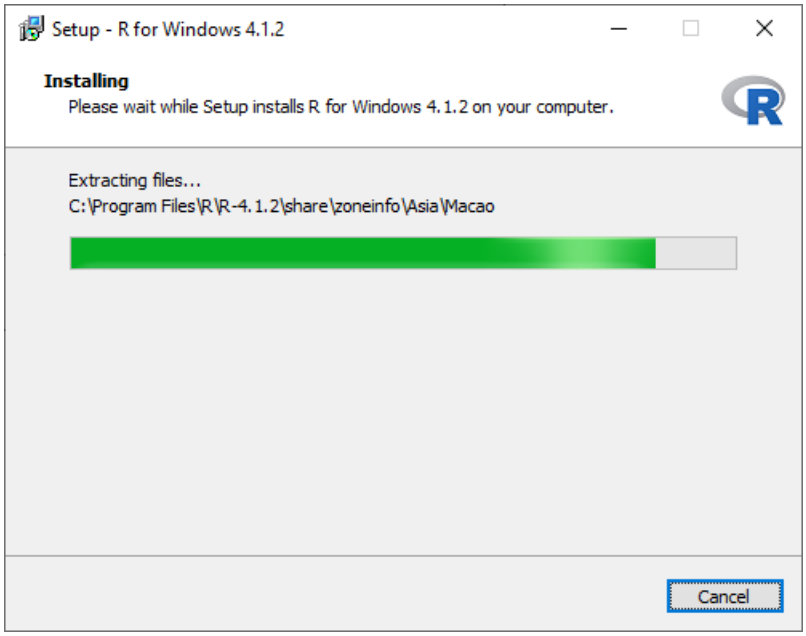


Step 6 Select Start Menu Folder: **Next**

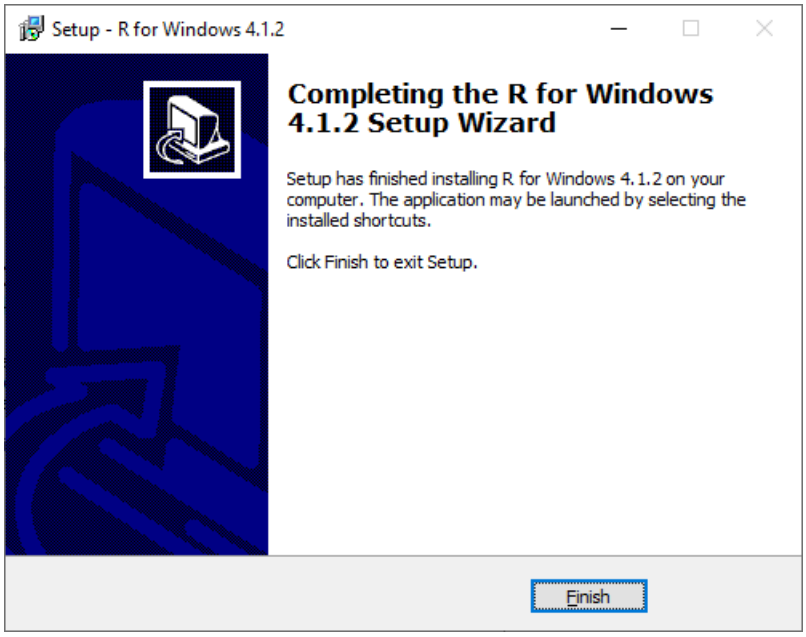
Step 6 Select Additional Task: **Next**



Step 7 Select Additional Task: **Next**

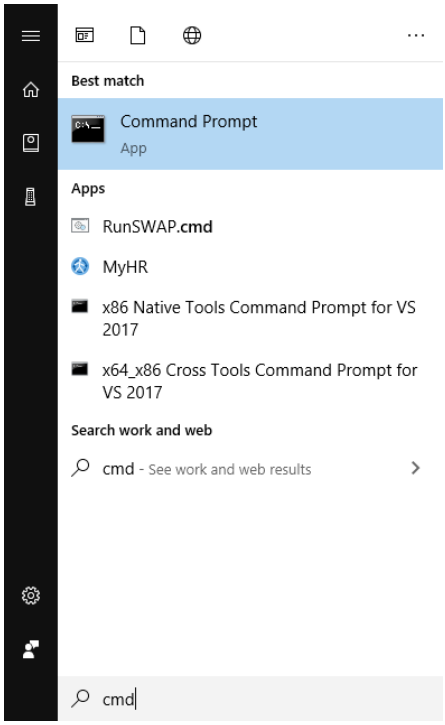


Step 8 Select Additional Task: **Finish**

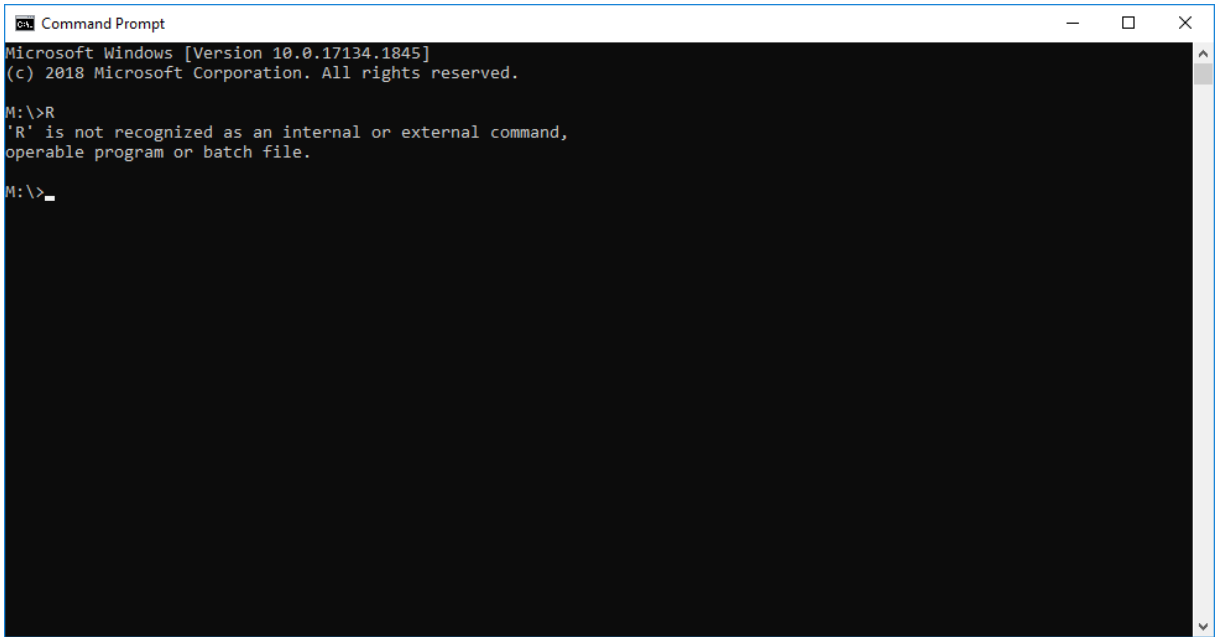


2. Communication with WINDOWS

Check if WINDOWS is recognizing the installation of R by opening a Command Prompt:

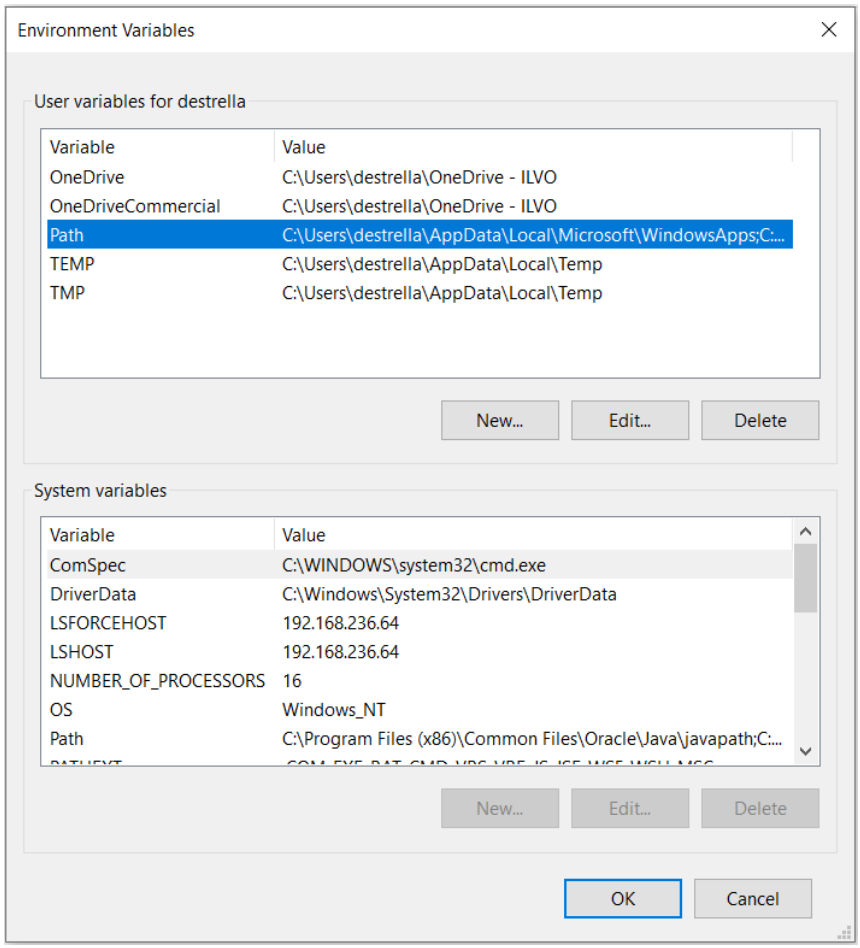


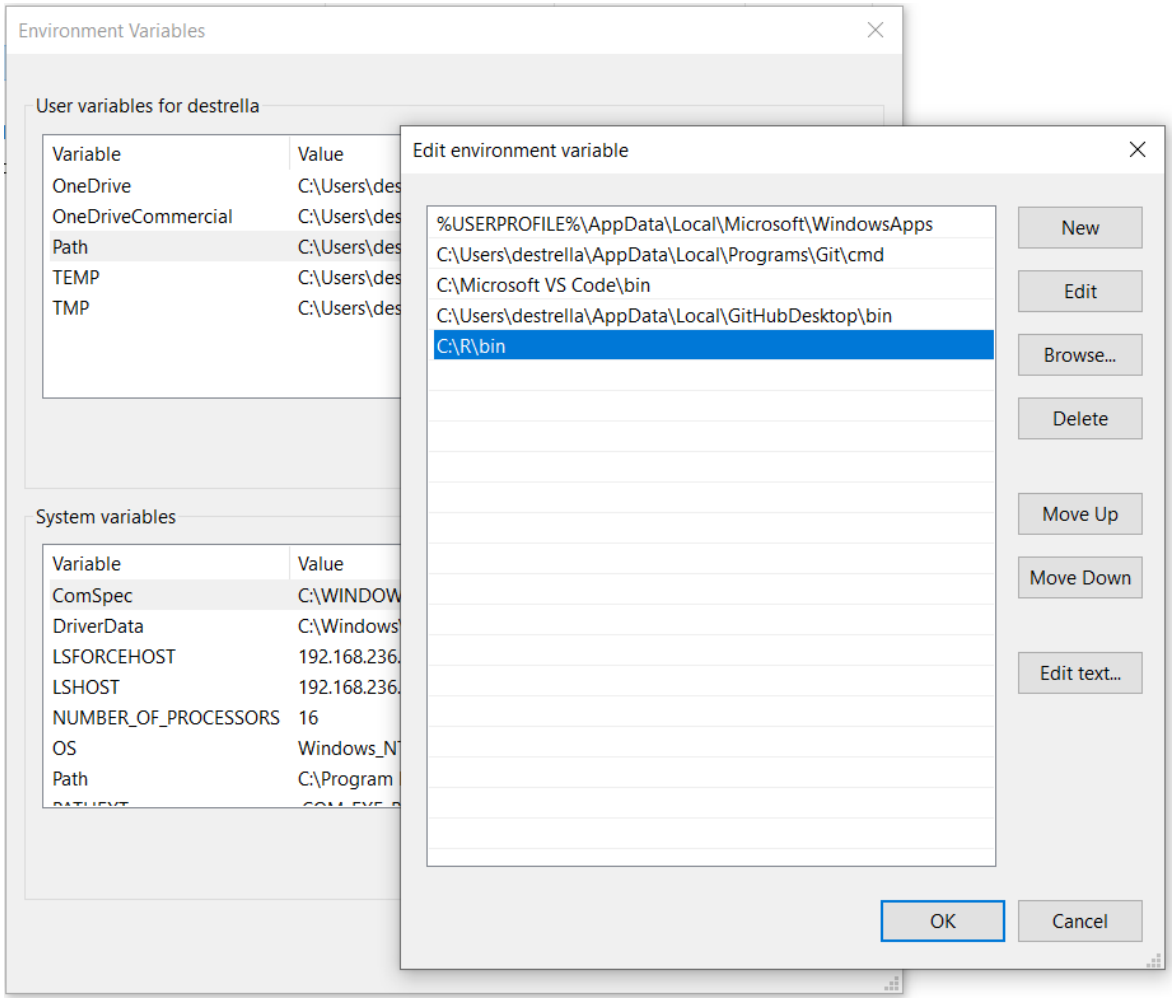
And give the command ‘R’:



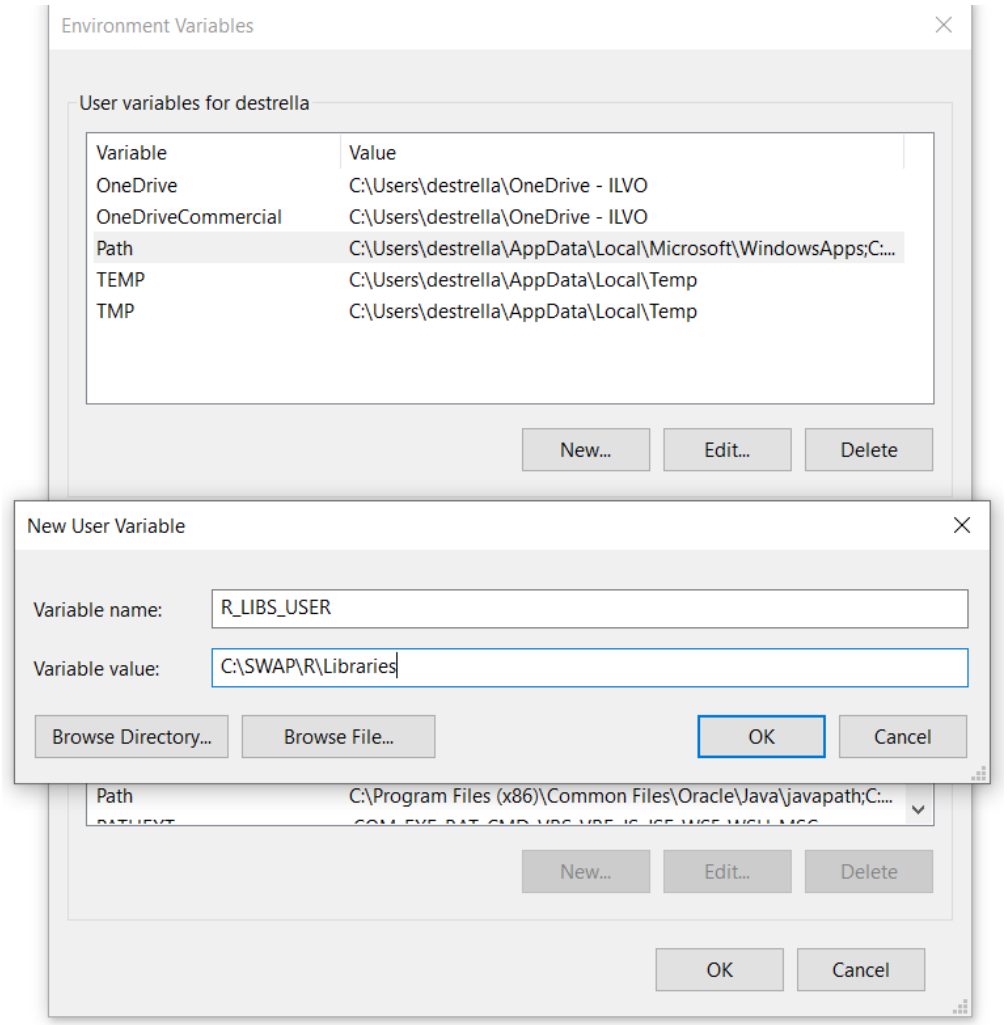
In case WINDOWS does not recognize the ‘R’ command (like in the example above), you’ll have to add an extra Environment Variable. Type “edit environment variables for your account” in Windows search.

Edit *Path* at Environment Variables by adding the folder with the R installation:




Environment Variables
User variables for destrella
Variable
Value
OneDrive
OneDriveCommercial
Path
TEMP
TMP
System variables
Variable
Value
ComSpec
DriverData
LSFORCEHOST
LSHOST
NUMBER_OF_PROCESSORS
16
OS
Path
Edit environment variable
%USERPROFILE%\AppData\Local\Microsoft\WindowsApps
C:\Users\destrella\AppData\Local\Programs\Git\cmd
C:\Microsoft VS Code\bin
C:\Users\destrella\AppData\Local\GitHubDesktop\bin
C:\R\bin
New
Edit
Browse...
Delete
Move Up
Move Down
Edit text...
OK
Cancel

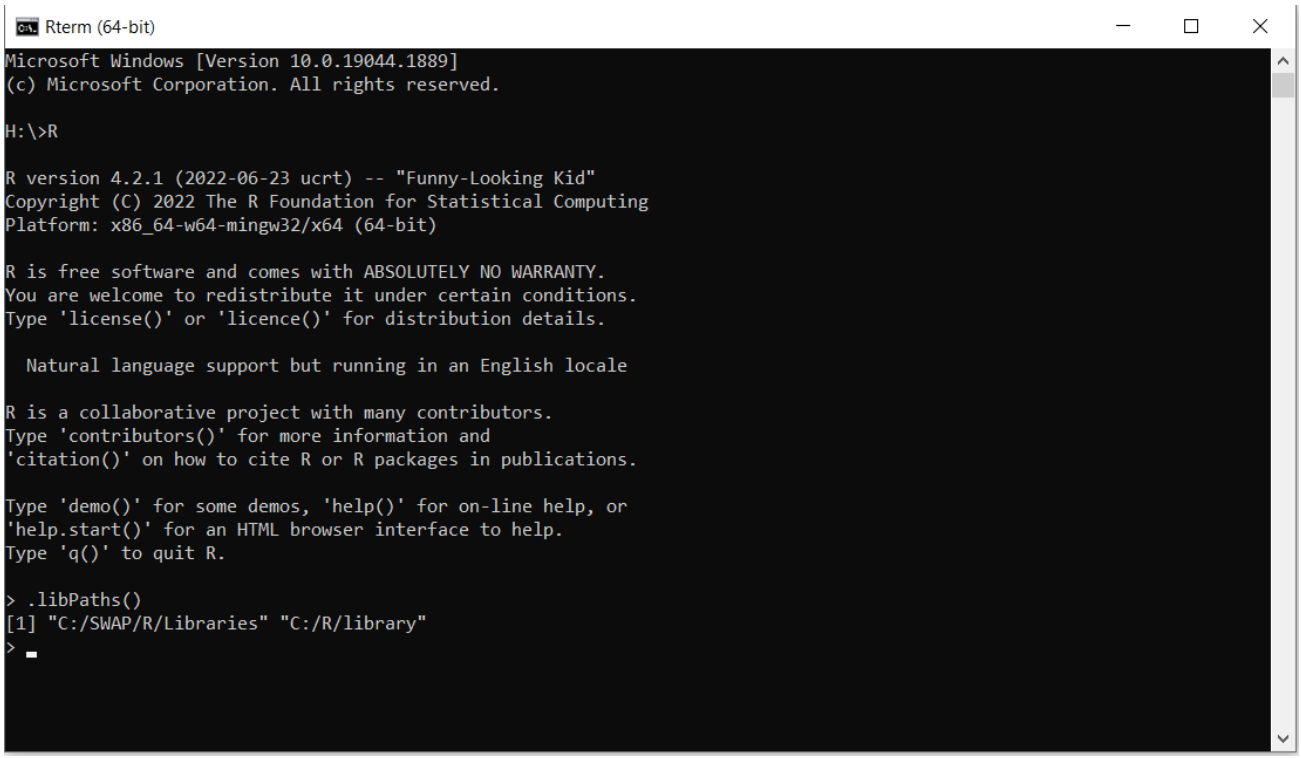
Optional: If you want to store all the R libraries in one specific folder, you can add a new variable 'R_LIBS_USER' at Environment Variable. You can use 'Browse Directory' and select the folder in which R-libraries will be installed[2]:



If you want to do these changes in your computer and not just in your account, go to the section System Variables. For this you will need administrative rights.

[2] Make sure this is an existing folder with writing permissions.

Check if WINDOWS is recognizing the installation of R again by opening a Command Prompt and give the command ‘R’:



In case of successful installation, the R program will start with the message in the example above. To check if the default folder for installation of R-packages is set successfully, give the command ‘.libPaths()’, this should be the same as the system variable R_LIBS_USER.

Close the R-program by the command ‘q()’ and close the Command Prompt.

Installing R-libraries

By Martin Mulder (Wageningen University & Research)

Once R is installed, it is time to install R-libraries. For this purpose, double click the file 'install_libraries.cmd'. This can take a few minutes.

Make sure to run any command file (.cmd) in the same folder where it is executed.

To check if all libraries are installed, rerun this procedure ('install_libraries.cmd'). In the MSDOS box only messages of loading packages should appear.

```
Load packages...
- package 'stringr' loaded
- package 'fs' loaded
- package 'progress' loaded
- package 'tibble' loaded
- package 'dplyr' loaded
- package 'reshape2' loaded
- package 'readr' loaded
- package 'ggplot2' loaded
- package 'ggpubr' loaded
- package 'lubridate' loaded
- package 'grid' loaded
- package 'ascR' loaded
- package 'controlR' loaded
- package 'RSQLite' loaded
- package 'SWAPtools' loaded
- package 'WWLanalyse' loaded
```

Running SWAP-WOFOST

Once the R libraries are installed, the model can be run for the location (coordinates) you specify.

1. Input data by the user

Basic version using an average growing season

In the file "input_user.xlsx", specify the crop type, coordinates in latitude (lat) and longitude (lon), and start and end of simulation. See example below. The simulation period can start from 1979-01-01 until 2021-12-31.

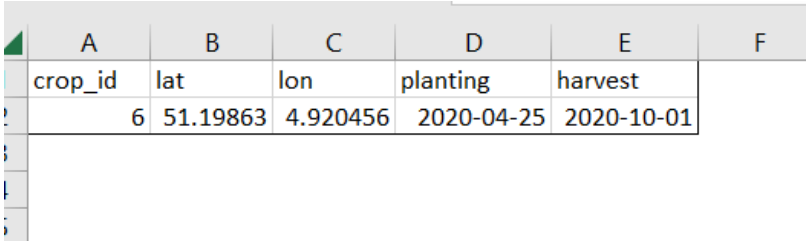
	A	B	C	D	E	F
1	crop_id	lat	lon	start	end	
2	9	51.13881	4.024977	2016-01-01	2020-12-31	
3						
4						
5						
6						

You can choose between 5 crops, each one has a certain crop_id. Select the one that corresponds to your crop. The model will use this average growing season for each of these crops.

crop_id	Crop	Planting date	Harvest data
1	Grass	January, 1st	December, 1st
6	Silage maize	April, 25th	October, 1st
7	Winter wheat	October, 10th	August, 20th
9	Potato	April, 15th	October, 1st
11	Sugar beet	March, 16th	November, 15th

Growing season is specified

In the file "input_user.xlsx", specify the crop type, coordinates in latitude (lat) and longitude (lon), and planting and harvest dates. See example below. This version of the model can simulate the crop growth from 1979 to 2021. Only one growing season can be simulated.



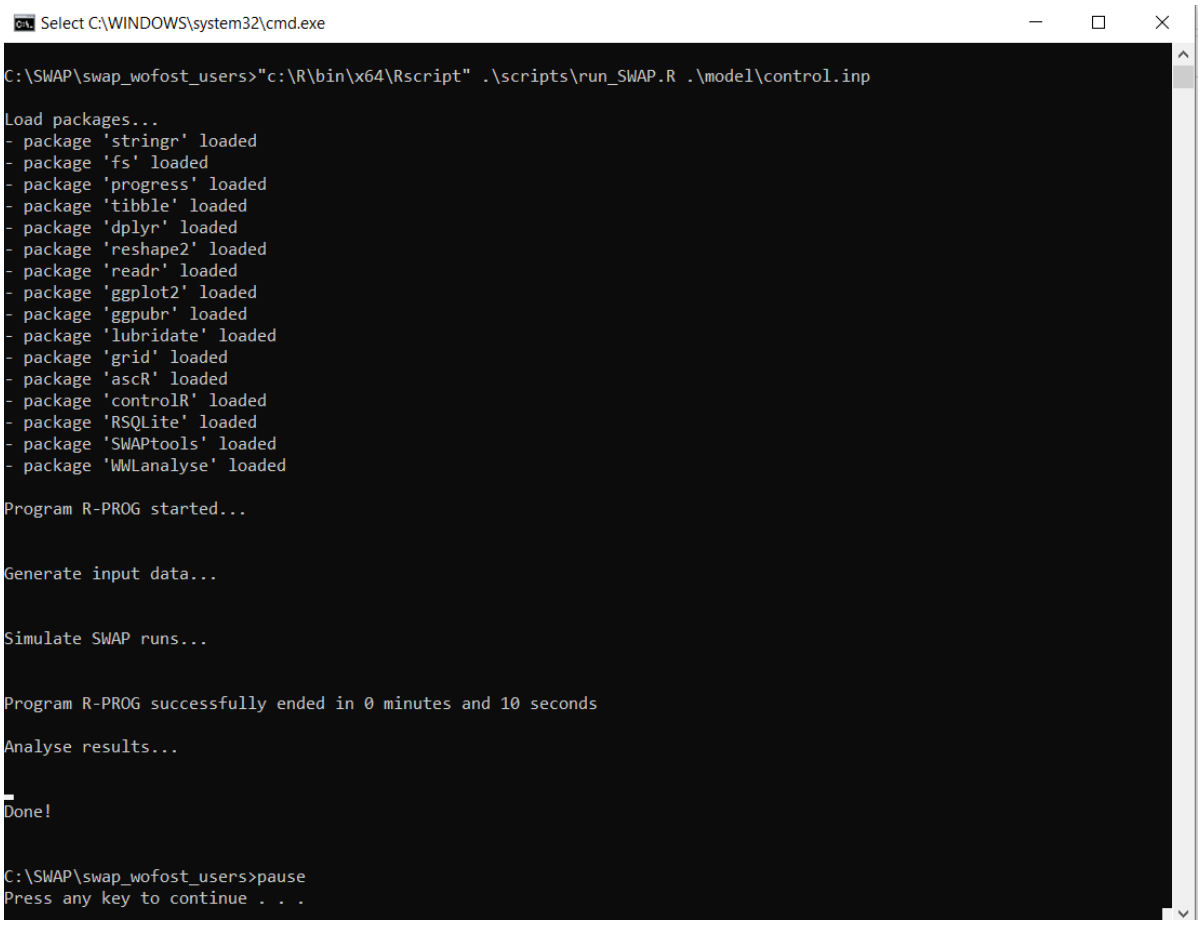
	A	B	C	D	E	F
	crop_id	lat	lon	planting	harvest	
2	6	51.19863	4.920456	2020-04-25	2020-10-01	
3						
4						
5						

If you want to run a new simulation, make sure to back up your previous results as the new simulation will overwrite it.

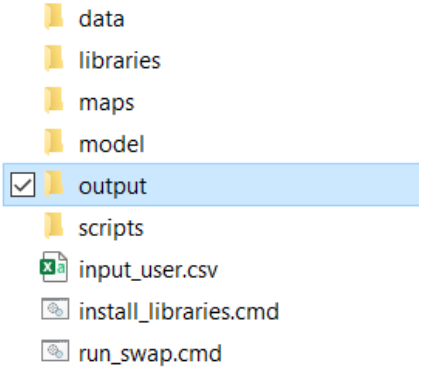
Save the file and close it.

2. Model run and postprocessing

Double click the file "run_swap.cmd" and wait until the model run is finished and the analysis of the model results is complete. This shouldn't take more than a few minutes.



A new folder called "output" will appear afterwards:



This folder contains a folder of the model run " run_000000001", which includes the raw output data from the model "result_output.csv", the crop (.crp) and main swap (.swp) files, and a summary file "summary.csv" with the yearly yields and the yield reduction due to water stress. The description of the output variables in these files can be checked in the Appendix A. This data is also shown graphically for a faster look of the results.

Appendix A

Output variables after postprocessing (file summary.csv)

Variable	Explanation	Unit
ghg	Average maximum groundwater level depth during the year	cm
glg	Average minimum groundwater level depth during the year	cm
GWL_avg	Average groundwater level depth during the year	cm
P_ET	Cummulative precipitation deficit (P-ET)	mm
soil_texture	Soil texture according to the Soil Belgian classification system	
Y_pot	Potential dry matter yield	kg/ha
Y_act	Actual dry matter yield (taking into account water stress and indirect effects)	kg/ha
hrvpotvem	Milk Feed Unit (Voedereenheid melk), only important for forage crops (grass and silage maize)	kVEM/ha
hrvpotdve	Gut digestible protein (Darm verteerbaar eiwit), only important for forage crops (grass and silage maize)	kDVE/ha
dmgtot	Total yield reduction	%
dmgind	Reduction due to indirect effects	%
dmgdir	Reduction due to direct effects	%
dmgwet	Fraction of dmgdir due to oxygen stress (wet)	%
dmgdry	Fraction of dmgdir due to water stress (drought)	%

SWAP user defined output

By Martin Mulder (Wageningen Environmental Research)

TABLE 0-1: List of possible variables (csv-output; timeseries)		
Variable	**Explanation**	**Unit**
RAIN	Rainfall for current time interval	cm
RAIN_NET	Net rainfall for current time interval	cm
SNOW	Snowfall for current time interval	cm
IRRIG	Irrigation for current time interval	cm
IRRIG_NET	Net irrigation for current time interval	cm
INTERC	Crop interception for current time interval	cm
RUNON	Runon for current time interval	cm
RUNOFF	Runoff for current time interval	cm
EPOT	Potential soil evaporation for current time interval	cm
EACT	Actual soil evaporation for current time interval	cm
SUBLIM	Snow sublimation for current time interval	cm
DRAINAGE	Total drainage for current time interval	cm
QBOTTOM	Net flow across bottom boundary for current time interval	cm
GWL	Groundwater level	cm
POND	Ponding height	cm
SSNOW	Amount of snow	cm
TPOT	Potential crop transpiration for current time interval	cm
TACT	Actual crop transpiration for current time interval	cm
TREDDRY	Transpiration reduction due to drought stress	cm
TREDWET	Transpiration reduction due to oxygen stress (too wet)	cm
TREDSOL	Transpiration reduction due to solute stress	cm
TREDFRS	Transpiration reduction due to frost stress	cm
ES0	Potential evaporation rate from a wet bare soil	mm d^{-1}
ET0	Potential transpiration rate from a dry crop	mm d^{-1}
EW0	Potential transpiration rate from a wet crop	mm d^{-1}
DSTOR	Change of storage for current time interval	cm
BALDEV	Error/difference in water balance for current time interval	cm

VOLACT	Actual water content in soil profile	cm
QSSDI	Intermediate amount of water input via subsurface drip irrigation	cm
WC10	Average water content in layer 0-10 cm	$cm^3\ cm^{-3}$
RUNOFFCN	Runoff according to curve number method	cm
QTOPIN	Cumulative incoming flux at soil surface for current time interval	cm
QTOPOUT	Cumulative outgoing flux at soil surface for current time interval	cm

TABLE 0-2: List of possible variables (csv-output; time-depth-series)		
Variable	**Explanation**	**Unit**
WTOT[...]	Total water content in subregion. A subregion is provided either as depths or compartment numbers between [...]. For example [0:-30] (depth; floating point, negative) or [1:25] (compartment numbers; integer, positive). A maximum of 5 subregions may be entered, e.g., WTOT[0:-30,-30:-60,-60:-90]	cm
QTRANS[...]	Total transpiration in subregion. See explanation provided for WTOT[...].	cm
QTOP[...]	Total net inflow of water at top of subregion. See explanation provided for WTOT[...].	cm
QBOT[...]	Total net inflow of water at bottom of subregion. See explanation provided for WTOT[...].	cm
QDRA[...]	Total net drainage water from subregion. See explanation provided for WTOT[...].	cm
QTOPIN[...]	Total inflow of water at top of subregion. See explanation provided for WTOT[...].	cm
QTOPOUT[...]	Total outflow of water at top of subregion. See explanation provided for WTOT[...].	cm
QBOTIN[...]	Total inflow of water at bottom of subregion. See explanation provided for WTOT[...].	cm
QBOTOUT[...]	Total outflow of water at bottom of subregion. See explanation provided for WTOT[...].	cm
QDRAIN[...]	Total inflow via drainage in subregion. See explanation provided for WTOT[...].	cm
QDRAOUT[...]	Total outflow via drainage in subregion. See explanation provided for WTOT[...].	cm

TABLE 0-3: List of possible variables for crop growth (csv-output; timeseries)		
Variable	**Explanation**	**Unit**
General		
TSUM	Temperature sum from start to end of growing season of the crop	^{0}C
DVS	Crop development stage	-
HEIGHT	Crop height	cm
CRPFAC	Crop factor	-
LAIPOT	Leaf area index for potential run	$m^2\ m^{-2}$
LAI	Leaf area index	$m^2\ m^{-2}$
RDPOT	Rooting depth for potential run	cm
RD	Rooting depth	cm
WOFOST		
PGASSPOT	Assimilation rate after nitrogen stress and maximum attainable yield, potential crop growth	kg ha^{-1}
PGASS	Assimilation rate after nitrogen stress and maximum attainable yield, actual crop growth	kg ha^{-1}
CPWDM	Dry weight of dead and living plant organs for potential growth	kg ha^{-1}
CWDM	Dry weight of dead and living plant organs	kg ha^{-1}
CPWSO	Dry weight of storage organ for potential growth	kg ha^{-1}
CWSO	Dry weight of storage organ	kg ha^{-1}
PWLV	Dry weight of plant leaves for potential growth	kg ha^{-1}
WLV	Dry weight of plant leaves	kg ha^{-1}
PWST	Dry weight of plant stem for potential growth	kg ha^{-1}
WST	Dry weight of plant stem	kg ha^{-1}
PWRT	Dry weight of plant root for potential growth	kg ha^{-1}
WRT	Dry weight of plant root	kg ha^{-1}
DWSO	Dry weight of plant storage organs of actual crop	kg ha^{-1}
DWLV	Dry weight of plant leaves of actual crop	kg ha^{-1}
DWLVPOT	Dry weight of plant leaves of potential crop	kg ha^{-1}
DWST	Dry weight of plant stem of actual crop	kg ha^{-1}
DWSTPOT	Dry weight of plant stem of potential crop	kg ha^{-1}
DWRT	Dry weight of plant roots of actual crop	kg ha^{-1}
DWRTPOT	Dry weight of plant roots of potential crop	kg ha^{-1}
GRASS		
PGRASSDM	Dry weight of dead and living grass organs for potential run	kg ha^{-1}
GRASSDM	Dry weight of dead and living grass organs	kg ha^{-1}
PMOWDM	Dry weight of harvested grass for potential run	kg ha^{-1}
MOWDM	Dry weight of harvested grass	kg ha^{-1}
PGRAZDM	Cumulative dry weight of grass consumed with grazing for potential run	kg ha^{-1}
GRAZDM	Cumulative dry weight of grass consumed with grazing	kg ha^{-1}
PLOSSDM	Total loss of potential harvest due to insufficient pressure head	kg ha^{-1}
LOSSDM	Total loss of actual harvest due to insufficient pressure head	kg ha^{-1}

TABLE 0-4: List of possible variables for solute transport (csv-output; timeseries)		
Variable	**Explanation**	**Unit**
SQPREC	Cumulative amount of solutes in precipitation	g cm^{-2}
SQIRRIG	Cumulative amount of solutes in irrigation water	g cm^{-2}
SQBOT	Cumulative amount of solutes passed through the soil column bottom	g cm^{-2}
SQDRA	Total amount of solutes transported to drainage canals	g cm^{-2}
DECTOT	Cumulative amount of solute decomposition	g cm^{-2}
ROTTOT	Cumulative amount of solutes extracted by plant roots	g cm^{-2}
SAMPRO	Total amount of solutes in soil column	g cm^{-2}
SOLBAL	Cumulative solute balance (M/L2) for current balance period	g cm^{-2}

TABLE 0-5: List of possible variables (csv-output; time-depth-series)		
Variable	**Explanation**	**Unit**
H[...]	Pressure head at specified depths or compartments. Multiple (max = 10) depths or compartments (comma separated) can be supplied between square brackets. Depths as negative floating point values (must include decimal point), and compartments as positive integer values. Mixed depths and compartments is not allowed. The output is representative for the average depth of the soil compartment. Examples: H[-10.0,-25.0,-90.0], or H[5,8,30]	cm
WC[...]	Volumetric water content at specified depths or compartments. See explanation provided for H[...].	$cm^3\ cm^{-3}$
TEMP[...]	Soil temperature at specified depths or compartments. See explanation provided for H[...].	^0C
K[...]	Hydraulic conductivity at specified depths or compartments. See explanation provided for H[...].	$cm\ d^{-1}$
CONC[....]	Solute concentration at specified depths or compartments. See explanation provided for H[...].	$g\ cm^{-3}$
CONCADS[...]	Adsorbed solute content at specified depths or compartments. See explanation provided for H[...].	$g\ cm^{-3}$
O2TOP[...]	Oxygen concentration at top of compartment at specified depths or compartments. See explanation provided for H[...].	$kg\ m^{-3}$
HEACAP[...]	Soil heat capacity	$J\ m^{-3}\ K^{-1}$
HEACON[...]	Soil heat conductivity	$W\ m^{-1}\ K^{-1}$
TETOP	Soil temperature at soil surface	^oC
TEBOT	Soil temperature at the bottom of the soil column	^oC
DRAIN[...]	Total drainage at specified depths or compartments. See explanation provided for H[...].	cm
RWU[...]	Total root water uptake at specified depths or compartments. See explanation provided for H[...].	cm
FLUX[...]	Water flux at top of specified depths or compartments. See explanation provided for H[...].	cm
SSDI[...]	Total subsurface (drip) irrigation at specified depths or compartments. See explanation provided for H[...].	cm