The Modell for Nitrogen and Carbon in Agro-Ecosystems

User Manual – Version 1.22

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MONICA – Documentation

Content

Installation

The MONICA installer leads you step-wise through the installation process. After having agreed to the licence terms you will be asked to define the program directory into which MONICA shall be copied for installation. As a default, MONICA is installed into the Program folder, typically C:\Program Files.

The model comes with a database that administers important model parameters. The provided example simulation contains a completely configured simulation in the required format, including climate data, soil profile, crop rotations, fertiliser scheme, irrigation, etc. Using these formats, own simulations can be developed.

The example files are automatically copied into the directory “%USERPROFILE%\MONICA\Examples. The environmental variable %USERPROFILE% points to your personal user profile directory (i.e. „C:\Dokumente und Einstellungen\Benutzername“). Copying %USERPROFILE% into the address line of the Windows File Explorer you will forwarded to your user directory.

Starting MONICA

Starting the Example simulation from the start menu

Links are created in the Start menu and on the Desktop, from which MONICA can be started with the example simulations. As a result of the MONICA simulations two files are created in the example simulation directory (rmout.dat and smout.dat). These files contain important outputs of crop development and soil processes in CSV format.

Starting MONICA using the command line

At present, MONICA is a command line program. This means that MONICA needs to be started directly from the Windows command line.

Open your command line editor in Windows using *Start* → *Execute* and the command "cmd". Alternatively, you will find the command line editor in the Start menu under *All Programs* → *Accessories* → *Command prompt*.

After having opened the command line editor change into the previously defined installation directory.

> cd C:\Programme\MONICA.

If you installed MONICA on to a separate hard disk or partition, you have to first change to the hard disk by typing the letter into the command prompt. For example, if you have MONICA installed on D, you have to type

> D:

into the prompt. After this you can change into the MONICA directory as explained above with the command *cd*.

In this directory you can now call MONICA. MONICA expects the path variable for the folder containing the simulation data as a parameter:

> monica.exe „%USERPROFILE%"\MONICA\Examples\Hohenfinow2

Note: The user directory %USERPROFILE% must be put in quotes! Otherwise MONICA cannot read the path correctly.

During the simulation MONICA writes various outputs into the command line. They can be used to follow the status of the simulation. The results are stored in the two output files rmout.dat and smout.dat in the simulation directory. These files are in CSV format and can be analysed using Microsoft Excel®.

Configuring own simulations

Using the example data you can now configure your own simulations. Various simulation settings are stored in a configuration file (monica.ini). MONICA expects such a configuration file in every simulation directory. When being started, the model reads the .ini file and configures the simulation run accordingly.

The monica.ini *configuration file*

Example monica.ini

```
[files]
soil=SOIL.txt
croprotation=ROTATION.txt
fertiliser=FERT.txt
irrigation=IRRIG.TXT
climate_prefix=MET_BS.

[simulation_time]
startyear=1999
endyear=2008

[nmin_fertiliser]
activated=0
;mineral_fert_id=1
;organic_fert_id=2
;min=10.0
;max=100.0
;delay_in_days=30

[automatic_irrigation]
activated=0
;amount=0
;treshhold=0.15
;nitrate=0
;sulfate=0

[site_parameters]
latitude=46.42
slope=0.01
heightNN=150.0
soilCNRatio=10.0
atmospheric_CO2=360.0
wind_speed_height=2.0
leaching_depth=1.2
;groundwater_depth_min=-1
;groundwater_depth_max=-1
;groundwater_depth_min_month=-1

[general_parameters]
;use_secondary_yields=1
nitrogen_response_on=true
water_deficit_response_on=true

[init_values]
init_percentage_FC=1.0        ; Initial soil moisture content in percent field capacity
```

```
init_soil_nitrate=0.01       ; Initial soil nitrate content [kg NO3-N m-3]
init_soil_ammonium=0.0001    ; Initial soil ammonium content [kg NH4-N m-3]
```

The monica.ini configuration file includes seven sections: files, simulation_time, nmin_fertiliser, automatic_irrigation, site_parameters, general_parameters and init_values. Within these sections a range of elements are used, which will be explained below.

Note: Comments start with a semicolon. The semicolon marks deactivated lines, which will be ignored by MONICA.

files

soil	Name of the soil data file
croprotation	Name of the crop rotation file
fertiliser	Name of the fertiliser file
irrigation	Name of the irrigation file
climate_prefix	Prefix of the climate files

simulation_time

startyear	Starting year of the simulation, four digit format
endyear	End year of the simulation, four digit format

nmin_fertiliser

activated	0 or 1; Deactivates or activates the automatic fertiliser application. When deactivated, all further elements of this section will be ignored. IN the above example they are uncommented thus deactivated.
mineral_fert_id	MONICA ID of the mineral fertiliser; the ID refers to the pre-configured fertilisers in the monica database.
organic_fert_id	MONICA ID of the organic fertiliser; the ID refers to the pre-configured fertilisers in the monica database.
min	Minimum amount, that will be applied automatically [kg N ha^{-1}]
max	Maximum amount, that will be applied automatically [kg N ha^{-1}]
delay_in_days	Delay in days for a possible head dressing [d]

automatic_irrigation

activated	0 or 1; Deactivates or activates the automatic irrigation application. When deactivated, all further elements of this section will be ignored. In the above example they are deactivated.
amount	Irrigation water amount [mm]
treshold	Soil water content, below which irrigation is triggered [m^3 m^{-3}]
nitrate	Nitrate concentration in the irrigation water [ppm]
sulfate	Sulfate concentration in the irrigation water [ppm]

site_parameters

latitude	Site latitude in decimal format
slope	Site slope [m m^{-1}]
heightNN	Altitude above sea level [m]
soilCNratio	C to N ratio of the soil organic matter
atmospheric_CO2	Atmospheric CO_2 concentration (0 = MONICA calculates the observed Mauna Loa concentration 1959 – 2010, or projects the IPCC A1B Scenario to 2100) [ppm]
wind_speed_height	Height of the wind speed measurement [m]
leaching_depth	Depth, below which nitrate is considered being leached [m]
groundwater_depth_min	Lowest annual groundwater distance to surface [m]
groundwater_depth_max	Highest annual groundwater distance to surface [m]
groundwater_depth_min_month	Month, in which the lowest groundwater distance to surface is observed on average

general_parameters

use_secondary_yields	0 or 1; Deactivates or activates the calculation of secondary yields e.g. straw
nitrogen_response_on	„false“ oder „true“; Deaktiviert oder aktiviert die Rückkopplung eines etwaigen Stickstoffdefizits auf das Pflanzenwachstum
water_deficit_response_on	„false“ oder „true“; Deaktiviert oder aktiviert die Rückkopplung eines etwaigen Wasserdefizits auf das Pflanzenwachstum

init_values

init_percentage_FC	Initial value for soil water content [% Field capacity]
init_soil_nitrate	Initial value for soil nitrate concentration [kg NO_3-N m^{-3}]
init_soil_ammonium	Initial value for soil ammonium concentration [kg NH_4-N m^{-3}]

Configuration of input files

Note: The files containing the input information for the simulations are taken from an earlier generation of simulation models, to facilitate comparisons between model versions. For this reason the file construction follows a strict format which must not be varied.

The soil data file „SOIL“

All essential soil information is contained in this csv file. *BdID* is the soil identification number, which can be freely assigned. *Corg* denotes the soil organic carbon content [%], *Bart* encodes the soil texture information according to the German Soil Survey Manual (Bodenkundliche Kartieranleitung, 5. Auflage (KA5); see Appendix). *UKT* gives the lower boundary of the respective soil horizon in [dm] and *LD* gives the bulk density class according

to KA5 (see Appendix). *Stn* represents the stone content in [%]. All other denotifiers have no function up until now. The different horizons of a soil are to be added in the lines below, using the same soil ID. **The profile must be defined down to 20 dm** (UKT = 20 for the lowest horizon).

BdID Corg Bart UKT LD Stn C/N C/S Hy Wmx AzHo

001 1.02 Sl3 02 3 00 010 --- 00 08 3

001 1.02 St2 03 3 00 010 --- 00 08

001 0.15 St2 20 3 00 010 --- 00 08

End

The crop rotation file „ROTATION“

This file contains data on the crops and their seed and harvest dates. The *field_ID* has no function right now, as the assignment of the crops to the soil is coded in the .ini file. *Crp* contains the crop ID. Currently, the following crops can be simulated:

- Winter wheat ("WW")
- Winter barley ("WG")
- Spring barley ("SG")
- Winter rye ("WR")
- Sugar beet ("ZR")
- Silage maize ("SM")
- Grain maize ("GM")
- Winter oil-seed rape ("WC")
- Fodder pea ("FP")
- Soybean maturity group VII (“S07”)
- Winter triticale (“WTR”)
- Oil radish (“OR”)
- Mustard (“MU”)
- Sorghum (“SOR”)
- Phacelia (“PH”)

The sowing date *sowing* and the harvest date *harves* follow, as well as a soil tillage date *tillag*. Using *dp* the depth of the soil tillage can be defined. All other entries have no function at present.

field_ID crp sowing harves tillag Exp dp Yld year comment

301000001 WG 250999 270600 280600 000 15 000 2000

301000001 ZR 100401 180901 041101 000 10 000 2001

301000001 WW 071101 010802 200902 000 15 000 2002

end

The fertiliser scheme file „FERT“

In this file the N fertiliser application scheme is included. *Schlag_ID* has currently no function. N denotes the amount of N applied as pure nutrient [kg N ha^{-1}] and *FRT* encodes the fertiliser type. At present MONICA can simulate the following fertiliser:

- Potassium nitrate ("KN")
- Calcium ammonium nitrate ("KAS")
- Ammonium urea solution ("AHL")
- Ammonium sulfate ("AS")
- Diammonium phosphate ("DAP")
- Pig slurry ("SG")
- Cattle slurry ("RG1")
- Pig manure ("SM")
- Urea ("UR")
- NPK compound fertiliser ("NPK")
- Alzon ("ALZ")
- Nitrophoska ("NIT")
- Poultry slurry ("HG")
- Broiler manure ("HFM")
- Poultry manure ("HM")
- Lime from sugar beet processing (Carbokalk) ("CK")
- Sewage sludge ("KSL")
- Bio-waste compost ("BAK")
- Yara Pellon Y3 ("YP3")

Furthermore follows the application date *Date* and a statement *Incorp* whether the fertiliser was incorporated into the soil (*1*) or not (*0*).

Schlag_ID N FRT Date Incorp

301000001 9600 FM 230899 0

301000001 113 RG1 080999 1

301000001 054 AHL 220300 1

end

The irrigation file „IRRIG“

The irrigation file contains a scheme for irrigation of the crop. *Field_ID* has currently no function. *mm* denotes the amount of water applied with each event in [mm]. *SCc* has currently no function. *IrrDat* gives the date of the irrigation event and *NCc* gives the N concentration in the irrigation water in [mg l^{-1}]

Field_ID mm SCc IrrDat NCc

301000001 24 334 050500 000

301000001 24 334 120500 000

End

The climate files

The climate files contain weather information in daily resolution for one year each. The respective year is used as file extension, e.g. „xxx.992“ for weather data of the year 1992 or „xxx.008“ for weather data of the year 2008. **All weather files must be present in the simulation directory for the period defined in the .ini file.** The format of the climate files is currently held very strict as it builds on earlier formats to ensure readability of past simulation projects. The format is a space-separated text. Such climate files are constructed easiest using a Windows Excel® template and export its content to the .csv fomat. In the .csv file comma must be exchanged for spaces using a text editor. Finally, the file extension .csv must be exchanged for the above-mentioned year extension.

The climate file format looks like this:

Tp_av Tpmin Tpmax T_s10 T_s20 vappd wind sundu radia prec tagesnummer RF

C_deg C_deg C_deg C_deg C_deg mm_Hg m/se hours J/cm² mm jday %

50 ----- ----- ----- ----- ----- 02 m ----- ------ -- - -

–000.6 –01.5 001.0 000.0 000.0 000.0 006.7 000.0 0052.0 000.0 001 090

0002.8 000.0 006.0 000.0 000.0 000.0 012.8 000.0 0052.0 000.0 002 085

The columns contain (from left to right) the daily mean air temperature in 2m height in [°C] (*Tp_av*), the daily minimum air temperature in 2m height in [°C] (*Tpmin*), the daily maximum air temperature in 2m height in [°C] (*Tpmax*), the daily soil temperature in 10cm depth in [°C] (*T_s10*), the daily soil temperature in 20cm depth in [°C] (*T_s20*), the daily air saturation deficit in [mm Hg] (*vappd*), the daily average wind speed in 2m height in [m s^{-1}], the daily sunshine duration in [h] (*sundu*), the daily sum of global radiation in [J cm^{-2}] (*radia*), the daily

sum of precipitation in [*mm*] (prec), the julian day (*tagesnummer*) and the daily average relative air humidity in [*%*] (RF).

For running MONICA the variables *Tp_av, Tpmin, Tpmax, wind, prec, tagesnummer* and *RF* are required, and furthermore *sundu* or *radia*. The remaining variables should be filled with 000.0 or –99.9.

The climate data must be complete, i.e. the must contain 365 lines in the above format below the three-line header (366 lines for leap years).

Evaluation of a simulation

The simulation results are written in two text files *rmout.dat* and *smout.dat*, which will be created in the respective simulation directory. These files are tab-separated and can be easily imported in Microsoft-Excel® for graphical analysis.

The result file smout.dat

The file *smout.dat* includes frequently used target variables in daily time step.

Header	Description	Unit
Datum	Date of the simulation day	[TT/MM/YYYY]
Stage	Crop's development stage, according to definition in the crop database	[0;1]
Height	Height of crop	[m]
Root	Dry matter mass of the root	[kg ha^{-1}]
Root10	Dry matter mass of the root in 0-10 cm soil depth	[kg ha^{-1}]
Leaf	Dry matter mass of the leaves	[kg ha^{-1}]
Shoot	Dry matter mass of stem (culm) and branches or shoots	[kg ha^{-1}]
Fruit	Dry matter mass of the fruit (ear, cob)	[kg ha^{-1}]
AbBiom	Aboveground dry matter mass of the crop	[kg ha^{-1}]
AbGBiom	(not yet implemented)	
Yield	Dry matter yield	[kg ha^{-1}]
EarNo	Cereal ear number (not yet implemented)	
GrainNo	Cereal grain number (not yet implemented)	
LAI	Leaf area index	[m^2 m^{-2}]
AbBiomNc	N concentration in aboveground dry matter biomass	[kg N kg DM^{-1}]
YieldNc	N concentration in dry matter yield	[kg N kg DM^{-1}]
AbBiomN	N content in aboveground biomass	[kg N ha^{-1}]
YieldN	N content in yield	[kg N ha^{-1}]
TotNup	Total N uptake of the crop	[kg N ha^{-1}]
NGrain	N concentration in the grain	[kg kg^{-1}]
Protein	Raw protein concentration in the grain	[kg kg^{-1}]
BedGrad	Soil coverage	[m^2 m^{-2}]
M0-10	Soil moisture in 0-10 cm depth	[m^3 m^{-3}]
M10-20	Soil moisture in 10-20 cm depth	[m^3 m^{-3}]
M20-30	Soil moisture in 20-30 cm depth	[m^3 m^{-3}]
M30-40	Soil moisture in 30-40 cm depth	[m^3 m^{-3}]
M40-50	Soil moisture in 40-50 cm depth	[m^3 m^{-3}]
M50-60	Soil moisture in 50-60 cm depth	[m^3 m^{-3}]
M60-70	Soil moisture in 60-70 cm depth	[m^3 m^{-3}]

Header	Description	Unit
M70-80	Soil moisture in 70-80 cm depth	[m^3 m^{-3}]
M80-90	Soil moisture in 80-90 cm depth	[m^3 m^{-3}]
M0-30	Soil moisture in 0-30 cm depth	[m^3 m^{-3}]
M30-60	Soil moisture in 30-60 cm depth	[m^3 m^{-3}]
M60-90	Soil moisture in 60-90 cm depth	[m^3 m^{-3}]
M0-60	Soil moisture in 0-60 cm depth	[m^3 m^{-3}]
M0-90	Soil moisture in 0-90 cm depth	[m^3 m^{-3}]
PAW0-200	Plant-available water 0-200 cm depth	[mm]
PAW0-130	Plant-available water 0-130 cm depth	[mm]
PAW0-120	Plant-available water 0-120 cm depth	[mm]
N0-30	Soil mineral N in 0-30 cm depth	[kg m^{-3}]
N30-60	Soil mineral N in 30-60 cm depth	[kg m^{-3}]
N60-90	Soil mineral N in 60-90 cm depth	[kg m^{-3}]
N0-60	Soil mineral N in 0-60 cm depth	[kg m^{-3}]
N0-90	Soil mineral N in 0-90 cm depth	[kg m^{-3}]
N0-200	Soil mineral N in 0-200 cm depth	[kg N ha^{-1}]
N0-130	Soil mineral N in 0-130 cm depth	[kg N ha^{-1}]
N0-120	Soil mineral N in 0-120 cm depth	[kg N ha^{-1}]
NH430	Soil ammonium in 0-30 cm depth	[kg N m^{-3}]
NH460	Soil ammonium in 0-60 cm depth	[kg N m^{-3}]
NH490	Soil ammonium in 0-90 cm depth	[kg N m^{-3}]
Co0-10	Soil organic carbon in 0-10 cm depth	[kg C m^{-3}]
Co0-30	Soil organic carbon in 0-30 cm depth	[kg C m^{-3}]
T0-10	Soil temperature in 0-10 cm depth	[°C]
T20-30	Soil temperature in 20-30 cm depth	[°C]
T50-60	Soil temperature in 50-60 cm depth	[°C]
CO2	CO_2 emission from soil	[kg C ha^{-1}]
NH3	NH_3 emission from soil	[kg N ha^{-1}]
N2O	N_2O emission from soil (not yet implemented)	
N2	N_2 emission from soil (not yet implemented)	
Ngas	Total gaseous N emission from soil (not yet implemented)	
NFert	N fertilisation	[kg N ha^{-1}]
Irrig	Irrigation	[mm]

The result file rmout.dat

The file *rmout.dat* contains – in daily time steps – target variables which can be used for detailed process analysis.

Header	Description	Unit
Datum	Date of the simulation day	[TT/MM/YYYY]
TraDef	Transpiration deficit	[0;1]
Tra	Transpiration	[mm]
NDef	Nitrogen nutrition deficit	[0;1]
HeatRed	Storage allocation reduction due to heat stress	[0;1]
OxRed	Oxygen deficit	[0;1]
Stage	Crop's developmental stage, according to definition in the crop database	[ ]
TempSum	Temperature sum during crop development	[°C d]
VernF	Degree of vernalisation	[0;1]
DaylF	Fraction of required daylength	[0;1]
IncRoot	Root growth rate	[kg CH_2O ha^{-1} d^{-1}]
IncLeaf	Leaf growth rate	[kg CH_2O ha^{-1} d^{-1}]
IncShoot	Shoot growth rate	[kg CH_2O ha^{-1} d^{-1}]
IncFruit	Storage organ growth rate	[kg CH_2O ha^{-1} d^{-1}]
NetPhot	Net photosynthesis	[kg CH_2O ha^{-1}]
RelDev	Relative development of the crop	[0; 1]
Root	Dry matter mass of the root	[kg ha^{-1}]
Leaf	Dry matter mass of the leaves	[kg ha^{-1}]
Shoot	Dry matter mass of the stem and branches or shoots	[kg ha^{-1}]
Fruit	Dry matter mass of the fruit (ear, cob)	[kg ha^{-1}]
GroPhot	Gross photosynthesis	[mol m^{-2} s^{-1}]
Assim	Assimilation rate	[kg CH_2O ha^{-1}]
Maint	Maintenance respiration	[kg CH_2O ha^{-1}]
GPP	Gross primary production	[kg C ha^{-1}]
NPP	Net primary production	[kg C ha^{-1}]
StomRes	Stomata resistance	[s^{-1}]
Height	Height of the crop	[m]
LAI	Leaf area index	[m^2 m^{-2}]
RootDep	Aktual effective rooting depth	[soil layer]
AbBiom	Aboveground dry matter biomass	[kg m^{-2}]
NBiom	N content in the biomasse	[kg ha^{-1}]
SumNUp	Sum of N uptake	[kg N ha^{-1}]
ActNup	actual N uptake	[kg N ha^{-1}]
PotNup	potential N uptake	[kg N ha^{-1}]
Target	Target value N fertilisation	[kg N kg^{-1} DM]
CritN	Critical N concentration	[kg N kg^{-1} DM]
AbBiomN	N concentration in aboveground biomass	[kg kg^{-1}]
NPP	Total crop net primary production	[kg C m^{-2}]
NPPRoot	Net primary production per root mass	[kg C m^{-2}]
NPPLeaf	Net primary production per leaf mass	[kg C m^{-2}]
NPPShoot	Net primary production per shoot mass	[kg C m^{-2}]

Header	Description	Unit
NPPFruit	Net primary production per storage organ mass	[kg C m^{-2}]
GPP	Total crop gross primary production	[kg C m^{-2}]
Ra	Total crop respiration	[kg C m^{-2}]
RaRoot	Root respiration	[kg C m^{-2}]
RaLeaf	Leaf respiration	[kg C m^{-2}]
RaShoot	Shoot respiration	[kg C m^{-2}]
RaFruit	Storage organ respiration	[kg C m^{-2}]
Mois0	Soil moisture in 0-10 cm depth	[m^3 m^{-3}]
Mois1	Soil moisture in 10-20 cm depth	[m^3 m^{-3}]
Mois2	Soil moisture in 20-30 cm depth	[m^3 m^{-3}]
Mois3	Soil moisture in 30-40 cm depth	[m^3 m^{-3}]
Mois4	Soil moisture in 40-50 cm depth	[m^3 m^{-3}]
Mois5	Soil moisture in 50-60 cm depth	[m^3 m^{-3}]
Mois6	Soil moisture in 60-70 cm depth	[m^3 m^{-3}]
Mois7	Soil moisture in 70-80 cm depth	[m^3 m^{-3}]
Mois8	Soil moisture in 80-90 cm depth	[m^3 m^{-3}]
Mois9	Soil moisture in 90-100 cm depth	[m^3 m^{-3}]
Mois10	Soil moisture in 100-110 cm depth	[m^3 m^{-3}]
Mois11	Soil moisture in 110-120 cm depth	[m^3 m^{-3}]
Mois12	Soil moisture in 120-130 cm depth	[m^3 m^{-3}]
Mois13	Soil moisture in 130-140 cm depth	[m^3 m^{-3}]
Mois14	Soil moisture in 140-150 cm depth	[m^3 m^{-3}]
Mois15	Soil moisture in 150-160 cm depth	[m^3 m^{-3}]
Mois16	Soil moisture in 160-170 cm depth	[m^3 m^{-3}]
Mois17	Soil moisture in 170-180 cm depth	[m^3 m^{-3}]
Mois18	Soil moisture in 180-190 cm depth	[m^3 m^{-3}]
Mois19	Soil moisture in 190-200 cm depth	[m^3 m^{-3}]
Precip	Precipitation	[mm]
Irrig	Irrigation	[mm]
Infilt	Infiltration	[mm]
Surface	Surface water storage	[mm]
RunOff	Surface water run-off	[mm]
SnowD	Snow layer thickness	[m]
FrostD	Depth frost boundary in soil	[m]
ThawD	Depth thaw boundary in soil	[m]
PASW-0	Plant-available soil water in 0-10 cm depth	[mm]
PASW-1	Plant-available soil water in 10-20 cm depth	[mm]
PASW-2	Plant-available soil water in 20-30 cm depth	[mm]
PASW-3	Plant-available soil water in 30-40 cm depth	[mm]
PASW-4	Plant-available soil water in 40-50 cm depth	[mm]
PASW-5	Plant-available soil water in 50-60 cm depth	[mm]
PASW-6	Plant-available soil water in 60-70 cm depth	[mm]
PASW-7	Plant-available soil water in 70-80 cm depth	[mm]
PASW-8	Plant-available soil water in 80-90 cm depth	[mm]
PASW-9	Plant-available soil water in 90-100 cm depth	[mm]
PASW-10	Plant-available soil water in 100-110 cm depth	[mm]

Header	Description	Unit
PASW-11	Plant-available soil water in 110-120 cm depth	[mm]
PASW-12	Plant-available soil water in 120-130 cm depth	[mm]
PASW-13	Plant-available soil water in 130-140 cm depth	[mm]
PASW-14	Plant-available soil water in 140-150 cm depth	[mm]
PASW-15	Plant-available soil water in 150-160 cm depth	[mm]
PASW-16	Plant-available soil water in 160-170 cm depth	[mm]
PASW-17	Plant-available soil water in 170-180 cm depth	[mm]
PASW-18	Plant-available soil water in 180-190 cm depth	[mm]
PASW-19	Plant-available soil water in 190-200 cm depth	[mm]
SurfTemp	Soil surface temperature	[°C]
STemp0	Soil temperature in 0-10 cm depth	[°C]
STemp1	Soil temperature in 10-20 cm depth	[°C]
STemp2	Soil temperature in 20-30 cm depth	[°C]
STemp3	Soil temperature in 30-40 cm depth	[°C]
STemp4	Soil temperature in 40-50 cm depth	[°C]
act_Ev	Actual evaporation	[mm]
act_ET	Actual evapotranspiration	[mm]
ET0	Reference evapotranspiration	[mm]
Kc	Kc factor for reference evapotranspiration	[ ]
atmCO2	Atmospheric CO_2 concentration	[10^{-6} m^3 m^{-3}]
Groundw	Groundwater distance to surface	[m]
Recharge	Percolation below rooting depth	[mm]
NLeach	N leaching	[kg N ha^{-1}]
NO3-0	Soil nitrate content in 0-10 cm depth	[kg NO_3-N m^{-3}]
NO3-1	Soil nitrate content in 10-20 cm depth	[kg NO_3-N m^{-3}]
NO3-2	Soil nitrate content in 20-30 cm depth	[kg NO_3-N m^{-3}]
NO3-3	Soil nitrate content in 30-40 cm depth	[kg NO_3-N m^{-3}]
NO3-4	Soil nitrate content in 40-50 cm depth	[kg NO_3-N m^{-3}]
NO3-5	Soil nitrate content in 50-60 cm depth	[kg NO_3-N m^{-3}]
NO3-6	Soil nitrate content in 60-70 cm depth	[kg NO_3-N m^{-3}]
NO3-7	Soil nitrate content in 70-80 cm depth	[kg NO_3-N m^{-3}]
NO3-8	Soil nitrate content in 80-90 cm depth	[kg NO_3-N m^{-3}]
NO3-9	Soil nitrate content in 90-100 cm depth	[kg NO_3-N m^{-3}]
NO3-10	Soil nitrate content in 100-110 cm depth	[kg NO_3-N m^{-3}]
NO3-11	Soil nitrate content in 110-120 cm depth	[kg NO_3-N m^{-3}]
NO3-12	Soil nitrate content in 120-130 cm depth	[kg NO_3-N m^{-3}]
NO3-13	Soil nitrate content in 130-140 cm depth	[kg NO_3-N m^{-3}]
NO3-14	Soil nitrate content in 140-150 cm depth	[kg NO_3-N m^{-3}]
NO3-15	Soil nitrate content in 150-160 cm depth	[kg NO_3-N m^{-3}]
NO3-16	Soil nitrate content in 160-170 cm depth	[kg NO_3-N m^{-3}]
NO3-17	Soil nitrate content in 170-180 cm depth	[kg NO_3-N m^{-3}]
NO3-18	Soil nitrate content in 180-190 cm depth	[kg NO_3-N m^{-3}]
NO3-19	Soil nitrate content in 190-200 cm depth	[kg NO_3-N m^{-3}]

Header	Description	Unit
Carb	Soil carbamide content in 0-10 cm depth	[kg $C(NH_3)_2$-N m^{-3}]
NH4-0	Soil ammonium content in 10-20 cm depth	[kg NH_4-N m^{-3}]
NH4-1	Soil ammonium content in 10-30 cm depth	[kg NH_4-N m^{-3}]
NH4-2	Soil ammonium content in 20-40 cm depth	[kg NH_4-N m^{-3}]
NH4-3	Soil ammonium content in 30-50 cm depth	[kg NH_4-N m^{-3}]
NH4-4	Soil ammonium content in 40-60 cm depth	[kg NH_4-N m^{-3}]
NH4-5	Soil ammonium content in 50-70 cm depth	[kg NH_4-N m^{-3}]
NH4-6	Soil ammonium content in 60-80 cm depth	[kg NH_4-N m^{-3}]
NH4-7	Soil ammonium content in 70-90 cm depth	[kg NH_4-N m^{-3}]
NH4-8	Soil ammonium content in 80-100 cm depth	[kg NH_4-N m^{-3}]
NH4-9	Soil ammonium content in 90-100 cm depth	[kg NH_4-N m^{-3}]
NH4-10	Soil ammonium content in 100-120 cm depth	[kg NH_4-N m^{-3}]
NH4-11	Soil ammonium content in 110-120 cm depth	[kg NH_4-N m^{-3}]
NH4-12	Soil ammonium content in 120-130 cm depth	[kg NH_4-N m^{-3}]
NH4-13	Soil ammonium content in 130-140 cm depth	[kg NH_4-N m^{-3}]
NH4-14	Soil ammonium content in 140-150 cm depth	[kg NH_4-N m^{-3}]
NH4-15	Soil ammonium content in 150-160 cm depth	[kg NH_4-N m^{-3}]
NH4-16	Soil ammonium content in 160-170 cm depth	[kg NH_4-N m^{-3}]
NH4-17	Soil ammonium content in 170-180 cm depth	[kg NH_4-N m^{-3}]
NH4-18	Soil ammonium content in 180-190 cm depth	[kg NH_4-N m^{-3}]
NH4-19	Soil ammonium content in 190-200 cm depth	[kg NH_4-N m^{-3}]
NO2-0	Soil nitrite content in 0-10 cm depth	[kg NO2-N m–3]
NO2-1	Soil nitrite content in 10-20 cm depth	[kg NO_2-N m^{-3}]
NO2-2	Soil nitrite content in 20-30 cm depth	[kg NO_2-N m^{-3}]
NO2-3	Soil nitrite content in 30-40 cm depth	[kg NO_2-N m^{-3}]
SOC-0	Organic carbon in 0-10 cm depth	[kg C m^{-3}]
SOC-1	Organic carbon in 10-20 cm depth	[kg C m^{-3}]
SOC-2	Organic carbon in 20-30 cm depth	[kg C m^{-3}]
SOC-3	Organic carbon in 30-40 cm depth	[kg C m^{-3}]
AOMf-0	Organic carbon in rapidly decomposable fresh matter 0-10 cm depth	[kg C m^{-3}]
AOMs-0	Organic carbon in slowly decomposable fresh matter 0-10 cm depth	[kg C m^{-3}]
SMBf-0	Organic carbon in rapidly processing micro-organisms in 0-10 cm depth	[kg C m^{-3}]
SMBs-0	Organic carbon in slowly processing micro-organisms in 0-10 cm depth	[kg C m^{-3}]
SOMf-0	Organic carbon in rapidly decomposing humified matter 0-10 cm depth	[kg C m^{-3}]
SOMs-0	Organic Carbon in slowly decomposing humified matter 0-10 cm depth	[kg C m^{-3}]
CBal-0	Carbon balance in 0-10 cm depth	[kg C m^{-3}]
Nmin-0	Net N mineralisation in 0-10 cm depth	[kg N m^{-2}]
Nmin-1	Net N mineralisation in 10-20 cm depth	[kg N m^{-2}]
Nmin-2	Net N mineralisation in 20-30 cm depth	[kg N m^{-2}]

Header	Description	Unit
NetNmin	Cumulated total net N mineralisation	[kg N m^{-2}]
Denit	N_2 production from denitrification	[kg N m^{-2}]
N2O	N_2O production	[kg N_2O-N m^{-2}]
SoilpH	Soil pH	[ ]
NEP	Net ecosystem production [kg C m^{-2}]	[kg C m^{-2}]
NEE	Net ecosystem exchange [kg C m^{-2}]	[kg C m^{-2}]
Rh	Heterotrophic respiration [kg C m^{-2} d^{-1}]	[kg C m^{-2} d^{-1}]
tmin	Daily minimum air temperature [°C]	[°C]
tavg	Daily average air temperature [°C]	[°C]
tmax	Daily maximum air temperature [°C]	[°C]
wind	Wind speed [m s^{-1}]	[m s^{-1}]
globrad	Global radiation [J cm^{-2}]	[J cm^{-2}]
relhumid	Relative air humidity [%]	[%]
sunhours	Sunshine duration [h]	[h]

Appendix

Table 1: Soil type classification following the German soil survey manual (5th issue).

German name	English name	Code	Clay %	Silt %	Sand %
reiner Sand	pure sand	Ss	0-5	0-10	85-100
schwach schluffiger Sand	siltic sand	Su2	0-5	10-25	70-90
schwach lehmiger Sand	loamic sand	Sl2	5-8	10-25	67-85
mittel lehmiger Sand	loamy sand	Sl3	8-12	10-40	48-82
schwach toniger Sand	clayic sand	St2	5-17	0-10	73-95
mittel schluffiger Sand	silty sand	Su3	0-8	25-40	52-75
stark schluffiger Sand	silt-sand	Su4	0-8	40-50	42-60
schluffig-lehmiger Sand	silty-loamy sand	Slu	8-17	40-50	33-52
stark lehmiger Sand	loam-sand	Sl4	12-17	10-40	43-78
mittel toniger Sand	clayey sand	St3	17-25	0-15	60-83
schwach sandiger Lehm	sandic loam	Ls2	17-25	40-50	25-43
mittel sandiger Lehm	sandy loam	Ls3	17-25	30-40	35-53
stark sandiger Lehm	sand-loam	Ls4	17-25	15-30	45-68
schwach toniger Lehm	clayic loam	Lt2	25-35	30-50	15-45
sandig-toniger Lehm	sandy-clayey loam	Lts	25-45	15-30	25-60
stark sandiger Ton	sand-clay	Ts4	25-35	0-15	50-75
mittel sandiger Ton	sandy clay	Ts3	35-45	0-15	40-65
reiner Schluff	pure silt	Uu	0-8	80-100	0-20
sandiger Schluff	sandy silt	Us	0-8	50-80	12-50
schwach toniger Schluff	clayic silt	Ut2	8-12	65-92	0-27
mittel toniger Schluff	clayey silt	Ut3	12-17	65-88	0-23
sandig-lehmiger Schluff	sandy-loamy silt	Uls	8-17	50-65	18-42
stark toniger Schluff	clay-silt	Ut4	17-25	65-83	0-18
schluffiger Lehm	silty loam	Lu	17-30	50-65	5-33
mittel toniger Lehm	clayey loam	Lt3	35-45	30-50	5-35
mittel schluffiger Ton	silty clay	Tu3	30-45	50-65	0-20
stark schluffiger Ton	silt-clay	Tu4	25-35	65-75	0-10
schwach sandiger Ton	sandic clay	Ts2	45-65	0-15	20-55
lehmiger Ton	loamy clay	Tl	45-65	15-30	5-40
schwach schluffiger Ton	siltic clay	Tu2	45-65	30-55	0-25
reiner Ton	pure clay	Tt	65-100	0-35	0-35

Table 2: Effective bulk density classes of the soil following the German soil survey manual (4th issue).

Code	German name	English name	Effective bulk density (Dry bulk density + 0.009 · Clay content [%])
Ld1	sehr gering	very low	< 1.4
Ld2	gering	low	1.4 – 1.6
Ld3	mittel	medium	1.6 – 1.8
Ld4	hoch	high	1.8 – 2.0
Ld5	sehr hoch	very high	> 2.0