General introduction to the application of the Daisy model

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Abstract

This introduction to the application of the Daisy model comprises minor 12 exercises. Exercise 1 illustrates how to set up a simple simulation using minimum information on the simulated system and how to extract simulation results. Exercises 2 & 3 are dealing with soil hydraulic properties and discretization of the soil profile. Exercise 4 is introducing irrigation. Exercise 5 is dealing with tile drains and the calibration of the interface to the groundwater. Exercise 6 & 7 are introducing the simulation of rotations and the use of organic fertilizers. Exercise 8 is illustrating the importance of introducing a "warm-up" period. In Exercise 9 the MIT-model (Mineralization-Immobilization Turnover) is calibrated. Exercise 10 builds a Daisy weather file. In Exercise 11 an organic fertilizer is parameterised. In Exercise 12 a crop is parameterised.

A technical description of the Daisy model is given by [Abrahamsen and Hansen, 2000] and [Hansen, 2002].

Contents

Introduction

In order to run a Daisy simulation the model needs parameterisation. The required information is parsed on to the model through setup-files (or `.dai` files), which are written in a special input-language. Daisy stores information in an internal database. The information parsed on to the model need not occur in any special order. The Daisy code contains a partial parameterisation, i.e. a number of parameters is given default values at initialisation. However, it is always possible to overwrite the default parameterisation. Information on soil horizons is stored in the internal database by the `horizon`–component:

```
(defhorizon "Ap JB6" FAO3
  "An optional description."
  ;; More parameters
  (clay 15.5 [%]))
```

where `defhorizon` is short for define horizon. Other similar expressions are `defcolumn` (defining a soil column including the soil surface and the bioclimate above it), `defcrop` (defining crop growth parameters), `defam` (defining added matter, e.g. fertilizers), `defaction` (defining an action list of management actions), and `deflog` (defining output-variables). "*Ap JB6*" is the name which the parameterisation will have in the internal database and which later can be referred to when one wants to retrieve the stored information. The `FAO3` keyword retrieves the structure of the internal database and, hence, it specifies the type of information that now can be expected and it also includes default values given to any of the parameters of the horizon. Alternatively, the name of an existing element in the database (a previously defined horizon) could be stated instead of the expression `FAO3`[1]. The expression "`(clay 15.5 [%])...`" refers to an attribute list (an attribute list is an unordered set of (*name, value*) pairs), which contains the parameters to be added or changed as compared to the selected database element (default or a previously defined horizon). In the present example the component "horizon" has a member "clay" of type "number" and furthermore the value 15.5 is assigned to this member. The square brackets after the number (15.5) is used to give the dimension of the number. In the present example the clay content is given as percent. If the brackets are left out, Daisy will use a default dimension, which may not be what you think. So don't leave out the dimension.

It is noted that parentheses are used to group information e.g. `(clay 0.155 [])`. Similarly all the information defined by the defhorizon statement and stored under the name "`Ap JB6`" are embedded in parentheses. Parentheses are the main structural element of the Daisy language syntax.

Furthermore it is noted that the name "`Ap JB6`" is imbedded in quotations marks. Names may always be imbedded in quotation marks, but it is only necessary if the name contains special symbols including white spaces. The only special symbol, which can be used without the use of quotation marks, is the underscore.

Comments, which are ignored by the parser, can be included in Daisy-setup-files by use of semicolons (;). The parser ignores any text occurring after a semicolon until end-of-line. The only exception is when the semicolon is imbedded in quotation marks, i.e. is a part of a name.

A comprehensive description of the Daisy input-language is given in *Daisy Program Reference Manual* [Abrahamsen, 2003a].

1 Writing a Daisy Setup File

The objective of this exercise is to illustrate how to write a Daisy-setup-file, run a simple simulation, and extract simulation results.

When writing a Daisy-setup-file it is practical first to define computational environment and the external library-files, which is going to be used by the simulation, as shown in box 1.1.

[1] `(defhorizon "Ap Askov" "Ap JB6" (humus 1.5 [%]))` this statement overwrites the humus content but retains all other information stored in "Ap JP6".

Box 1.1: Daisy-setup-file header

```
;; Including external library-files
(input file "tillage.dai")
(input file "crop.dai")
(input file "fertilizer.dai")
(input file "log.dai")

;; Weather data
(weather default "dk-taastrup.dwf")

;; Description that will occur in all output files
(description "Spring Barley; Soil: Fine sandy loam; Weather: Taastrup")
```

It is noted that first the working directory is set. The reason is that the Daisy code writes a log-file (`daisy.log`), where all messages from the simulation, including error messages, is stored. Hence if the working directory is set correctly then this log file will occur in the selected directory.

The external library-files are written in the same Daisy input-language as the Daisy-setup-file. In fact any information, which is supplied by the Daisy-setup-file, could be moved to an external file, which then could be included by the input file statement. On the other hand any information supplied by the external library-files could also be written directly to the Daisy-setup-file. The use of external library-files is just a convenient way of organising ones data. There is only one hard rule that must be obeyed and that is that any information that is used must be defined before any reference is made to it.

Weather data are driving variables in the simulation and is supplied to the model through a special file written in a special format (daisy weather format or `dwf`). This format shall be explained later.

Basic soil horizon information is given in table 1.1. This information is transferred to the internal library of the model using defhorizon as shown in box 1.2.

Table 1.1: Basic soil horizon parameters.

Depth cm	Dry bulk density g/cm^3	Humus	Clay $<2\mu$m	Silt	Sand $>50\mu$m
00 – 30	1.53	0.026	0.113	0.277	0.584
30 – 80	1.51	0.005	0.235	0.253	0.507
80 –	1.57	0.002	0.244	0.283	0.471

Using `defhorizon` many more parameters can be defined, see *Daisy Program Reference Manual* [Abrahamsen, 2003a]. When these parameters are not supplied by the `defhorizon`-statements then the model uses either predefined default values or pedotransfer functions to estimate the missing parameters. E.g., turnover rates of organic matter have been assigned default values, soil thermal properties are estimated by a modified de Vries model [Hansen, 2002], and soil hydraulic properties are estimated by the HYPRES pedotransfer function [Wösten et al., 1999].

Based on horizon information a column can now be build. In principle the column comprises the bioclimate (upper boundary, exchange with the atmosphere), the soil profile itself, and a groundwater condition (lower boundary, exchange with the groundwater). However the bioclimate component is fully parameterised by defaults, and hence it is not necessary to include it in the setup. A column

Box 1.2: Defining a horizon.

```
;;  Defining a soil horizon
(defhorizon "Ap F.S.L." FAO3
  "Data from Jacobsen, 1989"
  (dry_bulk_density 1.53 [g/cm^3])
  (clay 11.3 [%])
  (silt 27.7 [%])
  (sand 58.4 [%])
  (humus 2.6 [%])
  (C_per_N 11.0 [g C/g N]))
```

parameterisation based on minimum requirements is shown in box 1.3. Firstly, it is noticed, that

Box 1.3: Defining a column.

```
;;  Parameterisation of column (Fine sandy loam)
(defcolumn "Fine sandy loam" default
     (Soil (MaxRootingDepth 100 [cm])
           (horizons (  -30 [cm] "Ap F.S.L.")
                     (  -80 [cm] "B F.S.L.")
                     ( -400 [cm] "C F.S.L.")))
     (OrganicMatter original (init (input 3000 [kg C/ha/y])))
     (Groundwater deep))
```

the column is given the name `"Fine sandy loam"`, secondly, that the parameterisation comprises two sections, a soil section and a groundwater section, as the bioclimate section is omitted. The soil section contains information on the maximum rooting depth in the soil and the soil horizons of the profile. The A-horizon extends down to 30 cm depth, the B-horizon is found in the interval 30-80 cm and C-horizon starts at 80 cm depth and continues down to at least 400 cm depth, where the calculations stop.

The organic matter section gives information used in initialization of the MIT-model (*M*ineralization-*I*mmobilization-*T*urnover model). The figure 3000 kg C/ha/y indicated the average annual input of organic carbon in the soil in the decade before the start of the simulation. The carbon input comprises carbon in organic fertilizer, plant residuals, and rhizodeposition. The model contains a procedure that automatically parameterize the MIT-model based on this information.

The groundwater section tells that the position of the groundwater table is located deep below the 400 cm limit of the calculations. This means that a free drainage can be selected for the soil water dynamics calculations. Again, when only this minimum information is supplied then the model makes extensive use of default parameterisation.

The next step is to define a list of actions performed in order to grow spring barley; in this case the list is named `SBarley_management`, box 1.4. It is noted that the action list comprises of activities viz. to wait, to plow, to make a seedbed preparation, to sow, to fertilize and to harvest. The two tillage operations, `plowing` and `seed_bed_preparation`, are in fact lists of primitive actions found in the library “`tillage.dai`”. The command sow takes one parameter, which is the name of crop that is to be sown; in this case the name is `"Spring Barley"`. `"Spring Barley"` is the name of a list of crop

Box 1.4: Spring barley management.

```
;; Defining an action list related to management
(defaction SBarley_management activity
  (description "Management plan for spring barley.")
  (wait_mm_dd 3 20)
  (plowing)
  (wait_mm_dd 4 15)
  (seed_bed_preparation)
  (sow "Spring Barley")
  (wait_mm_dd 4 20)
  (fertilize (N25S (weight 95 [kg N/ha])))
  (wait (or (crop_ds_after "Spring Barley" 2.0) ;Ripe
            (mm_dd 9 1)))
  (harvest "Spring Barley"
           (stub 8 [cm])
           (stem 0.70 [])
           (leaf 0.70 [])))
```

parameters, which is found in the library "`crop.dai`", or in fact the parameter list is found in a file which is included (input file) in the `crop.dai`-file. The command fertilize takes up to arguments. The first argument comprises, a name, which in the present case is N25S, and an attribute list. However, only the weight parameter, `(weight 95 [kg N/ha])`, is given here, the remaining of the required parameters are to be found in the library file "fertilizer.dai". The first argument of command harvest is the name of the crop to be harvested, and then follows a list of attributes specifying the stubble length (here 8 cm) and the fraction of straw `(stem 0.70 [])` and leaf `(leaf 0.70 [])` removed from the field at harvest. Defaults are in this case that the stubble length is 0 cm and that all straw and leaf are removed.

Wait statements are used in order to govern the timing of the other management actions. Two types of wait statements are used in the present action list. The first statement tells the model to wait until a certain day in the year defined by month number and day number in the month, e.g. `(wait_mm_dd 3 20)`. The second type waits until a certain condition becomes true. The or-statement becomes true when one of its conditions becomes true. The `crop_ds_after` statement takes two arguments; the first is the name of the considered crop and the second is a boundary development state. If the development stage of the crop is greater or equal to the boundary development stage then the statement is true. The crop development stage is 0 at emergence, 1 at flowering, and 2 at maturing. Hence the statement gets true when the spring barley is ripe. The second condition of the or-statement becomes true when the date is 1^{st} of September `(mm_dd 9 1)`.

Now everything is ready so we can actually begin a simulation. As shown in box 1.5 we activate a column, a stating date and an agricultural management practice. However, we have not selected any output. This is done with the output statement as shown in box 1.6. In the present case we only make use of predefined output logs that can be found in the external library file "`log.dai`". When `harvest` is selected then the harvested yields are written to the output-file "`harvest.dlf`". The extension `.dlf` indicates that the file is written in Daisy-log-format, which is a format that easily can be opened in a spreadsheet. Furthermore it indicates that the output can be inspected by use of the Daisy output-viewer (`ShowDaisyOutput.exe`). However, the only exception from the latter is the `harvest.dlf`-file; all other

Box 1.5: Activate simulation.

```
;;  Selecting a previously defined column.
(column ‘‘Fine sandy loam’’)

;; Selecting the of the beginning of the simulation.
(time 1993 1 1)

;; Selecting the agricultural management and the end of simulation
(manager activity
   SBarley_management
   (wait_mm_dd 1 1)
   stop)
```

Box 1.6: Select output files.

```
(log_prefix "E1/")
(output harvest
        "Crop Production"
;;      Water balance of the upper 100 cm
        ("Soil water" (to -100 [cm])(when daily)
          (where "Daily_WB.dlf"))
        ("Soil water" (to -100 [cm])(when monthly)
          (where "Monthly_WB.dlf"))
;;      Nitrogen balance of the upper 100 cm
        ("Soil nitrogen" (to -100 [cm])(when daily)
          (where "Daily_NB.dlf"))
        ("Soil nitrogen" (to -100 [cm])(when monthly)
          (where "Monthly_NB.dlf"))
;;      Soil profile data
        ("Soil Water Content" (when daily))
        ("Soil Water Potential"(when daily))
        ("Soil NO3 Concentration"(when daily)))
```

output files can be viewed by the output-viewer. Furthermore `"Crop Production"` is selected. In this case daily (default) values of variables pertaining to crop production is written to "`crop_prod.dlf`". It is noted that the water and nitrogen balances is of the upper 100 cm (the command: `(to -100 [cm]))` and that both the output frequency daily and monthly is selected (the when-command) and that the different output frequencies are written to different output-files (the where–command). In addition some profile data are selected as daily-values.

The command `(log_prefix "E1/")` will place all output files in a subfolder (`E1`) of the current folder. You must create the subfolder before starting the simulation.

Fill in the necessary information in the Daisy-setup-file `Exercise01.dai` and run a simulation by dragging and dropping the setup-file at the Daisy executeable. Inspect the created output-files by use of the output-viewer and an EXCEL-spreadsheet. Construct a water balance, a mineral nitrogen balance, an ammonium balance and a nitrate balance.

2 Setting Hydraulic Properties

The objective of this exercise is to utilize measured soil hydraulic properties, e.g. the soil water retention curve and the hydraulic conductivity curve. Based on measurements soil water retention and unsaturated hydraulic conductivity table 2.1 has been prepared.

Table 2.1: Mualem-van Genuchten parameters of soil hydraulic properties based on data from [Jacobsen, 1989]. Parameter fitting is done by using the RETC software [Genuchten et al., 200]

Depth	θ_s	θ_r	α	n	K_s
cm			cm^{-1}		cm/h
00–30	0.403	0.000	0.0385	1.211	7.52
30–80	0.421	0.000	0.2605	1.135	14.5
80–	0.401	0.000	0.0570	1.131	1.65

The soil hydraulic properties are a part of the soil horizon. The Daisy code is able to use a number of different descriptions or models of soil hydraulic properties [Abrahamsen, 2003a]. The soil hydraulic properties parameters are written to the Daisy-setup-file in the `defhorizon` section as illustrated in box 2.1.

Box 2.1: Hydraulic parameters

```
(defhorizon "Ap F.S.L." FAO3
  (description "Data from O.H. Jacobsen (1989)")
  ;; Insert other parameters here.
  (hydraulic M_vG
             (Theta_res 0.0 [%])
             (Theta_sat 40.3 [%])
             (alpha 0.0385 [cm^-1])
             (n 1.211 [])
             (K_sat 7.52 [cm/h])))
```

`M_vG` is the name of the selected hydraulic model (Mualem-van Genuchten model) and the following attribute list is the parameterisation of this model.

Compare the water and nitrogen balance results obtained with the parameterised Mualem–van Genuchhten model with the corresponding results obtained with the pedotransfer function.

3 Calculating Hydraulic Properties

Measured basic soil data for a coarse sandy soil is shown in table 3.1 through table 3.3. Use the RETC software to estimate the necessary parameters in order to build a parameterisation of this soil.

Table 3.1: Basic soil horizon parameters of a coarse sandy soil [Jacobsen, 1989].

Depth cm	Dry bulk density g/cm^3	Humus	Clay $<2\mu$m	Silt	Sand $>50\mu$m
00–30	1.49	0.023	0.039	0.072	0.866
30–	1.49	0.004	0.029	0.023	0.944

Table 3.2: Soil water retention data [Jacobsen, 1989].

Depth cm	Porosity	pF 1.0	pF 1.2	pF 1.7	pF 2.0	pF 2.2	pF 2.7	pF 4.2
00–30	0.427	0.375	0.364	0.211	0.168	0.149	0.119	0.050
30–	0.436	0.369	0.343	0.097	0.073	0.059	0.045	0.020

Table 3.3: Soil hydraulic conductivity data [cm/h] [Jacobsen, 1989].

Depth cm	Saturation %	pF 1.0	pF 1.2	pF 1.4	pF 1.7
00–30	21.7	10.03	7.18	3.95	0.032
30–	39.5	4.59	2.93	0.15	0.002

So far we have used the default discretization in our simulations. Introduce your own discretization and run a simulation. It is hard rule that numeric layers may not cross horizon boundaries. It is a rule of thump that the size of a numeric layer should not exceed twice the dispercivity of the soil (the dispercivity is a member of the soil as defined within the column and its default value is 5 cm). The numeric layers are defined by their lower boundary (zplus) starting from the top. An example of a discretization is shown in box 3.1. In box 3.1 the specification of the dispercivity might as well be omitted as it only specifies the default value.

Does the crop in this example experience water stress?

4 Irrigation

The objective of this exercise is to introduce irrigation in the management practice.

Develop an irrigation strategy for the spring barley grown on a coarse sandy soil (exercise 3). The *Daisy Tutorial* section 5.5 describes how this can be done, and further information can be obtained from the *Daisy Program Reference Manual*.

Box 3.1: Discretization

```
(defcolumn "Coarse sand" default
  ;; Insert other parameters here.
  (Soil (MaxRootingDepth 50 [cm])
        (dispercivity 5 [cm])
        (horizons (  -30 [cm] "Ap C.S")
                  ( -320 [cm] "C C.S")))
  (Movement vertical
    (Geometry (zplus -2 -4 -7 -10 -13 -19 -22 -25 -27 -30 -35 -40 -45 -50
                     -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -120 -130
                     -140 -150 -160 -170 -180 --190 -200 -210 --220 -230
                     -240 -250 -260 -270 -280 -290 -300 -310 -320 [cm])))
```

5 Groundwater

The objective of this exercise is to introduce tile drains and the calibration of the interface to the groundwater.

How tile drains can be introduced in the simulation is described in *Daisy Tutorial*, section 4.4. The soil and the management are characterised as in exercise 2. We know the distance between the drainpipes are 18 m (default value) and that the pipes are located at 110 cm depth (default value. Assume further that an aquitard of thickness 2 m (default value) is located at 2.20 – 4.20 m depth and that the aquitard is overlaying an aquifer, which is characterised by a pressure potential of 200 cm at the top of the aquifer (the interface between the aquitard and the aquifer). Measurement shows that approximately 2/3 of the net precipitation in 1993 was lost through the drainpipes. Calibrate the hydraulic conductivity of the aquitard so that the simulated value matches the measured value.

In the present case the lowest soil horizon ends at 2.2 m depth (i.e. the top of the aquitard). The new lower boundary condition is introduced by entering

```
(Groundwater pipe (K_aquitard 0.01 [cm/h]))
```

instead of

```
(Groundwater deep)
```

The numerical value assigned to `K_aquitard` is the value used for the calibration.

6 Rotations

The objective of this exercise is to introduce the simulation of a crop rotation.

Assume the same setup for the column as in exercise 5.

A common crop rotation that is used at arable farms as well pig farms are: spring barley, winter barley, winter rape, winter wheat and winter wheat. A suggestion for management practices typical for Danish conditions pertaining to this rotation is shown in table 6.1.

It is recommended to build the management practices for each crop individually as in exercise 1 for the spring barley. Note that winter wheat following a winter rape and winter wheat following a winter

Box 6.1: Rotation.

```
;; Spring Barley setup for an arable farm rotation.
(defaction sbarley_A_F_R activity
  (wait_mm_dd 3 20)(plowing)
  (wait_mm_dd 4 05)(fertilize (N25S (weight 121 [kg N/ha])))
  (seed_bed_preparation)(sow "Spring Barley")
  (wait (or (crop_ds_after "Spring Barley" 2.0)(mm_dd 08 30)))
  (harvest "Spring Barley" (stub 8 [cm])(stem 1.0 [])(leaf 1.0 [])))

;; Winter Barley setup for an arable farm rotation.
(defaction wbarley_A_F_R activity
  ;; Insert management actions here.
)

;; Winter Rape setup for an arable farm rotation.
(defaction wrape_A_F_R activity
  ;; Insert management actions here.
)

;; Winter Wheat setup for an arable farm rotation (after a rape).

(defaction wwheat_A_F_R_1 activity
  ;; Insert management actions here.
)

;; Winter Wheat setup for an arable farm rotation (after a cereal).
(defaction wwheat_A_F_R_2 activity
  ;; Insert management actions here.
)

;; Building an arable farm rotation.
(defaction ArableFarmRotation activity
  sbarley_A_F_R wbarley_A_F_R wrape_A_F_R wwheat_A_F_R_1 wwheat_A_F_R_2)
```

Table 6.1: Management practices of the rotation: spring barley, winter barley, winter rape, winter wheat and winter wheat. Typical dates for the field operations are given parentheses.

Activity	S. Barley	W. Barley	W. Rape	W. Wheat	W. Wheat
Plowing	Spring (Mar. 20)	Autumn (Sep. 01)	Autumn (Aug. 15)	Autumn (Sep. 01)	Autumn (Sep. 01)
Seedbed preparation & sowing	Spring (Apr. 05)	Autumn (Sep. 10)	Autumn (Aug. 20)	Autumn (Sep. 10)	Autumn (Sep. 10)
Harvest	Ripe	Ripe	Ripe	Ripe	Ripe
Straw removal	Yes	Yes	No	No	No
Fertilization	121 kg N/ha (Apr. 05)	60 kg N/ha (Mar. 25) 81 kg N/ha (Apr. 25)	25 kg N/ha (Aug. 20) 130 kg N/ha (Mar. 05)	55 kg N/ha (Apr. 05) 74 kg N/ha (May 05)	60 kg N/ha (Apr. 05) 101 kg N/ha (May 05)

wheat are not identical. When a management practice for each of the individual crops has been build then the crop rotation can be build as illustrated in box 6.1.

Simulate the suggested arable farm rotation (only mineral fertilizer) begining the simulation period January 1st 1994. While running the simulation, try to guess when the simulation will end, i.e. the year the second winter wheat is harvested. Does the simulation run over time? If so, check that you always harvest the last crop before sowing the next.

7 Organic Fertilizer

The objective of this exercise is to introduce the use of organic fertilizer in the simulation of a rotation.

Modify the setup of exercise 6 in order to simulate a pig farm rotation where the main source of fertilizer is pig slurry. The fertilization practice is shown in table 7.1.

Table 7.1: Fertilization practices of the pig farm rotation: spring barley, winter barley, winter rape, winter wheat and winter wheat. Typical dates for the fertilization are given parentheses. Ammonium loss during application is given in squared brackets.

Activity	S. Barley	W. Barley	W. Rape	W. Wheat	W. Wheat
Plowing	Spring (Mar. 05)	Autumn (Sep. 01)	Autumn (Aug. 15)	Autumn (Sep. 01)	Autumn (Sep. 01)
Fertilization (pig slurry)	30 T.w.w./ha (Mar. 05) [5%]	18 T.w.w./ha (Apr. 20) [10%]	20 T.w.w./ha (Aug. 15) [5%] 20 T.w.w./ha (Mar. 20) [10%]	18 T.w.w./ha (Apr. 20) [10%]	18 T.w.w./ha (Apr. 20) [10%]
Fertilization (mineral fertilizer)		68 kg N/ha (Mar. 25)	24 kg N/ha (Mar. 05)	63 kg N/ha (May 05)	95 kg N/ha (Apr. 05)

The present version of the Daisy model has a deficiency in the way it treats organic fertilizers that are surface broadcasted. The mineral part of the organic fertilizer will eventually enter the soil and can subsequently be utilized by the plants, but the organic part will stay at the surface until the next soil tillage operation, and while staying at the surface no turnover takes place. To compensate for this it is recommended to incorporate the applied organic fertilizer into the upper few centimetres of the soil. Box 7.1 shows how this can be modelled. For further information see *Daisy Program Reference Manual* and *Daisy Tutorial*. Box 7.1 indicates that a pig slurry (name: `pig_slurry`) already has been

Box 7.1: Defining an organic fertilizer.

```
;; Defining a pig slurry where 5% of the ammonium content is lost at
;; pplication (defam = defining added matter)
(defam "Slurry_Vol05%" pig_slurry
  (volatilization 5 [%])
  ;; Other parameters.
)

;; Spring Barley setup for a pig farm rotation.
(defaction sbarley_P_F_R activity
  (wait_mm_dd 3 05)
  (fertilize ("Slurry_Vol05%" (weight 30 [Mg w.w./ha]))(to --5 [cm]))
  (plowing)
  (wait_mm_dd 4 05)
  (seed_bed_preparation)
  (sow "Spring Barley")
  (wait (or (crop_ds_after "Spring Barley" 2.0)(mm_dd 08 30)))
  (harvest "Spring Barley" (stub 8 [cm])(stem 1.0 [])(leaf 1.0 [])))
```

defined (see "`fertilizer.dai`"). How the volatilization is set can be found in *Daisy Program Reference Manual*. Look up "volatilization" in the index.

When inspecting the simulation results please notice the temporal development in soil microbial biomass pools. Does this development look reasonable?

8 Warm-Up Period

The objective of this exercise is to introduce a warm-up period, the purpose of which is to make the simulation less sensitive to the initial conditions.

Repeat the simulation of exercise 7 with the modification that a warm-up period is inserted in front of the simulation (1994–1998). It is a rule of thump to select one rotation or at least 4 years of simulation as a warm-up period. Hence in the present case the simulation should begin January 1^{st} 1989. Be sure to repeat the rotation; an example can be found in section 5.1.1 of *Daisy Tutorial*.

Did the warm-up period improve the credibility of the simulation?

9 The MIT Model

The objective of this exercise is to calibrate the MIT-model (Mineralization-Immobilization Turnover).

In box 1.3 organic matter section was introduced. The total carbon content of the soil is calculated from the humus contentwhich was defined in the horizon section (box 1.2). The MIT model comproses several organic matter pools and the toal carbon content is distributed among these pools by the initialization procedure that makes use of anual input of organic carbon. This, in combination with a warm-up period, will often give a reasonable initializatin and hence a reasonable N-mineralization. However this can be fine tuned by introducing the `background_mineralization` init parameter, like this:

```
(OrganicMatter original
               (init (input 3000 [kg C/ha/y])
                     (background_mineralization 30 [kg N/ha/y])))
```

Daisy will then attempt to initialize the organic matter pools so the total mineralization is 30 kg N/ha/y higher than the amount of organic bound nitrogen added to the system together with the 3000 kg C/ha/y we specified above. In other words, at the time we start the simulation the amount of organic bound nitrogen in the soil is expected to decrease (be released) at a rate of 30 kg N/ha/y.

In certain cases the model may not be able to initialize itself, and it may be necessary to park some of the soil organic carbon in an inactive pool. This is done be entreing the following parameter in the `defhorizon` section

```
(SOM_fractions -1 -1 xxx)
```

where *xxx* is the inactive fraction of the soil organic carbon.

A way to estimate the N mineralization level of the system is to grow an unfertilized plot and measure the nitrogen content of the crop at harvest. Consider the agro-ecosystem of exercise 8 and assume that in 1993 and 1994 an unfertilized plot were grown with winter wheat. The above ground part of the crop was harvested in the two years and the biomass was analyzed for its N content. The harvested nitrogen was 102 kg N/ha and 60 kg N/ha in 1993 and 1994, respectively. Use this information to calibrate the MIT model by modifying the background mineralization parameter, and if necessary, the `SOM_fractions` parameter.

10 Building a Weather File

The objective of this exercise is to build a weather file.

The Daisy weather-file is written in the Daisy weather format (extension `dwf`). In front the weather data is a header as shown in Box 10.1 The first line in the header tells Daisy that the present file is written in the Daisy weather format version 0.0 (the only version implemented so far). Then follows a number of keywords: `Station`, `Elevation`, `Longitude`, `Latitude`, and `TimeZone`; defining name and location of the weather station where the data were measured. `Surface`: reference refers to the surface above which the weather data was measured (reference is short grass common for most weather stations). `ScreenHeight` gives the height at which air temperature (and humidity and wind speed if measured) was recorded. `Begin` and `End` defines the date of the fist and last record in the dataset. `NH4WetDep`, `NH4DryDep`, `NO3WetDep`, and `NO3DryDep` define deposition parameters at the location. `TAverage`, `TAmplitude`, and `MaxTDay` define the thermal regime of locality (annual average air temperature, the amplitude of the annual air temperature cycle, and the day of the year when maximum air temperature is expected on average). The `Timestep` keyword tells the model basic time-step of the data, in the present case we are dealing with daily values. `PrecipCorrect` gives twelve correction factors used to correct the precipitation month by month. In the present case the precipitation is measured at the soil surface, hence no correction is needed for the aerodynamic effect. The next three lines form the header for the actual weather data, which in the present example are written in a TAB separated format.

Box 10.1: Beginning of weather file.

```
dwf-0.0
Station: Taastrup
Elevation: 30 m
Longitude: 12 dgEast
Latitude: 55 dgNorth
TimeZone: 15 dgEast
Surface: reference
ScreenHeight: 2 m
Begin: 1962-04-01
End: 2001-10-07
NH4WetDep: 0.9 ppm
NH4DryDep: 2.2 kgN/ha/year
NO3WetDep: 0.6 ppm
NO3DryDep: 1.1 kgN/ha/year
TAverage: 7.8 dgC
TAmplitude: 8.5 dgC
MaxTDay: 209 yday
Timestep: 24 hours
PrecipCorrect: 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
--------------------------------------------------------------
Year Month Day  GlobRad AirTemp Precip
year month mday W/m^2  dgC     mm/d
1962 4     1    120.4   2.8     0.0
1962 4     2    130.7   4.4     5.3
1962 4     3    39.1    6.8     2.9
... more climate data here ...
```

The present example shows a minimum weather data required. However, Daisy can make use of more detailed data (see *Daisy Program Reference Manual*).

Build a Daisy weather file based on the data in the spreadsheet `AArslevWeatherDat.xls`. Årslev is a locality located at the center of Funen. The precipitation is measured at 1.5 m height and the shelter category is B. The surface of weather station is short grass and the screen height is 2 m. The precipitation correction is found in table 10.1

Table 10.1: Correction of point precipitation as function of shelter categories [per cent], [Allerup et al., 1998].

Shelter	J	F	M	A	M	J	J	A	S	O	N	D	Year
A	29	30	26	19	11	9	8	8	9	10	17	26	16
B	41	42	35	24	13	11	10	10	11	14	23	37	21
C	53	53	45	29	16	13	12	12	13	17	29	48	27

11 A New Organic Fertilizer Parameterization

The objective of this exercise is to introduce a new organic fertilizer in fertilizer library.

The composition of a mixed slurry is: dry matter content 4.8%; carbon content 36% (dry matter basis); nitrogen content 10.5 % (dry matter basis); ammonium content 8.5% (dry matter basis); and nitrate contend 0.0% (dry matter basis). A batch experiment has shown that the mineralization of the mixed slurry approximately can be described by splitting the organic matter into two pools and assume first order degradation kinetics for the pools. The resistant pool constituted 79% of the C with a half-life of 150 days and the more easy decomposable pool constituted 21% of the C with a half-life of 15 days. From previous experience it was suggested that the C/N of the easy decomposable pool should be around 5.

Include the mixed slurry in the fertilizer library. Help on how to write a new parameterization of a new organic fertilizer can be found in the *Daisy Program Reference Manual*, section 11.2 and 3.

Compare the results obtained with the new mixed slurry with the results obtained in exercise 8.

12 Crop Parameterization

The objective of this exercise is to parameterize a maize crop.

The maize parameters found in the crop-file "`PioneerMaize.dai`" are mainly based on [de Vries et al., 1989]. However, the measured data of LAI, and leaf, stem, and cob weight from 1998 found in the spreadsheet "`MaizeProd.xls`" are from a silage maize. Define a new maize by assuming that the silage maize parameters partly resembles the Pioneer Maize parameters. Calibrate selected parameters making use of the measured data. When a new slightly different parameterization is defined it recommended not copying parameter settings and making changes, but instead to derive the new parameterization from the existing one. This makes it easy to see where the parameterizations differ.

The main elements of a crop definition are shown in box 12.1. The crop definition comprises a number of subsections: `Devel` contains parameters pertaining to the phenological development of the crop; `LeafPhot` parameters govern the leaf photosynthesis; `Canopy` parameters are describing LAI development and distribution; `Root` contains root penetration and root distribution parameters; `Partit` governs the partition of assimilates; `Prod` are dealing with respiration and production parameters; `CrpN` parameters are controlling the plant relations; and `Harvest` parameters are dealing with the harvest itself as well as

Box 12.1: Crop definition.

```
(defcrop "Pioneer Maize (WS)" default
  ;; Phenological development :
  ;; Emergence   DS = 0
  ;; Flowering   DS = 1
  ;; Maturity    DS = 2
  (Devel default
    ;; Temperature sum calculated from sowing to emergence.
    (EmrTSum  350)
    ;; Development rate [d^-1] in the vegetative period
    (DSRate1  0.0265)
    ;; Effect of temperature on development rate in the veg. period
    (TempEff1 (8. 0.00) (10. 0.30) (15. 0.75) (25. 1.00) (35.  1.20))
    ;; Effect of photoperiod on development rate in the veg. period
    (PhotEff1 (0. 0.90) (12. 1.00) (14. 0.95) (16. 0.90) (24.  0.90))
    ;; Development rate [d^-1] in the reproductive period
    (DSRate2  0.017)
    ;; Effect of temperature on development rate in the rep. period
    (TempEff2 (8. 0.00) (10. 0.30) (15. 0.75) (25. 1.00) (35.  1.20)))
  (LeafPhot
    ;; Insert parameters here.
  )
  (Canopy
    ;; Insert parameters here.
  )
  (Root
    ;; Insert parameters here.
  )
  (Partit
    ;; Insert parameters here.
  )
  (Prod
    ;; Insert parameters here.
  )
  (CrpN
    ;; Insert parameters here.
  )
  (Harvest
    ;; Insert parameters here.
  ))
```

the fate of plant residuals. All crop parameters are defined in *Daisy Program Reference Manual*. When consulting the manual it is noticed that more than one crop model is implemented in the Daisy code. However, in this case we use the standard crop model, which is the default crop model. This crop model resembles the SUCROS model [van Keulen et al., 1982].

Parameters can be given in two ways: 1. as a single value (e.g. `DSRate1`); 2. as a piecewise linear function (e.g. `TempEff1`). The piecewise linear function is defined by a number of points (x,y) on the considered curve. In the example, `TempEff1`, x equals temperature and y equals temperature effect. In the crop definition it is common to make a parameter a function of the development stage (DS). The only exception is the subsection `Devel`, where the parameters governing the DS are defined. Notice that `Devel` requires the keyword default because more that one model describing the development is implemented.

We have no information on roots, plant nitrogen dynamics or plant residues. Hence, in the calibration we need not consider the `Root`, `CrpN` (the nitrogen supply is ample so we need not consider N-stress), and `Harvest` sections. We have no reason to believe that the present maize variety should differ from the pioneer maize in respect to respiration, hence we may want to keep these parameters without change (keeping the `Prod`–parameters). The relevant `Canopy`-parameters in this context are pertaining to the leaf area. The specific leaf area (LAI per unit leaf weight) can be calculated directly from measured data (it is noticed that the value is not constant during the growth period, however the model can take this into account, see *Daisy Program Reference Manual*).

If we want to change the development rate of the maize in the vegetative period this can be done by writing:

```
(defcrop "Exercise 12 Maize" "Pioneer Maize (WS)"
  (Devel original
    (DSRate1  0.0160)))
```

The keyword original retains the original parameterization, hence only the `DSRate1` is changed.

In this way the selected parameters can be changed one by one in order to fit the data. We may have to do quite a number of simulations when calibrating the model. In order to save time it is possible to make use of the checkpoint facility (see *Daisy Tutorial*). By using this facility it is possible to write a checkpoint at a predefined time and then later continue the simulation from that point in time. In the present example we run the warm-up period and then make a checkpoint just before the sowing of the maize (e.g. `(checkpoint (when (at yyyy mm dd hh)))`). The checkpoint is to be inserted among the log files in the output section. Another facility which also often is helpful is the `(activate_output (after yyyy mm dd hh))`, which is used to suppress output during warm-up periods.

Use the calibrated setup of exercise 9 and assume that the maize is sow the year after the second year winter wheat. 50 ton w.w./ha was surface broadcasted and plowed in 27. April 1998. Maize was sown 4. May and 142 kg N/ha in ammonium nitrate was applied the same day. The Maize was harvested for silage 3. November, however it was not ripe at that date.

In the calibration procedure it is advisable to begin with the DS. We have no information of when the different growth stages of the maize occurred. But we have information on the onset of growth of the cobs and we can use this in order to calibrate the development rate in the vegetative period. We have no information that makes it possible do a similar calibration for the reproductive period.

It is recommended that when the DS is calibrated we should continue looking at the `Canopy`-parameters and afterwards at the `LeafPhot`-parameters and `Partit`-parameters.

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