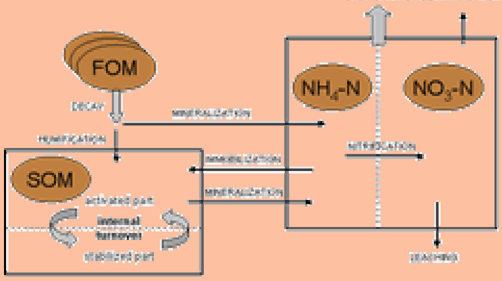
CANDY

Windows Version

CARBON AND NITROGEN DYNAMICS



USER MANUAL

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CANDY

windows version 2.4

CONTENTS

1. Introduction

CANDY simulates the dynamics of Carbon and Nitrogen in the unsaturated (vadose) zone of agricultural used soils. The model application should preferably be focused on sites with a rooting zone of up to 2m. The soil profile is divided into homogeneous layers of 1 dm. The simulation proceeds in daily time steps. Starting from initial values for all variables the model simulates the impact of management and climate on them. The following processes are included:

- Climate conditions (access to database or generating climate date , correction of systematic errors of observed precipitation)
- soil water dynamics (pot. and act. evapotranspiration, percolation through soil)
- soil temperature dynamics
- turnover (mineralisation and humification) of organic matter in soil
- nitrogen dynamics (mineralisation, immobilisation, uptake, leaching, gaseous losses, symbiontic N-fixation)

The system consists of a user interface that organises the access to the data and the preparation of simulation tasks and the simulation model itself. A simulation task consists of a site description and the scenario data. The site description includes the parameters of the soil profile – that is for each horizon at least:

- bulk and substrate density
- soil moisture at field capacity and wilting point
- texture indicator (particles < 6µm)
- saturated conductivity

and the time course of climate data (daily time steps)

- air temperature at 2m (°C)
- global radiation (J/cm²)
- precipitation (mm),

The scenario data consist of a description of initial conditions. These can be reconstructed from detailed observations but should include at least

- crop rotation and average yields before initial point
- relative filling of field capacity

and the farming activities (management) on the field:

- soil tillage and irrigation
- application of mineral fertiliser and organic matter,
- sowing(emergence) and harvest.

The model has successfully been evaluated with different site conditions and scenarios. Results are of course depending on the quality of input data. If high quality input data are available the model error is about 2 VOL% and 20 kg/ha mineral nitrogen.

2. First steps
2.1. Installation

Follow these instructions to install a CANDY system on your computer:

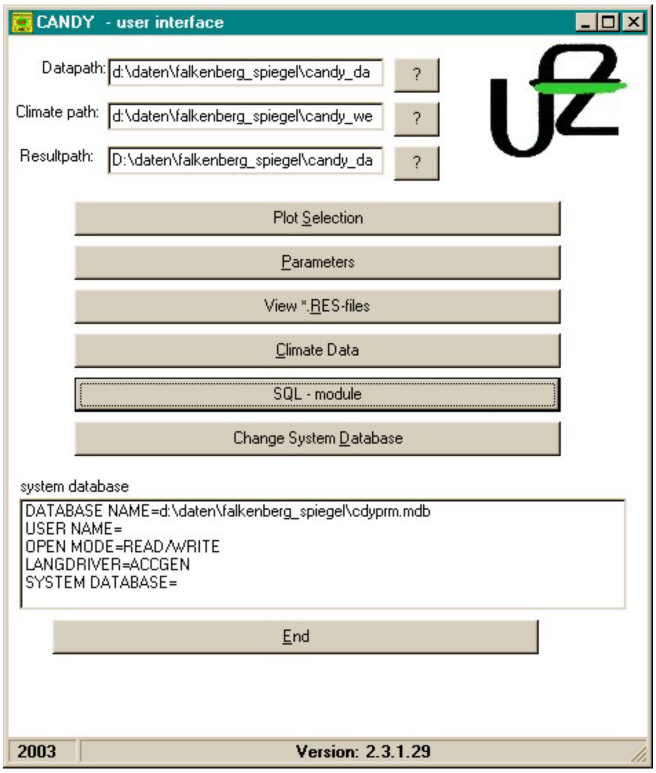
1.) If you have already a Borland Database Engine (BDE) installed on your computer, then be sure to have the configuration file saved to be able to reconstruct this state on your PC. To do that, you have to start the BDE-Administrator and save the current configuration with **Object > save as Configuration.**

2.) Run setup.exe from the installation CD and follow the instruction shown there. It is important to launch the program at the end of the installation process (don't uncheck the option). This runs a batch file *register.bat* which first registrates some important DLL files and afterwards launches the CANDY user interface. If the registration is finished successfully you don't need to start this batch file any more.

3.) After a successful installation you will find new software on your PC:

- the user interface	CDY_UI.EXE	for data processing
- the CANDY model	WCANDY.EXE	for process simulation
- the import module	DB_IMPORT.exe	to exchange data with other CANDY users

To start the system launch **CDY_UI.** Then click on the appropriate buttons to run the single modules. The buttons with a ‚?' label give you the opportunity to change the directories for your data pools.



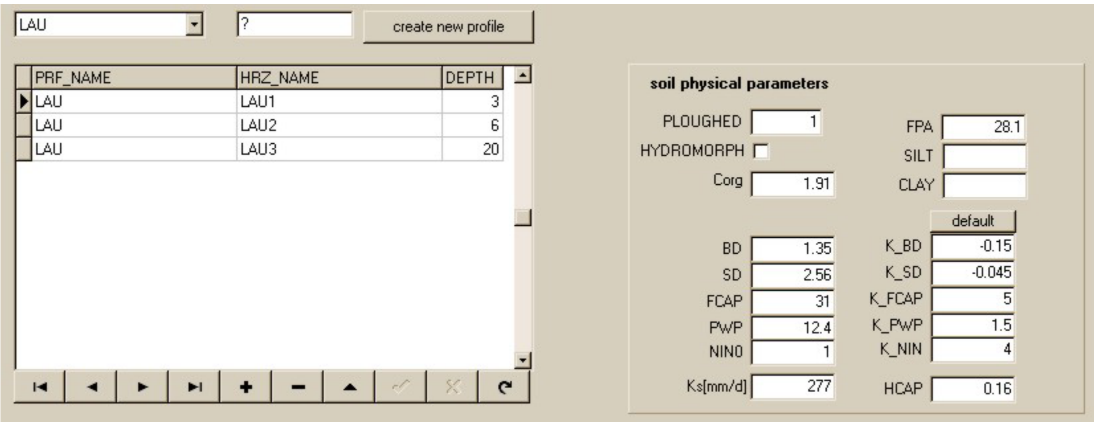
2.2. Preparing a simulation run

Any simulation run should include following steps:

- verification of the parameter environment
- provide or check-up climate date
- select a field or a plot in order to define the simulation object (plot Selection)
- provide data on farming activities (management module under plot selection
- provide data on observations (optional) (measurement module under plot selection)

Parameter environment

Any simulation result is based on the parameters used. As a first step the user should be verify that the available parameters are fitting the special purpose. It may be possible to extend the parameter files provided with the installation software or to adapt single parameter values according to local peculiarities. It is strongly recommended to lock at the description of model algorithms before changing the parameter set. Sensitivity analyses may help to find the most important parameters to be adapted to your local conditions.



editing soil parameters

In nearly all cases users will have to describe the soil profile that should be used for simulation. CANDY is shipped with only few examples of soil profiles. In order to create a new profile, fill in the new name and press the create button. Than you are able to edit the sequence of horizons and the soil physical parameter of each horizon. If you want to insert a new horizon record you can move the cursor to an empty line ([↓]-key) or click the [+] button with you mouse.
The parameters of each horizon are listed on the right hand side of the form. Soil texture is mainly characterised using the concentration of particles < 6.3 µm (clay + fine silt). If available you may as well add the values for clay and silt, but this is not necessary for simulation runs .The other parameters are:

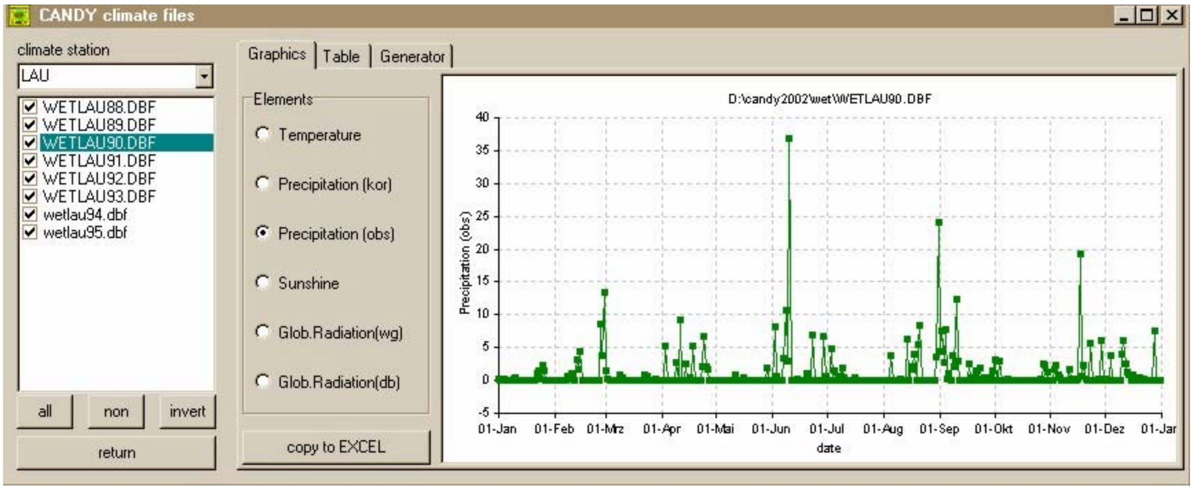
PLOUGHED: 1:tillage horizon, modelling of OM-turnover,   0: otherwise
HYDROMORPH:
if checked: horizon is permanent saturated with water
Corg: organic Carbon content (only required if SOM impact on soil physics should be simulated, in this case the parameters K_xxx specify the changes of BD,SD, FCAP and PWP per 1% Corg .)

BD: bulk density in g/cm³
SD: substrate density in g/cm³
FCAP field capacity in VOL%
PWP permanent wilting point in VOL%
NIN0 standard value (level 2) of Nitrate-N (in kg/ha) in a 1 dm soil layer., K_NIN gives the changing of this amount per level
Ks saturated conductivity in mm/d
HCAP heat capacity of soil substrate (0,16)

climate data

For the whole time interval of the simulation scenario the climate data has to be provided in daily time steps without any gaps. Practice shows that temperature and radiation data can also be used from distant stations, but precipitation data should be used from a local data set. Climate data have to be provided in dbf-files with following name convention.: WET*sssjjjj*.dbf;

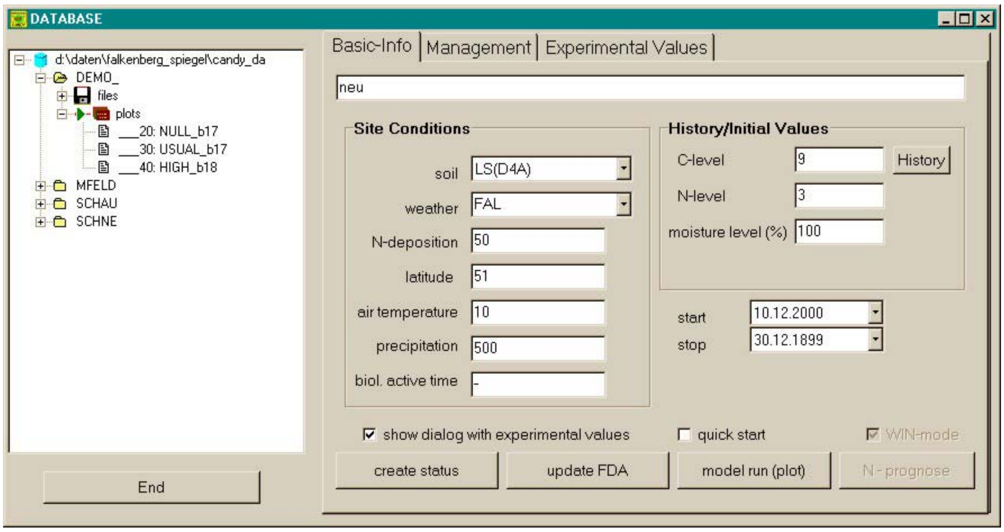
with sss: station shortcut (linked with fix-data)
jjjj: year (in 2 or 4 number format)



climate data module

The module ‚climate data‘ is a possibility to edit or verify the climate data. Of course you could as well use other tools to compile the data. The table –view of the selected climate data file supports also pasting of data from other sources. This has to be done separately for each column. Copy the data to the clipboard as usual and then click the right mouse button on the first (upper) cell where you want to start the pasting and click on the *paste* command of the appearing context menu.

Definition of simulation objects



Module ‚plot selection' – right-click on tree-view-items to activate context menus

A simulation object is a plot or subplot that is considered homogenous. Different plots are aggregated in a database consisting of: fixed data (FDAxxxxx.dbf), management data (MASxxxxx.dbf), measurement data (MWExxxxx.dbf), data about plot history concerning cropping and manure application (MMHxxxxx.dbf), results from manure/slurry analysis (GUExxxxx.dbf) and data about the system state that can be used as initial values (S__xxxxx.stc [binary file]).

A simulation object is defined by its fixed data:

name of the plot

soil profile (selection from popup)

climate data:

- climate station (selection from popup)
- long term average of precipitation and air temperature
- latitude (only to transform sunshine into global radiation)

information about plot history:

- annual input of reproducing Carbon(Crep): This information can be calculated from crop rotation, yield and amount of manure application.
- N input and moisture level: this information is used to select site specific values for mineral soil nitrogen or soil moisture according to the farming intensity as a rough estimation. A better adaptation to real site conditions is possible if measurement data are available.

simulation start:

- date (from here climate and management data are required)
- filling of usable field capacity (uFC) at this time (roughly:: 100% at 1.1.)
- annual nitrogen input from atmosphere in kg N/ha. This value will be varied during a season according to crop coverage (roughly: 60 kgN/ha)

basic information

The Basic-Info tableau shows all data describing the plot ore the simulation scenario. These fixed data are store in the FDA*.dbf file. After editing all fields you should press the *updateFDA* button to save your data. If you want to use status file support (recommended) you should as well press the *create status* button. The status calculation is based on the *History* data, the selected soil profile and the biological active time that will be calculated from soil texture, temperature and precipitation. If you change these data you should create a new status record in any case ! There are some crucial data on this tableau – which means that they are hard to estimate.

N-deposition: Whilst many agricultural advising services deny a considerable diffuse input of nitrogen from the atmosphere there is experimental proof of the relevance of this matter flux from long term experiments. Most European long term experiments have a control plot with an annual nitrogen offtake of about 50 to 60 kg/ha without depletion of soil. To enable this nitrogen in crop production you have to set the N-deposition rate to a similar value.

moisture level: If you start the simulation in the beginning of a year in most cases a 100% filling of field capacity is a wise estimation. If you start after harvest it needs local experience to guess a reasonable value. Anyway it would be best to have observations of soil moisture dynamics. In this case you could use the measurement data to adapt the model and to validate your soil parameters.

N level: Similar to the moisture level the best way of system adaptation in terms of mineral nitrogen would be based on measurement data. If they are not available you depend on local expertise to estimate this value. Since this is an indicator 1 stand for low input agriculture, 2 symbolises the normal level and 3 shows a high input farming. At run time the N-level value is used to initialise the mineral nitrogen distribution over the soil profile. The N-storage (nitrate N) of a soil layer i is calculated after following equation:

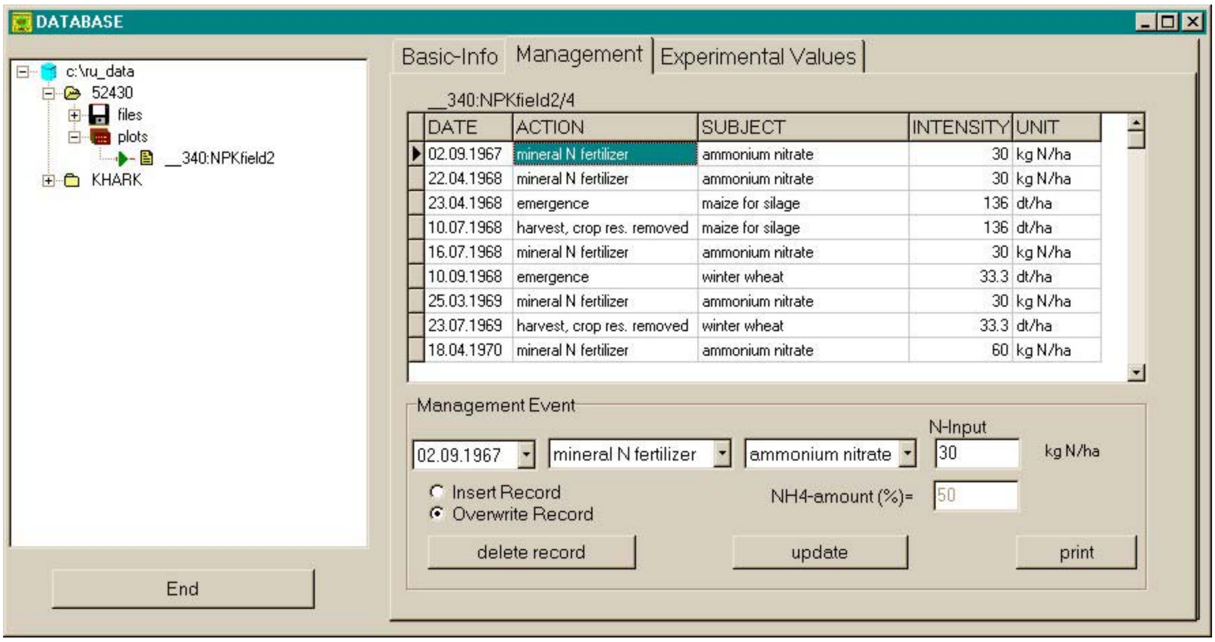
N[i]:= NIN0+k_NIN*(N-level-2)

with NIN0 and k_NIN reading from soil parameters (see there)

C-level: This value (also referred to as Crep) is important toinitialize the proper humus level of the simulation object. Again – the best way of adaptation would be measurements of hot water soluble Carbon, decomposable Carbon or organic Carbon (the first and the last will internally be changed into decomposable Carbon.

If you consider the soil to be near its steady state according the previous land use (which is the only possible hypothesis if there are no further information and you want to run a simualtion) the humus level will be calculated from the average flux of reproducing Carbon – which is entering the SOM – and the estimated biological activ time. To help you with the estimation of the C-level (which should be about 8..12) you could start a Crep-calculator clicking the *History* button. The History-window has a Croplist (left) and a list of added organic matter (right) – beside harvest residues and roots. You have to specify type and amount of the items and calculate their abundance in the crop rotation. If manure was applied at a rate of 300 dt/ha every 3 years you should specify 300 and 33% - or 100 and 100%. The coresponding Crep-value will be calculated and used in the basic-info after closing the History window.

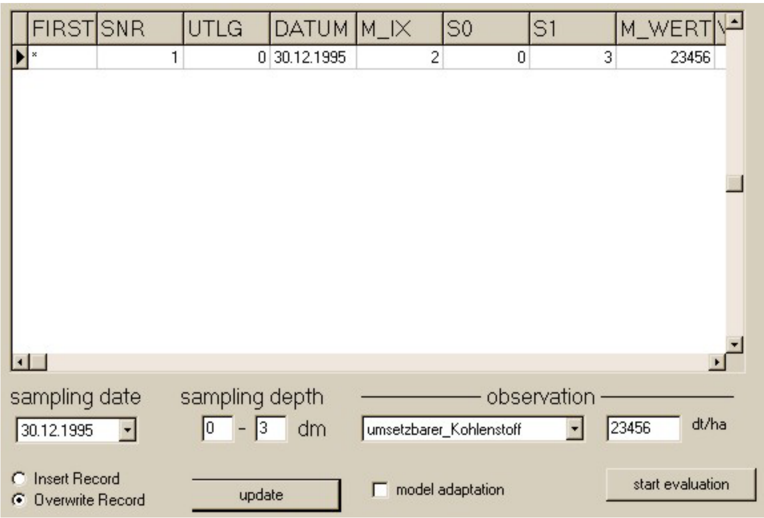
management data



editing management data

Select the management tableau to edit the farming activities for your simulation scenario. Click on a record in the table, change the information using the fields on the lower part of the form and press the insert/update button to save your data. If you want to insert new records you have to click on the appropriate radio button.

experimental values



editing measurement data

Select the measurement tableau in the plot selection module to edit your observation data in the same way as the management data. If you want the model to fit right through a data point, you should check the adaptation option. In this case internal model values will overwritten with the observed value. Usually you won't check this option and CANDY writes the internal value into the table to give you the opportunity for an assessment of the simulation results.

creating and deleting items

creating a new database:

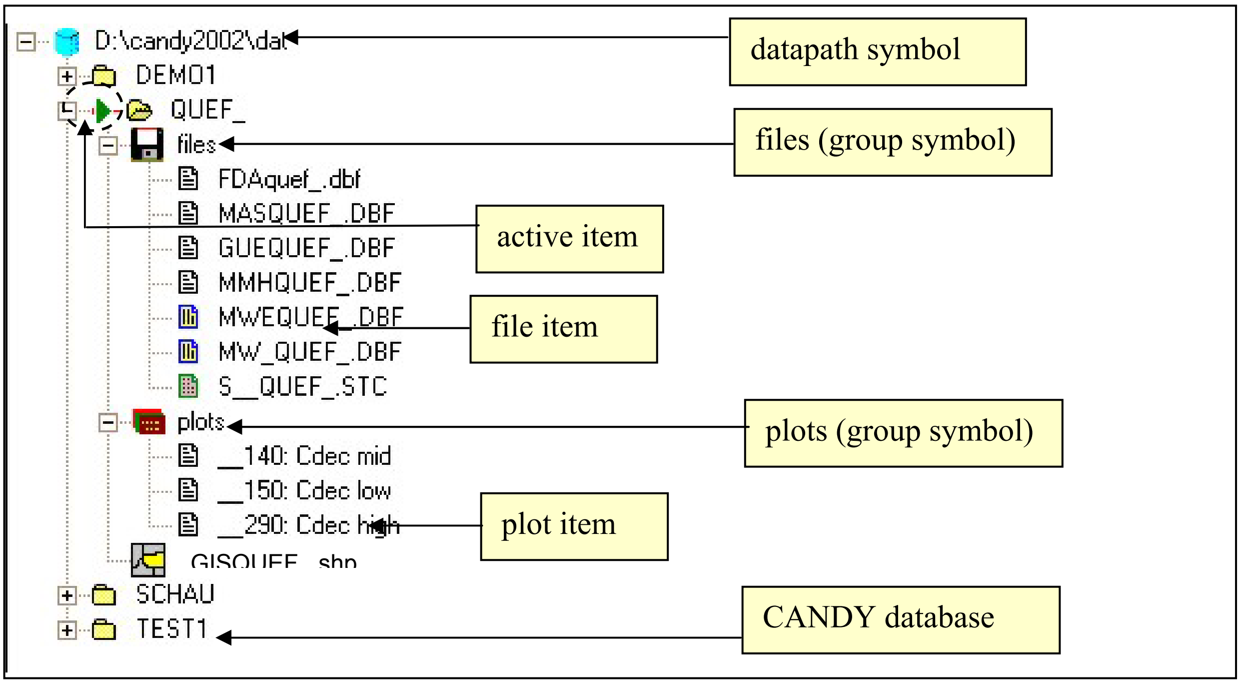
right-click the uppermost (database) symbol in the tree view and click on *create a new database* in the context menu. In the subsequent dialog you have to enter the name (5 characters) of the new CANDY database.

creating a new plot, deleting plots:

right-click the *plots* symbol of the database to be extended, select the *add a new plot* option in the context menu. If you want to use data from another plot (even from another database) - open the appropriate tableau (management for management data) and move the data (drag and drop) from one plot item on the tree view to another.
Select the option *delete active plot* from the context menu to delete the activated plot (indicated by a yellow symbol in the tree view)

editing tables of the user data:

Activate the *files* symbol of the appropriate database and then the table (dbf-files only) to be changed. You may edit the data directly in the table view. To insert new records, move the pointer to the last record and press the [↓] key. The data are saved leaving this record. To delete a record you have to press [CTRL]+[DEL] and confirm the deleting action. Deleting a record in your FDA table means to remove a plot from the database, but without deleting the corresponding records in the MWE and MAS file.
If you want to edit the MW_ table in this way you have to hold down the [ALT] key clicking on the MW_ item and you will have the table view instead of the evaluation module activated.



tree view of the plot selection module

deleting a database:

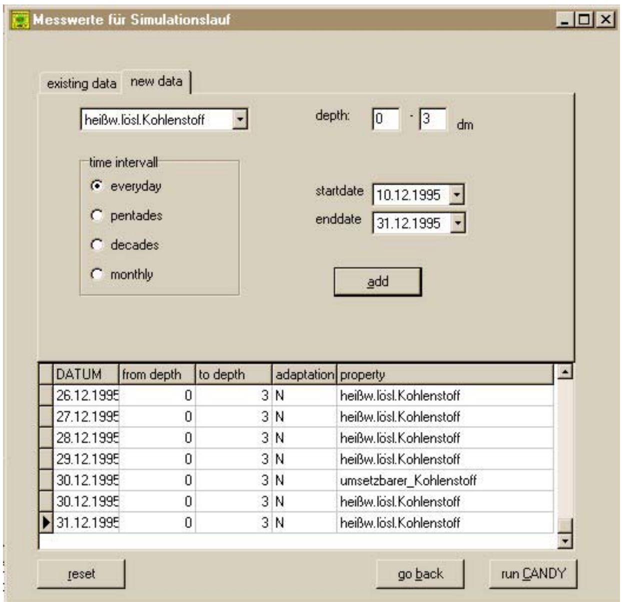
The context menu of a CANDY database includes this option. There will be a warning that you are going to delete **all** plots of this CANDY database.

2.3 Start of the simulation runs

This paragraph explains the way you will start simple model runs. There are some more sophisticated options to mange the simulation for a whole database that will write results into an ACCESS database. These options (scenario and group simulation) may be activated via the context menu of the CANDY database in the tree view. (see also 2.6).

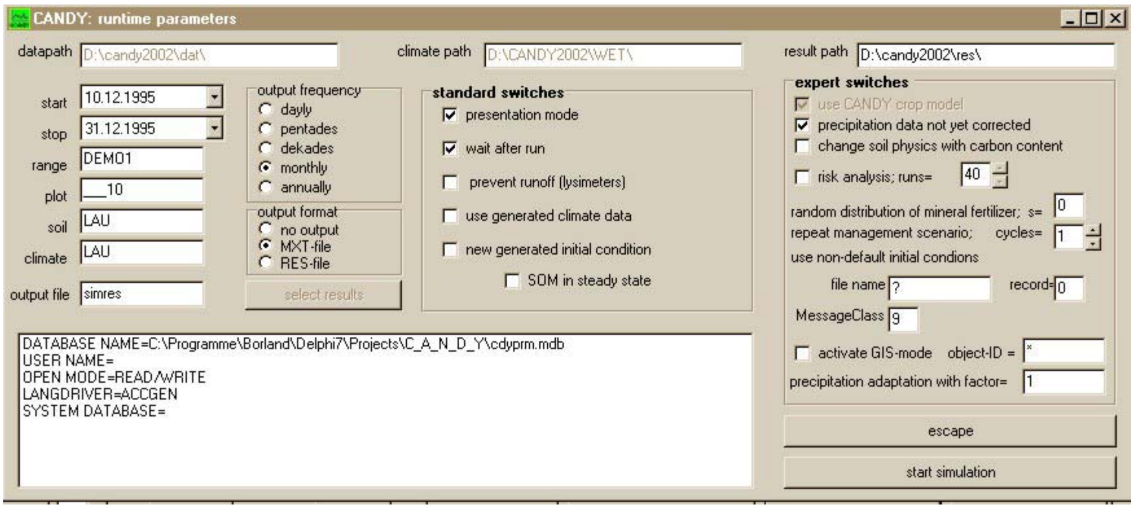
In the Basic-Info tableau of the plot selection module you will find the button to run the simulation model. If the button is pressed the system creates and activates a batch file to call the simulation model (cndrun.bat). This batch file can be saved and modified by experienced users in order to run the model without using the interface program.

There are two options to select. The dialog with experimental data (checked on default) gives you the opportunity to select records from the measurement data that should be used for this simulation run. Additionally you can create new records (without observation data) to extract specific results from the model. The records compiled within this dialog will be stored in a temporary file (MW_xxxxx.dbf).



measurement data dialog

The quick start option is usually unchecked. If you check this option you will immediately run the model without the opportunity to edit model switches. If the option is unchecked the model comes up with a window that contains all parameter for the simulation run and some elements to modify the behaviour of the model.



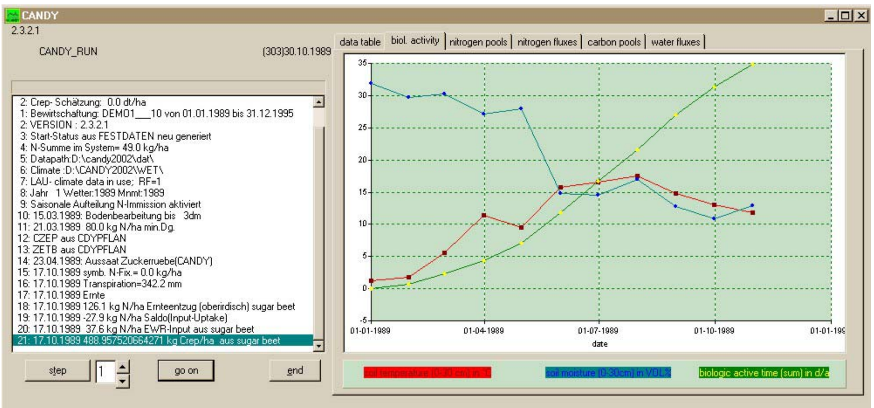
The recommended output format is the RES-file. You may select the results that you want to be recorded in the selected output frequency during the simulation. RES-files have an ASCII format and can be used with any text editor. From the user interface you may start a special viewer for these files with an option to export data into an EXCEL spreadsheet. The name of the output file can be changed by the user. There will be no warning if a file will be overwritten during simulation.

<u>standard switches:</u>

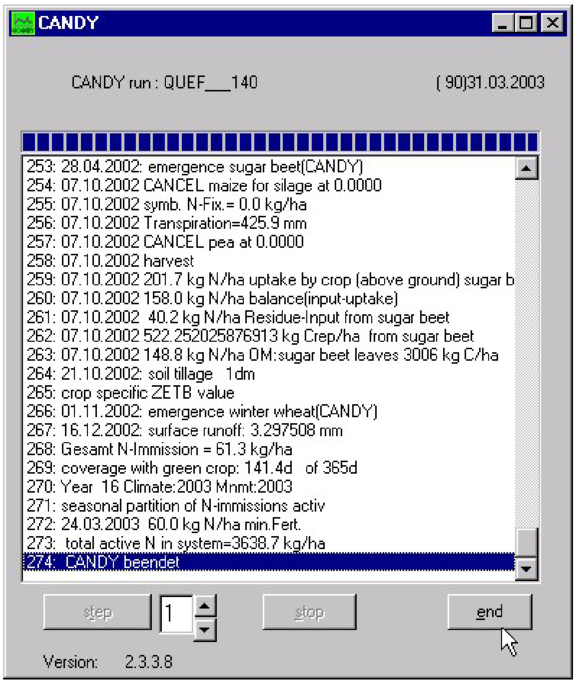
- presentation mode: producing an additional graphical output during simulation
- wait after run: model window stays on screen after finishing the simulation
- prevent runoff: no surface runoff occurs, water surplus stays on top
- generated climate: climate data will be generated during simulation; to use this option, the preparation of a generator file (*.per) is required.
- new initial cond.: model initialisation from fixed data and not from a status record as usual
- SOM in steady state: the initialisation of SOM will be based on the farming activity during the scenario and not on the Crep value in the fixed data

<u>expert switches</u>

- precipitation data not yet corrected (default):
  the model compensates the systematic errors of precipitation measurements
- change soil physics with carbon content
  the model adapts density, field capacity and wilting point according to the changing Carbon content
- risk analysis: repeated run of the same scenario with randomly distributed fertiliser
- repeat management scenario: check this option if you want to repeat a 5-year crop rotation for 100 years and specify 20 cycles
- non-default initial conditions:
  you may read the initial condition from any file in a *.stc format. Specify the file name and the record number you want to be used.
- message class: a higher message class will suppress less interesting messages
- GIS-mode: to be checked if the model is used in GIS mode
- precipitation adaptation factor:
  all precipitation data will be multiplied by this factor



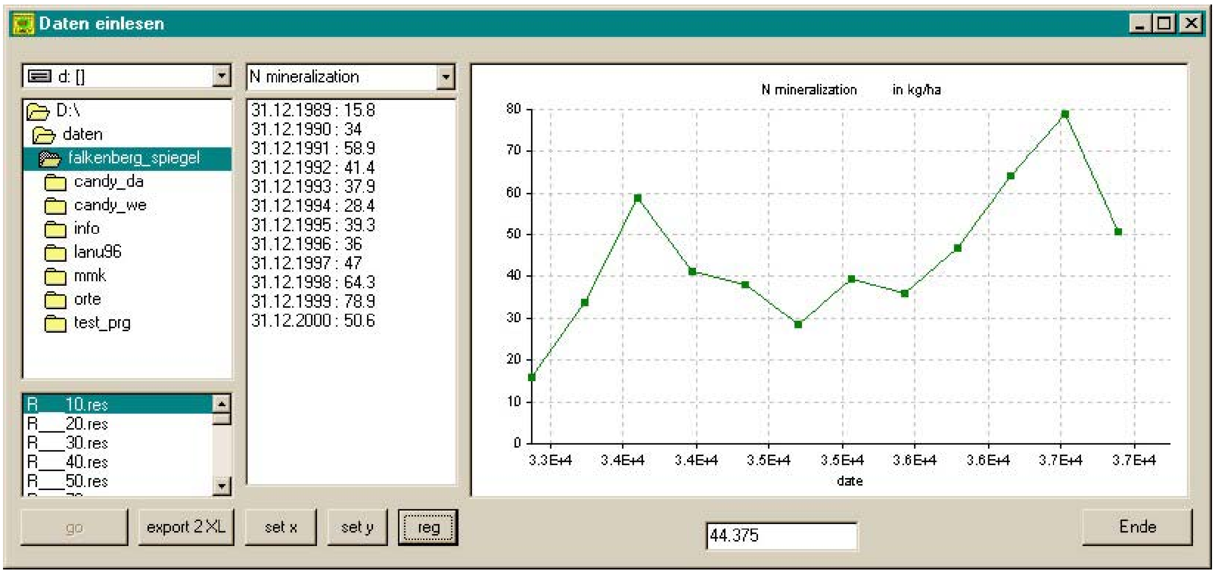
A mouse click on ‚start simulation‘ will start the model. In presentation mode you will find graphical outputs additional to the default simulation protocol, that is written into the ASCII file candymsg.$$$



In most cases you will not activate the ‚presentation mode‘ in order to save time. You may stop and continue the simulation at any time and you can calculate for certain time intervals to watch the model behaviour at certain dates. You may as well cancel the simulation and return to the initial window.

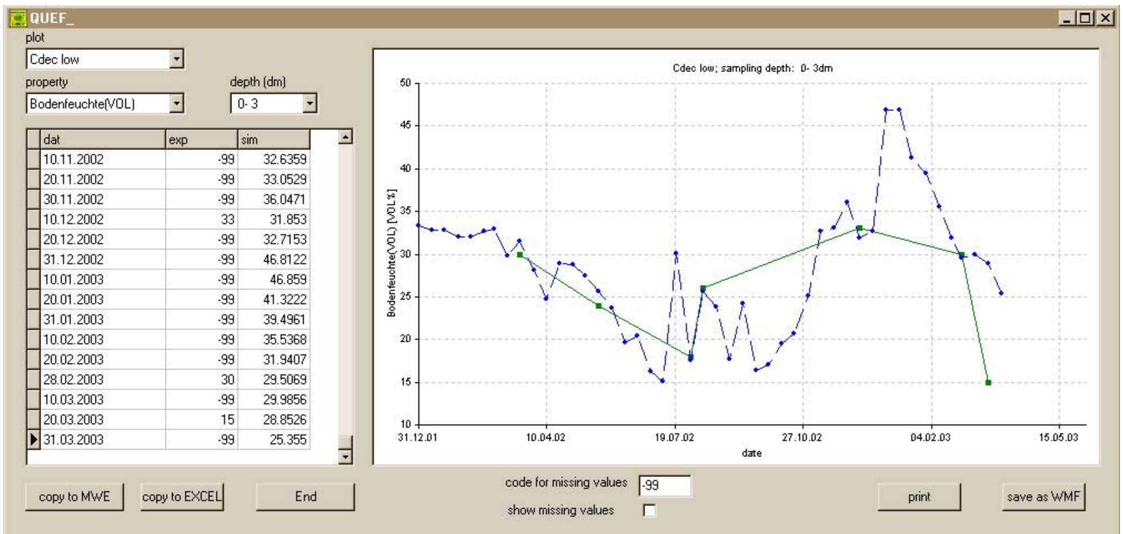
2.4. Result evaluation

All messages about the model activities are stored in a MESSAGE file (*.msg, bzw. candymsg.$$$). Depending on the settings you will find an fixed data set in text file (*.MXT) or a user defined result record in the result file (*.RES). It is not possible to have both outputs at the same time. Start the res-file viewer from the user interface to work with that type of results. Activate the file you want to analyse, click on *go* and then you may select the variable of your interest. You will see a numerical and a graphical representation as well as the average value of this result variable. It is possible to assign these variables to an x or y set to perform a simple linear regression.
Click on the export button to move the whole result data set (all variables) into an EXCEL spreadsheet.



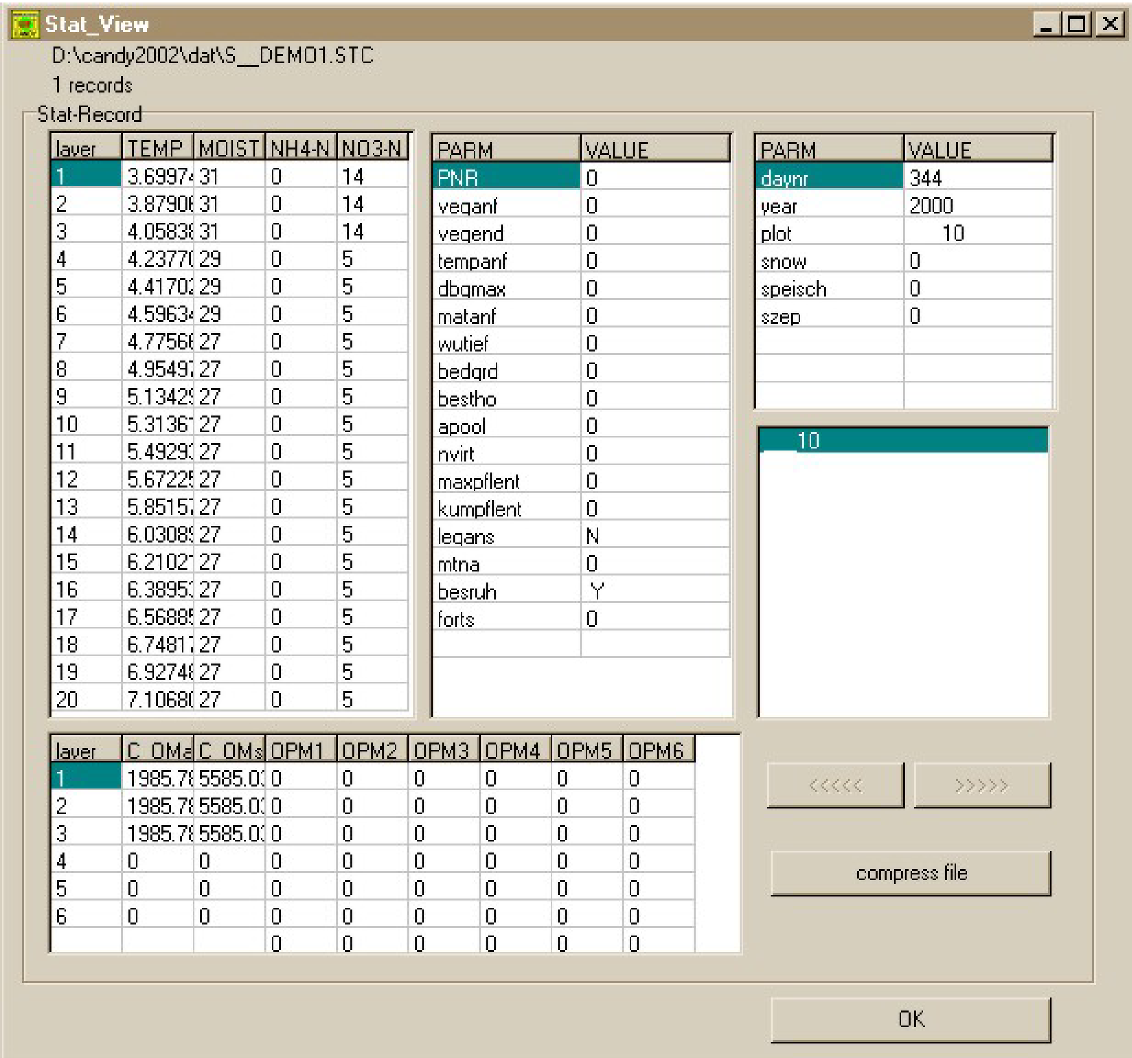
RES file viewer

A more flexible tool for model evaluations is the usage of evaluation module, that will be activated by a mouse click on a mw_ file on the plot selection module. To do that, you have to change from the plot to the file level where you should find your MW_-file after a successful finished simulation run.

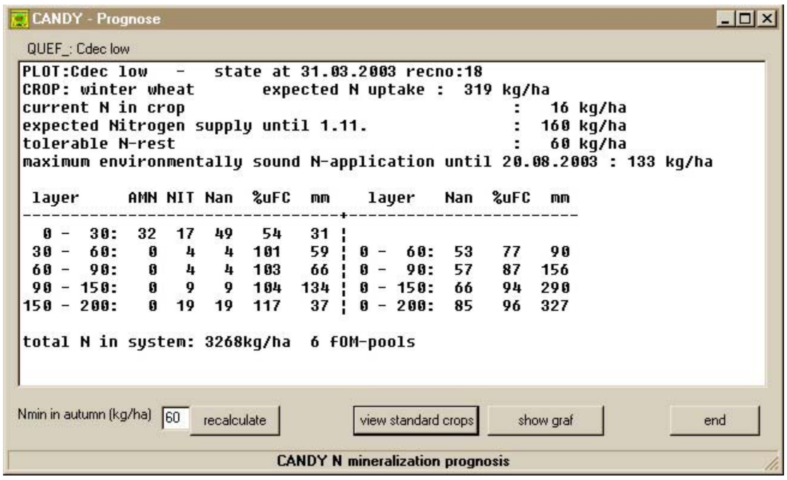


comparing measurement and simulation results with the evaluation module

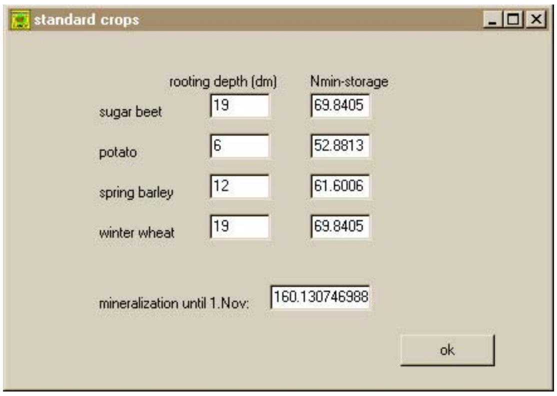
In the evaluation module the user has to select plot, property and depth. Measurement values and simulation results are shown as a table and in graphical format. Data may be moved into an EXCEL spreadsheet and simulation results can be saved in the MWE file.
If you did not activate to option for new generated initial conditions, the system will initalize from a valid record in the status file (S__?????.stc). During simulation a new status record is written before a new year starts and a additional record at the end of the simulation scenario.
The viewer for this file will be activated if you click on a S__-file item:



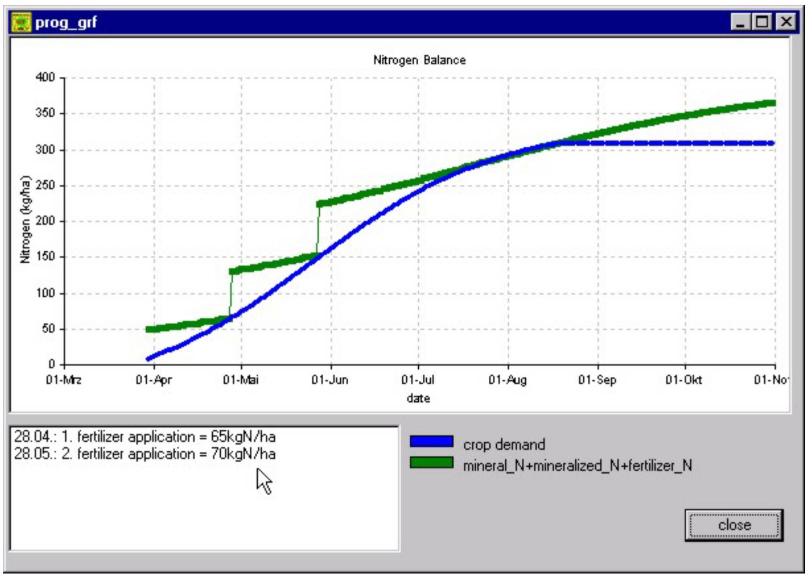
Whilst this feature might be more interesting for experts, the forecasting feature could find a more common interest. It is based on the last valid record of the system state and provides an overview about the nitrogen and water availability as well as a prognosis of nitrogen mineralisation. To activate this module you have to click the appropriate button on the basic-info tableau in the plot selection module. This button is only enabled if there are valid status records available, which is not the case if you let the system create new initial conditions during simulation. The forecasting feature has two modes of appearance. If there is an active crop with nitrogen demand you can activate a graphic overview about timecourse of demand and nitrogen supply. If there is no crop, the forecast will provide a standard estimation of nitrogen to be leached with 100 mm surplus of water.



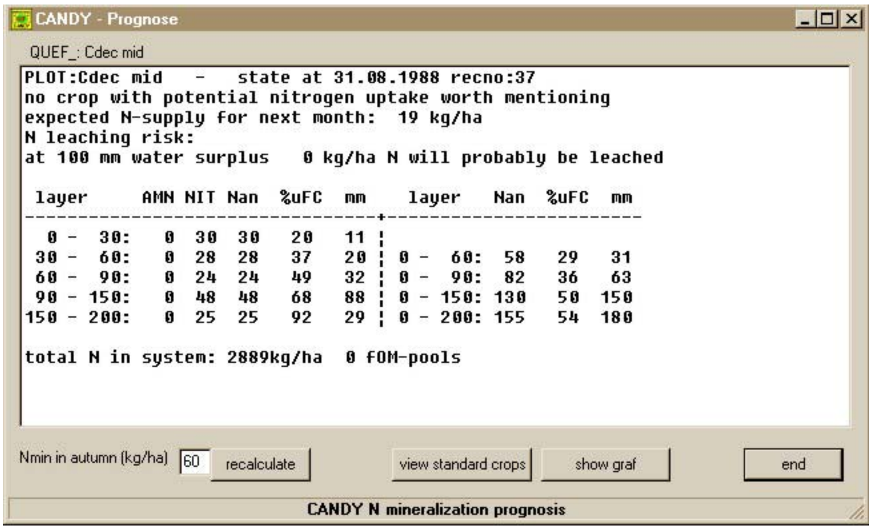
A crop is recognised, the N amount to be added without exceeding the critical value in autumn is calculated – if required you may change this value and recalculte



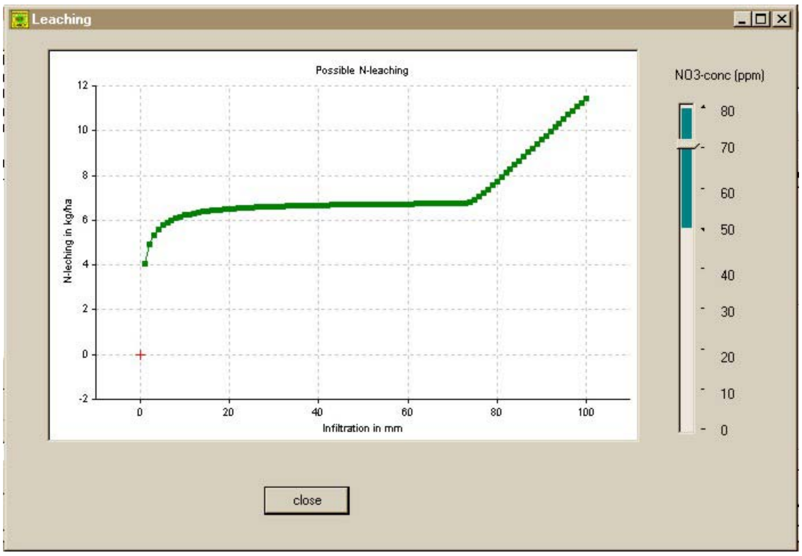
The standard crop view gives information about the nitrogen storage for different rooting depths



For an active crop, the graphic shows the expected time course of N-demand and supply. Right-click the diagram to simulate applications of mineral ferilizers (the amount is calculated according the mouse pointer)



Without an active crop the system calculates the leaching probability...



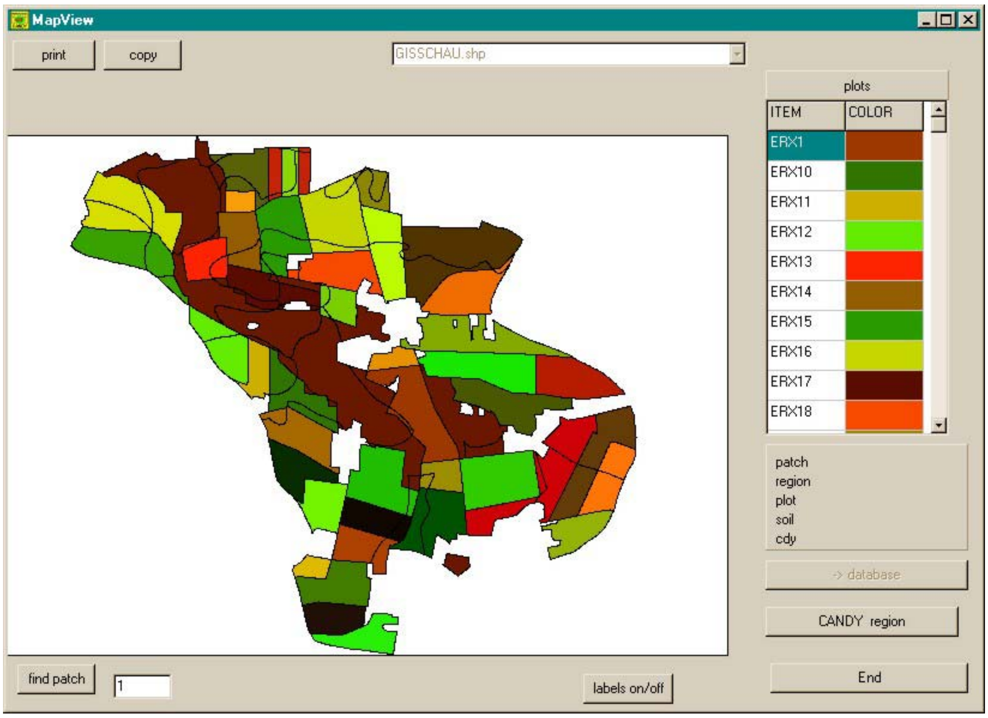
...and the graphic shows the nitrogen breakthrough with the expected nitrate concentration at the right hand side

2.5 GIS-support

CANDY supports the access to GIS data through mapobjects (ESRI). The user should provide the data as shapefile using ArcView. The filename has to be composed of the prefix ‘GIS’ and the CANDY database name (5 characters). If your database is called *FIELD* you should have the files GISfield.dbf, GISfield.shp and GISfield.shx in your data directory.
The DBF file should at least have following fields:

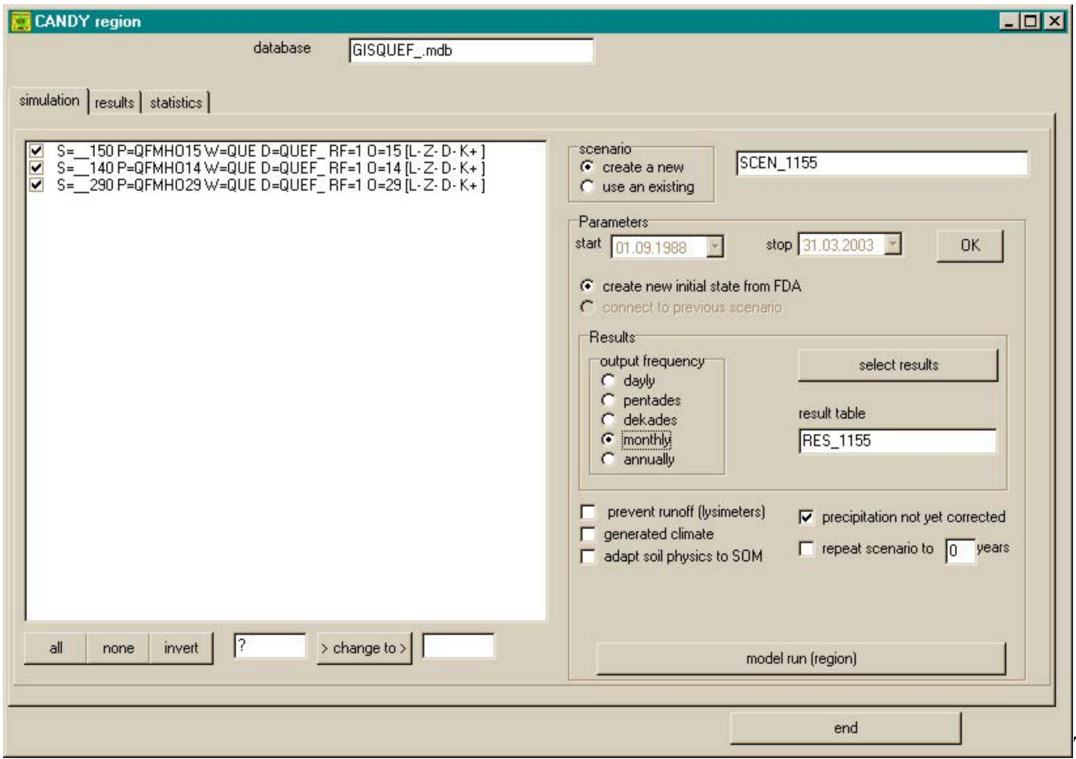
Field name	Type	Meaning
ID	integer	unique identifier of the patch
PATCH	character	unique identifier of the patch, used for result file name
FLAECHE	real	area of the patch in m²
GEBIET	characters (5)	name of the CANDY database
PARZELLE	characters	plot name identical with SBEZ in FDA-file
BODEN	characters	soil profile, should be
WETTER	characters (3)	pointer to climate station
R_FAKTOR	real	adaptation of local rainfall to observation at climate station
WERT	real	template for results

I f you want to extend your data for GIS related simulations you have to activate the option create GIS support from the context menu of the appropriate CANDY database.
If CANDY recognises GIS data it adds a special symbol in the selection tree of the plot selection module. A mouseclick on this item opens window with a map view:



Click on a patch and the database button opens the plot selection module to edit this data.

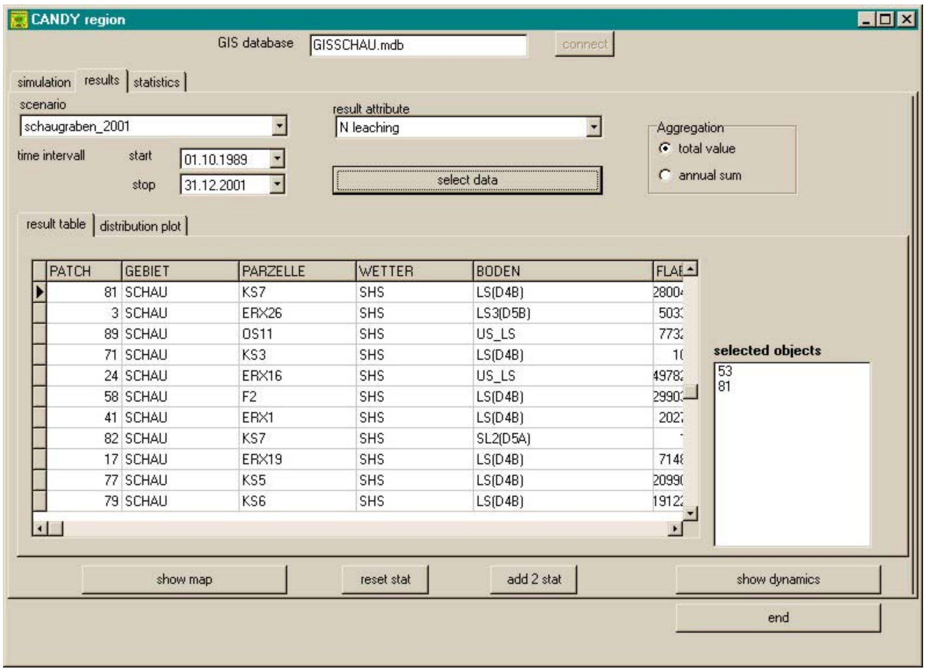
With a click on the *CANDY region* button you will open the window for regional simulations.



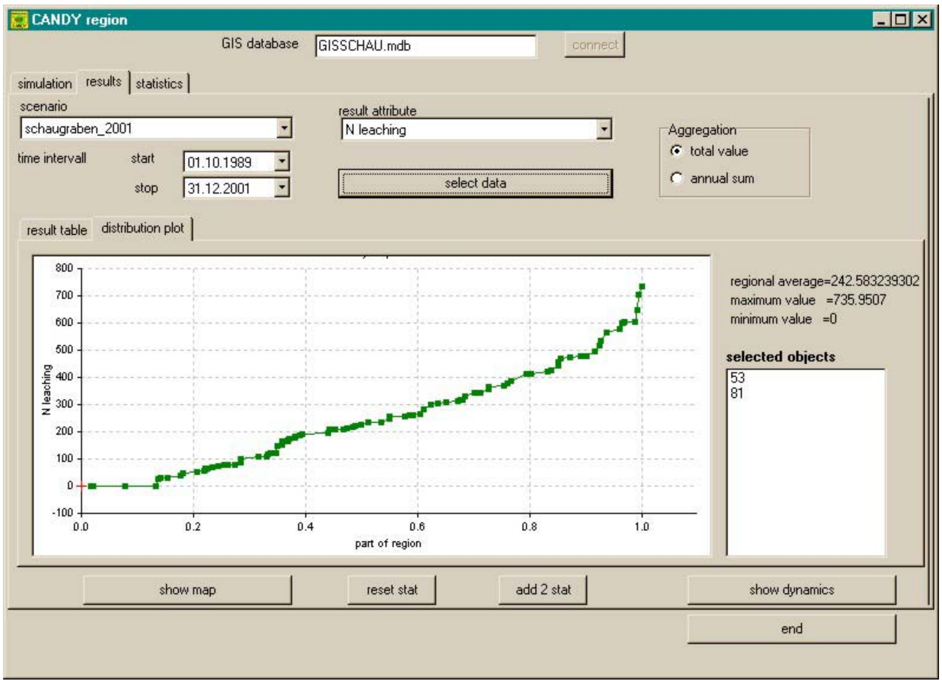
There is a special database for the GIS related results. Usually it is automatically created. The database structure is described in the chapter 4.4, a template for this database is in the CANDY directory (GIS_template.mdb).

It is possible to define several simulation scenarios or relate to an existing one. In most cases you will create a new scenario and the system will tell you the identifier (a number) for the scenario. This identifier is used as a default to name the result table that will be created if you click the run button. You have to select the plots to be included in simulation and may edit starting and ending point of the scenario as well as the results to be recorded during simulation. The simulation procedure is the same as usual but the rainfall correction factor of your GIS data will be used. It is possible to set switches according to the problem to be solved and you can decide to create new initial conditions from the FDA parameters or tell the model to use initial conditions from a STC-file. The recorded results and the frequency of the outputs has to be defined similar to all other simulations. After changing scenario parameters press the update button to save the settings in the database.

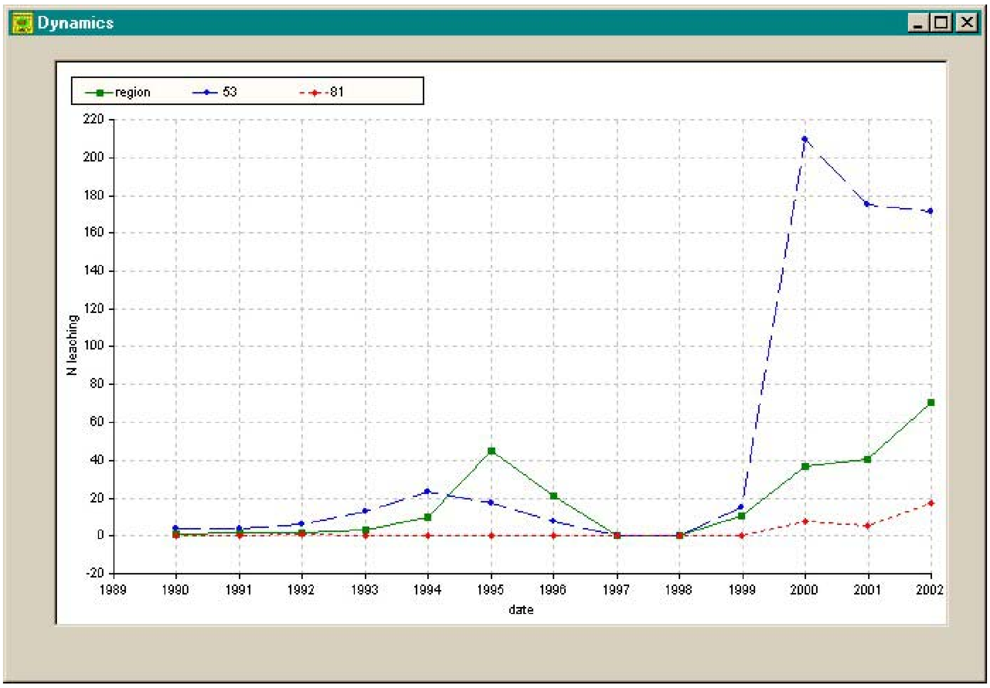
The model run will include all selected items. After a successful simulation run you may evaluate the output data in the ‘results’ tableau:



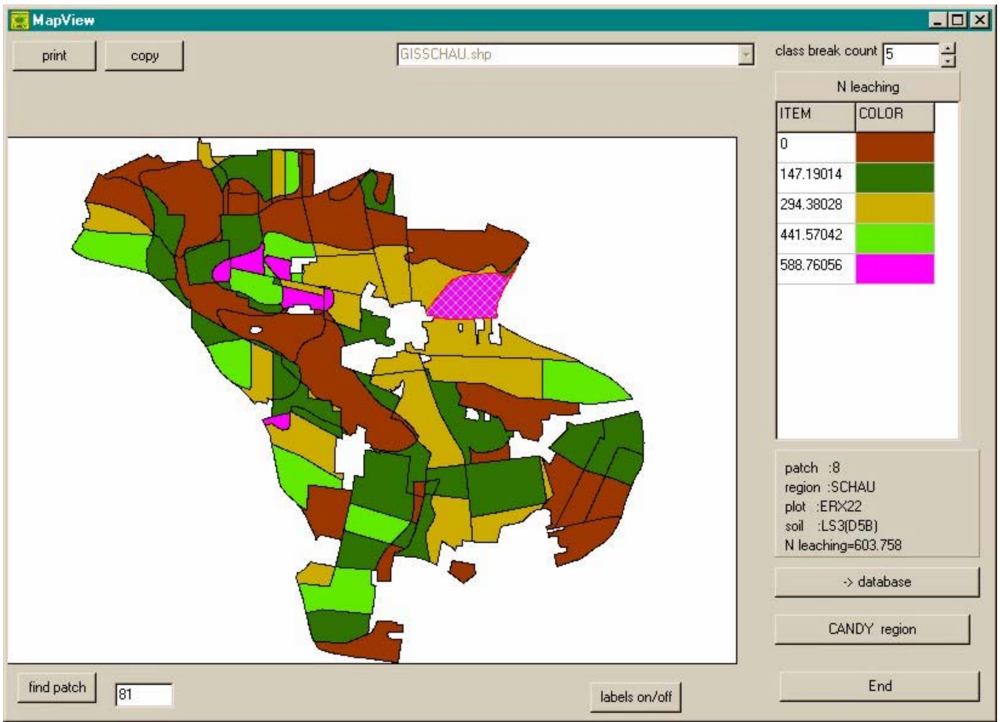
After selecting the scenario and the result attribute you will see the data in the result table and also as a distribution plot:



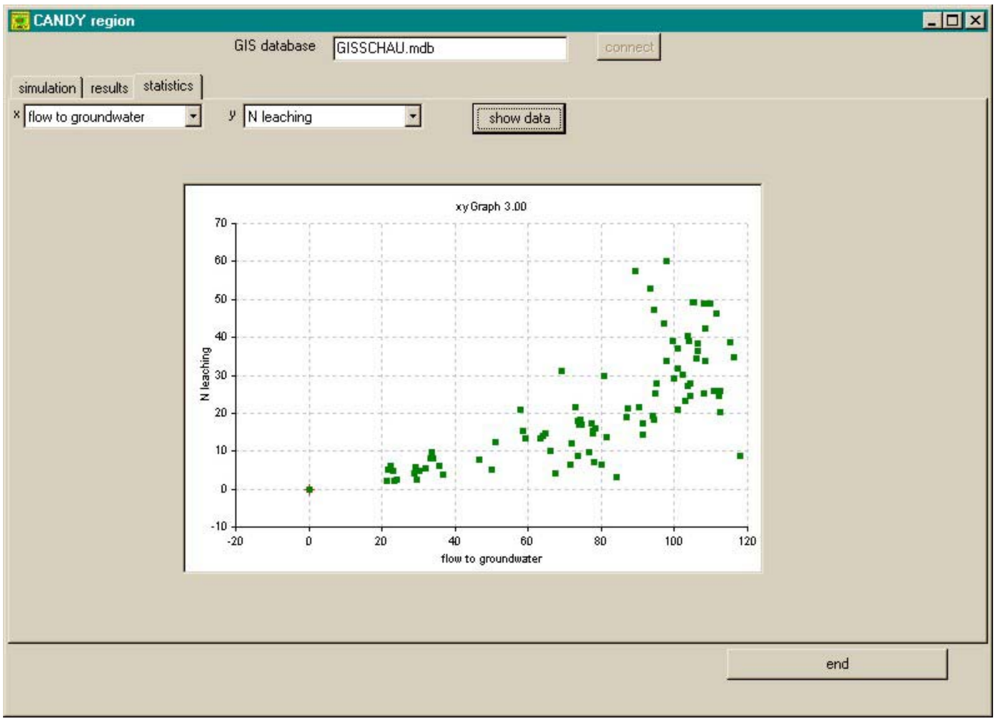
Doubleclick an item in the table or in the plot to add it to the list of selected objects. For these objects together with the regional average the dynamics over the whole simulation intervall will be shown after clicking the button ‘show dynamics’.



Clicking the button ‘ show map’ will produce a map view for the selected attribute. Colouring of the classes can be changed after doubleclick on the colour in the legend table.



The GIS database provides space for up to 10 variables for a statistical analysis. Starting a new analysis you should clear these tables (‘reset stat’ button). New items will be added after clicking the ‘add 2 stat’ button. Within the statistics tableau you can create an x-y-plot from this variables and export the whole dataset to an EXCEL file for further analysis.



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2.6 Simulation runs for several plots

If you have no GIS data but want to bundle your simulations for a number of plots from a CANDY database, you could activate options *scenario simulation* or *group simulation* from the context menu of the CANDY database in the tree view. There will be a list of all plots shown, where you can have a selection for the simulation run. The scenario simulation is very similar to the GIS mode and will save results too in an ACCESS database. The group simulation is more simple and aggregates just a number of simple plot simulations.

3. batch file settings

model switches: (all switches have a +/- option; the following settings are the non-default ones ; if a switch is not used in the model call at all, the default setting will be active anyway)

V+:	N-uptake proportional to transpiration, default V-
D+:	adapt soil physical properties to C_{org} , default D-
Z+:	generated climate data, Default Z- (real climate data)
S+:	generate initial conditions from fixed data, no status file necessary (S__xxxxx.STC), default S-
W-:	no stop after simulation run, default W+
G+:	simulations in GIS mode, default G-
P-:	no graphical results during simulation, default P+

parameters:

general information

DP=	data path (e.g. C:\CANDY\CANDY_DA)
WP=	path to climate
RP=	path to result files (*.res).
Z=	if assigned, the system will repeat simulations for the specified number of years circulation through the management data.
MC	MessageClass: determines the messages selected for output
RA*nn*	risc analysis with *nn* replications of the scenario
SS	steady state : (only effective with S+) Initial values for SOM are calculated from scenario data and not from Crep in fixed data
OF=	output frequency for simulation results(MXT and RES files). possible options are 1, 5, 10, 30 (for month) - annual is default

description of the simulation scenario

A=	start date (A=dd.mm.jjjj)
E=	end date(E=dd.mm.jjjj)
X=	MXT-file name(without extension).
R=	RES-file name(without extension).
P=	name of soil profile
D=	name of database (xxxxx). Basis for following file names: MASxxxxx.DBF : farming activities (management) FDAxxxxx.DBF : Basic Info (fixed data) MW_xxxxx.DBF : subset of MWExxxxx.dbf to be used for simulation
S=	plot index: nnnnu with nnnn: plot number (SNR field in DBF's) blanks have to be replaced by a low line – and subplot (UTLG field in DBF's); e.g.: __123: snr=12, utlg=3
W=	name(abbreviation) of climate station (sss). depending on the Z switch the following file names will be constructed: Z+: climate generator sss.PER / Z-:real climate data from WETssjjjj.DBF ; jjjj: year

4. Background Information

4.1 ACCESS-Tables in CDYPRM.mdb

Soil Parameters

(Profiles: profile)

Parameter	**Meaning**
PROFIL	name (abbreviation) of the profile
HORIZONT	depth (lower limit of the horizon in dm)
HORIZ_NAME	pointer to a record in CNDHRZN

(Horizons: CNDHRZN)

Parameter	**Meaning**
NAME	horizon name (refers to profile.HORIZ_NAME)
HYDROMORPH	(yes/no) yes: horizon is always saturated with groundwater
PV	pore volume (not required)
KRUME	switch : KRUME=1 means ploughed horizon
CT	typical value of C_{org}-content in % (reference basis for TRD, TSD, PWP and FKAP)
TRD	bulk density in g/cm^3
K_TRD	change of bulk density per 1% C_t
TSD	substrate density in g/cm^3
K_TSD	change of substrate density 1% C_t
PWP	permanent wilting point in VOL%
K_PWP	change of wilting point per 1% C_t
FKAP	field capacity in VOL% (good estimate soil moisture in spring time)
K_FKAP	change of field capacity per 1% C_t
KF	saturated conductivity in mm/d
LAMBDA	seepage parameter after Glugla (facultative)
HKAP	heat capacity (i. a. =0.16)
TON	clay content (facultative)
SCHLUFF	silt content (facultative)
FAT	content of particles <= 6.3 micrometer:= clay+fine silt
NIN0	Nmin-standard per 1dm soil at normal N-supply in kg/ha
K_NIN	change of Nmin-standard per intensity level in kg/ha

Pesticide parameters
(CDYAGCHM)

Parameter	Meaning
ITEM_IX	Index
NAME	name of pesticide
INDEX	unique number (e.g. CAS-registry number)
H	Henry – constant (J/mol)
DIFAIR	Diffusion coefficient in air (cm^2/d)
VOLGRE	height of the borderline between soil surface and clean atmosphere in cm
DEC_COEF	decomposition coefficient in 1/d
TEMPERATUR	reference temperature for DEC_COEF in °C
KOC	KOC-value in mg/kg
FRN	Freundlich –exponent

Parameters for OS-turnover:
(CDYOPSPA)

Parameter	Meaning
ITEM_IX	Index
NAME	name
CROP_IX	crop index
OD	organic matter for application (manure, slurry) (true/false)
K	decomposition coefficient
ETA	synthesis coefficient
CNR_ALT	total C/N-ratio
CNR	C/N-ration in organic matter
TS_GEHALT	dry matter content t
C_GEH_TS	C-content in dry matter
MOR	relation between mineral and organic Nitrogen

Parameters for mineral fertiliser
(CDYMINDG)

Parameter	Meaning
ITEM_IX	Index
NAME	name of fertiliser
AMMNANTEIL	part of NH4-N- in total N in %

Parameters for crops :
(CDYPFLAN)

Parameter	**Meaning**
ITEM_IX	Index
EWR_IX	pointer to a record in CDYOPSPA to characterise harvest residues and roots
GRD_IX	pointer to a record in CDYOPSPA to characterise aboveground biomass after ploughing up
NAME	name
ART	plant characteristic: non legume crops: 1: annual plant; 2: two year crop (winter wheat) 5: durable crop legume crops 3: annual plant; 4:durable crop
CZEP	specific interception capacity (overwrites default in CDYAPARM)
ZETB	parameter of withdrawal function (overwrites default in CDYAPARM)
MODELL	model algorithm, default: CANDY_S
TRANSKO	transpiration coefficient (only used with V+ setting and CANDY_S model)
VEGDAU	days from emergence to maturity
STEIL	parameter of N-uptake function
NBOK	for legumes: constant N-uptake rate from soil
LNUB	for legumes: part of N accumulated in deep soil
FEWR	Prop.factor between N in harvest residues and roots and N yield
CEWR	N-amount in harvest residues independent from yield
WTMAX	maximum rooting depth
WWG	days for 10 cm root growth (depth)
DBHMAX	days from emergence to maximum crop height
N_GEHALT	N-concentration in yield
DBGMAX	days from emergence to maximum crop coverage
BHMAX	maximum crop height
MATANF	days from starting maturity to harvest
BGMAX	maximum crop coverage (0..1)
TEMPANF	days from emergence to beginning influence on soil temperature

general parameters
(CDYAPARM)

Parameter	Meaning
ITEM_IX	index
NAME	name
PARMSATZ	name of parameter set
BT_MODELL	index of soil temperature model
N_IM_SOM	adaptation of N-immission during summer season
N_IM_BEW	adaptation of N-immission for cropped soil
K_AOS	decomposition coefficient (active OM)
K_AKT	activation coefficient (stabilised to active OM)
K_STAB	stabilisation coefficient (active to stabilised OM)
K_DENI	denitrification coefficient
K_MULCH	decomposition coefficient of mulch layer
MAXDENI	max. denitrification rate
CNR_OBS	C/N-ratio of decomposable OM
CZEP	interception capacity of a crop in mm/ m crop height
XSI	parameter of transpiration submodel
NUNB	max. evaporation depth in dm
TBED	ratio PET/V_{Turc} for covered soil
TUNB	ratio PET/V_{Turc} for bare soil
ZETU	parameter of evapotranspiration submodel (crop covered soil)
ZETB	parameter of evapotranspiration submodel (bare soil)
DISP_KF	weighing factor for dispersion effects; 0..1 (0: no dispersion)
DNG_EFF	fertiliser effect **<u>(usual value :1)</u>** . be careful, all applications of mineral fertiliser N will be multiplied by this factor during simulation.

organisation parameters
(Results: RSLTOBJ)

Parameter	Meaning
OBJEKTNR	Index – don’t change this !!!
RESULTAT	name of result
FLEN	column with in result table
DEC	decimals
AUSWAHL	selection mark. if selected: '*'; otherwise ' '

(measurement attributes: CND_MWML)

Parameter	Meaning
MERKMAL	alpha index
BEZEICHNUNG	name/property
KURZBEZ	abbreviation
INDEX	numeric index
EINHEIT	unit

4.2 User tables in DBF-Format
(xxxxx: database name)

fixed data /basic info FDAxxxxx.DBF

Name	Type	Length	DEC.	Meaning
SBEZ	C	30	0	plot/subplot name
SNR	N	3	0	plot number
UTLG	N	1	0	subplot number – usually 0
GEOBREITE	N	6	1	latitude
STANDORT	C	10	0	pointer to soil profile
WETTER	C	3	0	pointer to climate station
STATUSANF	N	4	0	first valid status record in S__xxxxx.stc
STATUSEND	N	4	0	last valid status record in S__xxxxx.stc
SIMSTAND	D	8	0	next date to be simulated
STARTDAT	D	8	0	minimum data to start a simulation
IMMISSION	N	5	1	anual N-input from atmosphere in kg/ha
LTEM	N	5	1	long term average of air temperature (°C)
NIED	N	5	1	long term average of precipitation (mm)
CREP	N	6	1	long term average of reproducing carbon input (dt/ha/a)
NLEVEL	N	5	1	N-input level before simulation
NFK0	N	3	0	filling of field capacity at STARTDAT

manure/ slurry analysis GUExxxxx.dbf

Name	Type	Length	DEC.	Meaning
DATUM	D	8	0	date of analysis
TS_GEHALT	N	5	1	dry matter content in %
NT_GEHALT	N	5	1	total N-content in %
CT_GEHALT	N	5	1	total C-content in %
STALL	C	1	0	stable index

measurement values MWExxxxx.dbf

Name	Type	Length	DEC.	Meaning
FIRST	C	1	0	'*': start of a serie; else ' '
SNR	N	3	0	plot
UTLG	N	1	0	subplot
DATUM	D	8	0	sampling date
M_IX	N	3	0	index in CND_MWML
S0	N	2	0	upper soil layer
S1	N	2	0	lower soil layer
M_WERT	N	10	4	value
VARIATION	N	4	1	variance
ANZAHL	N	2	0	replications
S_WERT	N	10	4	simulation result
KORREKTUR	C	1	0	'J': model adapts to observation 'N': model writes S_WERT

management data MASxxxxx.DBF

Name	Type	Length	DEC.	Meaning
SNR	N	3	0	plot
UTLG	N	1	0	subplot
DATUM	D	8	0	date
MACODE	N	2	0	code see CDYACTION
WERT1	N	3	0	quality value
WERT2	N	6	0	quantity value
ORIGWERT	N	10	2	original value
REIN	C	1	0	priority of user values (*)

* REIN="N" – N-Uptakes and C-Inputs are calculated from model parameters
  REIN="J" – user values for N-uptakes and C-inputs will be used instead of model parameters

Interpretation of quantity / quality and original value for different management codes

MACODE	Activity	WERT1	WERT2	ORIGWERT
0	fallowing	device index	tillage depth (dm)	tillage depth (cm)
1	sowing	crop index	expected N-uptake (kg/ha)	exp. natural yield (dt/ha)
2	harvest, by-products removed	crop index	real N-uptake (*) in kg N/ha	real yield (dt/ha)
3	org. matter application	OM index	added amount of C (kg C/ha)	amount of added substrate in dt/ha
4	mineral fertiliser application	fertiliser index	ammonium content%	total N-input kg N/ha
5	soil tillage	device index	tillage depth dm	tillage depth cm
6	Crop cutting			
7	Irrigation	-	water amount mm	water amount mm
8	pesticide application	substrate index	amount kg/ha	amount kg/ha
9	not removed	crop index	real N-uptake kg N/ha	real yield dt/ha
10	pasture start	animal index	animal number	
11	pasture stop	animal index	animal number	

* only if REIN="J"

CANDY climate data

file names: WETmmmjj.DBF
- mmm shortcut of climate station
- jjjj year (with 2 or 4 numbers possible)

all data are daily data !!

Name	Type	Length	Dec.	Meaning
DATUM	D	8		date
LTEM	N	5	1	air temperature at 2 m in °C
NIED	N	5	1	precipitation in mm
GLOB	N	5		global radiation in J/cm² (*)
SONN	N	5	1	sun shine duration in h (*)

* The model needs only global radiation data. If these are not available they will be calculated from sun shine duration and latitude during simulation runs.

4.3 Files in the CANDY directory

Dateiname	**Type**	**Meaning**
WCANDY	EXE	simulation model
DB_IMPORT	EXE	module for database transfer between CANDY users
CND_UI	EXE	user interface
FDAT	STR	file template
MASSNAHM	STR	file template
MESSWERT	STR	file template
WETTER	STR	file template
GUE	STR	file template
MMH	STR	file template

4.4 GIS-database

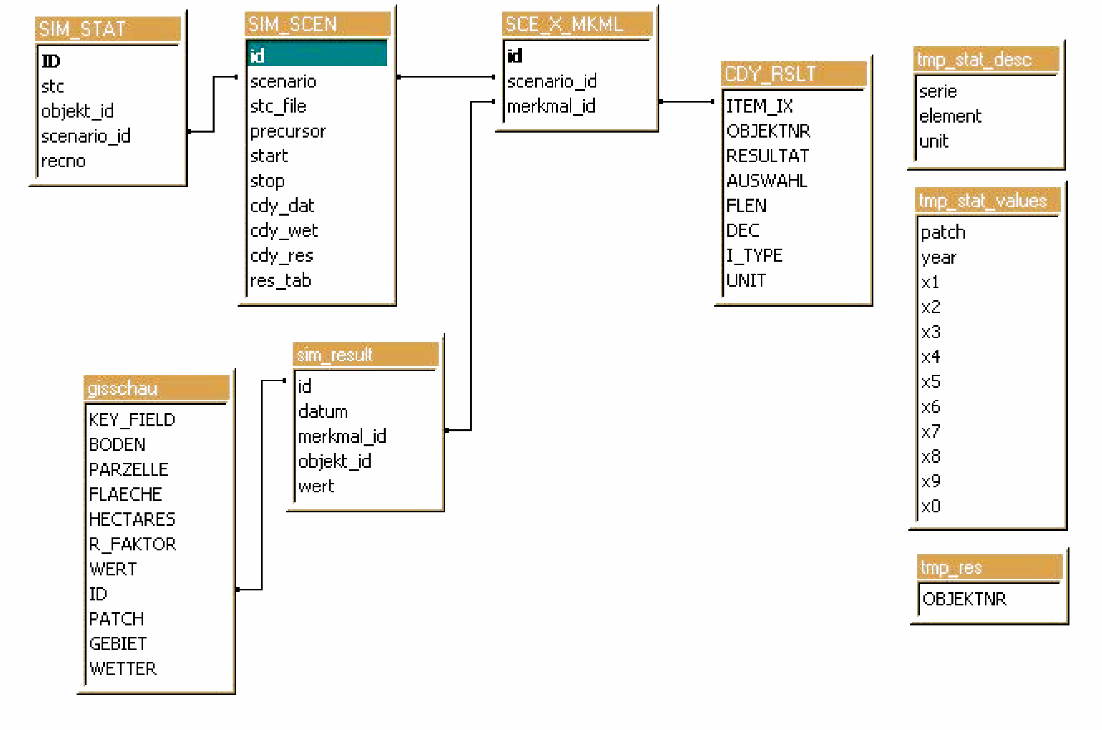


Table: CDY_RSLT

Name	Type	Size
ITEM_IX	Number (Long)	4
OBJEKTNR	Number (Double)	8
RESULTAT	Text	50
AUSWAHL	Text	1
FLEN	Number (Double)	8
DEC	Number (Double)	8
I_TYPE	Number (Byte)	1
UNIT	Text	50

Table: gisschau (example for an GIS attribute table. the 5 letters SCHAU have to be related to a candy database , this table has to be imported from the dbf file of the GIS dataset)

Name	Type	Size
BODEN	Text	25
PARZELLE	Text	16
FLAECHE	Number (Double)	8
HECTARES	Number (Double)	8
R_FAKTOR	Number (Double)	8
WERT	Number (Double)	8
ID	Number (Double)	8
PATCH	Number (Double)	8
GEBIET	Text	16
WETTER	Text	16

Table: SIM_STAT

Name	Type	Size
ID	Number (Long)	4
stc	OLE-Objekt	-
objekt_id	Number (Integer)	2
scenario_id	Number (Integer)	2
recno	Number (Long)	4

Table: sim_result, usually named RES_nnn where nnn is the scenario identifier, this table will be created during a simulation run

Name	Type	Size
id	Number (Long)	4
datum	Datum/Zeit	8
merkmal_id	Number (Long)	4
objekt_id	Number (Long)	4
wert	Number (Single)	4

Table: SCE_X_MKML

Name	Type	Size
id	Number (Long)	4
scenario_id	Number (Integer)	2
merkmal_id	Number (Integer)	2

Table: SIM_SCEN

_Name	Type	Size
id	Number (Long)	4
scenario	Text	30
stc_file	Text	30
precursor	Number (Integer)	2
start	Datum/Zeit	8
stop	Datum/Zeit	8
cdy_dat	Text	150
cdy_wet	Text	150
cdy_res	Text	150
res_tab	Text	15

following items are temporary tables that must not be deleted:

Table: tmp_res

Name	Type	Size
OBJEKTNR	Number (Double)	8

Table: tmp_stat_desc

Name	Type	Size
serie	Text	50
element	Text	50
unit	Text	50

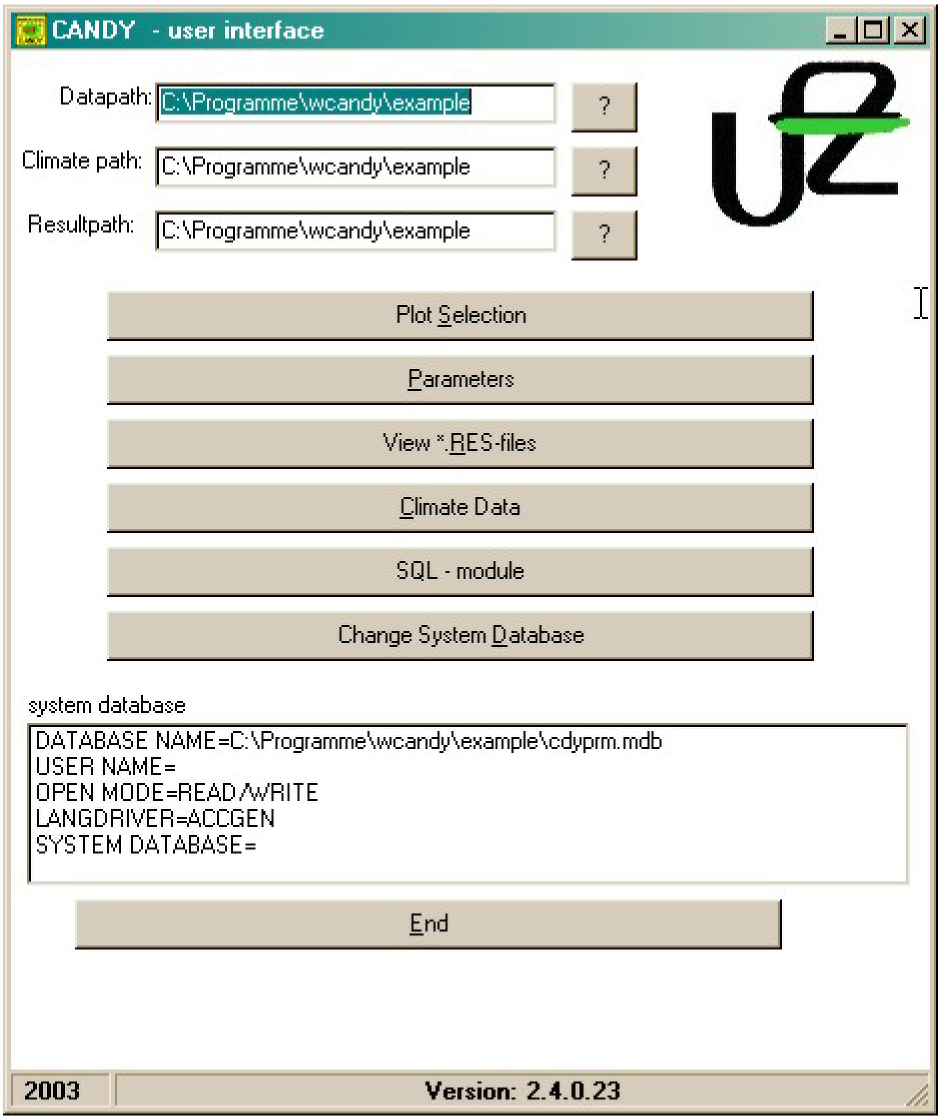
Table: tmp_stat_values

Name	Type	Size
patch	Number (Long)	4
t	Number (Integer)	2
x1	Number (Double)	8
x2	Number (Double)	8
x3	Number (Double)	8
x4	Number (Double)	8
x5	Number (Double)	8
x6	Number (Double)	8
x7	Number (Single)	4
x8	Number (Double)	8
x9	Number (Double)	8
x0	Number (Double)	8

5. Example with comments

Part 1: Introduction in the user interface (data input)

Start the CANDY programme by launching **CDY_UI.exe**.
You see the start window **CANDY – user interface.**

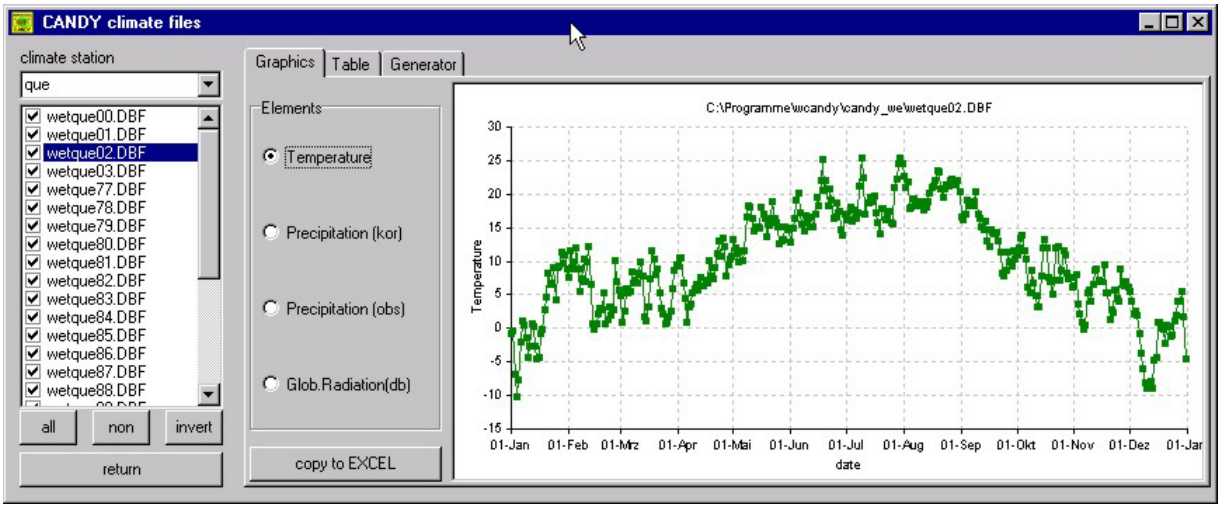


Change the

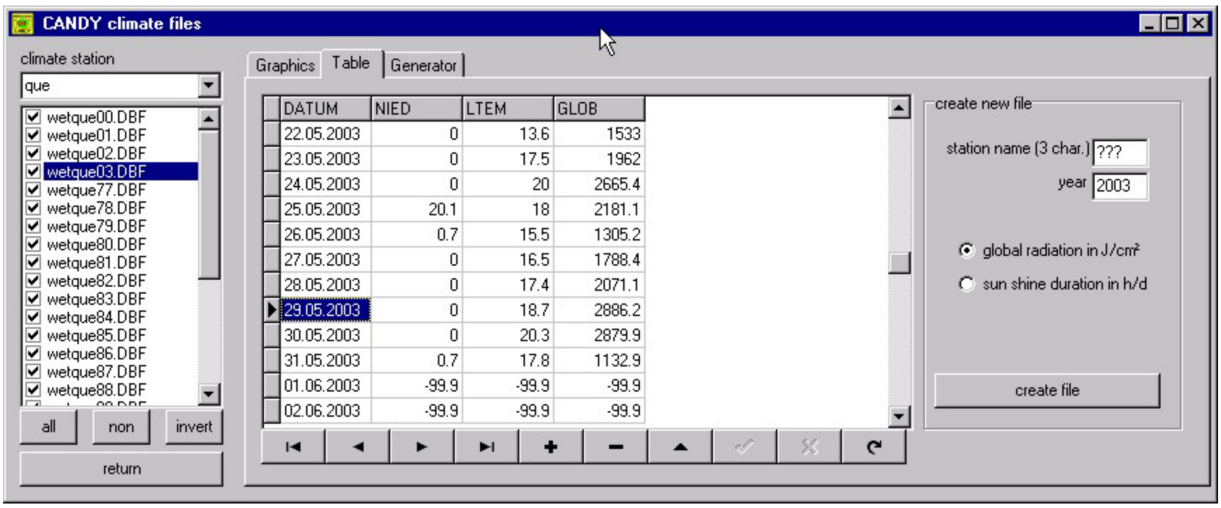
Data path to:	**C:\Programme\wcandy\example** (Press: ?)
Climate path to:	**C:\Programme\wcandy\candy_we** (Press: ?)
Result path to:	**C:\Programme\wcandy\example** (Press ?)
System Database to	**C:\Programme\wcandy\example\cdyprm.mdb (click button)**

Providing climate data

Click on the **climate data** button **in CANDY – user interface** to check the climate data (que). For all years/days of your simulation you need climate data (one file per year) in daily time steps without missing values. You can open a climate data file by double-clicking on the data file name on the left (see screenshot below). Check the data for the years 2002 (wetque02.dbf) and 2003 (wetque03.dbf) by using the **graphics** folder.



Please insert the data for the year 2003 from the table below. Therefore you have to change into the **table** folder and double-click on the **wetque03.dbf** file. To edit the climate data in the table click into the record you want to change and type in the data. You can use the buttons at the bottom of the window to move through the table, enter and delete records, etc. (for your information: if you have to create a new file you can use the right part of the window).

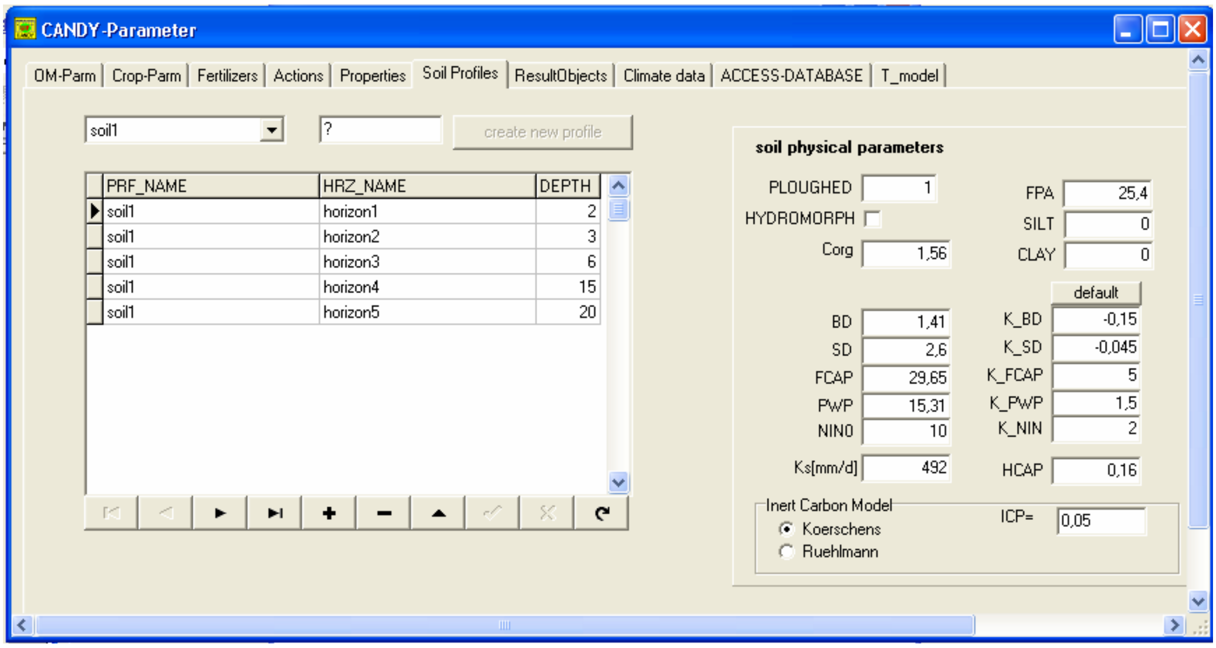


DATUM	NIED	LTEM	GLOB
29.5.2003	0	18.7	2886.2
30.5.2003	0	20.3	2879.9
31.5.2003	0.7	17.8	1132.9

Click the **return** button.

Create a new soil profile

One requirement to run a simulation is the definition of a soil profile. Therefore you have to start the **parameters** module **in CANDY – user interface** and click on the folder **soil profiles**.



Type the profile name in the edit field to the left of the **create new profile** button.

Click on the **create new profile** button. Type the horizon name (**horizon1**) and the depth (**2 in dm**) for the first horizon in the edit field in the window where the profile name appears. Please enter the soil physical parameters for the first horizon (right part of the window) by clicking first on the **default** button and then adding the missing data. You will find the data in the table below. Add the horizon names for all horizons as you see below (horizon1, horizon2, ..., horizon 5). You can use the button + to add a horizon. The data for the other horizons are already prepared and you will see them after you insert the horizon name or select it from the pull down menu (two clicks on the right site of the field HRZ_NAME) and click on the '✓' button.

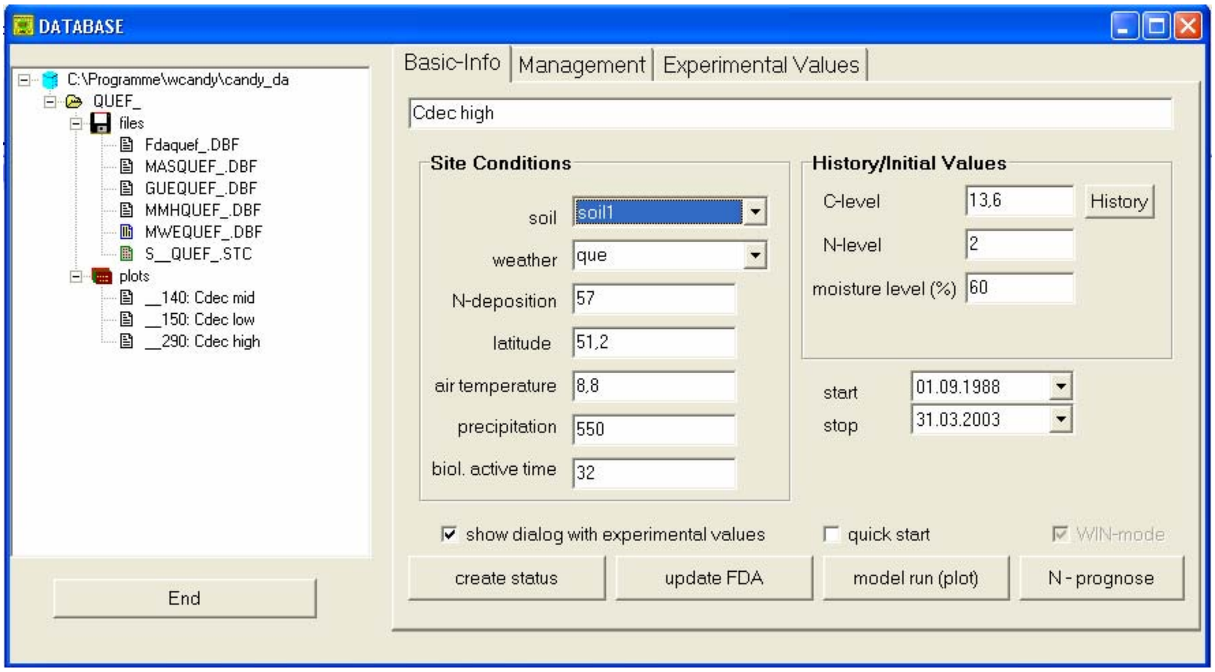
PRF_NAME	soil1	soil1	soil1	soil1	soil1
HRZ_NAME	horizon1	horizon2	horizon3	horizon4	horizon5
DEPTH	2	3	6	15	20
PLOUGHED	1	These data are already prepared (select HRZ_NAME from pull down menu and enter depth).			
HYDROMORPH	unchecked				
Corg	1.56				
BD	1.41				
SD	2.6				
FCAP	29.65				
PWP	15.31				
NIN0	10				
Ks(mm/d)	492				
FPA	25.4				
SILT	0				
CLAY	0				
K_BD	-0.15				
K_SD	-0.045				
K_FCAP	5				
K_PWP	1.5				
K_NIN	2				
HCAP	0.16				
Inert Carbon Model	check ‘Körschens’				
ICP	0.05				

Click the **end** button.

Defining a simulation object

To define a simulation object you have to start the **plot selection in CANDY – user interface**. Activate the context menu (right click) of the uppermost item (data path) and select the option **create a new database**. A window will open where you can enter a database name (5 letters/characters). Please enter **QUEF_** and click the **create** button. In the left part of the window the database **QUEF_** should appear. If you click on the + in front of QUEF_ you will see **files** and **plots**. Please add a new plot by selecting the proper option from the plot context menu (right click on plot). Please double-click on plots (or click +). Please change the plot name 'neu' into **Cdec high**. Type in the values/names for the soil conditions and history/initial values from the table below and select soil and weather with the **pull down menus**.

NAME	Cdec high
SOIL	soil1
WEATHER	que
N-DEPOSITION	57
LATITUDE	51.2
AIR TEMPERATURE	8.8
PRECIPITATION	550
BIOL. ACTIVE TIME	32
C-LEVEL	13.6
N-LEVEL	2
MOISTURE LEVEL	60
START	01.01.2002
STOP	31.03.2003

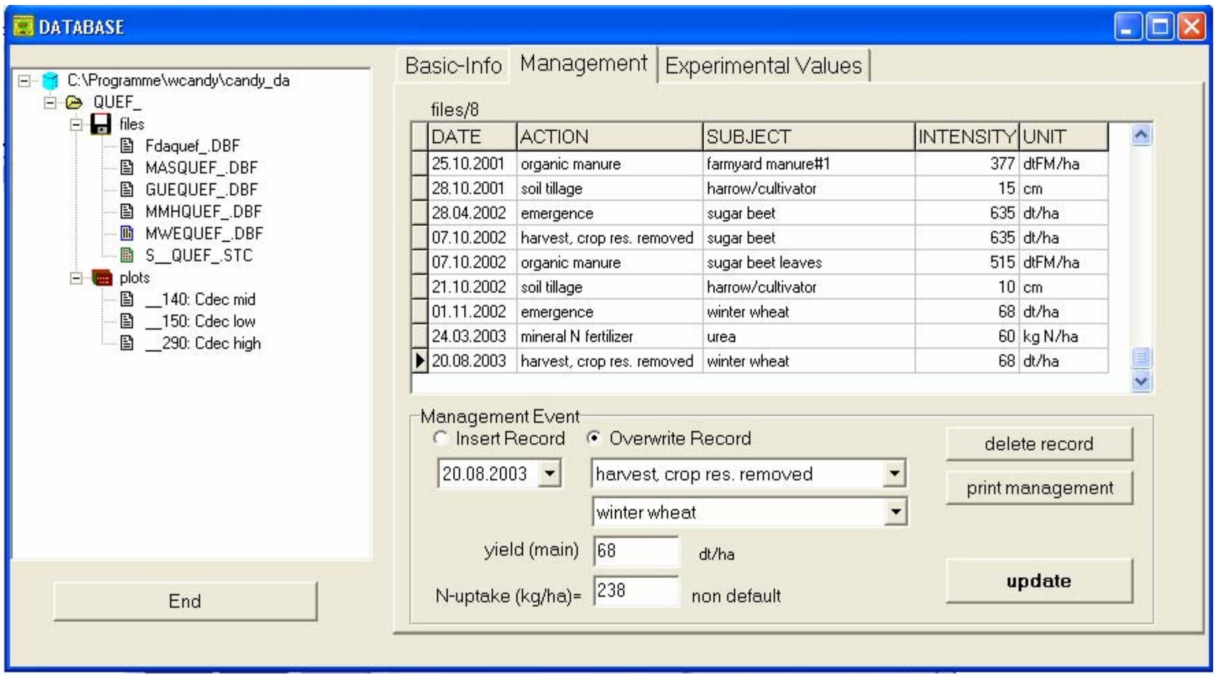


Input of management data

Click on the folder **management**. Activate the **insert record** radio button and select the date, action, subject and enter the intensity and the C-input (in case of emergence/harvest = N-uptake) for the first record you will find in the table below. Click the **insert** button. Now you can enter the next record from the table. Make sure that you are in insert modus and don't forget to click **insert** after every record you enter. You will see the management data ordered by date. To change a record click the **overwrite** radio button and select/enter the new data. If the changes are done, click the **update** button.

Date	Action	subject	intensity	C-input or N-uptake
7.10.2002	organic manure	sugar beet leaves	515	3440
21.10.2002	soil tillage	harrow/cultivator	15	----
1.11.2002	Emergence	winter wheat	68	238
24.3.2003	mineral N fertilizer	urea	60	----
20.8.2003	harvest, crop res. Removed	winter wheat	68	238

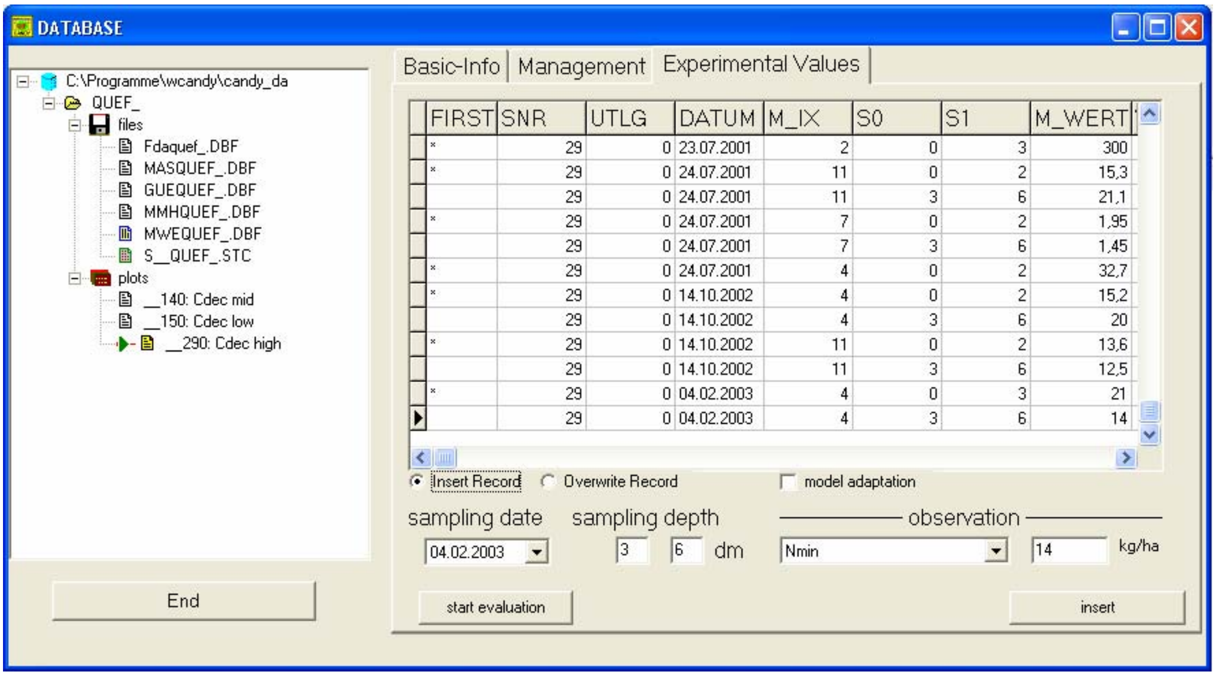
You can print or save (as *.txt-, *.htm-, *.csv-file) the management data by using the **print management** button.



Input of experimental values

Click on the folder **experimental values**. Activate the radio button **insert record** and type in the experimental values you will find in the table below. Use the **insert** button to insert the record into the table.

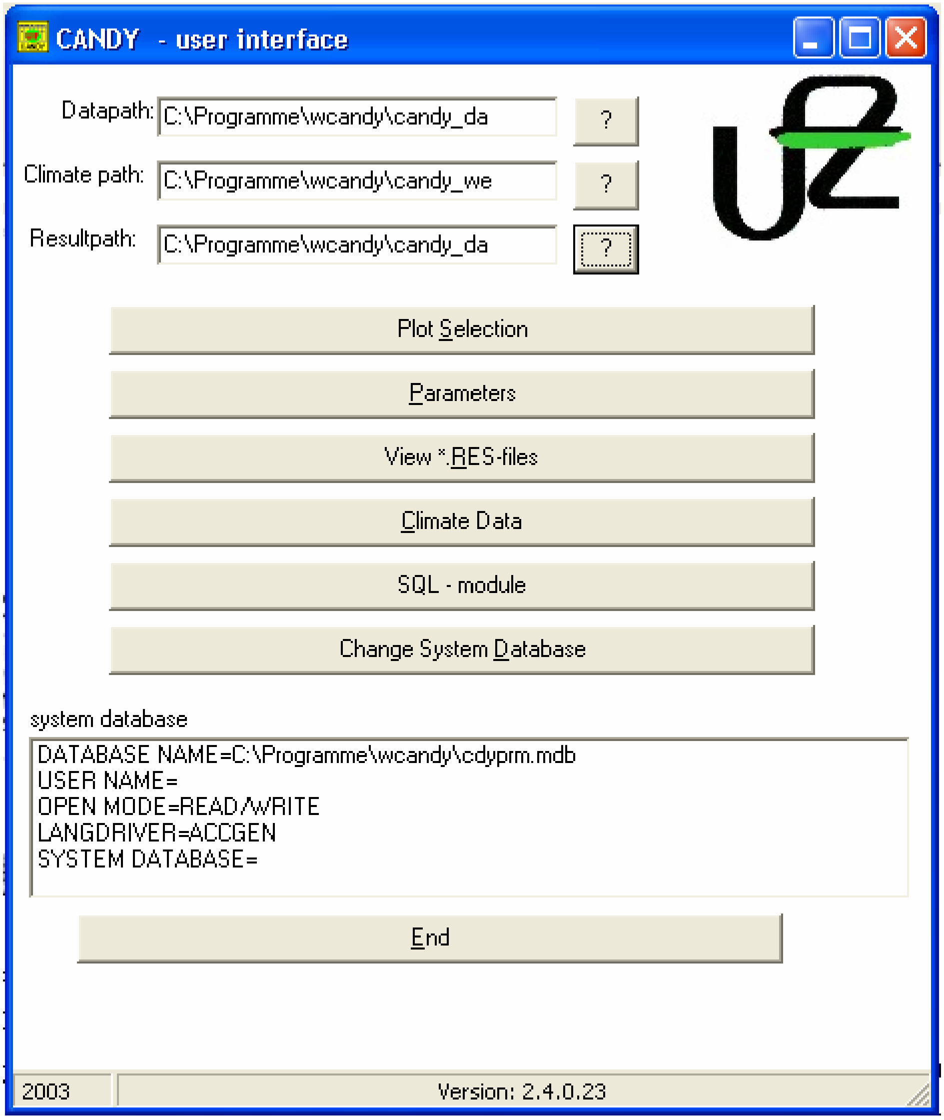
Sampling date	Sampling depth		Observation	
14.10.2002	0	2	Soil moisture (M%)	13.6
14.10.2002	3	6	Soil moisture (M%)	12.5
4.2.2003	0	3	Nmin	21
4.2.2003	3	6	Nmin	14



Now all data are available to run simulation.

Part 2: Standard simulation

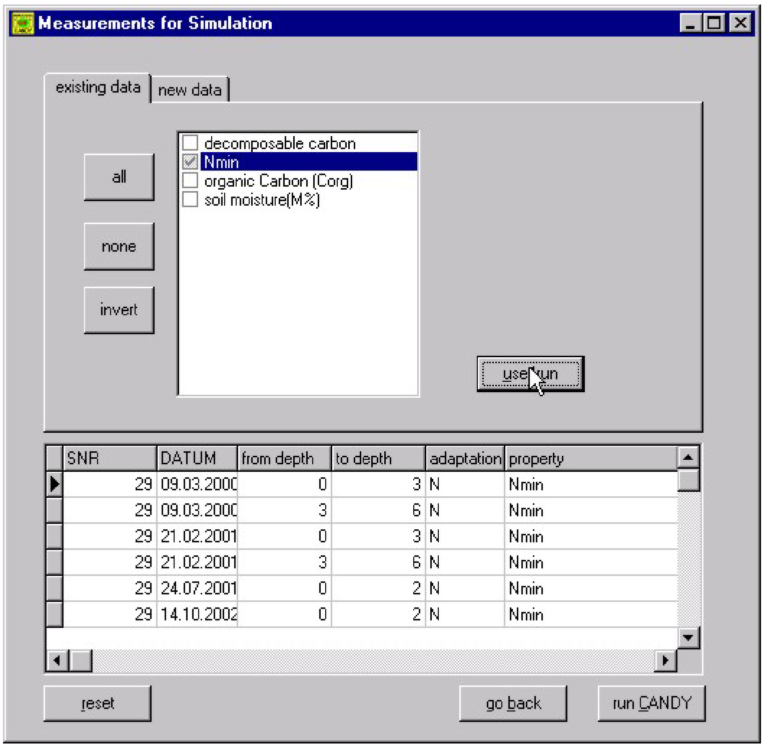
For the second part we prepared some data which you should use to run the model. The data are available in **C:\Programme\wcandy\candy_da.** Please change your data- and resultpath in the **CANDY – user interface** start window and change the system database to **C:\Programme\wcandy\cdyprm.mdb**.



To start a simulation you have to click on **plot selection** and select a plot in the left window (for example __140: Cdec mid). If you don't see the folder **basic-info** in the right window you have to change the folder. At the bottom you will find the button **model run (plot)**. Before clicking the button make sure that the **show dialog with experimental values** check box is checked.

A new window appears where you can select existing experimental values or create new data to evaluate your model run. Both kinds of data will be written in one output file (**MW_QUEF_.dbf**).

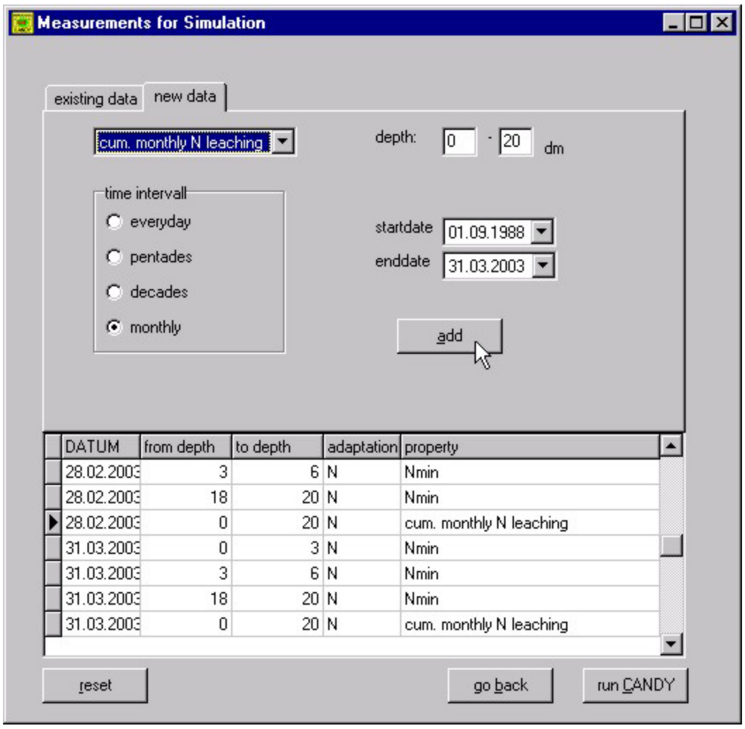
Click on the folder **existing data** to select existing experimental values for the simulation. Select **Nmin** from the shown experimental values in the upper window and click on the button **use4run**. The experimental values will appear in the bottom window.



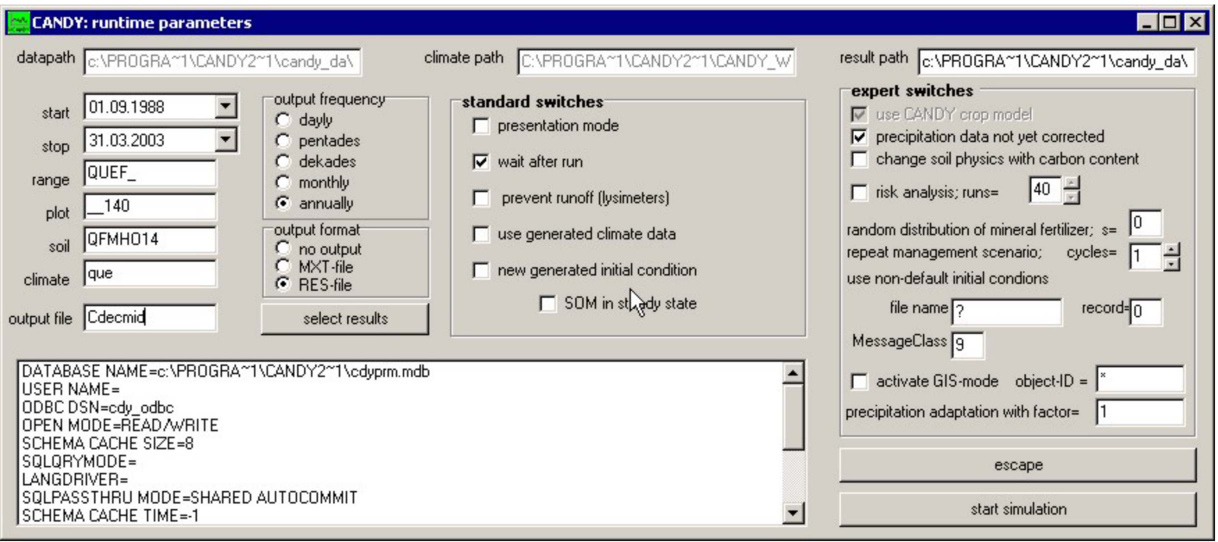
Change into the folder **new data** and select the following new data with the pull down menu:

Nmin, monthly, from 1.1.1989 to 31.3.2003, 0 – 3dm, 3 – 6dm, 18 –20dm and

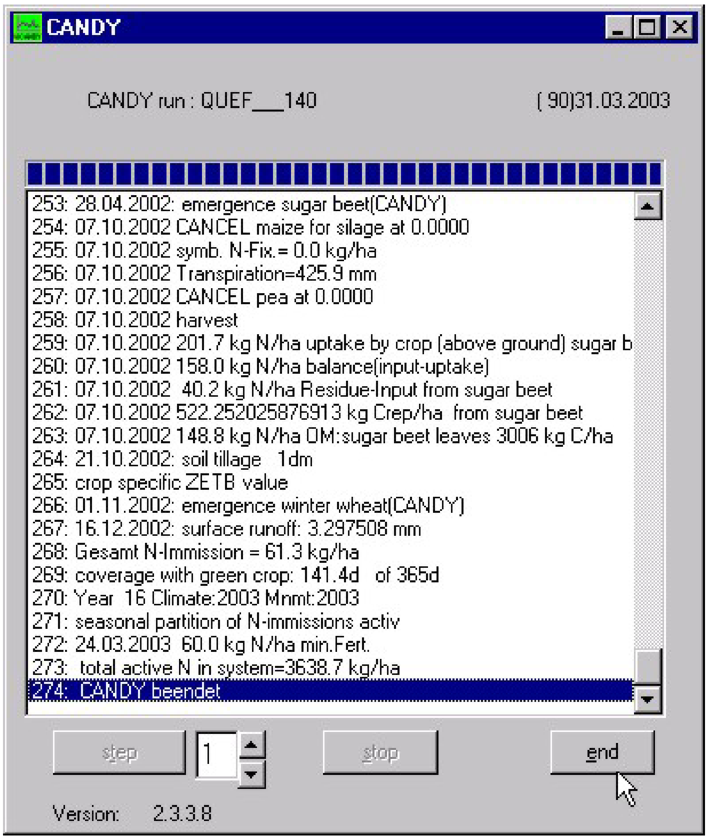
cum. monthly N leaching, from 1.1.1989 to 31.3.2003, 0 – 20dm.



Click the **run CANDY** button. Another window will appear where you can specify your simulation. Select an **annually** output frequency and **RES-file** as output format. With the **select result** button you can select your RES-file output data (select all). Change output file name ‘simres’ into ‘Cdecmid’. Activate the standard switch **wait after run**. No other switches should be selected except the default switches in the part expert switches on the right (see screenshot below). Click the button **start simulation**.



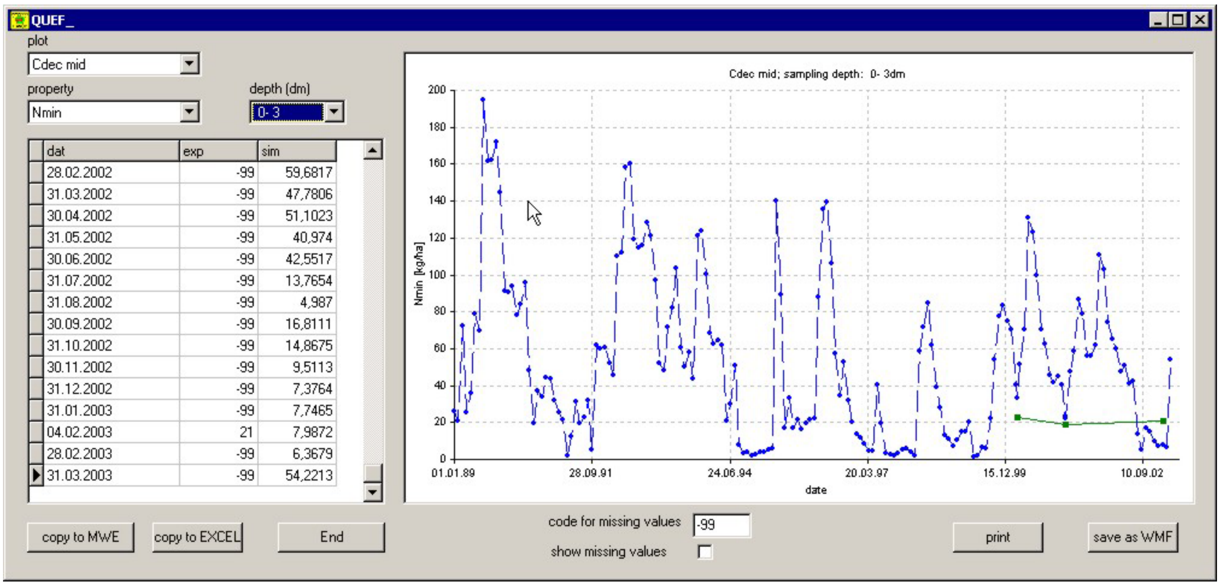
The CANDY model will run and a window with some information about the simulation will appear. If the simulation is finished, the information **CANDY finished** is written in the information window. Please scroll through the window and take a look at the information about the simulation.

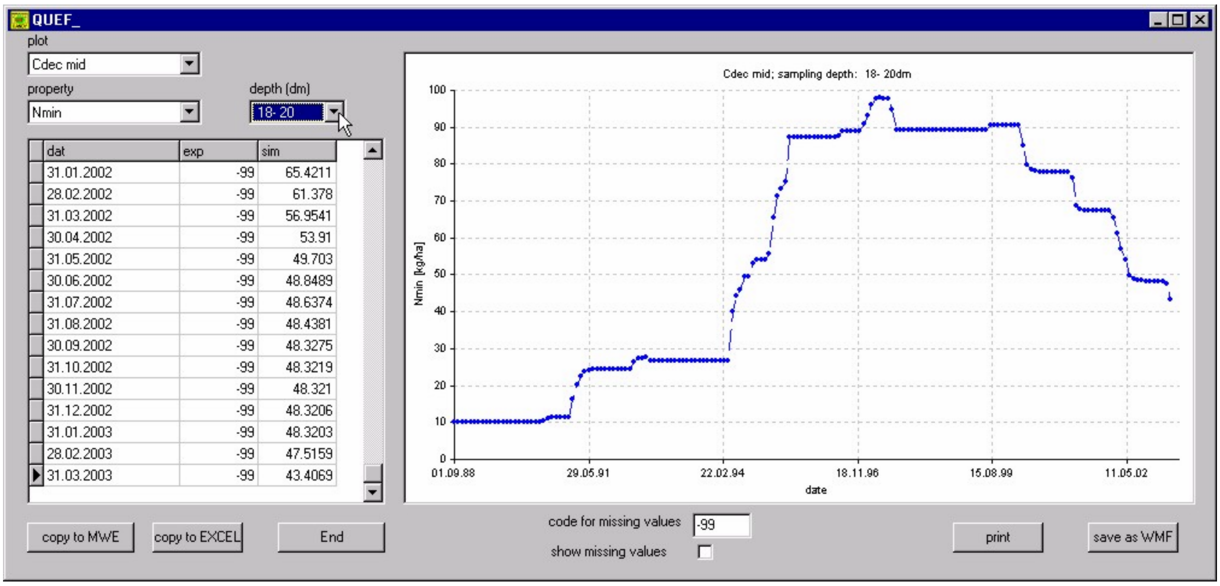


Click the **end** button.
Save the **MW_QUEF_,dbf file** (temporary file, it will be overwritten with the next model run for this plot) in another directory or change the file name (for example: Mid_quef.dbf).

Evaluating results

To evaluate the results click the **end** button of the database window and click the **plot selection** button again. Click on **files** and **MW_QUEF.dbf**. The **evaluate results** window appear. Please select the **plot Cdec mid**, the property **Nmin** and the depth **0-3dm**. After that the simulated data (blue) and the experimental data (green) will appear in the right window where you can evaluate your simulation. Do the simulated data meet your requirements? Are they comparable to the experimental values?

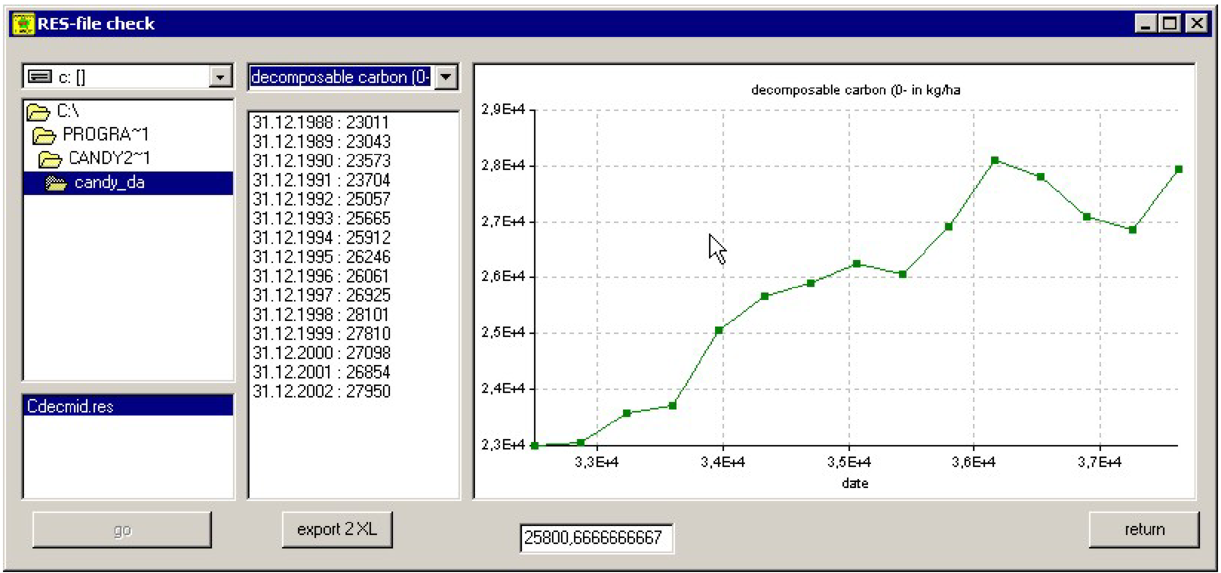




The simulated **Nmin** values in **18 to 20dm** depth show a high amount of mineral nitrogen in this depth which is decreasing at the end of the simulation. Take also a look at the **cum. monthly nitrogen leaching**. It would be interesting to calculate the nitrogen surplus (N-surplus = input mineral N + input organic N + input symbiontic N – in crop) for each year of the simulation to find the reason for this obvious over supply. This you can do with the annual simulated data from the RES-file. Prior to this, copy the simulated data (Nmin 18-20dm) to Excel by clicking on the **copy to Excel** button. The current selection will be copied to Excel. Click the **end** button of the **evaluate results** window and the **database** window.

To watch the results in the RES-file click on the **view RES-files** button. The **RES-file check** window will appear. There you can select a RES-file (double-click and go), watch the results (select a property) and copy the whole file to Excel. After transferring the data to Excel you can calculate the N-surplus (see above) and evaluate the different N-fertilizer strategies for the simulation period. Save the Excel file (Cdecmid_Res.xls).

Please select the property **decomposable carbon** in the **RES-file check** window and, after you watched the results, the property **C-REP-flux**. You can see that the decomposable carbon is increasing and that the CREP-level is high (value of 1200 kg/ha is the optimum for the site). So the organic fertilizer supply should be reduced (see some pages below).

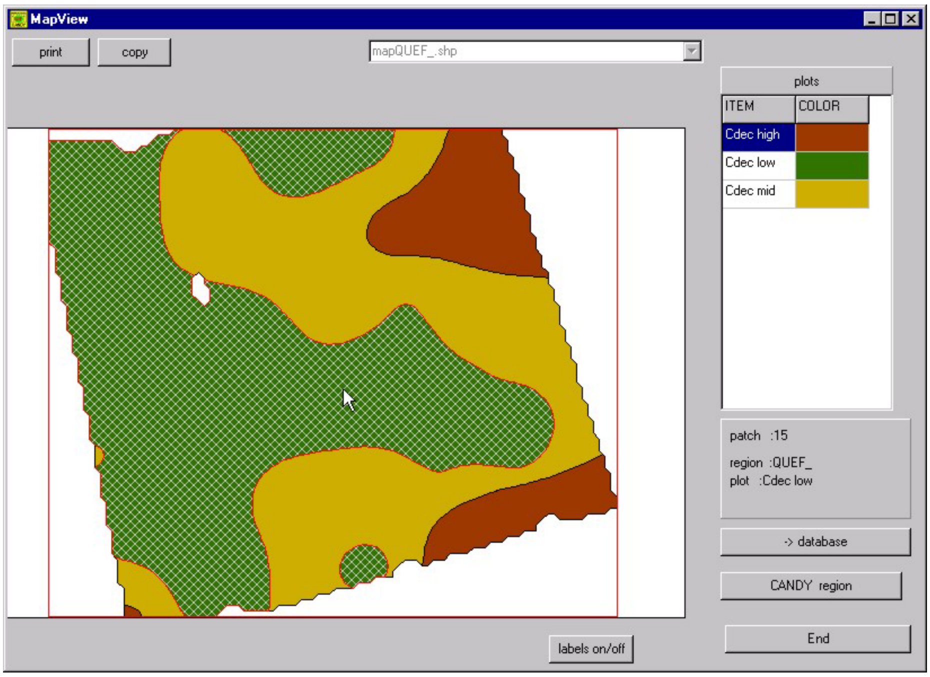


Click on the **return** button.
Go back to the **start** window (CANDY - user interface).

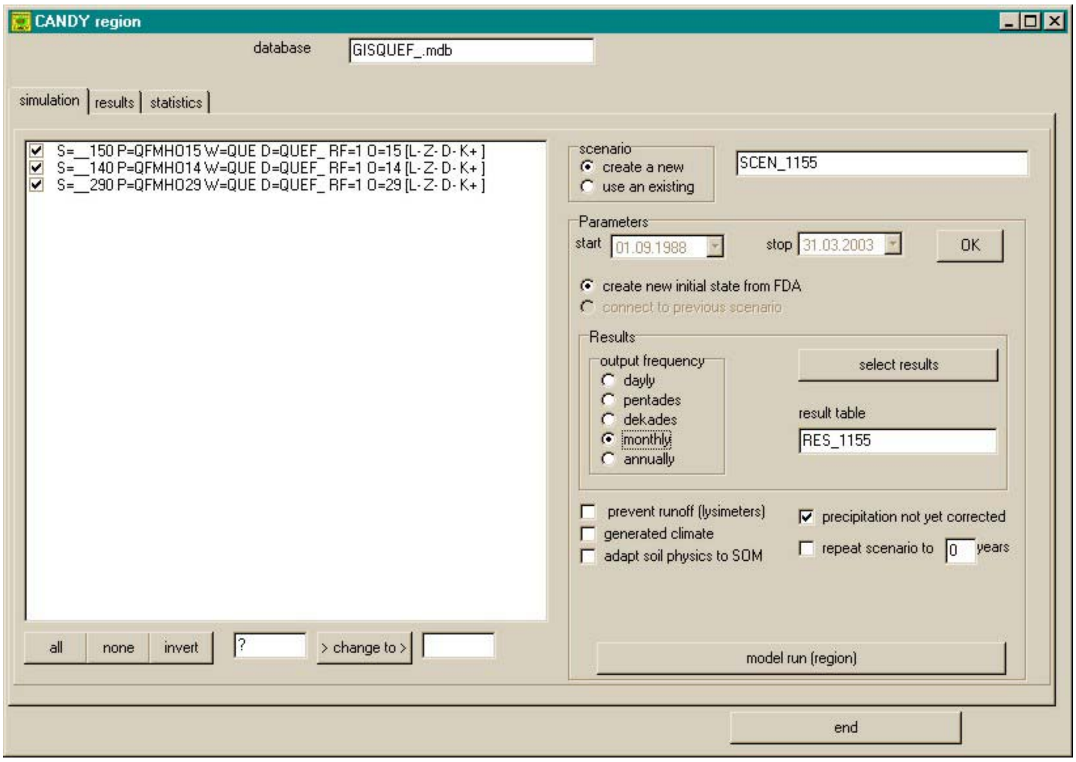
Part 3: Simulations in GIS mode

CANDY gives you the possibility to use prepared shape files from ArcView. If you have specific information about an agricultural field (for example: specific soil conditions which are related to yield) you can create a shape file with defined patches for the field.

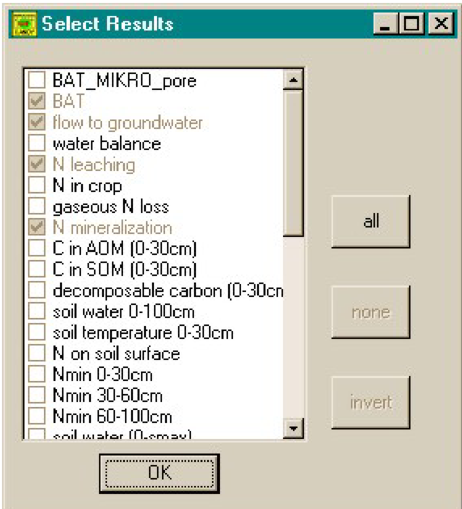
You can watch a prepared shape file in CANDY by clicking on **GISQUEF_.dbf**. A map with three patches appears. If you click on one **patch** of the map you can see the corresponding CANDY plot name on the right. Furthermore, you can change into the corresponding database (**basic information**, **management**, **experimental values**) for more information. (Click end and you will come back from the database view to the map view.)



To start a simulation for the map plots click on **CANDY region**.

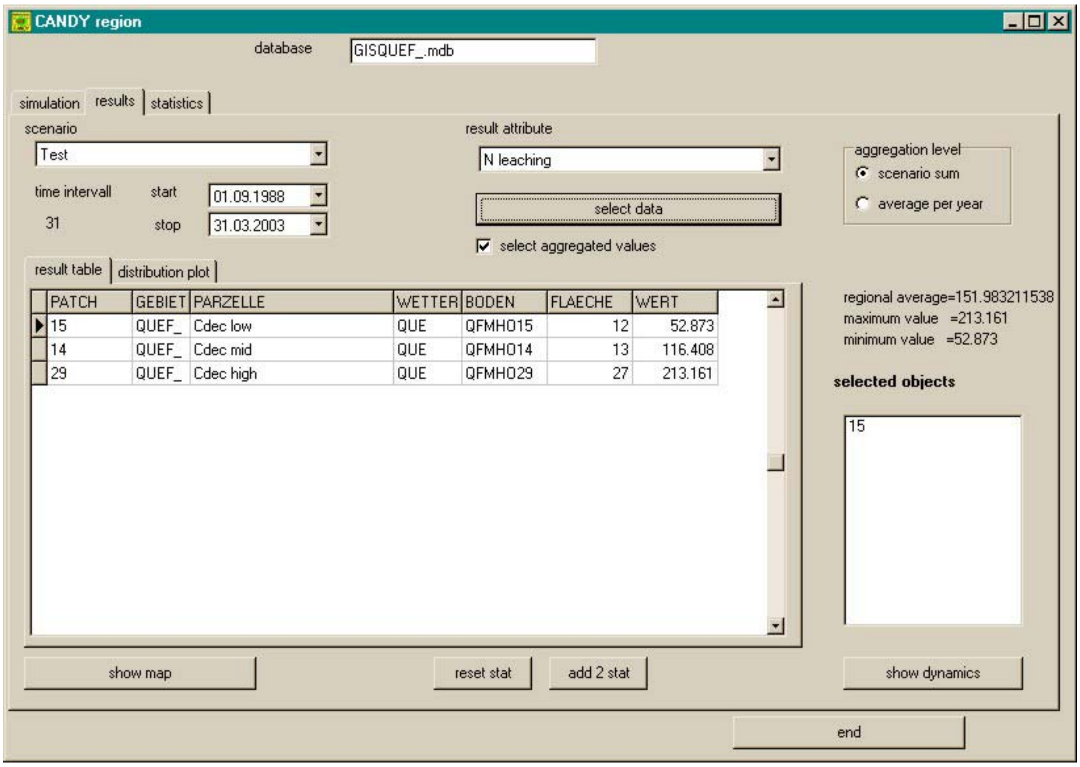


If this step is gone for the first time, the system tells you a scenario identifier. You should change the scenario name to **TEST** and press the **OK** button to accept the suggested time interval. Then select the result items for the simulations.

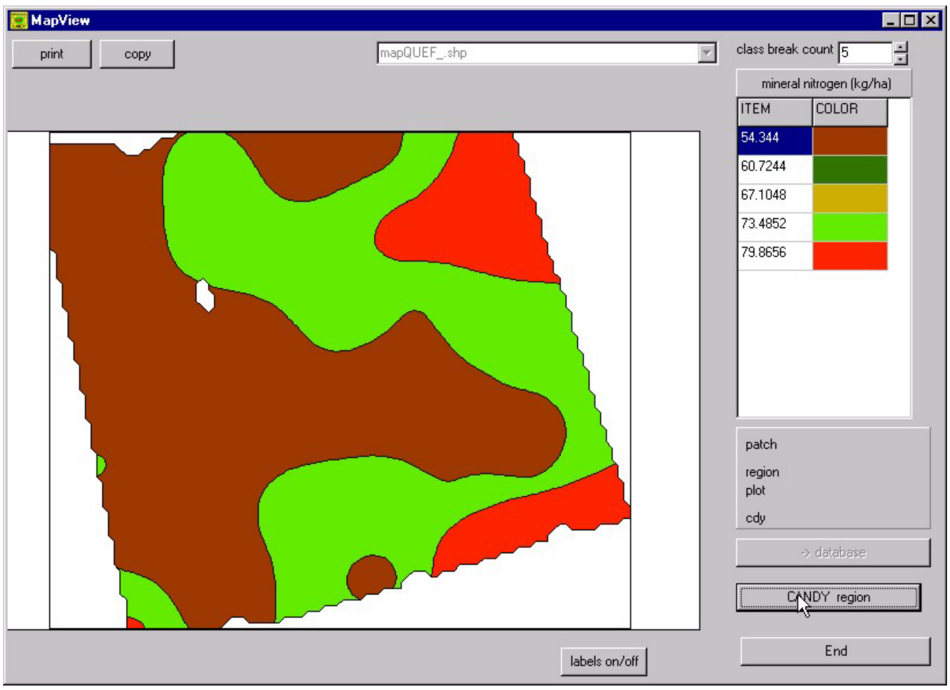


We use **monthly** outputs of biological activity (**BAT**), (water)**flow to groundwater, N-mineralisation** and **N-leaching**. To save the settings pleas press the button **UPDATE scenario settings**.

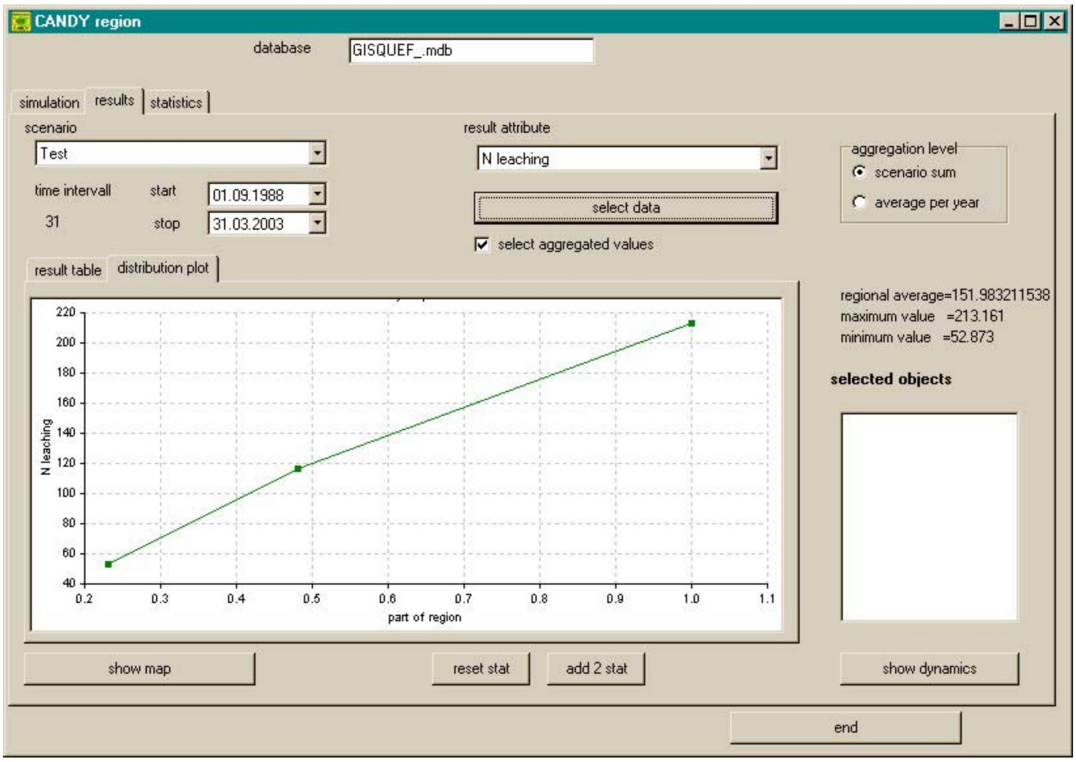
Click on **start simulation** and the model will start. After finishing simulation runs the result data are stored in the GIS related database and can be explored as follows.



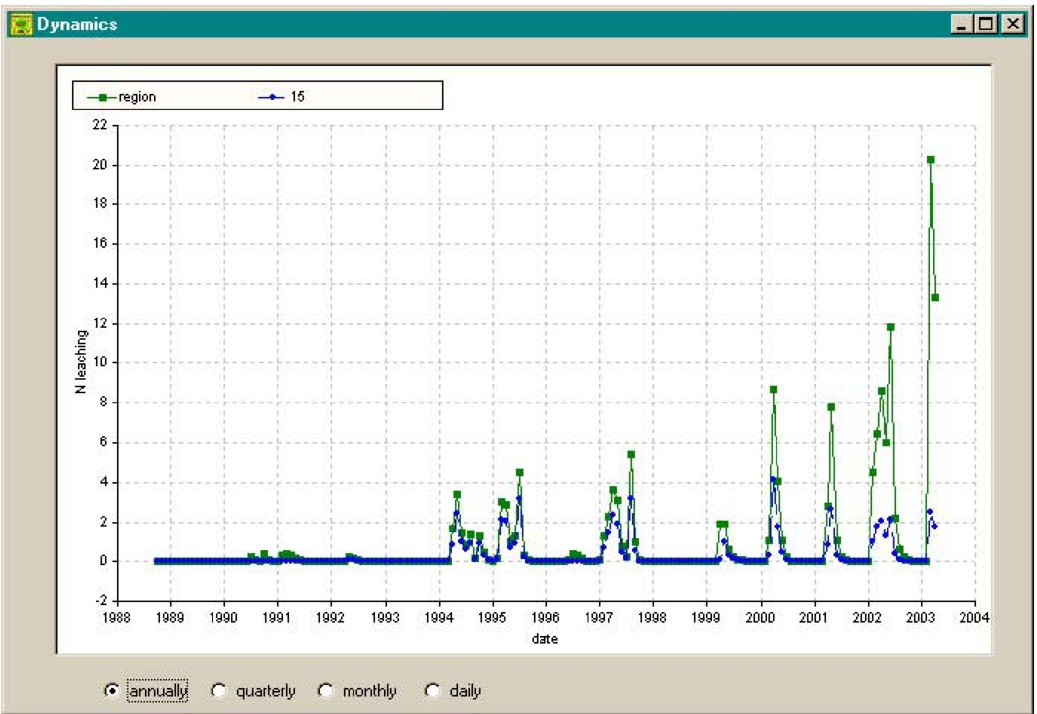
Use the results page to select the results for a given time interval (usually the whole scenario). You may decide to use aggregated values (as sum or as average) or the single results (in our example monthly data). The picture shows the selection of aggregated results that are ready for the map presentation.



Click on **show map** and the current results are shown in the map view. Click on CANDY region and you come back to the results folder.

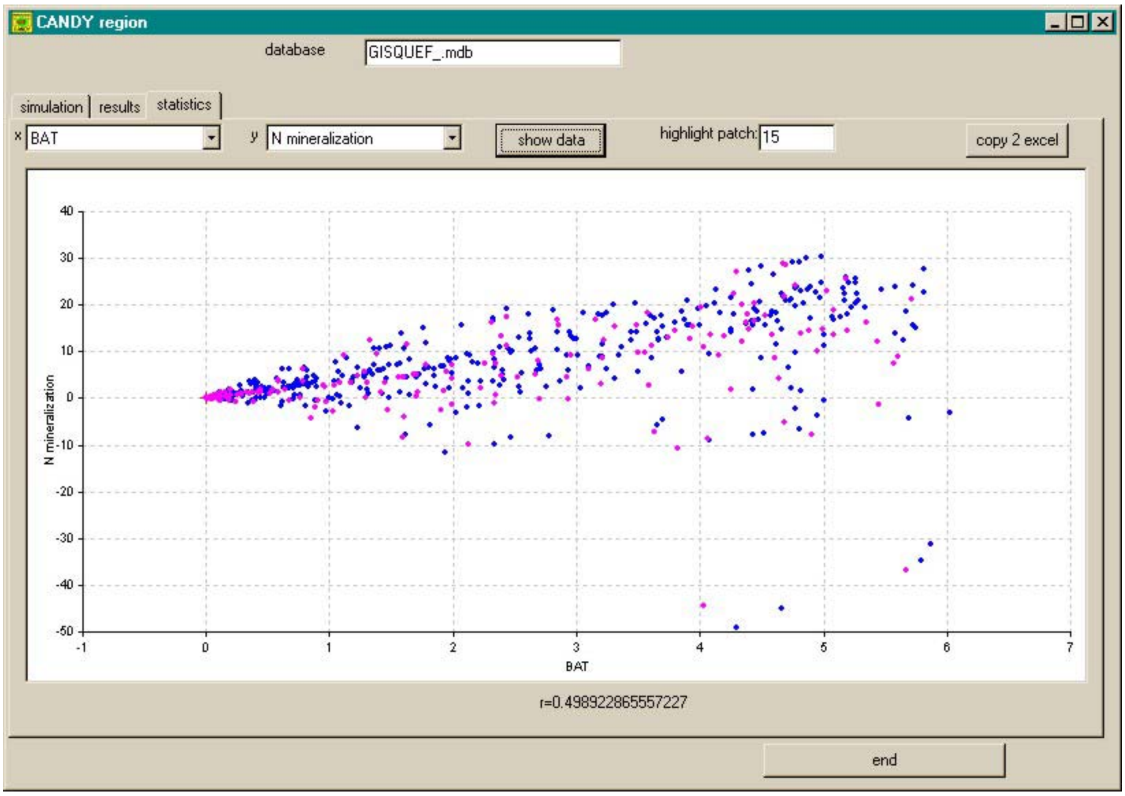


After closing the map view you may have a look at the distribution of the N-Leaching. Double-Click on a item (dot on the graph or record in the table) to add the object to the list of selected objects. For these areas you may show the dynamics of the select attribute (click **show dynamics**).



This graph shows the comparison of the selected objects with regional average.

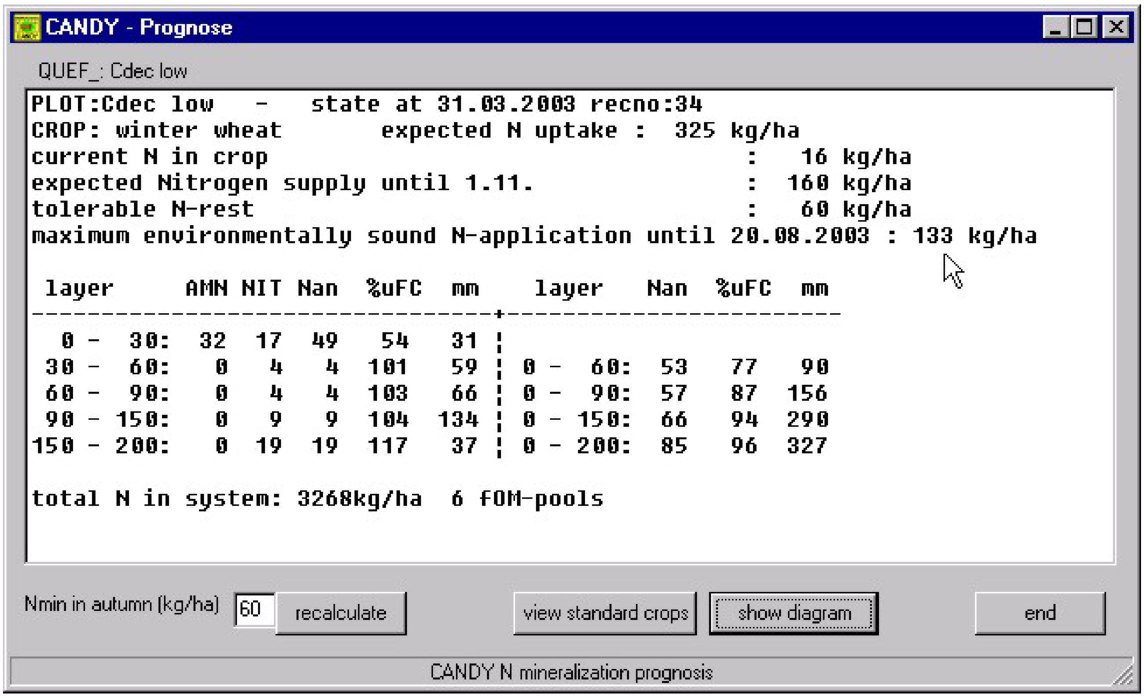
Now go back to the results page and **uncheck** the option **select aggregated values**. Now you will receive monthly data. Select BAT and then click on **add2stat** . This will bring the data to a buffer for simple statistical analyses. This buffer may hold up to 10 different variables. Next step is the selection of N-mineralisation. Put this data also into the statistics buffer and the change to the statistics page. There you may select x and y variables and click on **show data** to see the dependence between them. In order to evaluate a certain area you could specify the index of this patch in the highlight patch field and see the data of this patch in pink.



Part 4: Developing management strategies for N-fertilization

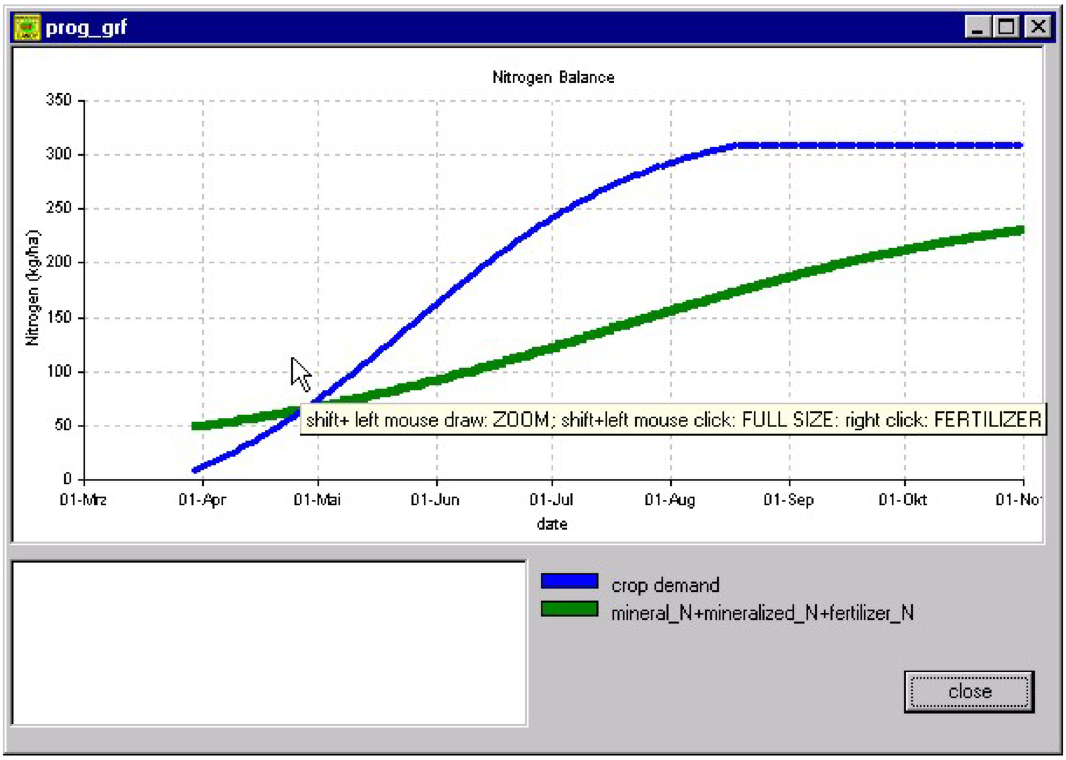
N-prognosis module

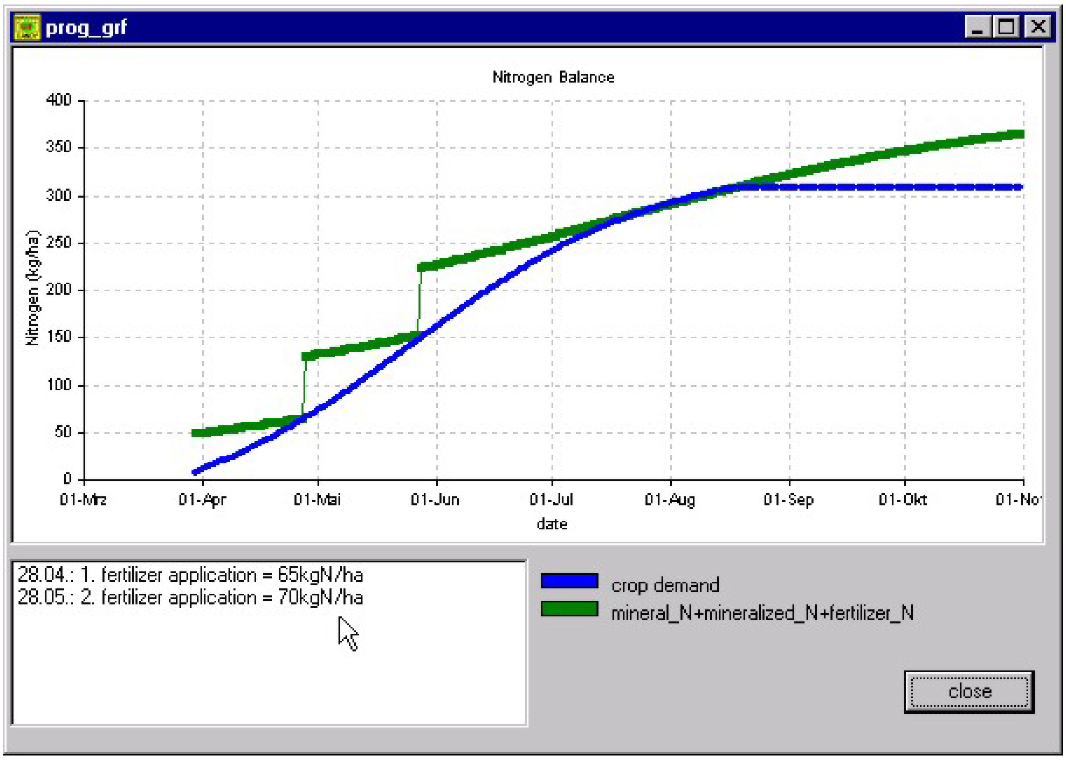
Go to the **database** window (plot selection). Click on plot **__150: Cdec** low and then on the **N-prognosis** button. In the appearing window you will find some information about the selected plot, the current nitrogen in the crop and the amount of nitrogen and water in the soil. The pre-set for the tolerable N-rest in autumn is 60kg/ha. You can change this to another value by entering the new value and clicking on the button recalculate. For the selected plot the current **maximum environmentally sound N-application until 20.8.2003** is 133kg/ha.



Click on the button **show diagram**. The **prognosis** diagram will appear.

There you can decide about some nitrogen fertilization by clicking on a point (nitrogen amount at a date you choose) on the graph with the **right mouse key** (see screenshot next page). A virtual nitrogen fertilization will be added (see window below) if you choose fertilizer in the appearing menu. Try to place a first nitrogen fertilization of about 65 kg/ha at the end of April and a second of about 70 kg/ha at the end of Mai. Will this be enough or would you decide about another fertilization? After your decision about the nitrogen fertilization please add the mineral fertilization into the management data. Therefore you have to change to the **plot selection** (**database** window) and add the management in the **management** folder (see above).





Please enter your decision for the mineral fertilizer application for the current plot from the **N-prognosis** module and run the model until **31.5.2003** (standard run). Start the N-prognosis module again and watch the diagram. Will there be enough nitrogen in the soil for the plot or too much? If you have to modify the nitrogen fertilization, change the fertilizer application in the management data and run the simulation once again.

Part 5: Developing management strategies to optimize the organic carbon input

Copy the RES files into an Excel worksheet and calculate means for the average CREP-flux and biological active time (BAT) for the simulation period. Use these values to estimate the steady state decomposable carbon (CDEC) according to the following equation:

$$CDEC = 685.7 * CREP/BAT.$$

Compare the steady state CDEC with the current CDEC. This will show you the development of CDEC.

The optimum value for the CREP-flux for the site is between 1000 and 1200 kg/ha. Change your organic carbon input in the management data and run a new simulation for the plots.

For example: reduce the organic carbon input in the management data for the plot __290: Cdec high (delete all organic manure applications since 1988 by selecting the data records in the management folder and press the delete record button) and run the simulation again. How are the properties (Nmin and decomposable carbon) changing?