SURCOS: user manual

Version 5.6

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Warning!

To execute the program *surcos* on operative system Windows init the application on the subdirectory *win32/bin/winsurcos.exe*, with 32 bits versions, or *win64/bin/winsurcos.exe* with 64 bits versions.

- Real numbers are represented according to the international standard, overriding locale settings, separating the integer and decimal parts by ".".
- All units are in the International System.

The program has been tested in the following operative systems of Microsoft:

- Windows 7 32 bits.
- Windows 7 64 bits.
- Windows 8.1 32 bits.
- Windows 8.1 64 bits.
- Windows 10 32 bits.
- Windows 10 64 bits.

The language activation is perfomed through the regional configuration in the operative system. Version 5.6 is offered in English, Spanish, French and Italian.

Some problems with graphic representation have been reported due to OpenGL configuration failure in the graphical card driver. In that case, the latest driver should be installed.

Other failures have been reported when saving the graphical file if Windows is executed in a VirtualBox. In that case, the graphical acceleration should be desactivated in the VirtualBox configuration.

Windows 7, Windows 8.1 and Windows 10 are trademarks of Microsoft.

Chapter 1

Instalation instruction

1.1 Download

Program *surcos* can be freely downloaded from:

- *http://digital.csic.es/handle/10261/75830*

The latest program *surcos* source code can be freely downloaded, under a BSD type licence, from:

- *https://github.com/jburguete/surcos*

1.2 Instalation

To install *surcos* it must only be decompressed in the desired folder. It is recommended to avoid blank spaces and symbols in the names of the folder.

1.3 Program files

The program contains the following folders:

win32/bin

Folder with the executable file, the libraries executable files and the diagram files in the Windows 32 bits version.

win32/etc

win32/lib

These two folders contain some files of the libraries for Windows 32 bits.

win32/share

Contains the language files for Windows 32 bits.

win64/bin

win64/etc

win64/lib

win64/share

Equivalent for Windows 64 bits.

examples

Example files.

src

Source code of *surcos* and source code of the libraries used.

1.4 Source code compilation

The source code is written in C and has been compiled using the GNU free tools: gcc, gmake, aclocal, autoconf and pkg-config. The Windows version has been compiled using also msys2.

Program *surcos* uses the following libraries:

libiconv (http://ftp.gnu.org/pub/gnu/libiconv)

zlib (http://sourceforge.net/projects/libpng)

libxml (http://xmlsoft.org)

libffi (ftp://sourceware.org/pub/libffi)

glib (http://ftp.gnome.org/pub/gnome/sources/glib)

gettext (http://ftp.gnu.org/pub/gnu/gettext)

libpng (http://sourceforge.net/projects/libpng)

freetype (http://sourceforge.net/projects/freetype)

fontconfig (http://fontconfig.freedesktop.org)

pixman (http://www.cairographics.org)

cairo (http://www.cairographics.org)

atk (http://ftp.gnome.org/pub/gnome/sources/atk)

pango (http://ftp.gnome.org/pub/gnome/sources/pango)

gdk-pixbuf (http://ftp.gnome.org/pub/gnome/sources/gdk-pixbuf)

gtk+ (http://ftp.gnome.org/pub/gnome/sources/gtk+)

freeglut (http://sourceforge.net/projects/freeglut)

Once installed and configurated all the tools and libraries, the sequence to compile is made of four steps:

1. aclocal
2. autoconf
3. ./configure
4. make

Some systems require corrections. Look at the beginning of the file configure.ac where more detailed instructions are provided.

The program *surcos* has been compiled and tested in the following operative systems:

- Debian Linux 8
- Debian kFreeBSD 8
- Debian Hurd 8
- DragonFly BSD 4.6
- Dyson Illumos
- Fedora Linux 25
- FreeBSD 11.0

- Linux Mint DE 2
- Microsoft Windows 7 32 bits
- Microsoft Windows 7 64 bits
- Microsoft Windows 8.1 32 bits
- Microsoft Windows 8.1 64 bits
- Microsoft Windows 10 32 bits
- Microsoft Windows 10 64 bits
- NetBSD 7.0
- OpenBSD 6.0
- OpenIndiana Hipster
- OpenSUSE Linux Tumbleweed
- Ubuntu Linux 16.10

Chapter 2

Application windows

This chapter describes the windows in the program.

2.1 Main window

The main window appears when launching the program and is used as basic interface with the user. It contains the links to get access to the rest of the windows.

Figure 2.1: Initial and main window in the application *surcos*

Element		
Icon	Action	Utility
Exit	Click	Exit the application
Open	Click	Open window to load project
Configure	Click	Open window to configure project
Run	Click	Run project
Graphics	Click	Open window for visualization of the results
Summary	Click	Open summary window
Help	Click	Information

Table 2.1: Description of the different actions offered by the main menu *surcos*

Using the icons in table 2.1 it is possible to get access to the different utlities in the program.

2.2 Configuration of a project

2.2.1 Geometry configuration window

Program *surcos* simulates irrigation in a quadrilateral network of furrows. The geometry configuration window (see figure 2.2) can be used to edit/modify the project topographic data by means of the coordinates of the four vertices that define the furrow plot.

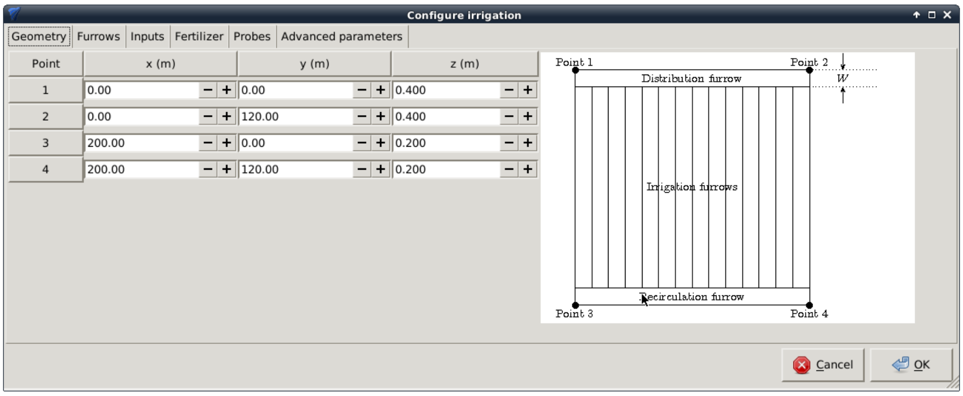

Figure 2.2: Geometry configuration window

As displayed in figure 2.2, the distribution furrow runs between points 1 and 2 and the recirculation furrow, if any, can be defined between points 3 and 4. The irrigation furrows are assumed in the normal direction to the former.

2.2.2 Furrow configuration window

The window displayed in 2.3 allows to define the geometric properties of the furrows as divided in three types: distribution, recirculation and irrigation furrows. The different options appear as active or inactive depending on the previous definition of the furrow in our project. The available characteristic to edit are all displayed in figure 2.3.

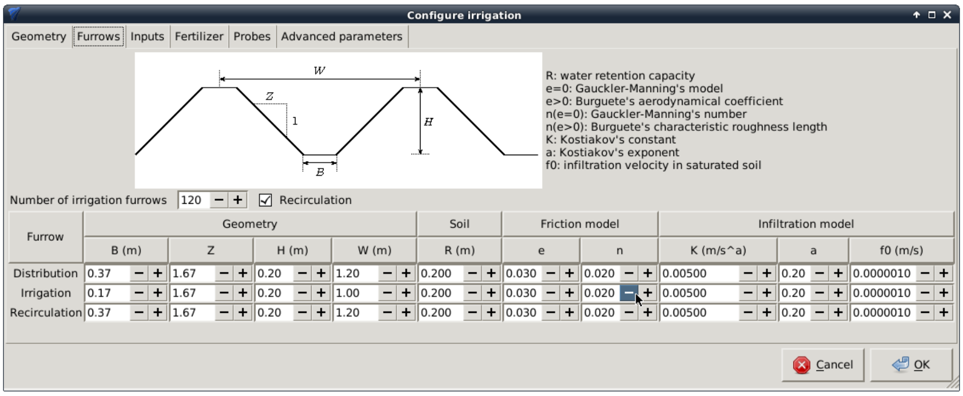

Figure 2.3: Furrow configuration window

2.2.3 Inlet configuration window

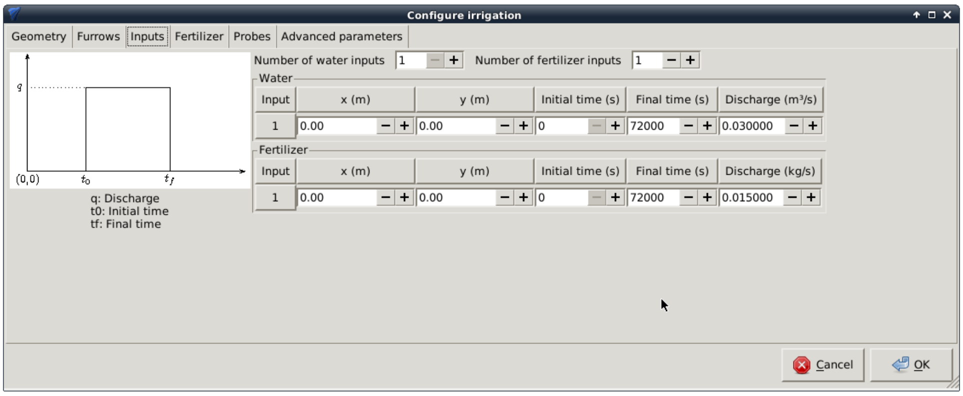

Figure 2.4: Inlet configuration window

Window 2.4 can be used to configure the total water and fertilizer inlet to the furrow system. Every inlet is assigned to a point in the plot where the flow is applied, and is characterized by the initial and the final application times of a constant discharge. The discharge is volumetric rate flow for the water and a mass flow rate for the fertilizer. It is possible to define more complex inlet hydrographs by means of a sequence of inlet discharges at the same point.

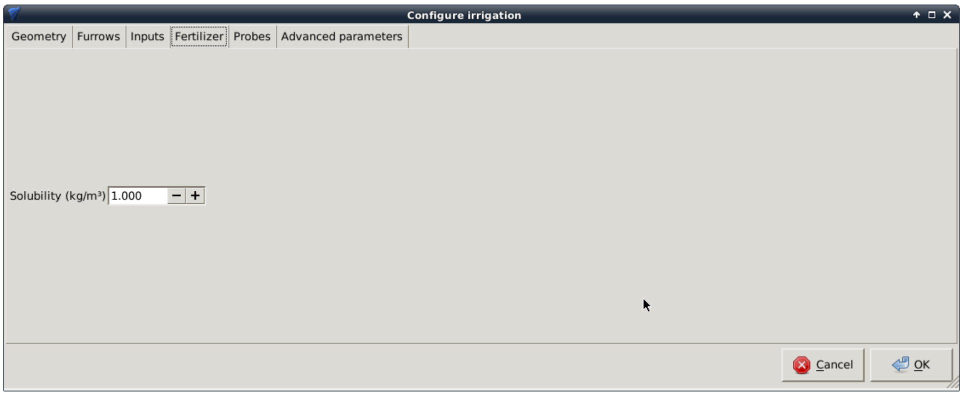

Figure 2.5: Fertilizer configuration window

2.2.4 Fertilizer configuration window

Window 2.5 is used to state the solubility characteristics of the fertilizer.

2.2.5 Probe configuration window

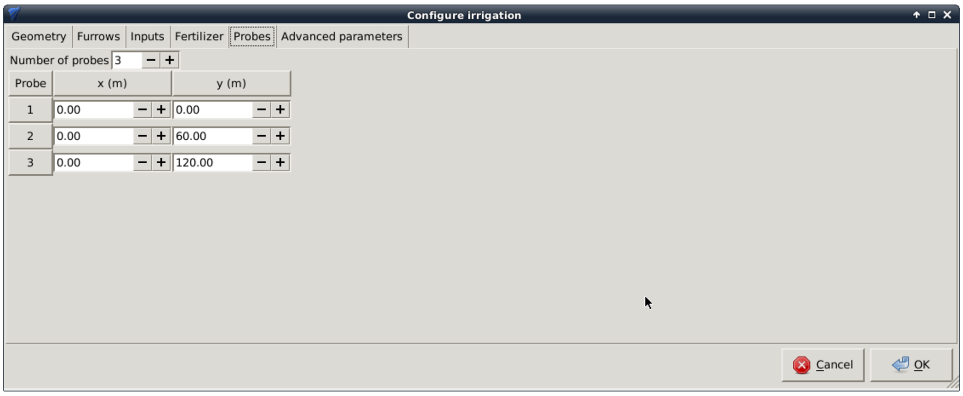

Figure 2.6: Probe configuration window

Window 2.6 can be used to define the number of probes and their location in the plot. Note that, if the point assigned falls out of a furrow, the program finds the nearest position within a furrow.

2.2.6 Advanced parameters configuration window

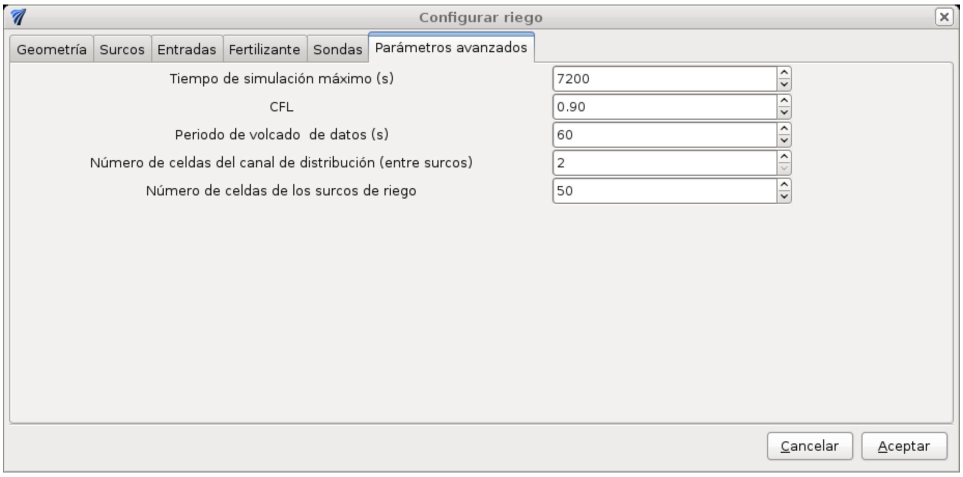

Figure 2.7: Advanced parameter configuration window

Window 2.7 contains different options to configure the numerical simulation, as follow:

Maximum simulation time: Usually, program *surcos* runs the simulation from the initial conditions up to the moment all the applied water has infiltrated in the terrain. In order to avoid excessively long simulation times, this parameter can be used to state a horizon or target time. From that limit, the computation stops even though some water still remains on the surface.

CFL: Dimensionless numerical parameter proportional to the time step used by the resolution method. It takes values between 0 and 1 for numerical stability reasons. Values close to 1 are optimal. Excessively low values can slow the computation.

Data saving period: Simulation time interval used to save series of numerical results in a file. It is possible to have $n = \frac{t_s}{p_v}$ snapshots of the irrigation event, with t_s the simulation time and p_v the data saving period.

Number of cells in the distribution furrow (between irrigation furrows): Number of computational cells in the distribution/recirculation furrow between 2 irrigation furrows. (Minimum 3).

Number of cells in the irrigation furrows: Number of computational cells in every irrigation furrow. More cells implies better quality in the results and slower computations.

2.3 Simulation

After the configuration, the simulation of the project is performed by pressing run in the main menu: 

2.4 Results visualization

2.4.1 Graphical results

The graphics are controlled from the window 2.8, where an interactive dial can be used to move forward and backward in time the evolution of the variables represented. It is also possible to choose the furrow, the variable and the probe to view.

The program offers the possibility to save the graphical results by pressin the button at the bottom of the menu. The image of the plot appearing on the screen in that moment is saved in format *png*.

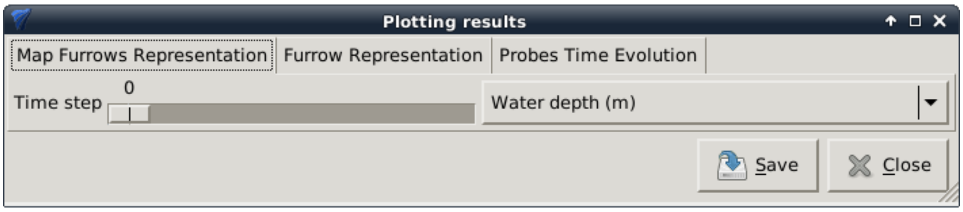

Figure 2.8: Plot selection window

Program *Surcos* produces three types of plots. The first is a plan view of the furrow network, with the possibility to display the distribution in the network of the variables described in table 2.2.

The second graphical option is a cartesian XY plot of the longitudinal profile along different furrows.

The variables that can be plotted in the longitudinal profile are those in table 2.3.

Variable	Units
Water depth	m
Fertilizer concentration	kg/m^3
Infiltrated water volume per unit furrow length	m^2
Fertilizer mass per unit furrow length	kg/m

Table 2.2: Variables to view on the furrow network plot

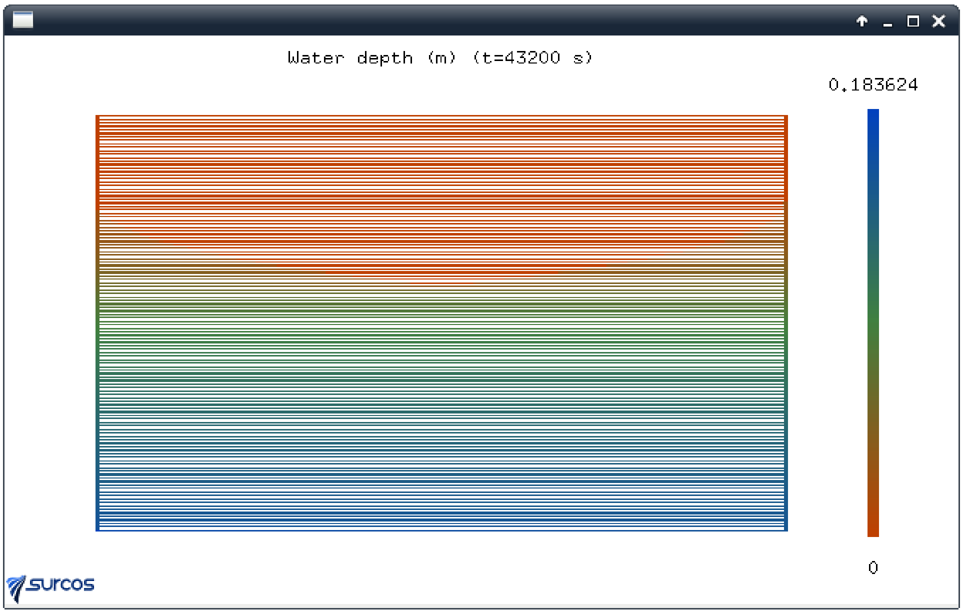

Figure 2.9: Example of graphical view in a map of the water depth

The third graphical option is a time evolution of the variables in the different probes. These are contained in table 2.4.

2.4.2 Summary

The access to the summary is through the button . This is useful to produce a brief text report with the description of the irrigation configuration and the most relevant results obtained. An example is displayed in figure 2.12.

The results include the surface, infiltrated and percolated water and fertilizer mass both in the irrigation furrows and in the distribution/recirculation furrows. The infiltrated water mass in the soil that remains available to the crops by retention forces, contrary to the percolated water.

Variable	Units
Water depth	m
Discharge	m^3/s
Surface level (Water surface and bottom)	m
Fertilizer concentration	kg/m^3
Surface and infiltrated water volume and fertilizer mass	m^2, kg/m
Irrigation advance and recession times	s

Table 2.3: Variables that can be plotted in every furrow

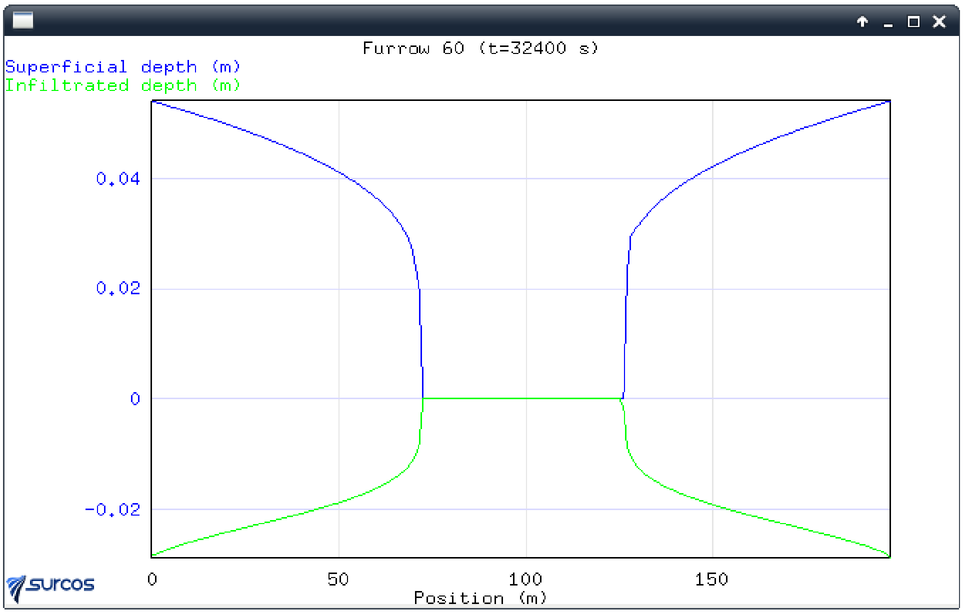

Figure 2.10: Example of the longitudinal profile of the surface and infiltrated water volume and fertilizer mass in a furrow

The uniformity of distribution is calculated only in the irrigation furrows. It follows the ratio between the infiltration average of the 25% of the less irrigated points and the total infiltration average.

Finally, the efficiency is computed as the infiltrated mass in the irrigation furrows divided by the total applied mass. Therefore, both the percolated mass and that present in the distribution/recirculation furrow are considered losses in the estimation of the efficiency.

The summary window cannot be saved in a file. In order to save the summary data, one option is to select the text with the mouse, copy with the key *Control+C* and paste it in any text editor such as Microsoft Word.

Variable	Units	Observations
Water depth	m	
Fertilizer concentration	kg/m^3	

Table 2.4: Variables that can be plotted in a probe.

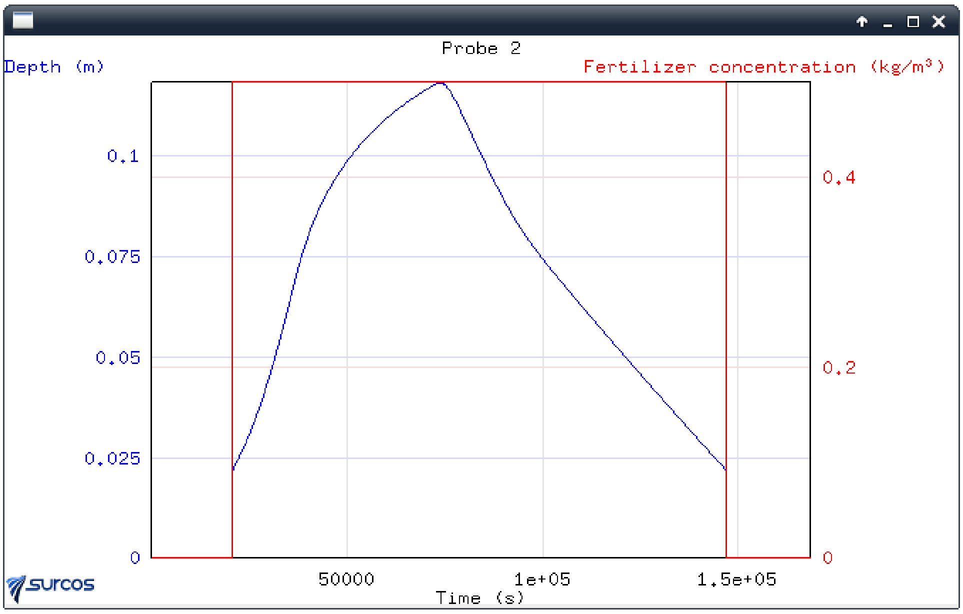

Figure 2.11: Example of time evolution at a probe.

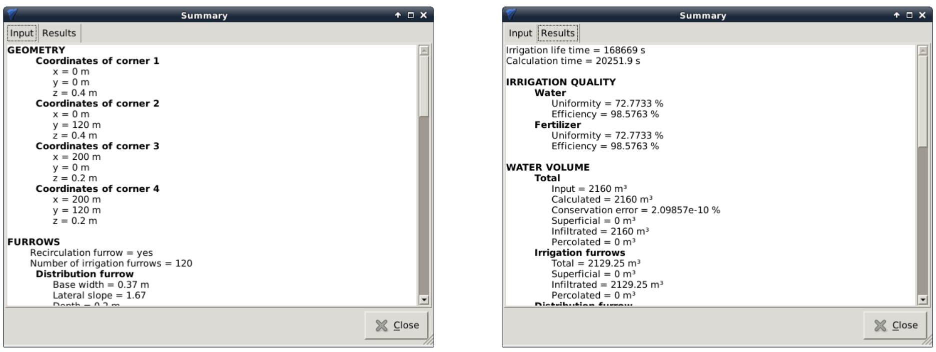

Figure 2.12: Summary of the input data (Left) and results (Right)

Chapter 3

Input and Output files format

In program *Surcos*, the input and output files are stored in a single common folder whose name can be chosen by the user. However, the input and output files are plain ASCII files with a fixed name that follows the structure detailed in next sections

3.1 Input files

3.1.1 The geometry file: field.in

The geometry file is always named:

- Case_folder\field.in

This file contains the following set of numbers:
o n s
x_1 y_1 z_1
x_2 y_2 z_2
x_3 y_3 z_3
x_4 y_4 z_4
b_b z_b H_b D_b R_b ϵ_b r_b K_b a_b i_b d_b h_b Q_b c_b
b_i z_i H_i D_i R_i ϵ_i r_i K_i a_i i_i d_i h_i Q_i c_i
b_c z_c H_c D_c R_c ϵ_c r_c K_c a_c i_c d_c h_c Q_c c_c
with:

o 1 if there is recirculation furrow, 0 otherwise.

n Number of irrigation furrows. 0 if there is a single furrow. In that case, the flow in the distribution furrow is simulated.

s Fertilizer solubility.

x_j, y_j, z_j Spatial coordinates of vertex j defining one corner of the furrow network plot.

b_k Base width in furrow k.

z_k Lateral slope in furrow k.

H_k Maximum depth in furrow k.

D_k Furrow separation at furrow k.

R_k Water retention capacity in furrow k.

ϵ_k Burguete aerodynamic roughness coefficient ($\epsilon > 0$) or Gauckler-Manning roughness coefficient($\epsilon = 0$) at furrow k.

r_k Gauckler-Manning number ($\epsilon = 0$) or Burguete roughness characteristic length ($\epsilon > 0$) at furrow k.

K_k Kostiakov infiltration coefficient at furrow k.

a_k Kostiakov infiltration power at furrow k.

i_k Infiltration saturated rate at furrow k.

d_k Diffusion coefficient at furrow k.

h_k Initial surface water depth at furrow k.

Q_k Initial surface water discharge at furrow k.

c_k Initial fertilizer concentration at furrow k.

The subindex label k represents: b for the distribution furrow, i for all the irrigation furrows (they are all assumed to share the same geometry properties) and c for the recirculation furrow.

3.1.2 Inlet water and fertilizer file: input.in

Water and fertilizer inlet is defined in a file named:

- Case_folder\input.in

The following set of data must be provided:
n_w n_s
x_1 y_1 I_1 F_1 q_1
...
x_{n_w} y_{n_w} I_{n_w} F_{n_w} q_{n_w}
x_1 y_1 I_1 F_1 q_1
...
x_{n_s} y_{n_s} I_{n_s} F_{n_s} q_{n_s}
with:

n_w, n_s the number of water and fertilizer inlet points respectively,

x_i x coordinate of the i inlet point,

y_i y coordinate of the i inlet point,

I_i initial time at the i inlet point,

F_i final time at the i inlet point,

q_i Inlet discharge at the i inlet point, in m^3/s if it is a water inlet or in kg/s when it is a fertilizer inlet.

Note that first the n_w water inlet points must be defined and then the n_s fertilizer inlet points.

3.1.3 Simulation time file: times.in

The relevant time data in the simulation are defined in file:

- Case_folder\times.in

This file contains the following information:
t_f cfl t_m
where:

t_f is the total simulation time,

cfl is the CFL number controlling the time step,

t_m is the time interval to write intermediate numerical results in a file.

3.1.4 Grid file: mesh.in

The number of grid computational grid cells is defined in file:

- Case_folder\mesh.in

This file contains:
n_d n_i
with:

n_d number of cells inserted in the distribution/recirculation furrows between each pair of irrigation furrows,

n_i number of cells in every irrigation furrow.

3.1.5 Probes file: probe.in

The measurement points or probes are specified in the file:

- Case_folder\probe.in

This file contains the following data:
n_p
x_1 y_1
...
x_{n_p} y_{n_p}
with:

n_p total number of probes,

x_i x coordinate of the location of the i probe,

y_i y coordinate of the location of the i probe.

3.1.6 Model file: model.in

The models used are defined in the file:

- Case_folder\model.in

This file contains the following data:
m_f m_i m_u m_a
with:

m_f 1 if there is fertilizer transport, 0 otherwise.

m_i 1 if there is infiltration, 0 otherwise.

m_u 1 if there is turbulent diffusion, 0 otherwise.

m_a 1 if the Boussinesq convection model is used, 0 if the simple model is used.

3.2 Results files

In program *Surcos* the results are gathered in files according to the following names:

00b Distribution furrow.

00c Recirculation furrow.

xxx Irrigation furrow, with xxx representing the furrow number with 3 digits. The furrow numbering goes from 0 to n-1 with n the total number of irrigation furrows.

The results files are written in the same folder where the input data files are. The program generates 3 different results files, all of them in ASCII format.

3.2.1 Longitudinal profile files (xxx-yyy.out)

Surcos generates a file to store the longitudinal profile of every variable in every furrow for every intermediate time as defined in section 3.1.3). The name of these files is as follows:

- $xxx - yyy.out$

where xxx represents the furrows name with the above described codification and yyy represents the intermediate time step with 3 digits.

The profiles are provided using files with 12 columns in the form:

$$
\begin{array}{cccccccccccc}
x_1 & h_1 & A_1 & Q_1 & z_{s1} & z_{f1} & -A_{i1} & c_1 & -A_{ci1} & -A_{p1} & -A_{cp1} & \beta_1 \\
 & & & & & & \cdots & & & & & \\
x_n & h_n & A_n & Q_n & z_{sn} & z_{fn} & -A_{in} & c_n & -A_{cin} & -A_{pn} & -A_{cpn} & \beta_n
\end{array}
$$

with:

x_i the longitudinal coordinate of the i grid point,

h_i the surface water depth of the i grid point,

A_i the surface wetted cross section of the i grid point,

Q_i the surface water discharge of the i grid point,

z_{si} the water surface elevation of the i grid point,

z_{fi} the bed level elevation of the i grid point,

$-A_{ii}$ the infiltrated water volume (negative) per unit furroe length of the i grid point,

c_i the surface fertilizer concentration of the i grid point,

$-A_{cii}$ the mass of fertilizer infiltrated (negative) per unit furrow length of the i grid point,

$-A_{pi}$ the volume of percolated water per unit furrow length of the i grid point,

$-A_{cpi}$ the mass of percolated fertilizer per unit furrow length of the i grid point,

β_i the Boussinesq convection coefficient of the i grid point,

n the number of grid points in the furrow.

3.2.2 Advance and recession times files (xxx.out)

Surcos generates files with information concerning the advance and recession times in every furrow. The names of the files are in the following form:

- *xxx.out*

where *xxx* represents the name of the furrow with the above described codification.

These files contain 3 columns in the form:

$$\begin{array}{ccc} x_1 & t_{a1} & t_{r1} \\ & \cdots & \\ x_n & t_{an} & t_{rn} \end{array}$$

with:

x_i the longitudinual aoordinate of the i grid cell,

t_{ai} the advance time for the i grid cell,

t_{ri} the recession time for the i grid cell,

n the number of grid points in the furrow.

3.2.3 Probe files (probes.out)

The files where the probe information is stored are called *probes.out*. This file is written with the following format:

$$\begin{array}{cccccc} t_0 & h_{1,0} & c_{1,0} & \cdots & h_{n_p,0} & c_{n_p,0} \\ & & & \vdots & & \\ t_{n_t} & h_{1,n_t} & c_{1,n_t} & \cdots & h_{n_p,n_t} & c_{n_p,n_t} \end{array}$$

with:

t_j the j time level, with 0 the initial time,

$h_{i,j}$ the surface water depth measured in probe i at time j,

$c_{i,j}$ the surface fertilizer concentration measured in probe i at time j,

n_p the total number of probes,

n_t the total number of time steps.