Short User GUIDE

Version 4.3

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1. Hi-sAFe overview

Hi-sAFe is a dynamic generic model simulating interactions between plants (trees and crops) in three dimensions, which account for the classical balance of materials and energy (water, nitrogen, light).
Hi-sAFe is implemented under the **CAPSIS** modelling platform (De Coligny et al, 2002) which is portable software, freely available under a GNU license (http://capsis.cirad.fr/capsis/home). The Capsis project aims at integrating several types of forest growth and dynamic models and providing forest management tools to establish and compare different silviculture scenarios.

Hi-sAFe is designed to simulate scenes such as:

- Mixtures of trees and crops, whether trees are aligned, dispersed or isolated
- Perennial row crops with ground cover
- Mixtures of herbaceous crops, foot, row or strip
- Multi-species forests
- Isolated trees (urban trees, hedges) with or without ground vegetation
- Plots of pure crops with spatial heterogeneity
- Precision agriculture (technical itineraries adapted to the spatial heterogeneity of the stand)

A tree model has been specifically developed with 8 main modules:

- Phenology
- Light interception
- Water demand calculation
- C allocation
- Fruit production module
- Nitrogen fixation module
- Fine root growth
- Coarse root topology growth

STICS (Brisson et al, 2001) is the crop model embedded in Hi-sAFe. It has been in development at INRA-Avignon (France) since 1996 (http://www6.paca.inra.fr/stics). STICS simulates crop growth as well as soil water and nitrogen balances driven by daily climatic data. It calculates both agricultural variables (yield, input consumption) and environmental variables (water and nitrogen losses). One of the key elements of STICS is its adaptability to various crops. This is achieved by the use of generic parameters relevant for most crops and with options in the model concepts concerning both physiology and management, which have to be chosen for each crop.

The water and nitrogen repartition module between trees and crop also has been specially designed for HisAFe with a **minimisation of energy approach**. This simply means that the resources will be extracted where it is the easiest (plants are lazy). The model should be able to describe the opportunism of plants in heterogeneous environments, and especially when heterogeneity results from plant competition.

2. Hi-sAFe simulated scene

Usual agroforestry projects will take place at a variety of scales, but the Hi-sAFe belowground modules must operate at relatively small horizontal and vertical scales, over which local conditions can vary significantly. The following diagrams describe the process by which we move from the field scale through to the soil scale at which the Hi-sAFe belowground modules will operate.

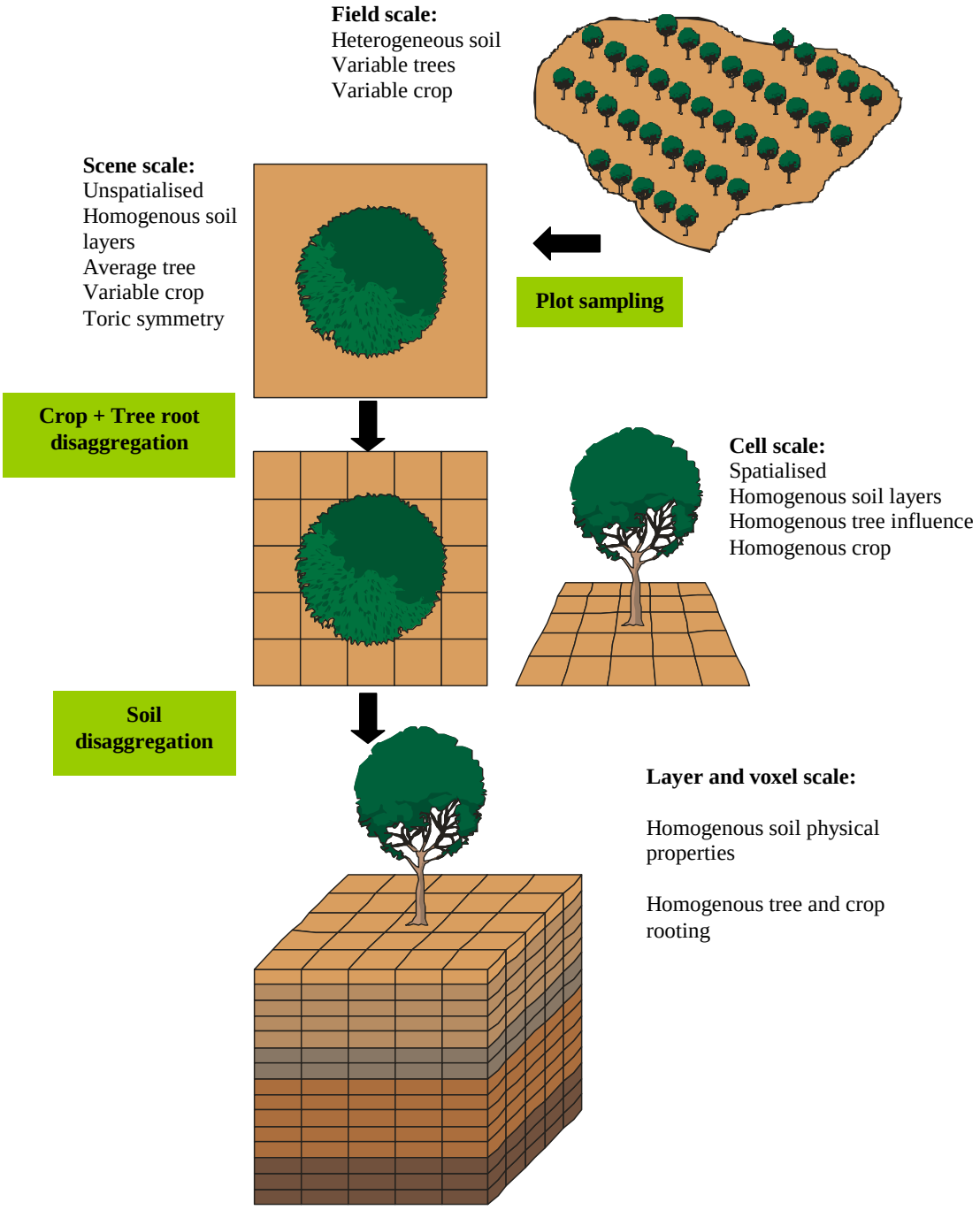


Figure 1: Spatial resolution – from the field scale to the voxel scale

The Hi-sAFe soil resolution is not only based on structural characteristics (pedologic layers) but also on a *maximum* thickness of soil suitable for the water extraction and the cellular automata module (for tree root growth) being simultaneously developed. The decision was reached to call these

intermediate sub-layers "*voxels"*. The term is a contraction of "volume element" (by analogy with 'pixel'), and is commonly used in three-dimensional modelling. A voxel is defined as '"*the smallest distinguishable box-shaped part of a three-dimensional space*". The voxels will differ in terms of their water content, even if they share similar soil structural parameters. Further discussions centred on whether to consider only voxels of uniform dimensions (*e.g.* 1m X 1m X 1m), or whether it was necessary to be able to have non-cubic voxels. Eventually it was decided that the horizontal X-Y dimensions of voxels in Hi-sAFe would be uniform (*i.e.* square), but that the depth (Z-dimension) could vary. This was necessary in order to be able to divide the compartments (of variable depth due to the heterogeneity of the soil pedological layers) into discrete voxels.

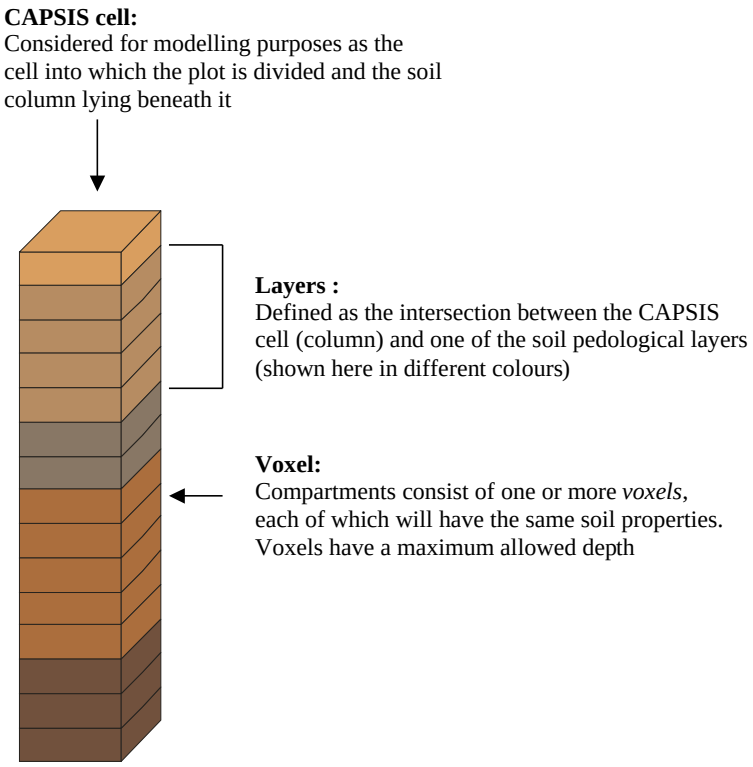


Figure 2: Definition of terms used in modules describing soil processes

Hi-sAFe includes toric symmetry algorithms option that avoid generating artificial edge effects for heterogeneous stands (the scene is surrounded virtually by identical scenes)
Hi-sAFe can be used on simple scenes (for example centered on an average tree) or on complex scenes (eg including many trees with varying developments).

3. Running Hi-sAFe

Hi-sAFe installation creates a **capsis_install_folder\capsis4\data\safe** folder on your computer containing:

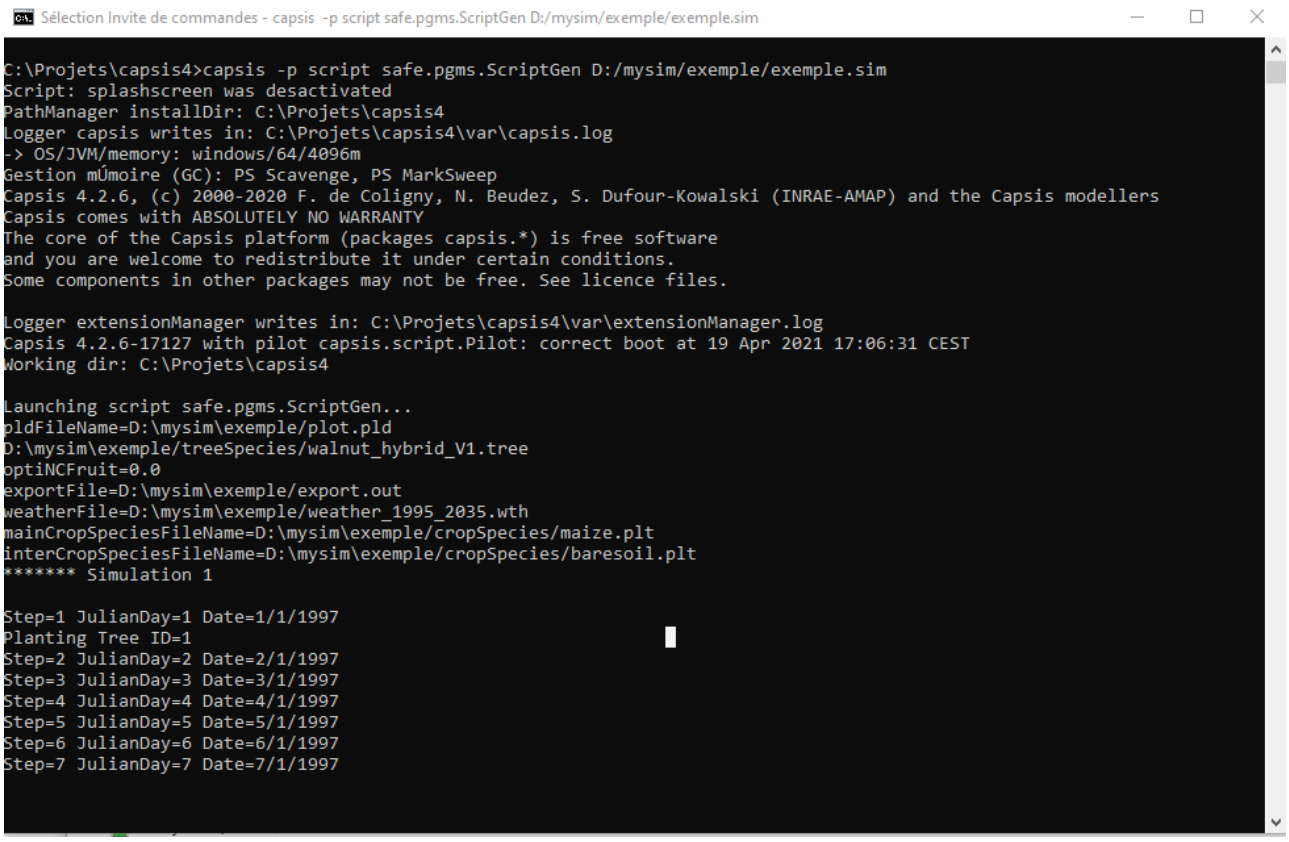
- cropInterventions: containing 27 crop interventions input files (*.tec)
- cropSpecies: containing 27 crops species parameters files (*.plt)
- generalParameters: containing STICS and Hi-sAFe general parameters file (*.par)
- plotDescription: containing 3 examples of plot description input file (*.pld)
- simSettings: containing 4 simulation folder example
- treenterventions: containing 5 tree interventions input files (*.ttec)
- treeSpecies: containing 5 tree species parameters files (*.tree)
- weather: containing 2 weather input file (*.wth)
- export.out : the export definition for output results

Each time you re-install or upgrade Hi-sAFe, this folder will be erased!
Create a specific folder to store your own simulation data.

Copy the \capsis4\data\safe\simSettings\exemple in a user simulation folder (**D:/mysim/exemple)**

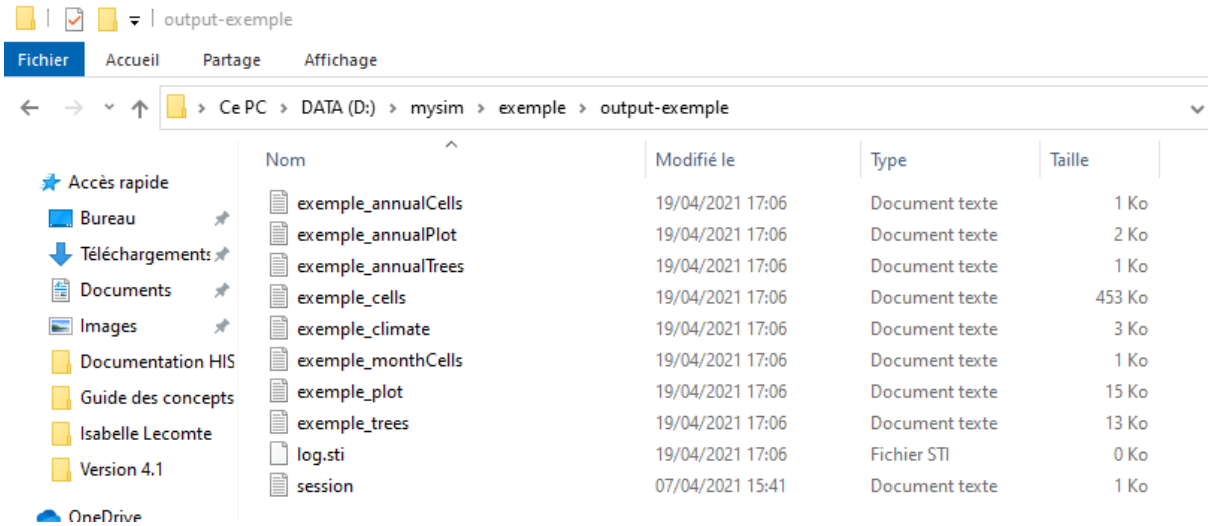
Open a DOS prompt and execute

```
> capsis -p script safe.pgms.ScriptGen D:/mysim/exemple/exemple.sim
```



Starting messages for BATCH execution mode

Execution will automatically generate an output folder named **output-exemple** containing one cvs file for each export described in the export.out file.



Log.sti contains errors in case the simuation stop anormally.

Session.txt contains informations about the model version and simulation time.

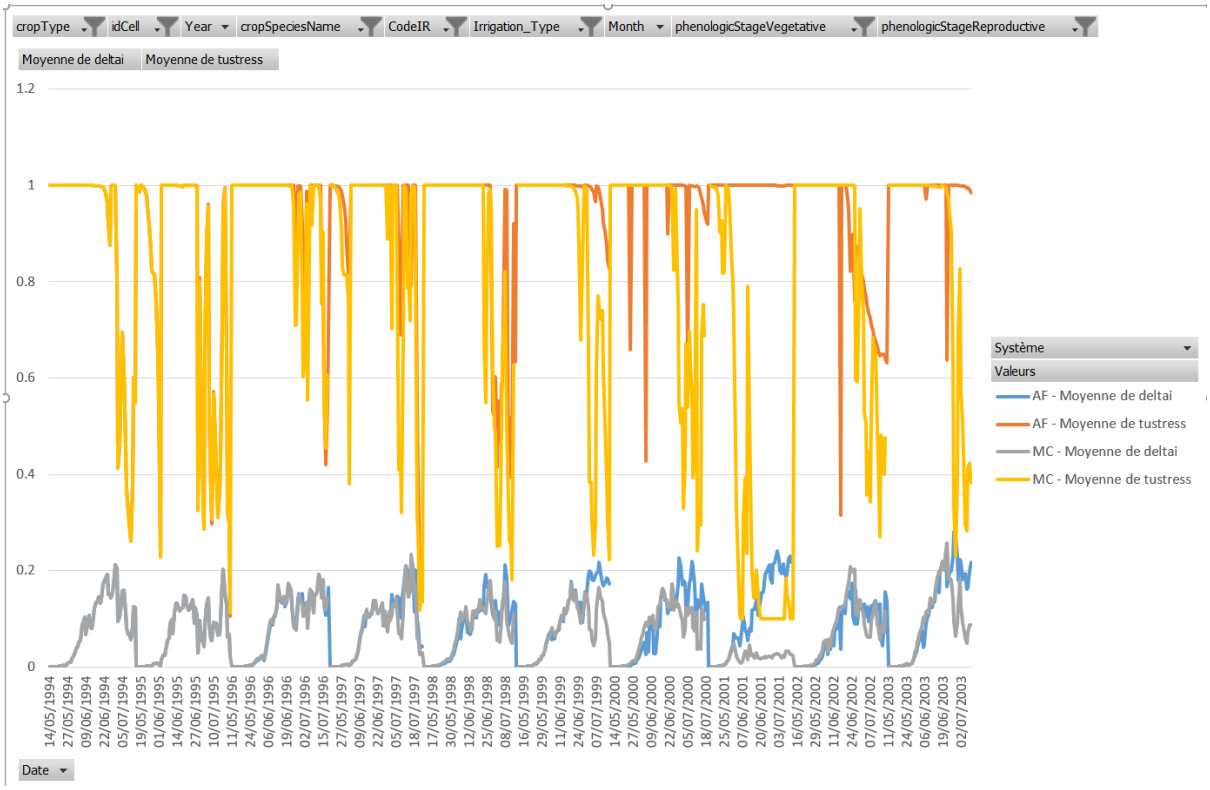
session.txt

```
Version-Hi-sAFe = 4.3.21404
Version-STICS = 8.5
Version-Capsis = 4.2.6
Start of simulation = 2024-12-18 14:23:13
Duration of simulation in seconds = 12
```

Output file format is the same as in GUI export. You can explore results with excel or R or any software you are used to.

exemple_trees.txt

	SimulationName	SimulationDate	Date	Day	Month	Year	JulianDay	idTree	age	dbh	height	leafArea
2	exemple	Tue Apr 20 10:04:26 CEST 2021	1/1/1997	1	1	1997	1	1	1	8.38833e-01	1.00000e+00	(
3	exemple	Tue Apr 20 10:04:26 CEST 2021	2/1/1997	2	1	1997	2	1	2	8.38833e-01	1.00000e+00	(
4	exemple	Tue Apr 20 10:04:26 CEST 2021	3/1/1997	3	1	1997	3	1	3	8.38833e-01	1.00000e+00	(
5	exemple	Tue Apr 20 10:04:26 CEST 2021	4/1/1997	4	1	1997	4	1	4	8.38833e-01	1.00000e+00	(
6	exemple	Tue Apr 20 10:04:26 CEST 2021	5/1/1997	5	1	1997	5	1	5	8.38833e-01	1.00000e+00	(
7	exemple	Tue Apr 20 10:04:26 CEST 2021	6/1/1997	6	1	1997	6	1	6	8.38833e-01	1.00000e+00	(
8	exemple	Tue Apr 20 10:04:26 CEST 2021	7/1/1997	7	1	1997	7	1	7	8.38833e-01	1.00000e+00	(
9	exemple	Tue Apr 20 10:04:26 CEST 2021	8/1/1997	8	1	1997	8	1	8	8.38833e-01	1.00000e+00	(
10	exemple	Tue Apr 20 10:04:26 CEST 2021	9/1/1997	9	1	1997	9	1	9	8.38833e-01	1.00000e+00	(
11	exemple	Tue Apr 20 10:04:26 CEST 2021	10/1/1997	10	1	1997	10	1	10	8.38833e-01	1.00000e+00	(
12	exemple	Tue Apr 20 10:04:26 CEST 2021	11/1/1997	11	1	1997	11	1	11	8.38833e-01	1.00000e+00	(
13	exemple	Tue Apr 20 10:04:26 CEST 2021	12/1/1997	12	1	1997	12	1	12	8.38833e-01	1.00000e+00	(


cropType
idCell
Year
cropSpeciesName
CodeIR
Irrigation_Type
Month
phenologicStageVegetative
phenologicStageReproductive
Moyenne de deltai
Moyenne de tustress
1.2
1
0.8
0.6
0.4
0.2
0
14/05/1994
27/05/1994
09/06/1994
22/06/1994
05/07/1994
19/05/1995
01/06/1995
14/06/1995
27/06/1995
10/07/1995
11/05/1996
24/05/1996
06/06/1996
19/06/1996
02/07/1996
15/07/1996
27/05/1997
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24/06/2002
07/07/2002
11/05/2003
24/05/2003
06/06/2003
19/06/2003
02/07/2003
Date
Système
Valeurs
AF - Moyenne de deltai
AF - Moyenne de tustress
MC - Moyenne de deltai
MC - Moyenne de tustress

4. Exporting Hi-sAFe results

Export files are automatically generated in the output folder according to rules written in the export.out file. This file has to be in the simulation root folder or in capsis/data/exportParameter.
The export file can be opened in EXCEL, columns are separated by a TAB.
NEVER CHANGE the name and extension (export.out) or the file format (.txt separated by tab).
NEVER DELETE or ADD a line.
UPDATE ONLY the profile and variables selections as explain below:

- A first part is used for **PROFILES** selection (climat, tree, plot, annualplot, cell, voxel etc…). Each selected profile will generate a separate output file.
  By default, all profiles are selected. To remove one, put a "#" in front of the line.

```
#=============================================================================
#  PART 1 : Profile definition
#=============================================================================

#Profile    Object  Frequency
ProfileDef  climate SafeMacroClimat 1
ProfileDef  trees   SafeTree    1
#ProfileDef annualTrees SafeTree    365
#ProfileDef plot    SafePlot    1
#ProfileDef annualPlot  SafePlot    365
ProfileDef  cells   SafeCell    1   1
#ProfileDef monthCells  SafeCell    30
#ProfileDef annualCells SafeCell    365

#ProfileDef voxels  SafeVoxel   1
#ProfileDef voxelsDetail    SafeVoxel   1
#ProfileDef voxelsOptim SafeVoxel   1
#ProfileDef voxels3D    SafeVoxel   1
```

Frequency can be 1 (each day), 30 (each month), 365 (each year) or another number.

Ids column is used for trees, cells or voxels selection. If no id is set, all collection will be exported. Each selected id should be separated by ";" or by "-" (range).
Example: 1;2;3;10;15-20: export cells 1,2,3,10 and 15 to 20

Depths column is used for voxels depth (m) selection only. The data used for selection is voxel Z gravity center. If no depth is set, all depths will be exported.
Each selected depth should be separated by ";" or by "-" (range).
Example: 0-1;2-3.5: export voxel if depth is from 0 to 1 meters and from 2 to 3.5 meters

- A second part is used for **VARIABLES** selection.

```
#=====================================================================
#  PART 2 : Variable selection
#=====================================================================

#Profile    Object  Variable    Unit    Description Order   Export
annualCells SafeCell    cropSpeciesName -   Crop species name   1   1
annualCells SafeCell    yieldMax    t.ha-1  Maximum value of harvested yield (grain and hay) for the year   1   1
annualCells SafeCell    heightMax    m  Maximum crop height for the year    2   1
annualCells SafeCell    biomassMax   t.ha-1 Maximum crop biomass for the year   3   1
annualCells SafeCell    laiMax  m2 leaf m-2 soil    Maximum crop LAI for the year   4   1
annualCells SafeCell    eaiMax  m2 leaf m-2 soil    Maximum crop EAI for the year   5   1
annualCells SafeCell    rootDepthMax    m   Maximum crop root depth for the year    6   1
annualCells SafeCell    cropMaxTemperature  °C  Crop max temperature    7   1
annualCells SafeCell    cropMinTemperature  °C  Crop min temperature    8   1
annualCells SafeCell    annualSoilEvaporation   mm  annual evaporation  9   1
annualCells SafeCell    annualCapillaryRise mm  annual capillary rise   10  1
annualCells SafeCell    annualDrainageBottom    mm  annual drainage bottom  11  1
annualCells SafeCell    annualDrainageArtificial    mm  annual drainage artificial  12  1
annualCells SafeCell    annualIrrigation    mm  annual irrigations  13  1
annualCells SafeCell    annualRunOff    mm  annual run off  14  1
annualCells SafeCell    annualSurfaceRunOff mm  annual surface run off  15  1
annualCells SafeCell    annualWaterDemand   liters  annual water demad  16  1
annualCells SafeCell    annualWaterUptake   liters  annual water uptake 17  1
annualCells SafeCell    annualWaterUptakeByTrees    liters  annual water uptake by trees    18  1
```

By default, all variables are selected. Put 0 in last column (export) to remove the variable.

The order column is not used, data are exported on the same order as they are in export.out file.

5. Input and parameter files

All files are in **CSV ASCII** format that can be edited with standard editing software such as NotePad, TextPad or Microsoft Excel.

Comments are always preceded by the special character # and most of the times are in capital letters

```
#PLOT DESCRIPTION
```

Single data are formatted as keyword = value with only a space (not tabulation) between them.

```
elevation = 130
```

Numbers are in US format

```
latitude = 43.7
```

String doesn't need to be notified with special quotation marks.

```
Zones mainCrop    1-25  maize.tec
```

Boolean values are 1= true or 0=false

```
waterTable = 1
```

List data are separated by tabulations with an identifying keyword in the first column. Lines of comment should always explain what the columns contain and their units.

```
#LAYER INITIALISATION
#           waterContent      n03Concentration  nh4concentration
#           %                 kg ha-1           kg ha-1
LAYERINIT   0.10  32.0  0.0
LAYERINIT   0.10  12.0  0.0
```

The Hi-sAFe model loads input files before running a simulation. If a modification is done in one file, the user doesn't have to close Capsis and reload Hi-sAFe to take the modification into account. He or she will only need to run a new simulation.

These file names, extensions and physical locations can be changed but our advice is to give explicit names and extensions to easily recognise these files and their use.

5.1 Simulation file (*.sim)

This file will define your experiment details such as:

- Date of start
- Date of end
- Crop zone definition
- Tree interventions definition
- Toric symmetry activation/desactivation

5.2 Plot description (*.pld)

The plot description will give all information about the virtual scene (dimensions, orientation, tree spacing, soil characteristics etc.)

Name and extension can be changed, but our advice is to call these files with the real explicit name of your experimental plot and .pld extension (example: restincliere-A2.pld)

5.3 Tree interventions (*.ttec)

This file will give all information about interventions planed for a tree on the virtual scene (sowing date, soil management, irrigation, fertilisation etc.)

Names are free but one advice is to call these files with the name of the tree species with .ttec extension (example: walnut.tec)

5.4 Crop interventions (*.tec)

This file will give all information about interventions planed for a crop on the virtual scene (sowing date, soil management, irrigation, fertilisation etc.)

Names are free but one advice is to call these files with the name of the crop species with .tec extension (example: wheat.tec)

5.5 Weather data (*.wth)

Hi-sAFe simulation in interactive mode cannot exceed 365 days, so weather data file doesn't need to be more than 365 days either. It is sometimes necessary to store several years of weather data in the same file to run winter cropped plots simulations (for example durum wheat seeded in October and harvested in June the next year)

For batch execution a weather file covering the whole simulation duration have to be provided. By default Hi-sAFe provides capsis4\data\safe\weather\weather-1995-2035.wth corresponding to 40 years of French Mediterranean climate. Last 20 years have been randomly generated with previous ones.

Name and extension are free but one advice is to call these files with the real explicit name of your weather station – start year – end year - with .wth extension (example: restinclieres-1996-2014.wth)

5.6 Tree species parameters (*.tree)

5 species are available:

1. olive tree
2. poplar

3. wild cherry
4. walnut hybrid
5. robinia

5.7 Crop species parameters (*.plt)

27 species are available:

1. Alfalfa
2. Banana
3. Baresoil
4. Barley
5. Durum wheat
6. Durum wheat restinclieres
7. Fescue
8. Flax
9. Grass
10. Lettuce
11. Maize
12. Mustard
13. Pea
14. Potato
15. Rape
16. Ryegrass
17. Sorghum
18. Soybean
19. Sugarbet
20. Sugarcane
21. Sunflower
22. Tomato
23. Vine
24. Weed restinclieres
25. Wheat
26. Winter barley
27. Winter pea

5.8 General parameters for Hi-sAFe (hisafe.par) and STICS (stics.par)

These files contain general parameters that are not related to tree or crop.

Name and location of the parameters files have been fixed by the authors and cannot be modified without a complete recompilation of the model.

A complete detailed guide of these files content is provided in EXCEL