Short User GUIDE

Version 4.4

Isabelle LECOMTE

January 2026

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)

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.

A tree model has been specifically developed with main modules:

- Phenology
- Light interception
- Water and nitrogen demand
- C allocation
- Tree aerial growth
- Fine root growth
- Coarse root topology
- Fruit production
- Nitrogen fixation

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.

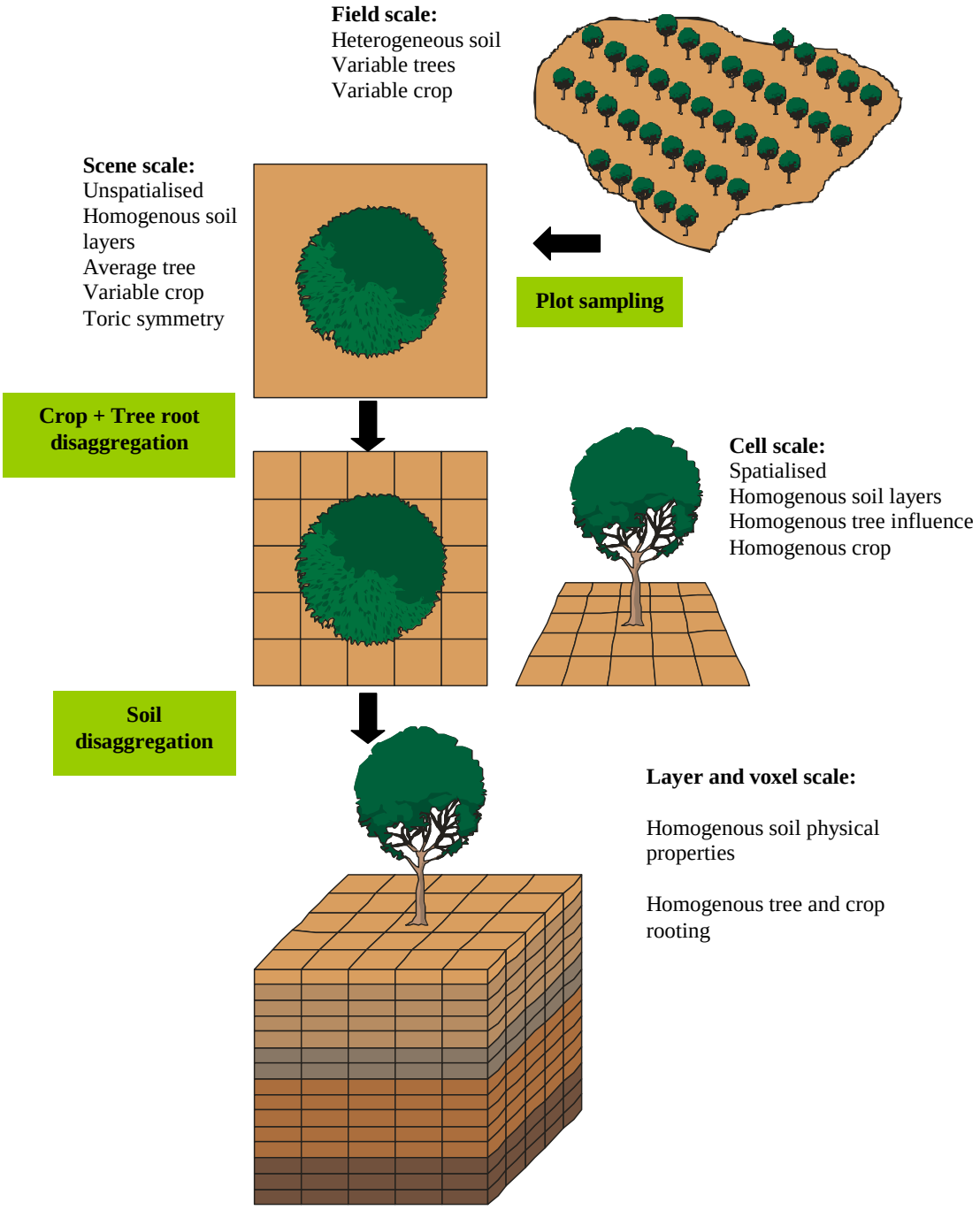


Figure 1: Spatial resolution – from the field scale to the voxel scale

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.

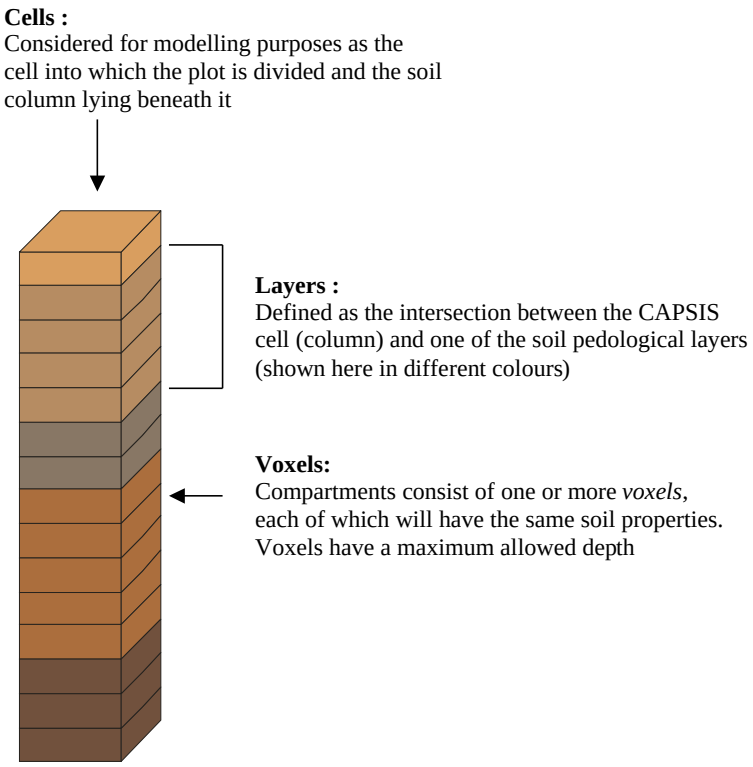
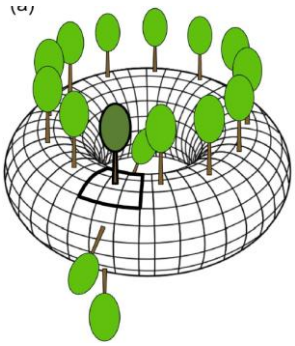


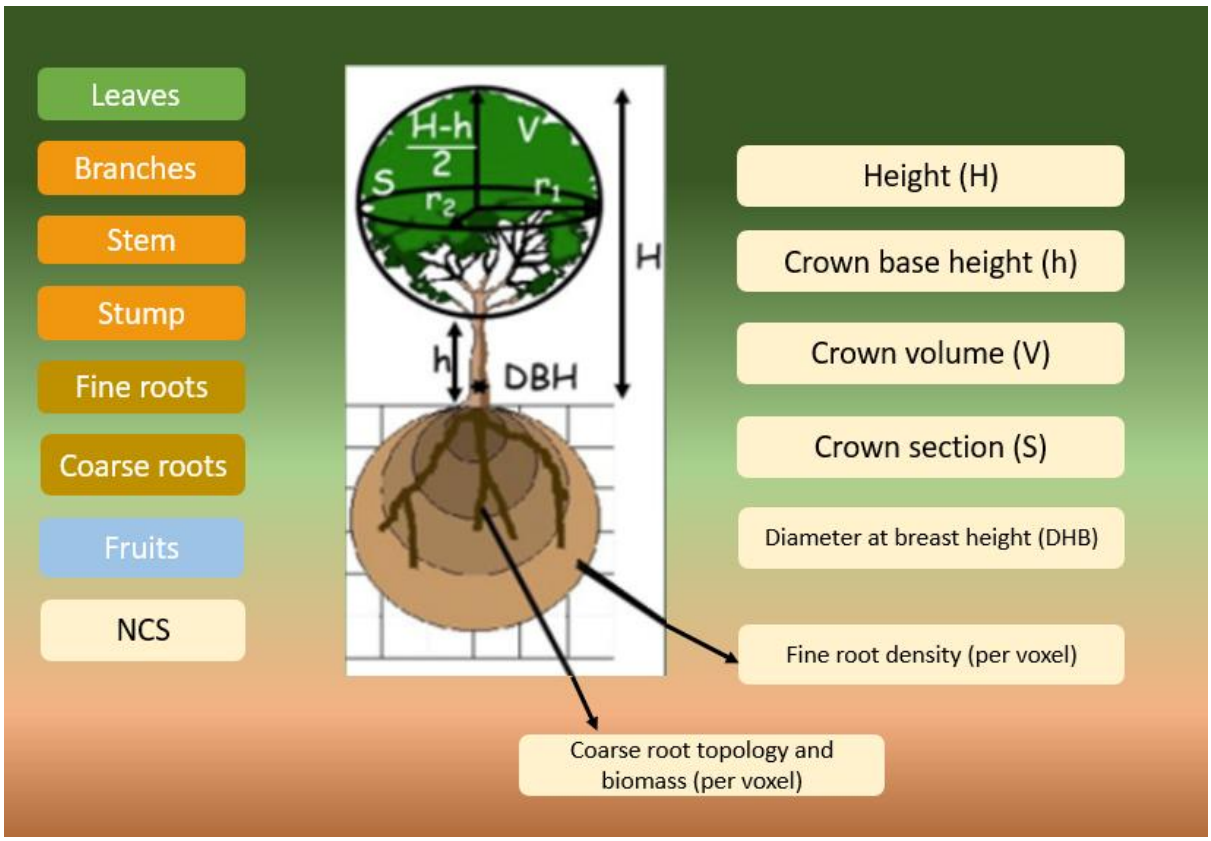
Figure 2: Definition of terms used in modules describing soil processes



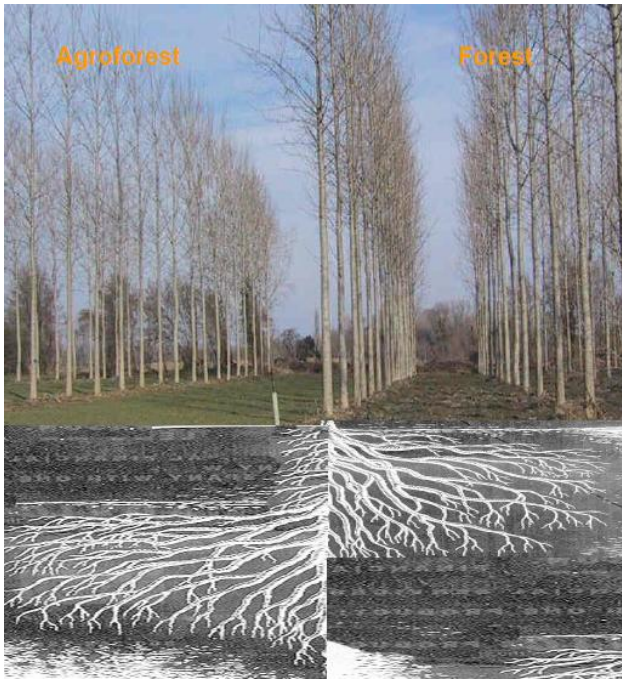
Hi-sAFe includes toric symmetry algorithms option that avoid generating artificial edge effects for heterogeneous stands (the scene is surrounded virtually by identical scenes)

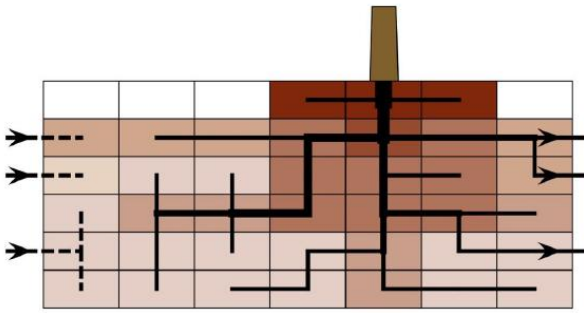
Hi-sAFe can be used on simple scenes (for example centered on an average tree) or on complex scenes (eg including many trees with varying developments).

The tree is represented at the individual scale with 8 compartments of carbon. It is also described geometrically in 3D by several variables such as height, dbh and crown ellipsoid or paraboloid shape.



Hisafe also includes an original opportunistic and reactive fine roots growth algorithm as well as the coarse roots topology





3. Input and parameter files

Hisafe installation create a data/safe directory on your installation folder. It contains 8 subdirectories:

1. cropInterventions : 28 crop management inputs files
2. cropSpecies : 28 differents crop species parameters files
3. generalParameters : stics and hisafe general parameters files
4. plotDescription : 4 plot description input files
5. simSettings : several examples of simulation folders (AF- F - MC)
6. treeInterventions : 6 tree managements inputs files
7. treeSpecies : 6 tree species parameters files
8. weather : 3 weather inputs files

All files are in **TXT ASCII** format seperated by tabulation and can be edited with standard editing software such as NotePad, TextPad or Microsoft Excel.

Comments are always preceded by one or several special character # and most of the times are in capital letters
Single data are formatted as keyword = value with only a space (not tabulation) between them.
Numbers are in US format
Boolean values are 1= true or 0=false
String doesn't need to be notified with special quotation marks.

```
## AGROFORESTRY PLOT EXEMPLE

## PLOT
latitude = 43.7
elevation = 62
cellWidth = 1
northOrientation = 80.5
plotHeight = 7
plotWidth = 5
slopeIntensity = 0
slopeAspect = 0
```

Data table 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.

```
## LAYERS INITIALIZATION
#   waterContent    no3Concentration    nh4concentration
#   %       kg ha-1          kg ha-1
LAYERINIT   0.20    30   0
LAYERINIT   0.30    14   0
LAYERINIT   0.30    5    0
LAYERINIT   0.30    2    0
LAYERINIT   0.30    0    0
```

A complete detailed guide is provided in Hi-sAFe-V4.4-Parameters and outputs.xlsx

3.1 Plot description (*.pld)

The plot description will give all information about the virtual scene

- orientation
- dimensions
- soil characteristics
- layers definitions
- layers initilalisation
- trees positions

Extension .pld can NOT be changed

Names can be changed, but advice is to call these files with the real explicit name of your experimental plot : restincliere-A2.pld

Line orders can be changed but it is not recommended.

```
## AGROFORESTRY PLOT EXEMPLE

## PLOT
latitude = 43.7
elevation = 62
cellWidth = 1
northOrientation = 80.5
plotHeight = 7
plotWidth = 5
slopeIntensity = 0
slopeAspect = 0

## SOIL
voxelThicknessMax = 0.4
humificationDepth = 0.4
albedo = 0.2
cropRootObstruction = 5
ph = 8.1
swellingClaySoil = 0
macroporosity = 0
soilCrustRainMin = 50.0
soilCrustDepth = 0.50
roughnessLength = 0.01
soilHumusCN = 12.2

## WATER
waterTable = 1
evaporationValue = 9
evaporationMaxDepth = 60.00
evaporationDepthContribution = 5.00
runOffCoefPlantMulch = 0.33
rainRunOffFraction = 0.2
capillary = 0
capillaryUptake = 1
capillaryUptakeMinWater = 0.3
artificialDrainage = 0
drainagePipesSpacing = 0
drainagePipesDepth = 0
waterConductivity = 0
impermeableLayerDepth = 0
```

```
## LAYERS DEFINITION
#   thick   sand    clay    limeStone   organicMatter   partSizeS
#   (m) %   %   %       %       µm  %   l-10         mm j-1
LAYER   0.4 37.61   16.37   45.7    1.81    290 0   6   50
LAYER   0.4 26.92   23.11   49.1    1.09    290 0   6   50
LAYER   0.6 13.36   29.94   47.1    0.91    290 0   6   50
LAYER   1   8.64    32.45   50.4    0.94    290 0   6   50
LAYER   1   8.64    32.45   52.1    0.94    290 0   6   50

## LAYERS INITIALIZATION
#   waterContent    no3Concentration    nh4concentration
#   %       kg ha-1         kg ha-1
LAYERINIT   0.20    30  0
LAYERINIT   0.30    14  0
LAYERINIT   0.30    5   0
LAYERINIT   0.30    2   0
LAYERINIT   0.30    0   0

## TREES POSITION
#   speciesFileName treeX   treeY
TREE    walnut_hybrid   0   0
```

3.2 Tree interventions (*.ttec)

This file will give all information about interventions planed for a tree on the scene

- planting
- harvesting
- pruning
- root pruning
- leaf area density reduction
- canopy trimming
- fruit thinning
- fruit harvest
- irrigation
- fertilisation

Extension .ttec can NOT be changed

Names are free but advice is to call these files with the name of the tree species and the number of the tree: walnut1.ttec , walnut2.ttec

It is advisable not to delete unnecessary lines but to comment them out

```
## WALNUT TREE INTERVENTIONS

## TREE PLANTING
plantingYear = 1
plantingDay = 01-01
plantingCohortAge = 0
plantingAge = 1
plantingHeight = 0.75
plantingCrownBaseHeight = 0.375
plantingCrownRadius = 0.25
plantingRootShape = 1
plantingRootRepartition = 3
plantingRootShapeParam1 = 0.4
plantingRootShapeParam2 = 0
plantingRootShapeParam3 = 0

## TREE HARVEST
treeHarvestYear = 40
treeHarvestDay = 01-01

## TREE PRUNING
treePruningYears = 5,10,15,20,25,35
treePruningDays = 01-01,01-01,01-01,01-01,01-01,01-01
treePruningProp = 0.3,0.3,0.3,0.3,0.3,0.3
treePruningMaxHeight = 1,1,1.5,1.5,2,2
treePruningResiduesIncorporation = 1,1,1,1,1,1
treePruningResiduesSpreading = 1,1,1,1,1,1

## TREE ROOT PRUNING
#treeRootPruningYears = 5
#treeRootPruningDays = 12-31
#treeRootPruningDistance = 1.5
#treeRootPruningDepth = 1

## TREE IRRIGATION
#treeIrrigationType = 2
#treeIrrigationYears = 1,2
#treeIrrigationMethod = 1
#treeIrrigationRadius = 0.5
#treeIrrigationDriporSprinklerX = 0
#treeIrrigationDriporSprinklerY = 0
#treeIrrigationWaterStressTrigger = 0
#treeIrrigationAutomaticDose = 0
#treeIrrigationDays = 06-30,07-30,08-30
#treeIrrigationDose = 20,20,20
```

3.3 Crop interventions (*.tec)

This file will give all information about interventions planed for a crop on the scene

- species and variety
- date start - end
- soil management
- residus incorporation
- sowing
- irrigation
- fertilisation
- harvest
- cutting
- etc…

Extension .tec can NOT be changed

Names are free but advice is to call these files with the name of the crop species and the year: wheat-1996.tec, wheat-1997.tec

It is advisable not to delete unnecessary lines but to comment them out

```
##DURUM WHEAT ALLUR(BLE DUR)
species = durum-wheat.plt
variete = 1
daystart = 08-31
dayend = 08-30

## SOIL MANAGEMENT
nbjres = 1
nbjtrav = 1

## RESIDUE INCORPORATION TABLE
#julres coderes qres Crespc CsurNres Nminres eaures
RESIDUEINC  10-10   1   1.00    42.00   15.00   0.00    0.00

## TILLAGE TABLE
#jultrav profres proftrav
TILLAGE 10-10   15  22

## SOWING OPTIONS
iplt0 = 10-27
profsem = 3.00000
densitesem = 268.00000
codetradtec = 2
interrang = 0.00000
orientrang = 0.00000
```

3.4 Weather data (*.wth)

It contains:

- Julian day
- Year
- Month
- Day
- Max temperature (degrees C)
- Min temperature (degrees C)
- Max relative humidity (%)
- Min relative humidity (%)
- Global radiation(MJ m-2)
- Precipitation (mm)
- Windspeed (m s-1)
- Water table depth (m)
- Co2Concentration (pp3)
- RealYear (in case of data copy)

The weather file have to cover the whole simulation duration. 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.

Extension .wth can NOT be changed.

Line and column orders can NOT be changed.

Names are free, but advice is to call these files with the real explicit name of your weather station restincliere-A2-1996-2014.wth.

Colums are separated by TAB, do not change this format if you save this file in EXCEL.

#CLIMATIC DAILY VALUES													
#julianDay	year	month	day	maxTemperature	minTemperature	maxRelativeHumidity	minRelativeHumidity	globalRadiation	precipitation	windSpeed	waterTableDepth	cO2Concentration	realYear
#				degreeC	degreeC	%	%	MJ m-2 day-1	mm day-1	m s-1	m	ppm	
1	1995	1	1	3.5	-4.8	88	77	1.79	14	0	-5.97	330	1995
2	1995	1	2	4.7	0.1	88	78	0.69	31.4	0.8	-5.97	330	1995
3	1995	1	3	9.6	2.3	91	85	1.19	14.6	1.3	-5.52716	330	1995
4	1995	1	4	5.8	-1	91	61	2.19	7	1.8	-5.273867	330	1995
5	1995	1	5	8	-1	89	56	5.39	0	1.6	-5.137316	330	1995
6	1995	1	6	7.7	-1.4	89	54	4.89	0	0.6	-5.199352	330	1995
7	1995	1	7	9.4	-1.4	81	42	6.69	0.6	0.4	-5.258742	330	1995
8	1995	1	8	8.4	-3	90	74	0.49	97.6	1.8	-5.271497	330	1995
9	1995	1	9	7.5	3.5	91	85	1.39	4.4	0.2	-4.390713	330	1995

3.5 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

Extension .sim can NOT be changed

Names are free, but our advice is to call these files with the real explicit name of your experimentation restincliere-A2-1996-2014.sim

Line orders can be changed but it is not recommended.

```
## SIMULATION
simulationDateStart = 2010-08-31
simulationDateEnd = 2012-08-30
saveProjectOption = 0
#projectFileName = none.prj
debugMode = 0
sticsReport = 0

## ZONES DEFINITION
ZONE    Z1  1-3,5-10,12-17,19-21    durum-wheat.tec
ZONE    Z2  4,11,18 baresoil.tec

## TREES TECHNICAL FILES
TREETEC walnut.ttec

## TORIC SYMETRY OPTIONS
toricXp = 1
toricXn = 1
toricYp = 1
toricYn = 1
```

Neither the plot file name nor the climate file name is specified because the model will automatically search for .pld and .wth files in the simulation directory, regardless of their names. This is why you should never change file extensions.

3.6 Tree species parameters (*.tree)

5 species are available:

1. olive tree
2. poplar
3. wild cherry
4. walnut hybrid
5. robinia

3.7 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

3.8 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 extension of these both files can NOT be changed.

4. Output files

Output 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

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:

PART 1 PROFILE DEFINITION

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.

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

```
#=============================================
#  PART 1 : Profile definition
#=============================================
#Profile    Object  Frequency
ProfileDef  climate SafeMacroClimat 1
ProfileDef  plot    SafePlot    1
ProfileDef  zones   SafeCropZone    1
ProfileDef  cells   SafeCell    1
ProfileDef  trees   SafeTree    1
ProfileDef  monthCells  SafeCell    30
ProfileDef  annualPlot  SafePlot    365
ProfileDef  annualCells SafeCell    365
ProfileDef  annualTrees SafeTree    365
ProfileDef  voxels  SafeVoxel   1
```

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

PART 2 VARIABLE SELECTION

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.

```
#=========================================================================
#  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
```

5. Running Hi-sAFe

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

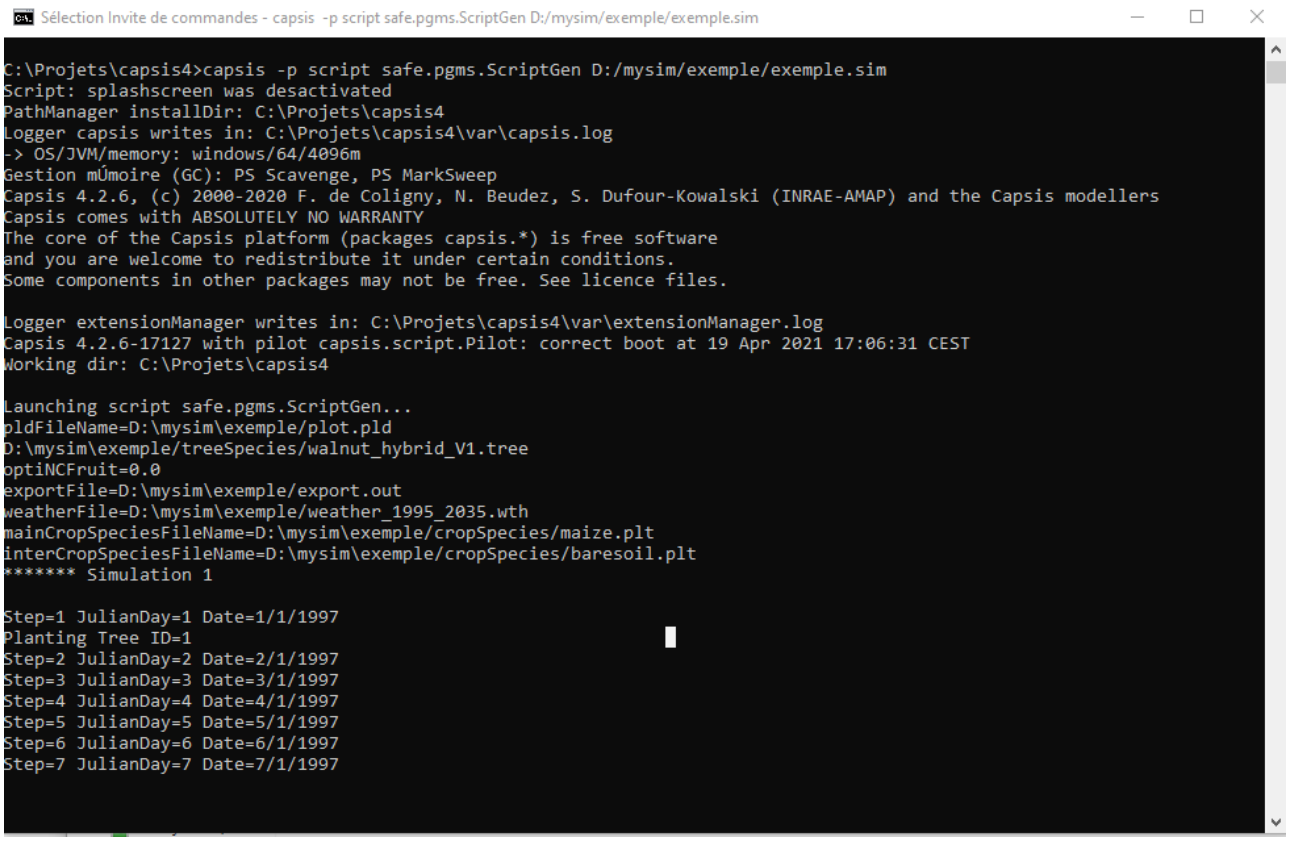
- cropInterventions: containing 27 crop interventions input files (*.tec)
- cropSpecies: containing 27 crops species parameters files (*.plt)
- generalParameters: containing STICS and Hi-sAFe general parameters file (*.par)
- plotDescription: containing 3 examples of plot description input file (*.pld)
- 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)**

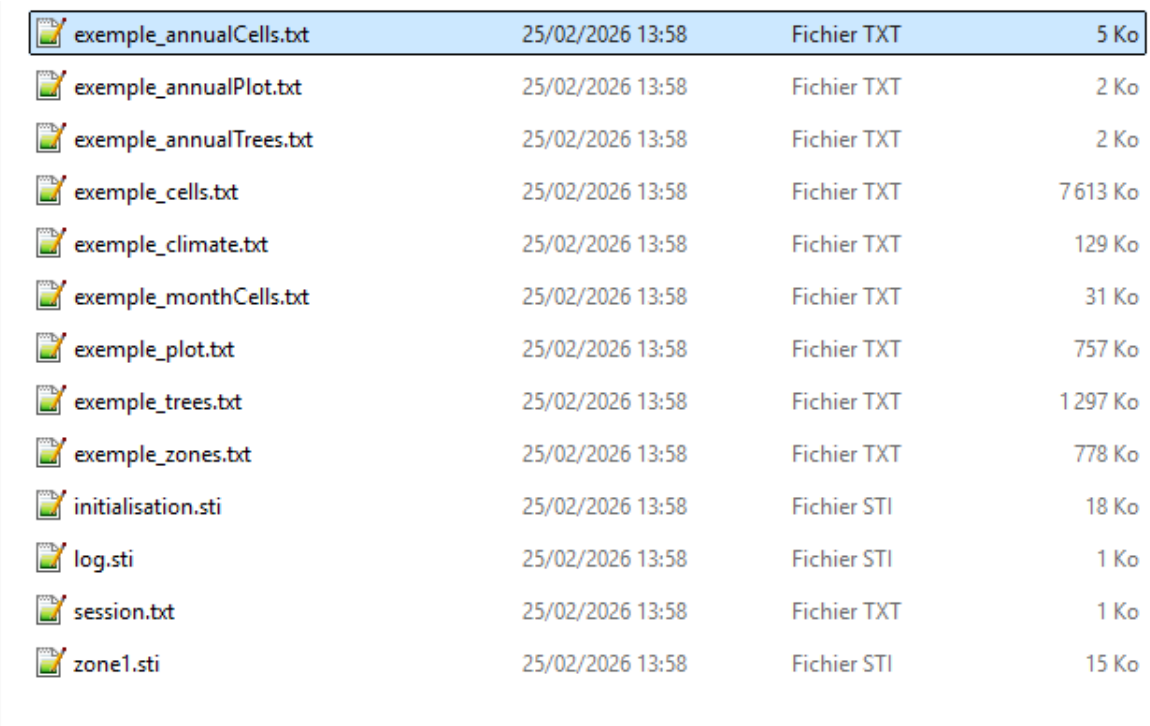
Open a DOS prompt and execute

```
> 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.



exemple_annualCells.txt	25/02/2026 13:58	Fichier TXT	5 Ko
exemple_annualPlot.txt	25/02/2026 13:58	Fichier TXT	2 Ko
exemple_annualTrees.txt	25/02/2026 13:58	Fichier TXT	2 Ko
exemple_cells.txt	25/02/2026 13:58	Fichier TXT	7 613 Ko
exemple_climate.txt	25/02/2026 13:58	Fichier TXT	129 Ko
exemple_monthCells.txt	25/02/2026 13:58	Fichier TXT	31 Ko
exemple_plot.txt	25/02/2026 13:58	Fichier TXT	757 Ko
exemple_trees.txt	25/02/2026 13:58	Fichier TXT	1 297 Ko
exemple_zones.txt	25/02/2026 13:58	Fichier TXT	778 Ko
initialisation.sti	25/02/2026 13:58	Fichier STI	18 Ko
log.sti	25/02/2026 13:58	Fichier STI	1 Ko
session.txt	25/02/2026 13:58	Fichier TXT	1 Ko
zone1.sti	25/02/2026 13:58	Fichier STI	15 Ko

initilialisation.sti contains STICS log about general initialization
log.sti contains errors in case the simuation stop anormally.
session.txt contains informations about the model version and simulation time.
zone.sti contains contains STICS log about crop zones initialization

```
Version-Hi-sAFe = 4.4.22496
Version-STICS = 8.5
Version-Capsis = 4.2.6
Simulation date start = 2000-1-1
##=============================================
## ZONE main
##=============================================
CROP = maize
Date start = 1-1
Sowing = 4-27
Residue incorporation = 4-22
Tillage = 4-22
Irrigation = 6-27 7-4 7-12 7-17 7-19 7-23 7-26 7-30 8-2 8-6 8-9 8-20 8-27 9-6 9-14 9-21
Fertilization = 4-22
Date end = 12-31
##=============================================
Simulation date end = 2000-12-31
Start of simulation = 2026-02-25 13:53:45
Duration of simulation in seconds = 30
```

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
1	exemple	Tue Apr 20 10:04:26 CEST 2021	1/1/1997	1	1	1997	1	1	1	8.38833e-01	1.00000e+00	(
2	exemple	Tue Apr 20 10:04:26 CEST 2021	2/1/1997	2	1	1997	2	1	2	8.38833e-01	1.00000e+00	(
3	exemple	Tue Apr 20 10:04:26 CEST 2021	3/1/1997	3	1	1997	3	1	3	8.38833e-01	1.00000e+00	(
4	exemple	Tue Apr 20 10:04:26 CEST 2021	4/1/1997	4	1	1997	4	1	4	8.38833e-01	1.00000e+00	(
5	exemple	Tue Apr 20 10:04:26 CEST 2021	5/1/1997	5	1	1997	5	1	5	8.38833e-01	1.00000e+00	(
6	exemple	Tue Apr 20 10:04:26 CEST 2021	6/1/1997	6	1	1997	6	1	6	8.38833e-01	1.00000e+00	(
7	exemple	Tue Apr 20 10:04:26 CEST 2021	7/1/1997	7	1	1997	7	1	7	8.38833e-01	1.00000e+00	(
8	exemple	Tue Apr 20 10:04:26 CEST 2021	8/1/1997	8	1	1997	8	1	8	8.38833e-01	1.00000e+00	(
9	exemple	Tue Apr 20 10:04:26 CEST 2021	9/1/1997	9	1	1997	9	1	9	8.38833e-01	1.00000e+00	(
10	exemple	Tue Apr 20 10:04:26 CEST 2021	10/1/1997	10	1	1997	10	1	10	8.38833e-01	1.00000e+00	(
11	exemple	Tue Apr 20 10:04:26 CEST 2021	11/1/1997	11	1	1997	11	1	11	8.38833e-01	1.00000e+00	(
12	exemple	Tue Apr 20 10:04:26 CEST 2021	12/1/1997	12	1	1997	12	1	12	8.38833e-01	1.00000e+00	(