VegeSTAR3

Light interception and photosynthesis calculation

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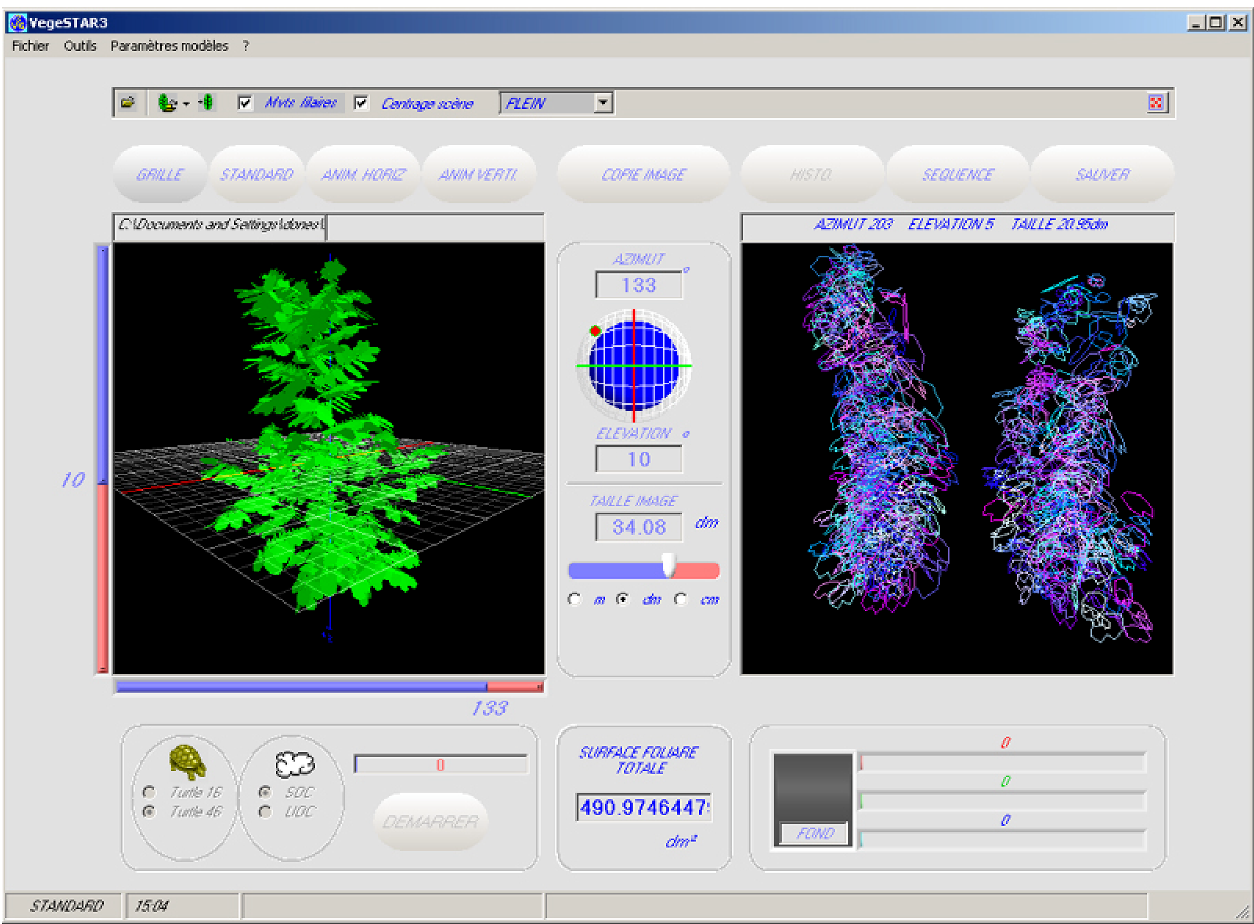

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I. Calculation principles

I-1. General presentation

VegeSTAR3 is a software package which allows 3D visualisation of plant structure and computation of light interception and carbon acquisition by photosynthesis.

The plants are represented by a collection of organs, which are described by a triangle set or simple geometrical shapes: polygons, ellipses, cylinders, cones, spheres…These shapes are modified by geometrical parameters which take into account organ form, size, spatial orientation and position.

To distinguish different organ types, or to highlight variations in physiological characteristics, in the scene, false colour can be assigned dependent on user defined variable.

I-2. Light interception

Light interception is calculated by virtual image processing of digitised plant (*Sinoquet et al., 1998*). The standard use takes place in the plant STAR (Silhouette to Total Area Ratio, *Stenberg, 1995)* calculation of the projected leaf area in the direction perpendicular to the incident radiation.

The principle of this method is simple: the leaf area is seen from a point representing the radiation source, for example the sun direction. This is the projection surface which is illuminated by this radiation source, meaning that it intercepts the light. All you have to do is count the number of plant image pixels seen from the radiation source direction. Remember this calculation principle must be applied to directional irradiance.

Taking into account the set of the incident irradiance (direct and diffuse radiation) demands representing the sky as a set of directional sources.

The user-defined assignment of false colours to leaf components allows different visualisation applications, such as light partitioning between vegetation components, or the spatial distribution of diffuse or direct leaf irradiance.

Notice that this method does not take scattering into account. By consequence, it allows interception estimation and radiation balance computation in wavebands where the leaf absorption is high (eg. UV, even PAR)

I-3. Canopy photosynthesis

I-3-1. General principles

The leaf photosynthesis depends mainly on leaf irradiance, leaf temperature, carbon dioxide content in the atmosphere, and leaf photosynthesis characteristics.

The principle used in VegeSTAR3 is based on the calculation of each leaf or leaf part irradiance, then assigning to each leaf a photosynthetic response depending on the irradiance.

Leaf irradiance results from the interception of radiation from all sky directions andand scattering-transmission, in addition to leaf soil reflection. In VegeSTAR3, the scattering process is disregarded, because the leaf reflectance and transmittance are quite low on wavebands needed for photosynthesis (400-700 nm). The incident radiation is divided into diffuse radiation and direct radiation. The diffuse radiation is represented by a set of 16 or 46 point sources, whose direction has been chosen to optimise representation of the sky.

(Turtle sky, *den Dulk, 1989*). The direct irradiance is represented by a unique source, in the sun direction.

As the photosynthetic response to irradiance is not linear, calculating average leaf irradiance and applying to it the leaf photosynthetic response leads to a systematic underestimation of plant carbon acquisition. On the other hand, it should be noted that there is large variability in plant photosynthetic response (e.g., *Le Roux et al. 1999*). It is necessary to calculate the leaf to leaf photosynthetic response, then to sum up the individual responses on the plant or canopy scale.

In VegeSTAR3, the integrated irradiance from all sky directions is calculated for each plant, leaf or leaf part component. In order to be able to track every element (component), false colours are assigned in automatically by the software.

During the first step, the diffuse radiation fraction received by each component is calculated by image analysis in 16 or 46 directions representing the sky (see Light interception). In the second step, the direct irradiance of each leaf is calculated from image processing in the sun direction. Finally, the carbon assimilated by the leaf is calculated on the base of its photosynthetic light response.

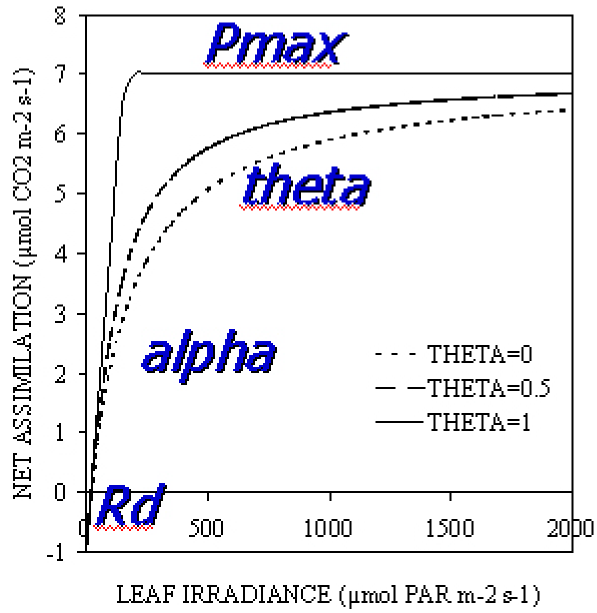
Two photosynthesis models have been set up in the VegeSTAR3 software:
- The non-rectangular hyperbola model.
- Farquhar's biochemical model (*Farquhar et al. 1980*).

Note that, in VegeSTAR3, each leaf component can have its own photosynthetic assimilating characteristics.

I-3-2. Non rectangular hyperbola model

This is an empirical 4 parameter model (*Prioul and Chartier, 1977*). The parameters are as follows:

- Pmax (µmol CO_2 m^{-2} s^{-1}): maximum photosynthesis rate, i.e. for saturated irradiance, meaning the photosynthesis plateau level.
- α (µmol CO_2 µmol PAR^{-1}): apparent quantum yield, meaning the initial irradiance response slope.
- θ (dimensionless, from 0 to 1): convexity of the response curve; the higher the value the maximum photosynthesis rate is reached at lower irradiance.
- Rd (µmol CO_2 m^{-2} s^{-1}): dark respiration rate, meaning the abscissa at assimilation curve origin depending on the irradiance. By agreement, Rd is positive.



I-3-3. Farquhar's model

The Farquhar model traces the main steps in photosynthesis biochemistry: the Rubisco carboxylation and the Rubisco regeneration by electron transfer (Farquhar et al., 1980). The model input parameters are:
Vcmax (µmol CO_2 m^{-2} s^{-1}): maximum carboxylation rate at 25° Celsius
Jmax (µmol CO_2 m^{-2} s^{-1}): maximum rate of electron transfer at 25° Celsius
Rd (µmol CO_2 m^{-2} s^{-1}): dark respiration rate at a 25° Celsius

Note that these parameters are generally related to leaf nitrogen content per unit leaf surface area, which varies within the plant. These parameters are also strongly dependent on leaf temperature. (*Dreyer et al., 2001*).

The Farquhar model requires other parameters, which are not easily evaluated. However, some of these are considered to be constant for a given species, but are known for only a limited number of species. These parameters include:

- The quantum yield α (µmol CO2 µmol PAR-1)
- Dark respiration : scale factor (dimensionless) and activation energy (J mol^{-1})
- Electron transport capacity: scale factor (dimensionless) and activation energy (J mol^{-1}), deactivation energy (J mol^{-1}) et entropy term (J K^{-1} mol^{-1})
- Carboxylation capacity: scale factor (dimensionless) and activation energy (J mol^{-1}) deactivation energy (J mol^{-1}) et entropy term (J K^{-1} mol^{-1})
- The constants of Michaelis-Menten for carboxylation and oxygenation : scale factor (dimensionless) and activation energy (J mol^{-1})
- and in an indirect way, the stomatal conductance via a relation between the ratio of internal and surrounding atmosphere CO_2 concentration and leaf irradiance.

- VegeSTAR3 allows to the user to define these parameters.VegeSTAR3 also allows setting of values for these parameters. Default values included in the software are derived from the following references: *Harley et al, 1992* ; *Le Roux et al., 1999* ; *Balandier et al., 2000*.

II. Input files

II-1. General items

The input files are of two different types: “Scene” files and “Microclimate” files. They are text files (ASCII), in which data is separated by “Tab” (although it is possible to use files delimited by “Comma” or “Space” or “;”)

II-2. Scene files

The file extension is “.vgx”

II-2-1. File header

The files are arranged in columns. The first row is a series of keywords which corresponds to column headings. The file has as many lines as the number of objects described in the scene.

Possible header list (i.e. keywords)
- Obj : object shape represented by an integer code,
- EchX, EchY, EchZ : parameters for object scaling
- TransX, TransY, TransZ : object co-ordinates in the scene reference
- RotX, RotY, RotZ : object orientation (Euler angles)
- R, G, B : object colour,
- X1, Y1, Z1, X2, Y2, Z2, X3, Y3, Z3 spatial co-ordinates of triangle tops in a triangulated scene case.

Obj	EchX	EchY	EchZ	TransX	TransY	TransZ	RotX	RotY	RotZ	R	G	B

- Mask : visible or invisible object (0 or 1),
- Grp1, Grp2 : Columns in which objects are grouped for spatial integration.

X1	Y1	Z1	X2	Y2	Z2	X3	Y3	Z3	Mask	Grp1	Grp2

- Pmax, Alpha, Teta, Resp: parameters needed for photosynthesis calculation, using the non-rectangular hyperbola model.
- VCmax, Jmax, Resp : parameters needed for photosynthesis calculation, using Farquhar’s model

Pmax	Alpha	Teta	Resp	VCmax	Jmax

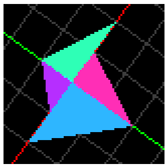
Obj	EchX	EchY	EchZ	TransX	TransY	TransZ	RotX	RotY	RotZ	R	G	B	Mask	Grp1
11	1	1	0.1	-2	0	-1	0	0	0	255	0	0	0	1
12	1	1	0.1	0	0	0	0	0	0	0	255	0	1	1
13	1	1	0.1	2	0	1	0	0	0	0	0	255	1	2

Sample from an input file

II-2-2. Canopy description

II-2-2-1. Triangulated scene

Code 0



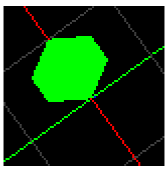
TRIANGLES

Triangulated scenes are made up of collection of triangles(grouping) described by their top co-ordinates X1, Y1, Z1 ; X2, Y2, Z2 ; X3, Y3, Z3.

II-2-2-2. Scene description by basic geometrical shapes

II-2-2-2-1. Surfaces

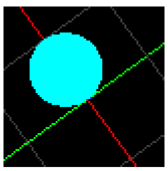
Code 11
Code 12
Code 13



POLYGONS

By default, this code generates unitary height hexagons.
These ones can be replaced by shapes of type "Polygon leaf", created by the user (see § II-2-2-2-4). Three leaf types can be represented on the same scene.

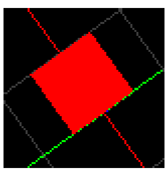
Code 21



DISC

The basic disc is of unitary diameter and its centre co-ordinates are: 0.5, 0, 0.
It allows any ellipse representation.

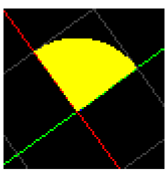
Code 22



SQUARE

The main square is of unitary side. Its diagonals meet each other at co-ordinates 0.5, 0, 0.
It allows any rectangle representation.

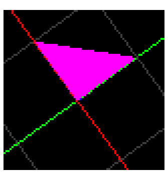
Code 23



DISC QUARTER

The disc quarter is of unitary radius placed by default on the side X+, Y+ of the reference, the disc centre being placed on the point of co-ordinates 0,0,0.

Code 24

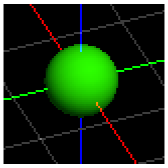


RECTANGLE TRIANGLE

The rectangle triangle of unitary side is placed by default on the side X+, Y+ of the reference. The right angle is located at co-ordinates 0,0,0.

II-2-2-2-2. Volumes

Code 31

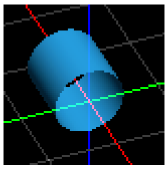


SPHERE

The basic sphere has unitary diameter and its centre co-ordinates are 0, 0, 0

It allows any ellipsoid representation.

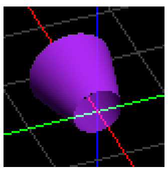
Code 32



CYLINDER

The basic cylinder has unitary height and diameter, its base centre is located in 0,0,0, its top centre is located in 1, 0, 0.

Code 33



CONE

The basic cone has a unitary height, its base centre is located in 0,0,0, and its top centre is located in 1,0,0.

Attention : In this cone situation, values EchY and EchZ represent respectively the base and top diameter (EchX represents the height).

II-2-2-2-3. Size and position

The object size is specified in columns EchX, EchY and EchZ of the input file. In the case of leaves that are represented by surface objects (polygons, ellipses), EchX and EchY are leaf length and width, and EchZ is arbitrarily fixed at 1. Concerning the axis represented by truncated cones, EchX is the axis length; EchY and EchZ are the diameters at the base and at the top of the axis, respectively.

The object position is defined by TransX, TransY, TransZ columns.

Object orientation is described in columns RotX, RotY and RotZ which are object Euler angles. Concerning the leaves, the rotation angles can be obtained by 3D digitisation (Fastrak, Polhemus) by placing the sensor plane parallel to the lamina with its axis parallel to the midrib. In this case, RotZ corresponds to the midrib azimuth, RotY is the inclination angle of the vein and RotX is the lamina roll angle around the vein. Notice that the leaf is generally digitised at the petiole- lamina junction point, by setting the sensor on the lamina in order to determine the orientation. Consequently, the sensor is directed in opposite direction to the leaf real orientation. The result is that Euler angles A, B and C given by the digitiser have to suffer the following transformation in order to obtain angles RotX, RotY and RotZ.

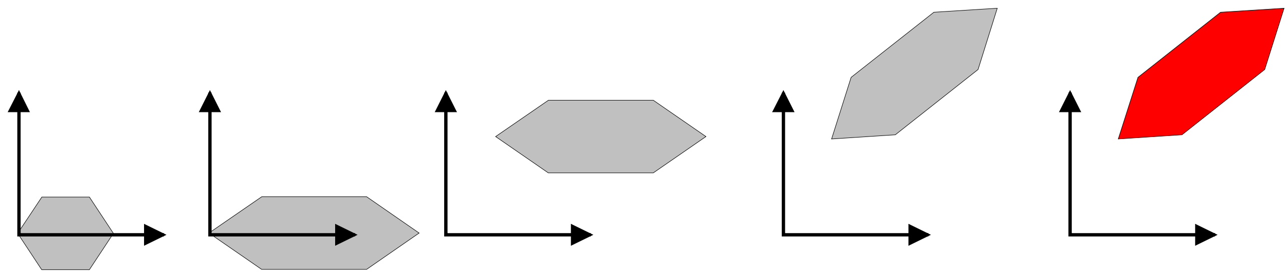
In VegeSTAR1, this transformation was performed by default. However, starting with VegeSTAR2 and VegeSTAR3, the initial surface object position has been unified to standard arrangements, therefore the operation on angles has to be applied beforehand by the user.

To obtain a correct view of these leaves, the following transformation has to be done:

RotX = angleC * (-1)

RotY = angleB * (-1)   where A, B and C are the angles given by the Fastrak (polhemus) digitiser.

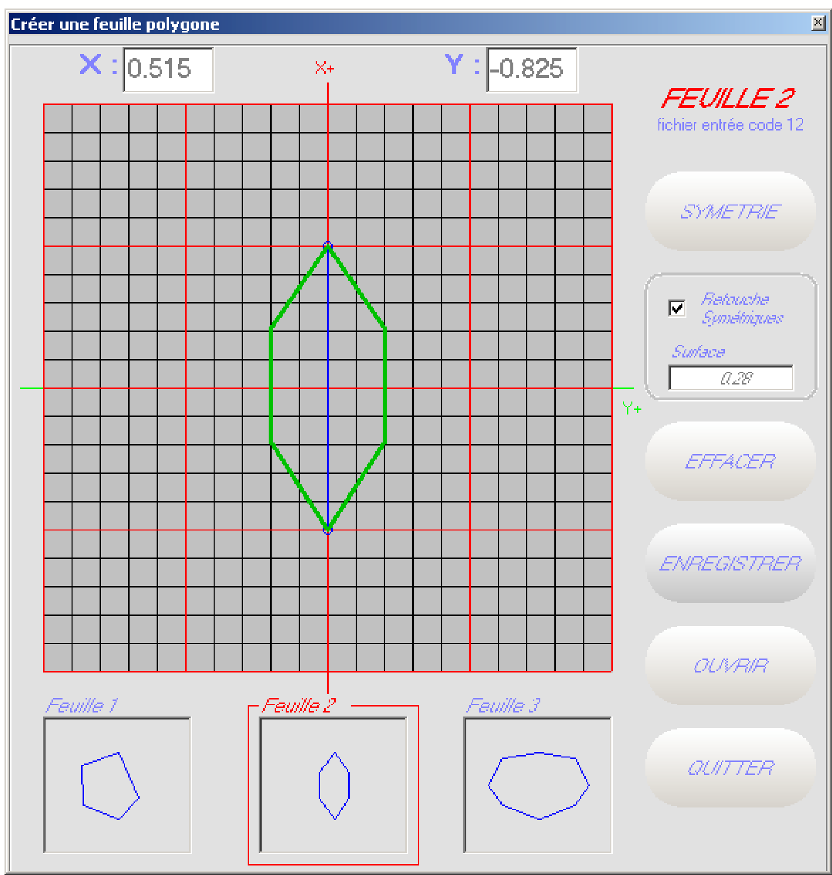
RotZ = angleA +180°



II-2-2-2-4. Using a Polygon leaf

VegeSTAR3 allows simultaneous creation of three types of polygonal leaves.

To create them, choose “Create a polygon leaf” in the “Tools” menu.



Window for polygon leaf creation

Leaf type 1, 2 and 3 of this editor will replace respectively object type 11, 12 and 13 in the scene.

The grid shown allows any polygon shape to be drawn. Remember these polygons are unitary, which means that the “midrib” represented by the vertical blue line has a length of 1. On the other side, only the convex polygons are correctly represented on the scene. If the desired shape is symmetrical to the midrib, only half of it needs to be drawn, then click on “SYMETRIE” button to get the set polygon. Once the leaf created, its area is shown on the screen. This possibly allows verification of the allometric relation between dimensions and leaf area.

Once the leaf is completely drawn, you can retouch its shape by placing the mouse pointer on one of the sides and using the right mouse button to position it. The retouches will be executed symmetrically by default.

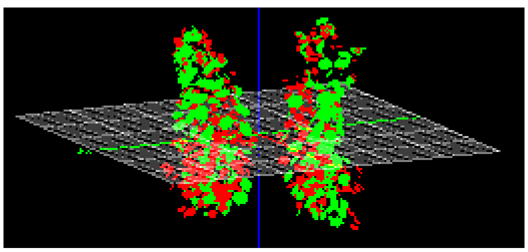
The polygons that have been created can be saved in text (ASCII) format with the .pol extension;

II-2-2-3. Colours

VegeSTAR3 uses RGB (Red, Green, Blue) colours. Each object can have:
-a RED component coded from 0 to 255 (column R)
-a GREEN component coded from 0 to 255 (column G)
-a BLUE component coded from 0 to 255 (column B)

Attention:

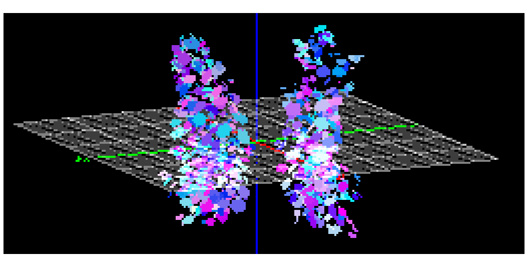
- Using this file for STAR calculation:



-

  - If no colour is specified, VegeSTAR3 sets a green colour by default (R=0, G=255, B=0) for all the objects in the scene.
  - VegeSTAR3 calculates the STAR by RGB image processing, by drawing a pixel number histogram for every independent band. Every R, G, B band may be used for coding object information: for instance, R can code leaf age, G - the branching order, B - the height from the ground level. This coding is limited to the 255 colour level (between 1 and 255, as 0 is used for the background) for each band. Finally, information should not be coded using all the possible colour combinations ($(255)^3$ = 16 million colours), as histograms are calculated on each independent band. VegeSTAR3 STAR analysis allows identification of 255x3 object types on the scene, but not 255^3
  -

- File use for the photosynthesis calculation:



In this case, VegeSTAR3 automatically assigns colours to objects on the scene so the R, G, B columns are not used.

II-2-2-4. Mask

VegeSTAR3 allows the inclusion of “black” objects to the scene. The STAR and photosynthesis rate are not computed for these objects which act only to shade the plant objects. If “Mask” value is 1, the object is hidden, if the value is 0, it is included in the analysed vegetation.

II-2-2-5. Group

In case of photosynthesis calculation, VegeSTAR3 allows object grouping in order to facilitate output data analysis for a spatial integration of the results. To do this, two columns can be added together with key words ‘’Grp1’’ and ‘’Grp2’’. For each object from the scene there is a strictly positive whole number corresponding to a set of objects (these different sets are from 1 to n). In this way, the results can be integrated according to these object sets, and no longer object by object. One object can belong to two different sets, by using the two available columns, Grp1 and Grp2.

II-2-3. Scene file analysing

VegeSTAR3 has a lexical analyser and shows, after file analysis, the possible calculation. The window hereafter indicates the available data in the file, and the button colour shows what possible computations are allowed by information contained in this file (STAR, Hyperbole, Farquhar).

Analysis selection window

II-3. Microclimatic sequence file

II-3-1. File description

The file extension is ‘.seq ‘

The files are organised into columns. The first row is a series of keywords corresponding to the column headings. The file has as many lines as there are simulated conditions.

Possible header list (keywords):

- Az: azimuth (°),
- El: elevation (°),
- Global: PAR global incident (µmol of photon m^{-2} s^{-1}),
- Diffus: PAR diffuse incident (µmol of photon m^{-2} s^{-1}),
- Temp : temperature (°C),
- CO2: partial pressure of CO_2 (Pa).

Az	El	Global	Diffus	Temp	CO2
12.23	9.23	1300	400	25	35
59.77	9.23	1300	400	25	35
84.23	9.23	1300	400	25	35

Sample of a sequence file

For the STAR calculation, only Az and El are necessary.

For the photosynthesis calculation, with the hyperbola model, columns Az, El, Global and Diffus are necessary.

For the photosynthesis calculation, with Farquhar's model, all 6 columns are necessary.

II-3-2. Model parameters

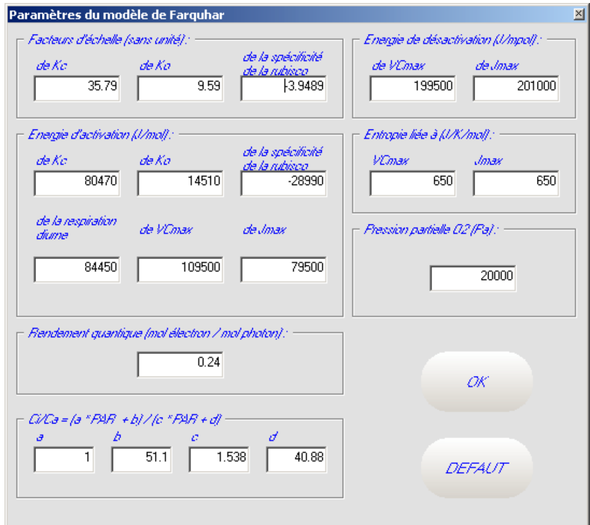
II-3-2-1. Farquhar's model (this is exact duplication of section 1-3-3)

The Farquhar's model requires other parameters, which are not easily evaluated. However, some of these are considered to be constant for a given species, but are known for only a limited number of species. These parameters include:

- Quantum yield α (µmol CO_2 µmol PAR-1)
- Dark respiration : scale factor (dimensionless) and activation energy (J mol^{-1})
- Electron transport capacity:: scale factor (dimensionless) and activation energy (J mol^{-1}), deactivation energy (J mol^{-1}) et entropy term (J K^{-1} mol^{-1})
- Carboxylation capacity: scale factor (dimensionless) and activation energy (J mol^{-1}) deactivation energy (J mol^{-1}) et entropy term (J K^{-1} mol^{-1})
- The constants of Michaelis-Menten for carboxylation and oxygenation : scale factor (dimensionless) and activation energy (J mol^{-1})
- and in an indirect way, the (stomatal) conductance via a relation between the ratio of internal and surrounding atmosphere CO2 concentration and leaf irradiance.

VegeSTAR3 allows these the user to define these parameters or to usethe default parameters, which are those given by *Le Roux et al*; (*1995)* for walnut tree species.

To change parameters, choose 'Parameters' on the tool bar.



Window for Farquhar's model parameters

III. Output files

III-1. Basic STAR computation

The first column of an output file of a manual analysis indicates the colour level, between 0 and 255. Then it has one, two or three additional columns (depending on the number of colour bands, involved in the scene) containing interception area measured for each colour level, in Red, Green and blue bands.

The first row in the file lists the measurement conditions: Azimuth and Elevation angles, image size and its unity.

Note that the unity used for projected areas is the square value of image size unity.

It can also be noticed that the rows which do not contain information (no area measured for the corresponding colour level) are not shown in the output file;

	AZIMUT -116 °	ELEVATION 78 °	TAILLE 59.29dm	
	ROUGE	VERT	BLEU	
0	3397.698294	3398.890995	3397.69829	
1	1.386860916	0	0	
2	0	1.719707535	0	
4	0.887590986	0	0	

Sample of a manual STAR output file

III-2. Automated STAR computation

The output file of an automatic STAR analysis has C*N+1 columns, where N is the number of positions in the sequence file and C the number of colour bands which are used (1, 2 or 3). The first column contains the colour level from 0 to 255.

The columns that follow contain the interception area measured for each colour level, in Red, Green, Blue bands.

The first row contains the Scene file name used for calculation; the next three rows list the measuring conditions: Azimuth and elevation, image size and unity.

Note that the unity used for projected areas is the square image size unity.

As in the case of the manual STAR, rows containing only "0" are not included in the output file.

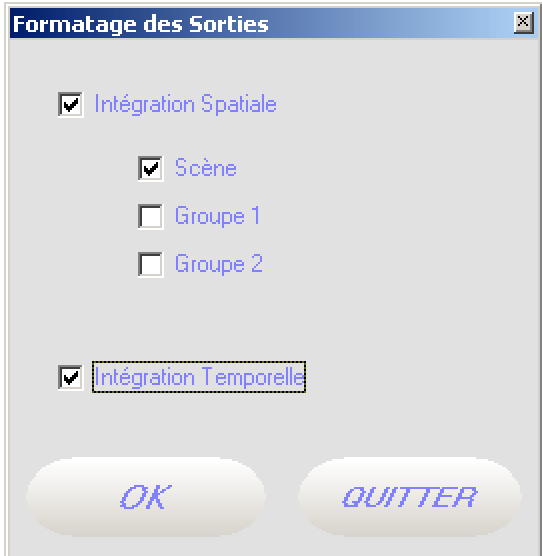
Attention: Excel files allow only 256 columns, which means a number N ≤ 85 of position in the file .seq, if all three bands are used.

C:\Documents and Settings\dones\Mes documents\3feuilplate.vgs									
	AZ=12.23°			AZ=59.77°			AZ=84.23°		
	EL=9.230003°			EL=9.230003°			EL=9.230003°		
	T=53.61cm			T=53.61cm			T=53.61cm		
	ROUGE	VERT	BLEU	ROUGE	VERT	BLEU	ROUGE	VERT	BLEU
0	2873.896	2873.851	2873.873	2873.873	2873.851	2873.873	2873.896	2873.851	2873.896
255	0.1360639	0.1814185	0.1587412	0.1587412	0.1814185	0.1587412	0.1360639	0.1814185	0.1360639

Sample of an automatic STAR output file

III-3. Photosynthesis

After the sequence calculation, VegeSTAR3 offers several options for output file formatting. The next window offers different options for integration.



Output file formatting window

III-3-1. No integration

If no integration is chosen, the output file contains all the spatial and time information, meaning 2N+3 columns, where N is the number of positions in the sequence file.

The first column contains the scene leaf component number. There is a row for each leaf component in the scene, and as many rows as there are components in the scene.

The second column indicates the component leaf area.

The third column shows the fraction of the diffuse radiation intercepted by the component.

The next N columns show the irradiance received by the component, in µmol on m^{-2} leaf area s^{-1}.

Finally, the last N columns contain the component net assimilation rate, in µmol CO_2 m^{-2} leaf area s^{-1}.

The first row contains the 'Scene photosynthesis' file name used for analysis, the image size and the metric unity which is used.

The second row contains the column headers.

C:\VGST	C:\Mes document:	TAILLE: 53.61 cm		
Objet	SURFACE en cm²	Diffus	Global AZ. 12.23 EL. 9.23	Phot. AZ. 12.23 EL. 9.23
1	0.323462307	0.596701972	2396.373518	11.89332544
2	0.181971252	0.523768218	2126.550099	11.86267948
3	0.223060936	0.410491168	2740.543868	11.92322806

Sample of photosynthesis output file

III-3-2. Spatial integration

The spatial integration allows summing up of the results of grouped objects; this is done on the whole scene or according to the pre-defined groups in the input files (Grp1, Grp2).

III-3-3. Time Integration

Time integration allows summing up of all time steps used in the sequence file. The calculated values are average values expressed in $\mu mol.m^{-2}.s^{-1}$.

IV. User's Manual

IV-1. Material configuration

Windows 9x, NTx, 2000, XP.

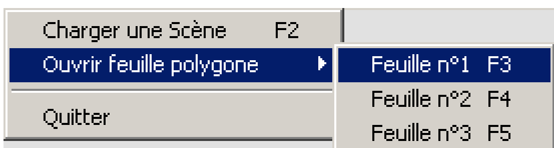
System Requirements:

- Screen of 1024 x 768 pixels.
- 16 million colours

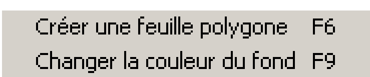
IV-2. Main page

IV-2.1 Menu

File menu: Allows scene loading, opening of one or several polygon leaves, application output.



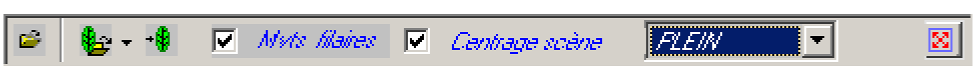
Tools menu: Where to openthe polygon file editor and to change the background colour



Model parameters menu: allows access to the Farquhar model parameter window.

Help menu: for VegeSTAR3.

IV-2-2. Tool bar



The first three icons allow scene loading, "polygon leaf" file opening, leaf editor access, respectively.

The first box to tick allows specification of the display type when the scene is moving.

The second one allows placement of the scene in the viewer reference centre (active centring by default)

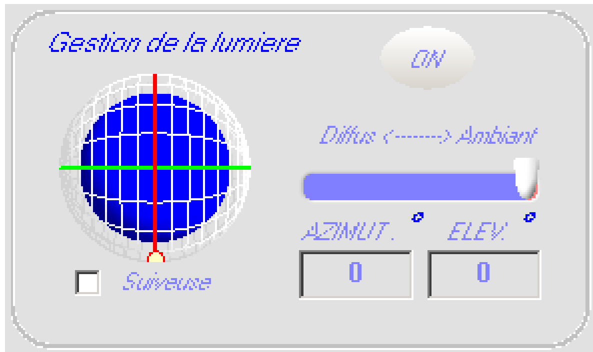
The display menu provides the choice between the following representation options: full, silhouette, point.

The last button places VegeSTAR3 in a large size 3D viewer configuration.

In the large size configuration VegeSTAR3 offers the possibility to light the scene and define the object irradiating characteristics (ambiant-diffuse).

The scene can be lit or not (on/off button). When the scene is lit, the light source can be independent or related to the view direction (tick the "tracking" box)

<u>*Attention*</u>: The light has an effect only when the diffuse component is greater than 0.



Light management window

<u>IV-2-3. Buttons</u>

Visualisation buttons

GRID: VegeSTAR3 designs a scene using a grid; the grid can be shown or hidden.

CAMERA (ORTHO or STANDARD): By default, VegeSTAR3 designs a scene seen with an orthographic camera, meaning by a perspective in which the rays (radiation) coming from the camera are parallel. This camera is REQUIRED to be used for creating images that will serve for light interception computation as these interception characteristics are generally directional;

ANIMATION: These buttons allow scene animation for horizontal or vertical rotation.

Analysis buttons

COPIE IMAGE (copy image): This button allows the current view of the scene in the analysis window to be copied.

HISTO: This button allows the image histogram to be displayed and saved.

SEQUENCE : This button is used to choose a microclimate sequence file.

SAUVER (save): This button saves the imagein bitmap format.

IV-2-4. Visualisation 3D

VIEW:

Several options allow view direction adjustment: It can be done by:

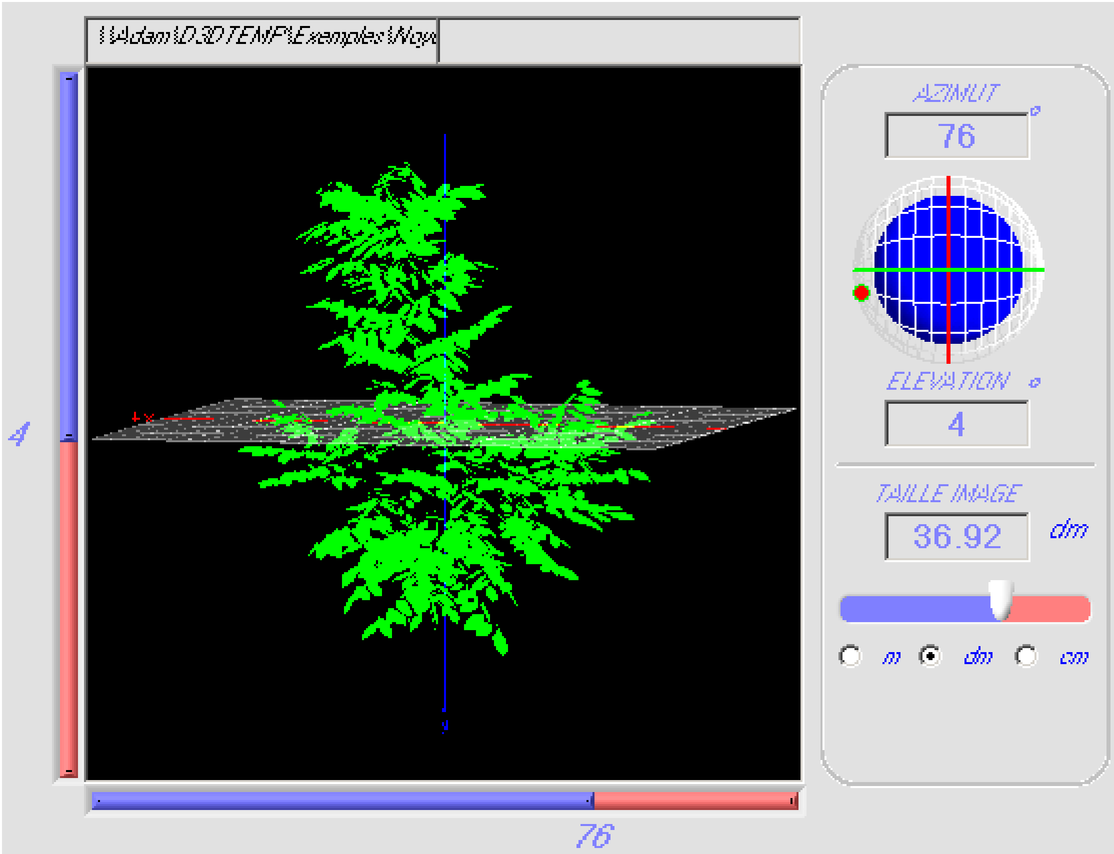
Using text boxes ' AZIMUT' and 'ELEVATION'
- make the scene rotate by pressing the mouse left button
- pull the cursor over the spherical sight
- use the cursors placed at the bottom left of the 3D window

IMAGE SIZE:

The zoom cursor allows the scene size to be adjusted (the scene window is square shaped). You can also manually enter the image height you want in the text box TAILLE IMAGE (IMAGE SIZE) and choose the unit of measurement: cm, dm or m. By default, the metric unit is cm, i.e. the unit used by a Fastrak (Polhemus) digitiser.

REFERENCE TRANSLATION :

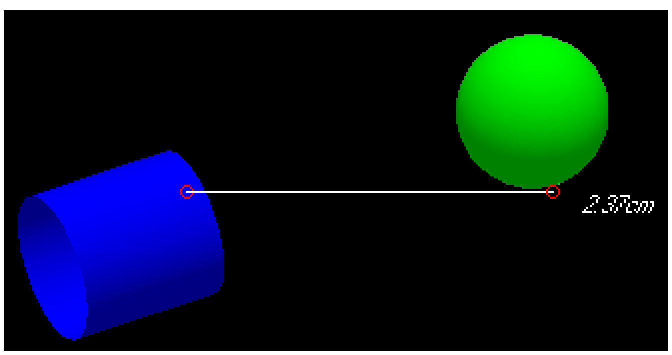
The mouse right button allows scene translatory movement in the visualisation window



Visualisation area

IV-2-5. Analysis window

VegeSTAR3 allows the measurement of distance on the analysis image. To do that, you have to click on an image point and pull the mouse cursor by keeping the left button pressed. To delete, click the right button.



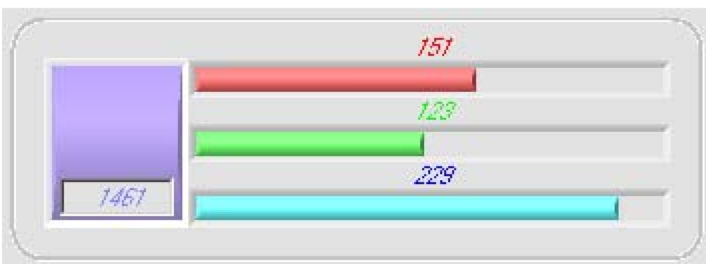
VegeSTAR3 also allows the image to be saved in Bitmap format by clicking on the “SAVE” button.

IV-2-6. Leaf area

This text box shows the total plant surface area included in the scene.

RGB level

This field shows the red-green-blue components of any pixel highlighted with the mouse in the analysis window, and also the highlighted geometrical object number in a “photosynthesis” scene



IV-2-7. Run

After opening a sequence scene and file, this field starts the analysis. For a “photosynthesis” analysis, the user has to choose a sky discretisation (turtle 16 or 46) and also a directional distribution law of the diffuse irradiance: SOC (Standard Overcast sky, by default) or UOC (Uniform Standard sky):

A gauge indicates the progress of the analysis.

<u>Important observations:</u>

Avoid executing other tasks while the sequence calculation is running.

Check that every scene element is visible on the image, regardless of the view direction. Note that if elements (components) are not visible, i.e. they are off-screen, then their contribution to light interception will not be taken into account and the calculation will be incorrect.

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