Biomass Production Chain and Growth Simulation Model for Kenaf

QLK5-CT-2002-01729

WP3. Development of the Kenaf growth simulation model

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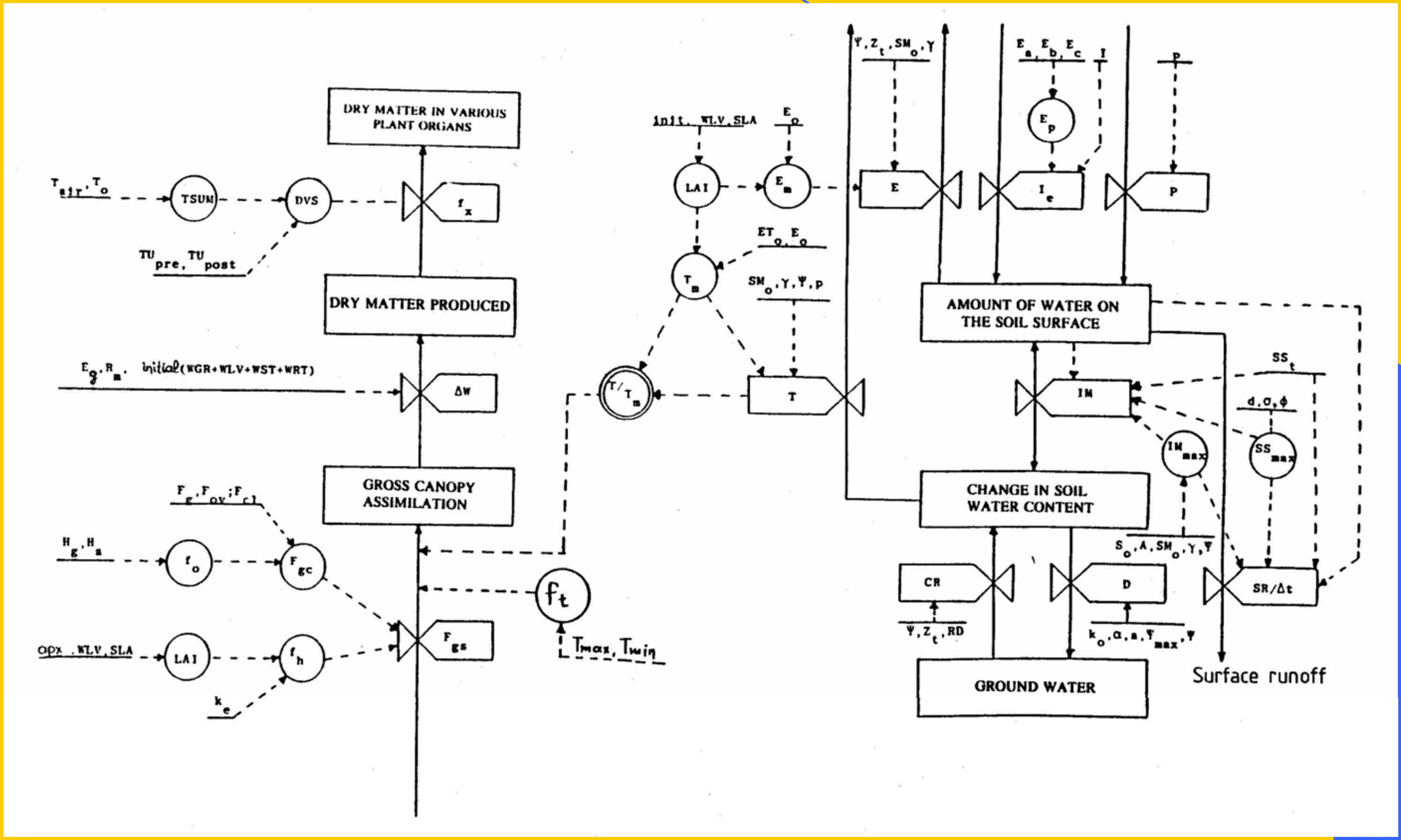
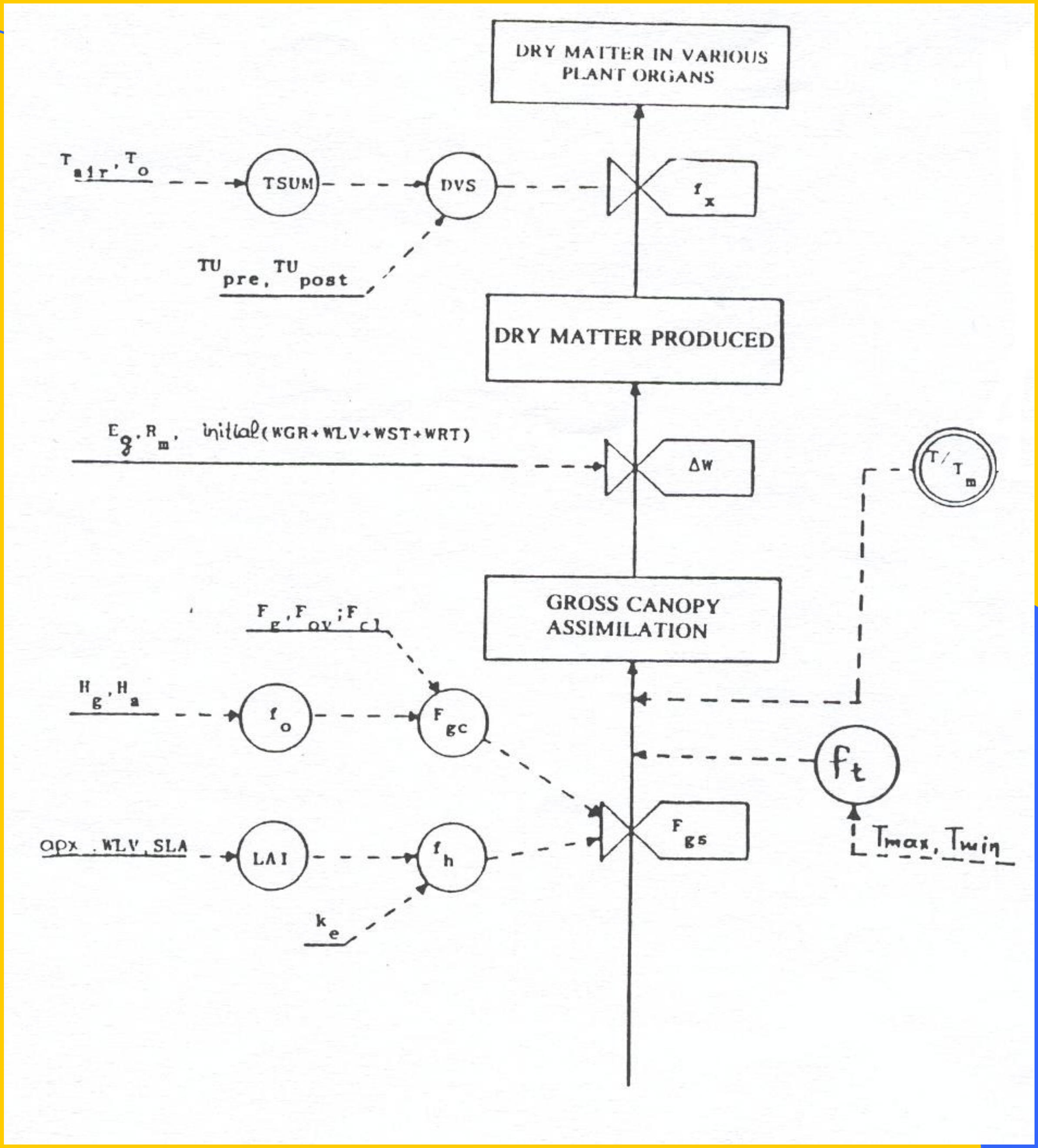
Simplified flow chart of kenaf production during one interval of calculations

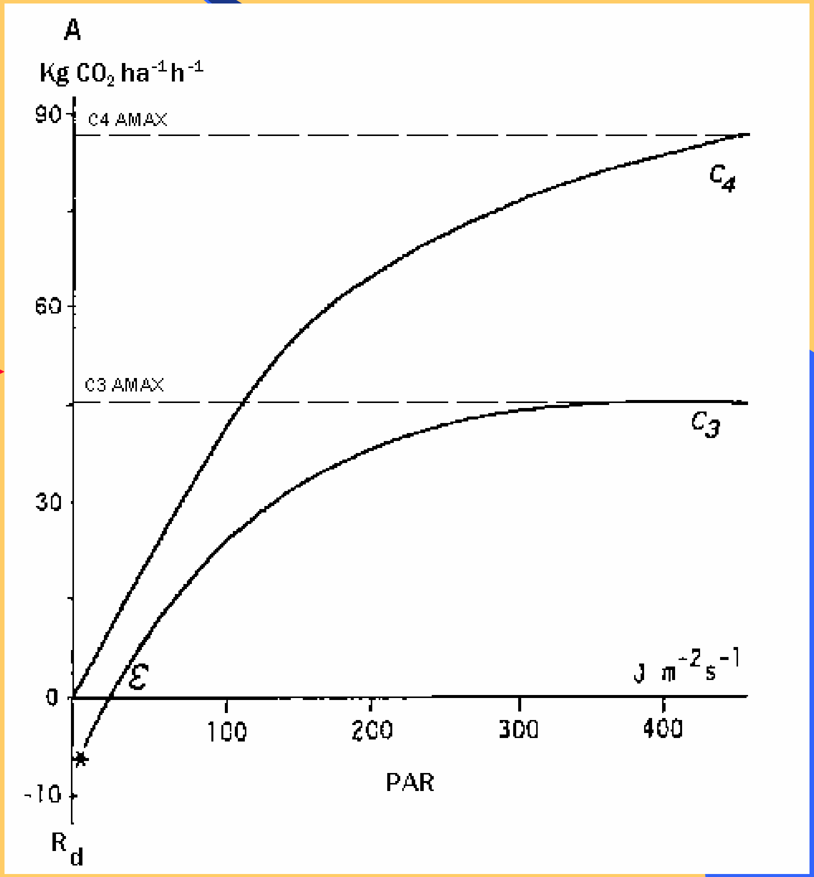


Production Situation 1



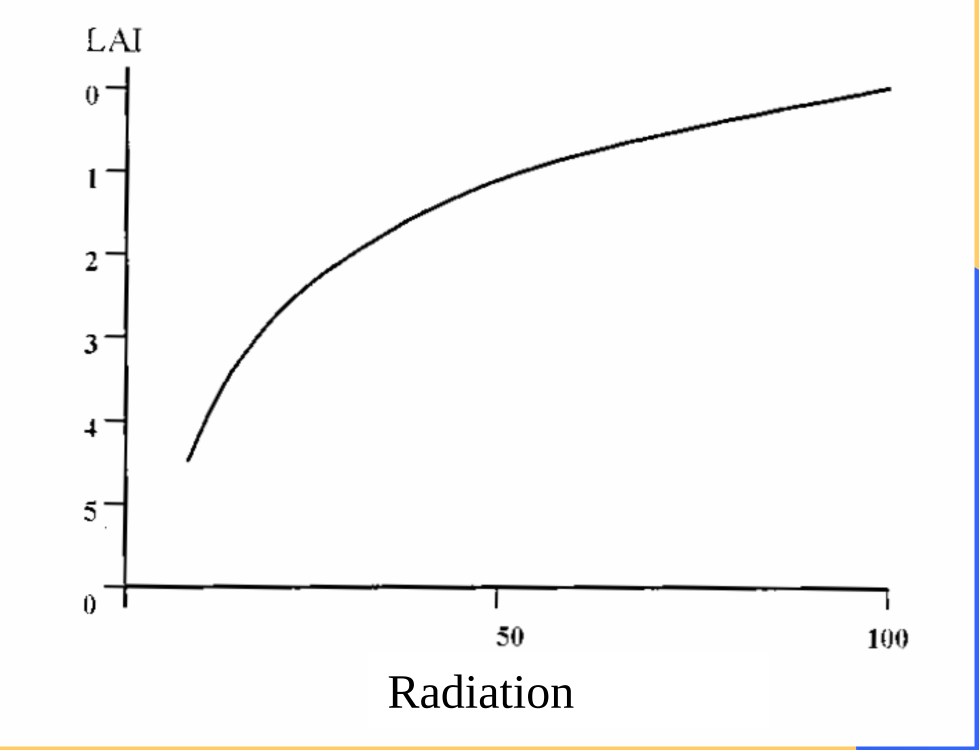
Single leaf assimilation

$$A = AMAX \times \left(1 - e^{Radiation}\right)$$



Canopy Assimilation

$$PAR_{ef} = 1 - e^{-kc \times LAI}$$



Canopy Assimilation

- ✓Angle of radiation interception
- ✓Light distribution within the crop canopy
- ✓ Effect of direct and diffuse radiation
- ✓Leaf area (index)
- ✓Leaf angle (extinction coefficient)

Model operations

- ✓ Calculation of global radiation
- ✓ Differentiation of direct from diffuse radiation
- ✓ Calculation of PAR
- ✓ Calculation of radiation within the canopy
- ✓ Calculation of gross canopy assimilation rate
- ✓Calculation of dry mass productivity
- ✓Dry mass separation to plant organs

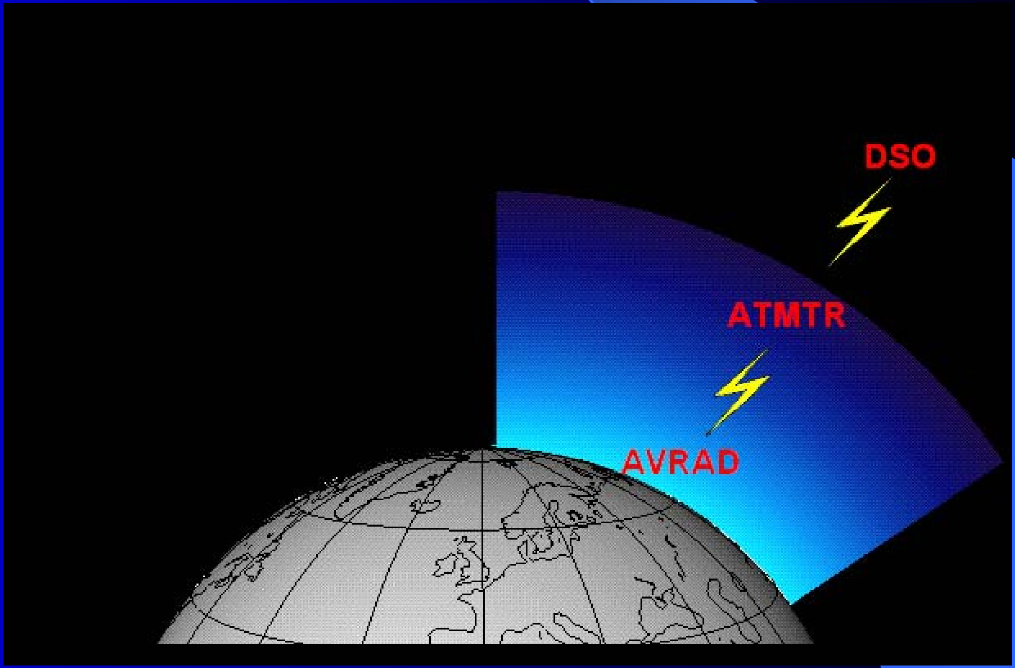
Total radiation.

AVRAD ($J\ m^{-2}\ d^{-1}$)

From the total radiation reaching the atmosphere (DSO = 1370 W/m^2), only a part reaches the earth's surface (AVRAD) according to the value of the atmospheric transmission (ATMTR).

AVRAD = DSO x ATMTR

(300-3000nm)



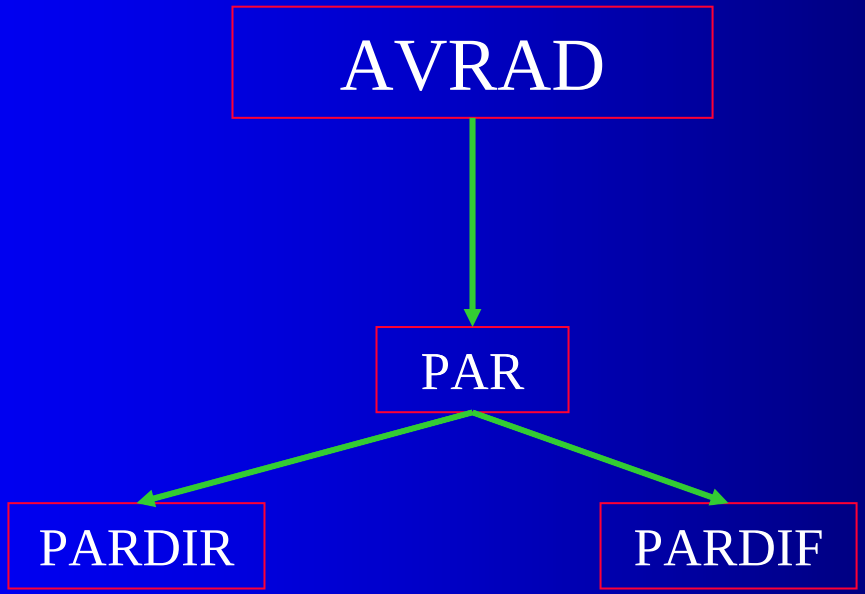
Direct and diffuse radiation
Coefficient FRDIF

Important improvement of the model comprises the differentiation between of the direct and diffuse parts of the global radiation.

$$
\begin{array}{llll}
\dfrac{FRDIF}{AVRAD} = 1 & & \gamma\iota\alpha & ATMTR < 0.07 \\
\dfrac{FRDIF}{AVRAD} = 1 - 2.3\left(ATMTR - 0.07\right)^2 & for & & 0.07 \le ATMTR < 0.35 \\
\dfrac{FRDIF}{AVRAD} = 1.33 - 1.46 \times ATMTR & for & & 0.35 \le ATMTR < 0.75 \\
\dfrac{FRDIF}{AVRAD} = 0.23 & for & & 0.75 \le ATMTR
\end{array}
$$

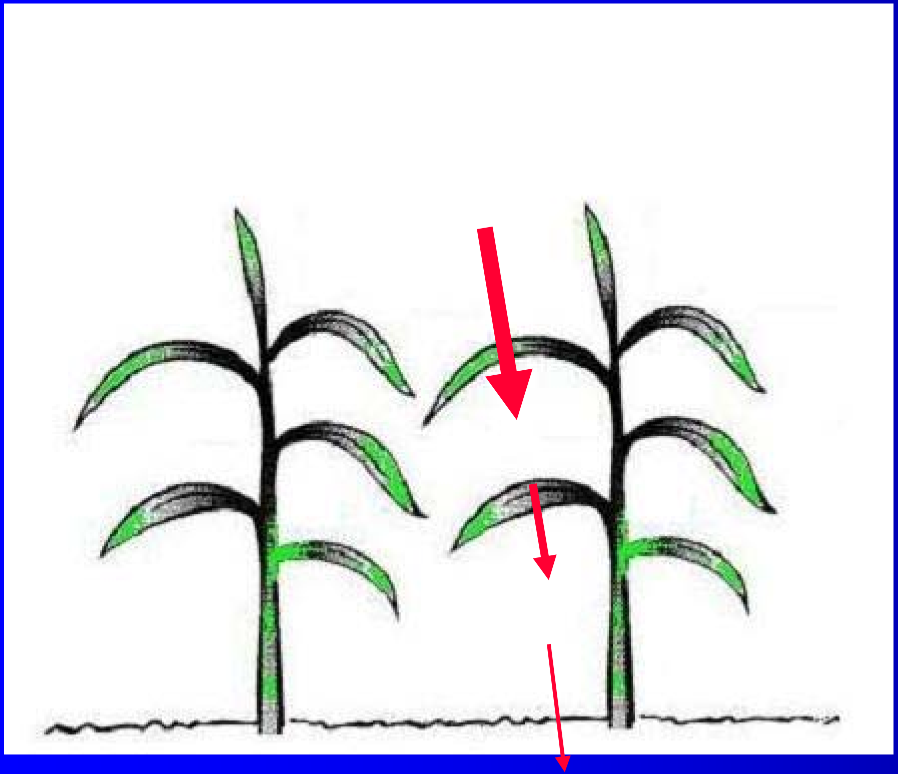
PAR (J m^{-2} s^{-1})

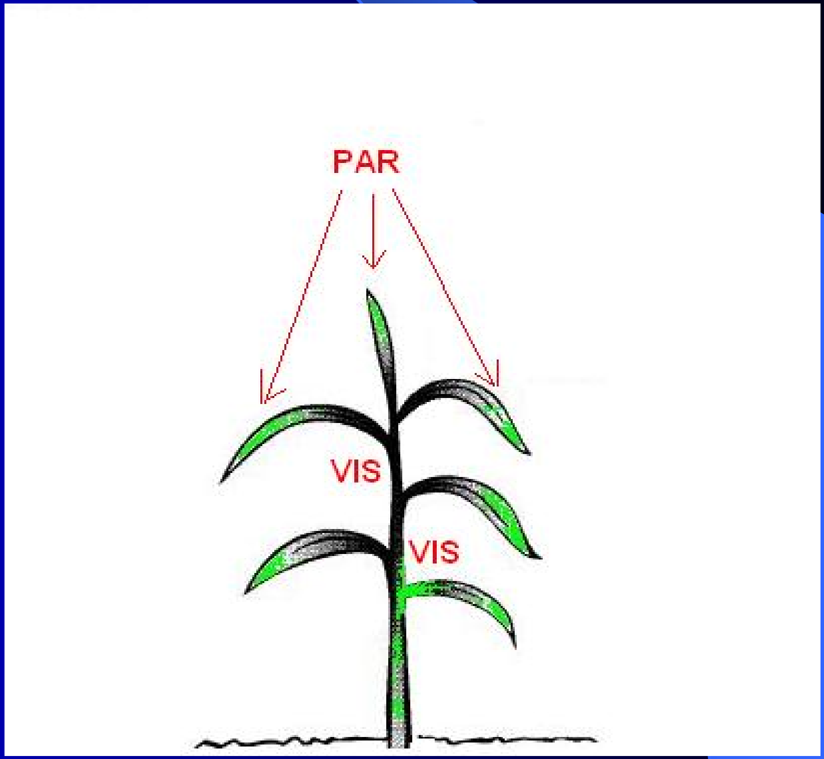
The part of AVRAD (300-3000 nm) that is photosynthetically active (400-700 nm).



Radiation within the canopy
VIS (J m^{-2} s^{-1})

PAR is not constant within the canopy but it degreases exponentially with increasing leaf area index. VIS is the value of PAR in every canopy level.





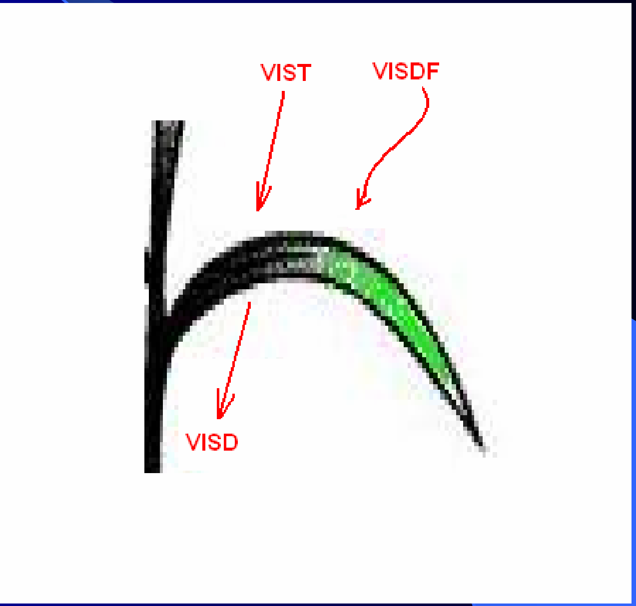
Radiation within the canopy
VIS (J m^{-2} s^{-1})

VIS

VIST
(PARDIR)

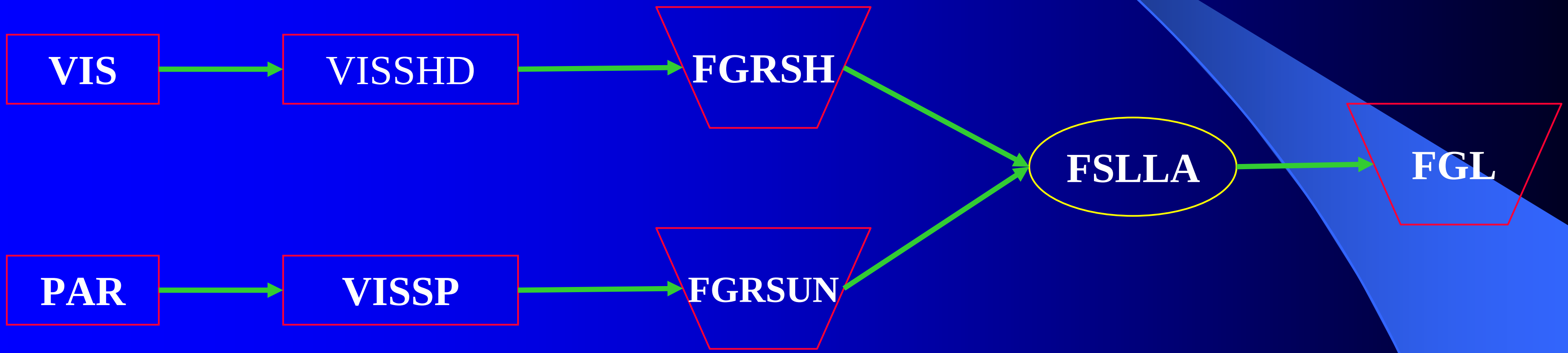
VISDF
(PARDIF)

VISD
(PARDIR)



Instant assimilation rate at any canopy level

FGL (kg (CO_2) ha^{-1} h^{-1})



Dry weight increase

DWI (kg ha^{-1} d^{-1})

FGL → FGC → **FGASS** → DWI

Integrated for day length

APPLICATION

Materials

<u>HARDWARE</u>

• **Processor:**	**AMD ATHLON XP 2800+**
• **Mother board:**	**Gigabyte 7N400-Pro**
• **RAM:**	**512 MB 400 Mhz**
• **Hard disk:**	**W.Digital 160 GB**
• **Graphics:**	**ATI 9600 pro 128 MB Ram**
• **Screen:**	**LG 1710S**

<u>SOFTWARE</u>

- **Microsoft Visual Basic 6**
- **Microsoft Excel 2000**
- **Helexis Icon Catcher v3.0**
- **Microsoft Paint for windows XP**

Functions

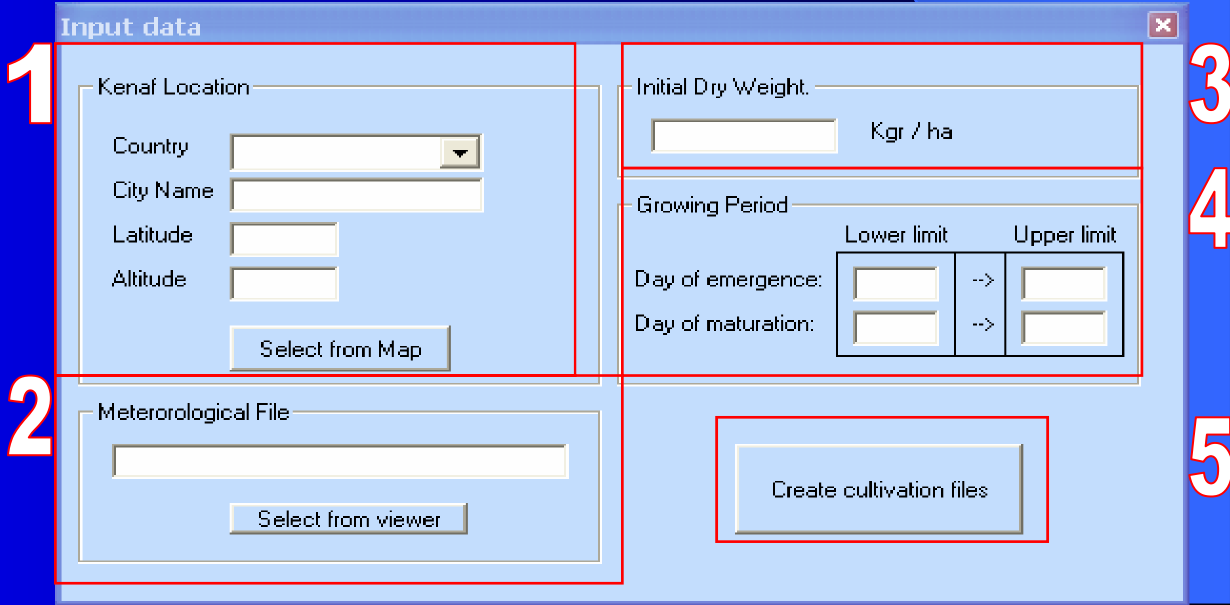
kenaf simulation

Data inputs

1. Location
2. Meteorological data (daily values of Tmax, Tmin, W/m^2)
3. Initial Dry weight (half of seed weight)
4. Growing period

Outputs

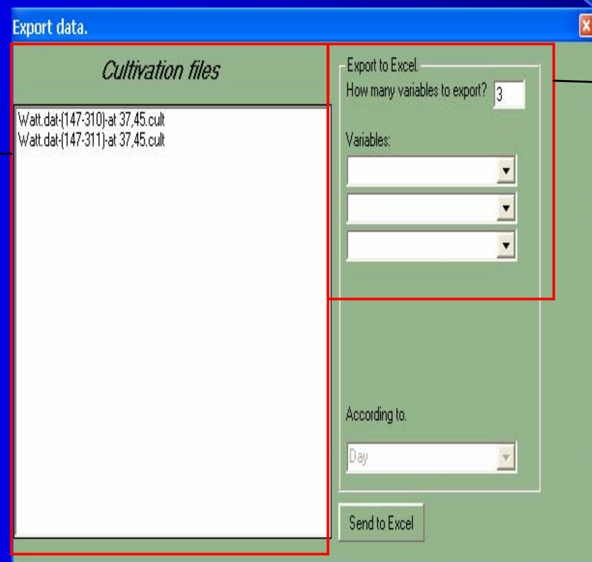
"Cultivation file"



Functions

Data export

Cultivation files viewer



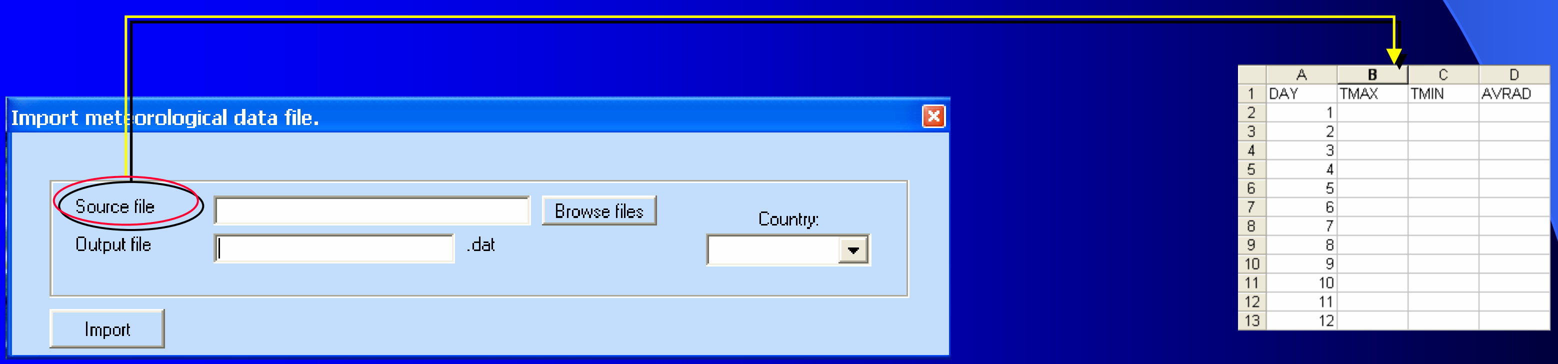
Variables to export

Functions

Meteorological data input.

Data inputs

1. Source file
2. Output file
3. Country



What follows next

$$DWI = FGC * (30/44) * CFT * CFW * 0.6 \quad kg\ ha^{-1}\ d^{-1}$$

Corrected: Growth respiration

Maintenance respiration

Corrected: Influence of (leaf canopy) temperature

Influence of water availability (TRa/TRm)

Functional relations

$$DSO = 1370 \times \left[1 + 0.033 \times \cos\left(2 \times \pi \times \frac{DAY}{365}\right)\right] \times \int_0^{DAYL} \sin(B)\,dt \quad Jm^{-2}d^{-1}$$

$$AVRAD = DSO \times ATMTR \quad Jm^{-2}d^{-1}$$

$$ATMTR = \left(a + b \times \frac{n}{DAYL}\right)$$

$$DEC = -\arcsin(\sin(23.45 \times RAD) \times \cos(2 \times \pi \times \frac{DAY + 10}{365})$$

$$SSIN = \sin(RAD \times LAT) \times \sin(DEC)$$

$$CCOS = \cos(RAD \times LAT) \times \cos(DEC)$$

$$DAYL = 12 \times \left[1 + \frac{2 \times \arcsin\left(\frac{SSIN}{CCOS}\right)}{\pi}\right] \quad hours$$

$$\sin(B) = SSIN + CCOS \times \cos(\frac{2 \times \pi \times (HOUR + 12)}{24})$$

$$\frac{FRDIF}{AVRAD} = 1 \qquad \gamma\iota\alpha \qquad ATMTR < 0.07 \qquad (3.11a)$$

$$\frac{FRDIF}{AVRAD} = 1 - 2.3\left(ATMTR - 0.07\right)^2 \qquad \gamma\iota\alpha \qquad 0.07 \le ATMTR < 0.35 \qquad (3.11b)$$

$$\frac{FRDIF}{AVRAD} = 1.33 - 1.46 \times ATMTR \qquad \gamma\iota\alpha \qquad 0.35 \le ATMTR < 0.75 \qquad (3.11c)$$

$$\frac{FRDIF}{AVRAD} = 0.23 \qquad \gamma\iota\alpha \qquad 0.75 \le ATMTR \qquad (3.11d)$$

$$PAR = \frac{0.5 \times AVRAD \times \sin'(B)}{\int_0^{DAYL} \sin'(B)dt} \qquad Jm^{-2}s^{-1}$$

$$PARDIF = 0.5 \times AVRAD \times FRDFIR \times \sin(B) \qquad Jm^{-2}s^{-1}$$

$$PARDIR = PAR = PARDIF \quad Jm^{-2}s^{-1}$$

$$VIS = (1 - REFS) \times PAR \times e^{-k \times LAI} \qquad Jm^{-2}(leaf)s^{-1}$$

$$VISDF = (1 - REFS) \times PARDIF \times KDIF \times e^{-KDIF \times LAI} \quad Jm^{-2}(leaf)s^{-1}$$

$$VIST = (1 - REFS) \times PARDIR \times KDIRT \times e^{-KDIRT \times LAI} \quad Jm^{-2}(leaf)s^{-1}$$

$$VISD = (1 - SCV) \times PARDIR \times KDIRBL \times e^{-KDIRBL \times LAI} \; Jm^{-2}(leaf)s^{-1}$$

$$KDIF = 0.8 \times \sqrt{1 - SCV} \qquad SCV = 0.2$$

$$KDIRBL = \frac{0.5}{\sin(B)}$$

$$KDIRT = KDIRBL \times \sqrt{1 - SCV}$$

$$REFH = \frac{1 - \sqrt{1 - SCV}}{1 + \sqrt{1 - SCV}}$$

$$REFS = REFH \times \frac{1}{0.5 + \sin(B)}$$

$$VISSHD = VISDF + VIST - VISD \qquad Jm^{-2}(leaf)s^{-1}$$

$$FGRSH = AMAX \times \left(1 - e^{\frac{-VISSHD \times EFF}{AMAX}}\right) \qquad kg(CO_2)ha^{-1}h^{-1}$$

$$VISSP = (1 - SCV) \times \frac{PARDIR}{\sin(B)} \qquad Jm^{-2}(leaf)s^{-1}$$

$$FGRSUN = AMAX \times \left[1 - (AMAX - FGRSH) \times \frac{\left(1 - e^{\frac{-VISPP \times EFF}{AMAX}}\right)}{EFF - VISPP}\right] \qquad kg(CO_2)ha^{-1}h^{-1}$$

$$FGL = FSLLA \times FGRSUN + (1 - FSLLA) \times FGRSH \quad kg(CO_2)ha^{-1}h^{-1}$$

$$FSLLA = e^{-KDIRBL \times LAI}$$

$$LAIC(I) = 0.5 \times LAI + I \times LAI \times \sqrt{0.15}$$

$$HOUR(I) = 12 + DAYL \times 0.5 \times \left(0.5 + I \times \sqrt{0.15}\right) \qquad I = -1,0,1$$

$$FGROS(I) = \left(FGL(-1) + 1.6 \times FGL(0) + FGL(1)\right) \times \frac{LAI}{3.6} \qquad kg(CO_2)ha^{-1}d^{-1}$$

$$FGC = \left(FGROS(-1) + 1.6 \times FGROSS(0) + FGROS(1)\right) \times \frac{DAYL}{3.6} \; kg(CO_2)ha^{-1}d^{-1}$$

Data needs for calibration

For the treatments of pot. production

- Latitude (Area of plantation)
- Day of emergence
- Flowering day (10%,50%)
- Daily Tmax, Tmin, Av.Rad.
- SLA
- LAI
- Dry weights of stems, leaves, petioles and storage organs of every harvest

Discussion how to proceed for publishing the calibrated model, simulating production potentials of Kenaf.