Documentation

INTERCROPPING - CROPSYST VBA - UPDATED 8/28/2015

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Overview of program structure

The entry point of the CropSyst VBA program is the subroutine RunCropSystVB. This procedure handles reading model parameters, user input, running the model itself and writing output (Figure 1). To simulate the growth of more than one crop at a time, RunCropSystVB includes an object called Crops of class CropHandlersClass. The CropsHandlersClass holds zero or more objects of class CropHandler and contains functions for managing the crops (Figure 2). The CropHandler class contains a suite of crop-specific classes that deal with the majority of crop growth and other daily functions (Figure 2). Objects of the CropHandler class are added or removed to the Crops object as crops are grown and harvested as simulated in the model. To accurately apply field management and to update soil processes, the Crops object is passed to the respective management subroutines in RunCropSystVB (see Management.DailyManagementEvents and SoilProcesses in Figure 1, respectively).

A subroutine called ProcessIntercroppedRadiationInterception (Figure 3) was added to CropHandlers (Figure 1) that calculates radiation interception of crops undergoing light competition.

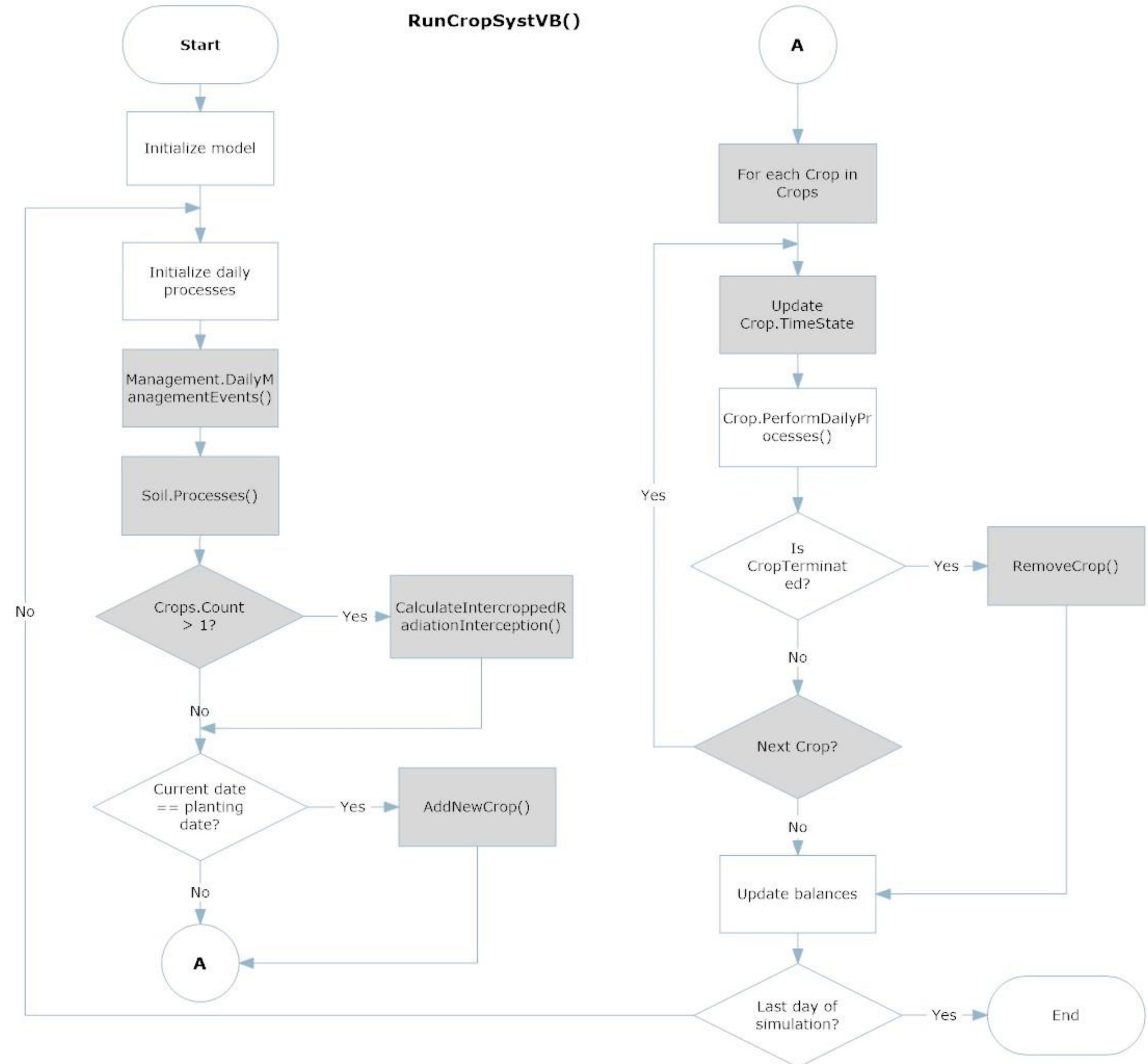

Figure 1: Flow chart giving an overview of RunCropSystVB(). Objects filled with gray indicate additions to, or modifications of, the procedure in the single-crop version of CropSyst VBA.

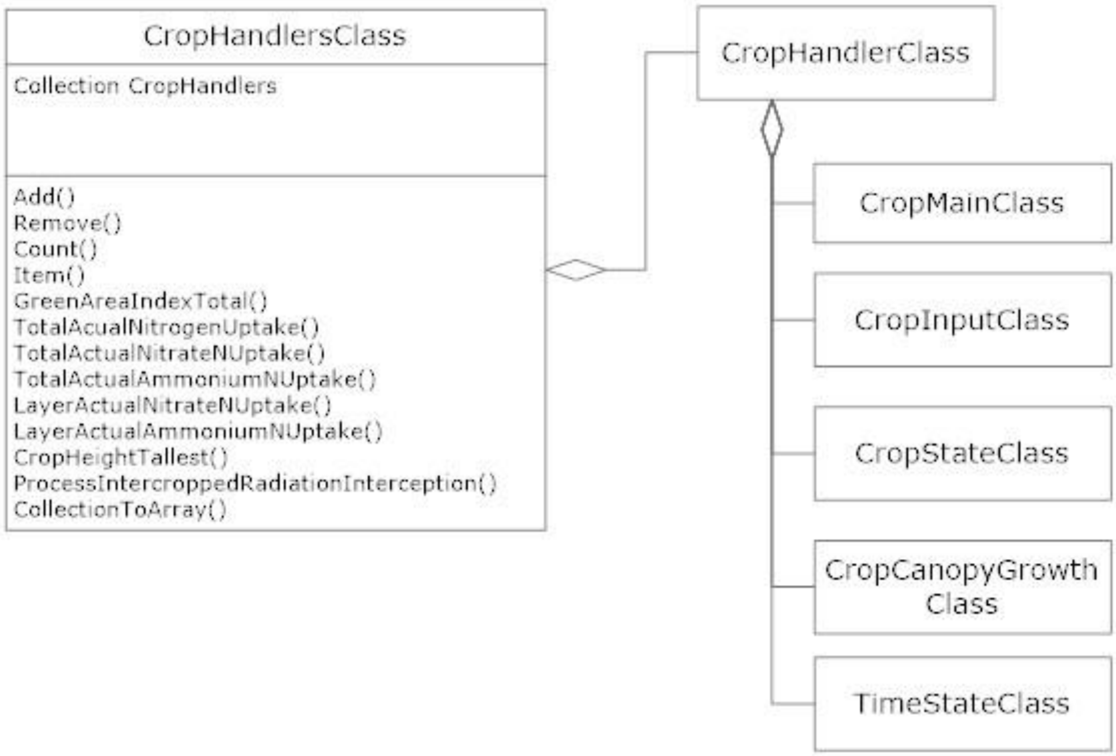

Figure 2: Overview of the member classes in CropHandlersClass. CropHandlersClass manages adding and removing objects of type CropHandlerClass and deals with logic the spans one or more of these types (such as summing nitrogen uptake). The objects of CropHandlerClass manage objects that deal with crop growth and related daily processes.

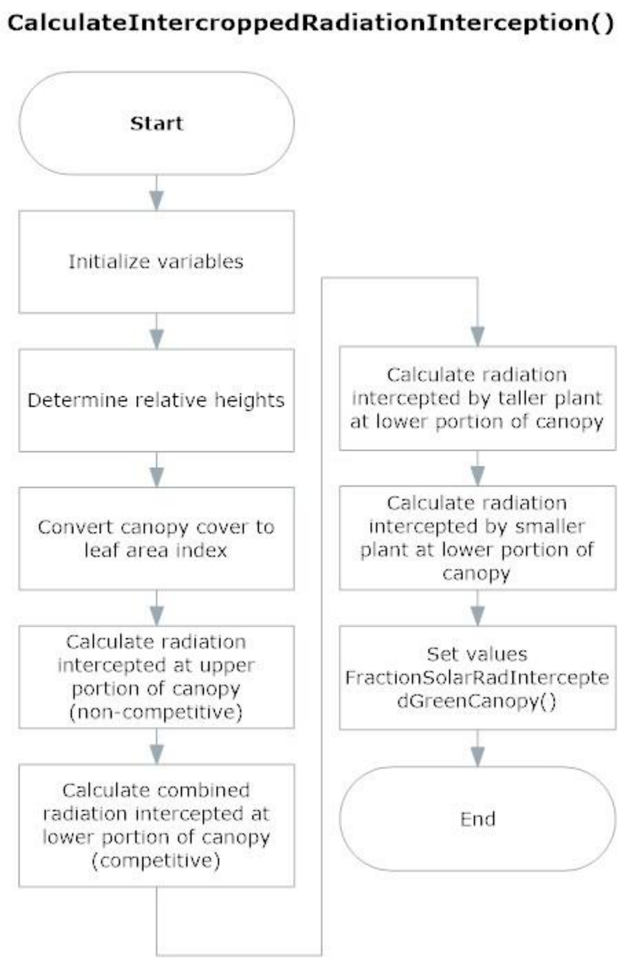

Figure 3: Flow chart depicting the CalculateIntercroppedRadiationInterception subroutine

Model descriptions

Radiation Interception

Canopy cover vs LAI

Photosynthetic active radiation (PAR) interception (I) is usually described by

$$I = f * PAR \qquad \text{eq. 1}$$

f, the intercepted fraction, is

$$f = 1 - e^{-k*LAI} \qquad \text{eq. 2}$$

where k is the (plant specific) radiation extinction coefficient, which depends on the leaf angle distribution and the zenith angle, and LAI the leave area index.

The percent canopy cover (%CC) can also be describes as a function of LAI. Some authors use:

$$\%CC = a * (1 - e^{-b*LAI})^{c} \qquad \text{eq. 3}$$

where a, b and c are empirical constants.

CropSyst VBA assumes that a = 100 and b = 1, thus assuming canopy cover (CC) is equal to the intercepted fraction (f). In this manner, LAI can be calculated from CC using:

$$LAI = \frac{-\ln(1-CC)}{k} \qquad \text{eq. 4}$$

where ln is the natural log, CC is canopy cover, and k is the plant-specific radiation extinction coefficient.

Radiation intercepted by a single plant species

If a single crop is present the model calculates intercepted radiation similarly to the methods in the single crop implementation.

Radiation interception by the two plant species

With two plant species (A and B) with different growth pattern (and height), an upper canopy (U) and a lower canopy (L) can be defined.

If leaves are vertically homogenously distributed, then the upper canopy LAI can be derived using the plant heights (h) of the two species:

$$LAI_U = \frac{|h_A - h_B|}{Max(h_A; h_b)} * LAI_T \qquad \text{eq. 5}$$

where the subscript T indicates the taller species.

The LAI of the two species at the lower canopy is:

$$LAI_{L\_T} = LAI_T - LAI_U \qquad \text{eq. 6}$$

$$LAI_{L\_S} = LAI_S \qquad \text{eq. 7}$$

subscript S indicating the shorter species.

The PAR fraction intercepted by the upper canopy is:

$$f_U = 1 - e^{-k_T * LAI_U} \qquad \text{eq. 8}$$

where k_T is the radiation extinction coefficient of the taller species.

The PAR fraction intercepted by the taller species at the lower canopy is:

$$f_{L\_T} = 1 - e^{-k_T * LAI_{L\_T}} \qquad \text{eq. 9}$$

and that of the shorter species:

$$f_{L\_S} = 1 - e^{-k_S * LAI_{L\_S}} \qquad \text{eq. 10}$$

where k_S is the radiation extinction coefficient of the shorter species.

The PAR intercepted at the upper canopy is:

$$I_U = f_U * PAR \qquad \text{eq. 11}$$

The available PAR reaching the lower canopy must be reduced by this intercepted radiation. Thus, the radiation intercepted by the two species at the lower canopy is:

$$I_{L\_T} = f_{L\_T} * (PAR - I_U) \qquad \text{eq. 12}$$

$$I_{L\_S} = f_{L\_S} * (PAR - I_U) \qquad \text{eq. 13}$$

Note that this approach deviates from that suggested by Tsubo *et al.* 2005.

Transpiration/crop water requirement/evaporative demand

Partitioning of evaporative demand between the upper and lower canopy and between species can be done using actual radiation interceptions as scaling factors.

Therefore, for instances, analogous to eq. 12 and 13,

$$I_{L\_T}' = f_{L\_T} * PAR \qquad \text{eq. 14}$$

$$I_{L\_S}' = f_{L\_S} * PAR \qquad \text{eq. 15}$$

could be calculated and used to derive transpiration scaling factors (sf):

$$sf_T = \frac{I_{L\_T} + I_U}{I_{L\_T}' + I_U} \qquad \text{eq. 16}$$

$$sf_S = \frac{I_{L\_S}}{I_{L\_S}'} \qquad \text{eq. 17}$$

These are then used as:

$$T_{pot\_intercropped} = sf * T_{pot\_monocropped} \qquad \text{eq. 18}$$

Crop growth

Canopy growth and expansion, root growth, and other morphological traits are simulated as usual but using, when needed, the modified values for PAR intercepted as outlined above.

Water Update

Water uptake is implemented similarly to how it is implemented in the single-crop version of CropSyst VBA. Water demand and supply are calculated within the crop loop (Figure 1) but soil water is updated outside of the crop loop. Under water-limited conditions, crops may reduce soil moisture artificially lower than if growing independently since growing crops calculate water uptake independently from the same “pool” of water before actual uptake occurs. Because crop water uptake is a function of water potential there remains a small amount of water in the soil that is unavailable to the crops. The unavailable water allows a small margin of error in the model. Preliminary tests show multiple crops grown under water-stress behave as expected, but the accuracy of this method needs to be further explored.

N-uptake

Analogous to the water uptake, but additionally taking into account crop-specific N-uptake characteristics, namely the *residual N not available for uptake,* the *soil N concentration at which uptake starts decreasing,* and the *plant available water at which N-uptake starts decreasing*.

As with water-uptake, multiple crops may uptake more nitrogen from the soil than is actually available. To dampen this inaccuracy, the “Residual Soil N Not Available For Uptake” crop parameter should be utilized to leave a small pool of N in the soil, analogous to soil moisture explained above.

P-update

Not yet determined.

Running the model

The following is a quick overview of running CropSyst VBA’s intercropping routine. The following only highlights features that have changed in the intercropping version of CropSyst VBA.

Crop Rotation

CropSyst VBA allows up to two crops to be grown simultaneously during a single year but multiple crops can be planted within a year. Furthermore, during a rotation, two crops can be grown one year and one crop grown the second year (Figure 4).

Crop Rotation			Rotation Cycle Length (Years)	2		Mineraliza
	Worksheet Name		Worksheet Name		Year	DOY
Crop 1	Cereal	Management 1	Management Crop1	Planting Date 1	2000	119
Crop 2	Corn	Management 2	Management Crop2	Planting Date 2	2000	120
Crop 3	Corn	Management 3	Management Crop2	Planting Date 3	2001	119

Figure 4: Example showing complex rotation with intercropping activated in the first year of the rotation and inactive the second year.

Note: Make sure to specify the number of years in the rotation (cell H11)

Crop Parameters

An “Intercropping” section was added to crop parameters with a single entry, “Extinction Coefficient for Total Irradiance”. This is a value that ranges between 0-1 and is used to calculate PAR interception (eq 8 – eq. 10).

It is advised to set a value greater than 0 for “Residual Soil N Not Available For Uptake (ppm)” under the “Plant-Nitogen Relations” section. A value greater than 0 reduces potential errors from the decoupling of calculating N-uptake by each crop before updating actual soil N.

Output

The worksheet “Daily Growth Output Compare” was added to better compare the growth of two crops. The output is cleared at the start of each simulation run and is populated at harvest. Daily output is written on a row that corresponds to the year and day of year of the simulation. This makes vertical scrolling essential to view the output.

Note: If you don't see output, SCROLL DOWN!

References

Hsiao, T.C., L. Heng, P. Steduto, B. Rojas-Lara, D. Raes, and E. Fereres 2009. AquaCrop – The FAO crop model to simulate yield response to water: III. Parameterization and testing for maize. Agron. J. 101, 448–459.

Nielsen, D., Miceli-Garcia, J.J., and D. J. Lyon 2012. Canopy Cover and Leaf Area Index Relationships for Wheat, Triticale, and Corn. Agron. J. 104, 1569–1573.

Tsubo, M., Walker, S. and H.O. Ogindo 2005. A simulation model of cereal–legume intercropping systems for semi-arid regions I. Model development. Field Crops Research 93, 10–22.

Zhang, W., Liu, W., Xue, Q., Chen, J. and X. Ha 2013. Evaluation of the AquaCrop model for simulating yield response of winter wheat to water on the southern Loess Plateau of China. Water Science and Technology 68, 821-828.