**VSIM - Vineyard Soil Irrigation Model ñ release 5/01/03 - User Guide**

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Introduction

VSIM is a simple water balance model embedded in an Excel spreadsheet (see Figure 1) that simulates the daily and seasonal water balance for a vineyard (block) given information about the vineyard climate, soils, and leaf area index (LAI). VSIM is a simplification of the Forest-BGC water balance model (Running and Coughlan, 1988) that takes advantage of the weather and evaporation data available from the California Irrigation Management Information System (CIMIS). The user can manipulate the climate, LAI, soil water parameters, crop coefficient (Kc), and a cover crop to examine the effects that these variables have on soil moisture, irrigation requirement, and vine water stress. Daily water gains and losses are used to calculate a daily water balance. Daily water gains are rainfall and irrigation, and water losses are evapotranspiration (ET) for the vine and cover crop (if desired) and runoff. Each day, the difference between soil water gains and losses are added (or subtracted) from soil moisture (SM) to estimate soil moisture on a daily basis. Crop ET (ETc) is calculated from the ETo/ETc CIMIS model where ETc = ETo * Kc, and ETo = daily evaporation for a well-watered, grass surface, and Kc = crop coefficient (CIMIS, 2002). Kc is calculated as a linear function of LAI and leaf/soil water potential (if desired). LAI is estimated from the growing degree day (GDD) sum based on a calculated relationship between LAI growth and GDD for a particular year and block . This relationship needs to be developed by the user given measurements of LAI and the GDD summation for different dates (e.g. Williams, 2001), although this relationship probably does not vary greatly from year-to-year (so the current relationship should be robust for the Napa area).

The simulation is contained on the ìDaily Water Balanceî worksheet. The delivered excel file also contains sheets that further describe the input parameters, contain CIMIS data from Oakville, and sheets that assist with irrigation and yearday conversion.

Daily Weather:

Average daily temperature (Tavg, C), Potential ET (ETo, mm), and daily rainfall (Precip, mm), represent the weather inputs and are downloaded from the California Irrigation Management Information System (CIMIS, 2002) web site to drive the model for any given period of time (note that although this service is free, you need to register with CIMIS in order to obtain a login name and password to access CIMIS weather data). Tavg is used to calculate Growing Degree Days (GDD) which are used to calculate the seasonal trajectory of LAI growth. Rainfall is supplied directly to the soil moisture storage compartment (SM), and ETo is used to calculate evapotranspiration of a cover crop (if desired) and the vine. The CIMIS data can occupy a separate sheet within the excel file, or can exist as a separate, external excel file. In either case, links to these data must be specified in the formulas for columns D, E, F, M, N of Water Balance. As delivered, these links point to a sheet containing year 2001 data from Oakville.

Daily Actual Irrigation inputs:

Irrigation (mm) can also be input if these data are available, otherwise the model will simulate the daily irrigation requirement. Irrigation data may need to be converted by the user into units of mm (depth) given the vine and row spacing (if irrigation data consists of gallons/vine, etc.). For convenience, an ìIrrig converterî worksheet is included.

Soil Moisture Characteristic:

You will need to know the soil texture and depth in order to calculate the maximum soil water-holding capacity (SWHC), and the soil moisture (SM) vs. water potential (WP) characteristic curve. To calculate maximum SWHC, you need to know, or have an estimate of, the gravel fraction (0-1), soil or rooting depth (m, whichever is shallower), and the %sand and %clay (or USDA soil texture class). Given %sand and %clay, you can estimate the fractional water storage at field capacity (WSFC) from the literature. The maximum SWHC = gravel fraction * WSFC * depth. Initial soil moisture should also be known, or can be guesstimated. If you begin your VSIM simulation on January 1, it is probably reasonable to assume (for

Napa) that the soil is saturated (i.e. initial soil moisture = maximum SWHC). The %sand and %clay are then used to calculate the soil water model A and B coefficients for the soil water content vs. water potential characteristic curve (Saxton et al., 1986). We assume that soil WP = pre-dawn leaf WP. The minimum soil moisture is used as a lower bound on soil moisture and is calculated as the amount of water in the soil at wilting point (-15 bars). Field capacity and wilting point can be estimated using the interactive USDA soil texture triangle hydraulic properties calculator at **Error! Bookmark not defined.**.

Leaf area index (LAI):
LAI is estimated from the growing degree day (GDD) sum based on a predetermined relationship between LAI and GDD for a particular year and block (e.g. Williams, 2001).

Daily GDD = Tavg ñ 10, for days when Tavg > 10, starting from budbreak (~April 1)

To determine the relationship between LAI and GDD sum, you need LAI data over the season, and the GDD sum from budbreak on each day that LAI is known. The LAI data should be normalized from 0-1 based on the peak LAI. A curve is then fit to this relationship, and this is used to calculate the fractional LAI from the GDD sum. This fractional LAI value is multiplied by the peak LAI of the block to estimate daily LAI. Daily Kc is based on an estimate of canopy radiation interception and is calculated from LAI using Beer's Law and a light extinction coefficient (greater LAI = greater light interception = greater Kc). A scalar for Kc is also calculated as a function of pre-dawn LWP, and this scalar can be used to reduce Kc when LWP is low (if desired - this can be set using the 0-1 switch "Alter Kc by LWP?"). LAI increases exponentially from the start of the growing season according to the GDD sum until it reaches the peak LAI value. LAI is set to 0 before budbreak and after the "Date of Leaf Drop". Date of budbreak is also determined from a GDD sum ñ in this case, GDDís are summed starting from Jan. 1, using a base temperature of $0^{o}$C (daily GDD = Tavg ñ 0, for days when Tavg > 0). For Napa-Tokalon, 865 GDDs are needed for budbreak and leafout to occur, while vines at Napa-Carneros need only 709 GDDs.

Cover Crop:
A cover crop can also be grown if desired to reduce soil moisture early in the season. Parameters describing the last day the cover crop is active (date) and cover crop Kc (Kcc) must be entered in the Parameter Worksheet. The cover crop Kc is estimated as the percent ground cover of the cover crop. The cover crop is assumed to be on the ground and actively transpiring from the start of the simulation until either the soil moisture is less than 60% of field capacity, or until the last date that the user specifies that the cover crop is active. Kcc is linearly adjusted in relation to soil moisture, and is at a maximum when soil moisture is at field capacity, and goes to 0 when soil moisture reaches 60% of field capacity. The ET of the cover crop, ETcc = Kcc * ETo. If no cover crop is desired, set Kcc = 0.

Simulated Irrigation:
Irrigation can be based on actual irrigation data, or it can be simulated, by setting the 0-1 parameter switch for "simulate irrigation?". Actual irrigation is added directly to soil moisture. Simulated irrigation, if desired, replaces actual irrigation, and is calculated by inverting the soil moisture vs. water potential characteristic curve and solving for the "optimal soil moisture" given an "optimal pre-dawn LWP" (must be supplied by the user, usually = optimal midday LWP minus 7 bars). Irrigation is simulated on any day when the soil moisture store falls below the dawn LWP threshold. The water required to increase soil moisture to the "optimal soil moisture" is added to the soil moisture store as simulated irrigation (typically ~10mm per irrigation event). Simulated irrigation is useful if you want to look at the effects of climate, LAI (vine spacing), and/or soil texture/depth on total irrigation requirement. Alternatively, actual irrigation data are useful to follow the seasonal course in soil moisture or leaf water potential. If actual irrigation data are available, they need to be in units of mm depth. See the ìIrrigationî worksheet to convert daily irrigation values from gallons/vine to mm depth. Finally, seasonal groundwater usage can be estimated by comparing the actual irrigation data with simulated irrigation. If simulated irrigation is greater than actual irrigation, vines may be accessing deep soil moisture or groundwater.

Water Balance:

The water balance is calculated by accounting for all gains and losses of water. Gains or inputs (considered positive values) are daily rainfall and irrigation (actual or simulated). Losses or outputs (considered negative values) are evapotranspiration of the cover crop (ETcc) and vine (ETc), and runoff. ETc = ETo * Final Kc. The vine Kc is scaled directly from vine LAI based on Beerís Law, using an extinction coefficient of 0.6 (Campbell and Norman, 1997). Vine Kc can also be scaled by the soil/leaf water potential, if desired (see Leaf Water Potential, below), where Kc decreases linearly with soil/leaf water potential. Daily runoff is calculated when water inputs + soil moisture exceed the maximum water-holding capacity of the soil. Inputs and outputs of water are added and subtracted from the soil moisture store each day to keep a running total of soil water content.

Leaf Water Potential:
The pre-dawn leaf water potential is calculated using the soil water content vs. water potential characteristic curve (described above based on Saxton et al., 1986), and assuming that pre-dawn leaf water potential is equal to soil water potential. Leaf water potential is used as a measure of vine water stress, and can also be used to scale Kc for the effects of plant water status on stomatal conductance and transpiration (after Allen et al., 1998). The Final Kc can be scaled by leaf water potential, if desired, so that Kc decreases as leaf water potential decreases (see the ìLeaf Area Indexî section above for details). The scalar for Kc is calculated as a function of pre-dawn LWP, and this scalar can be used to reduce Kc when LWP is low (if desired - this can be set using the 0-1 switch "Alter Kc by LWP?").

Running VSIM:
Each water balance variable is calculated on a daily basis by the Water Balance Worksheet. These values can be graphed, and the seasonal sums and/or averages can be compared. Two figures have already been set up. The first figure (left-hand side) graphs the daily values of all the important water balance variables over the season; Rainfall (Precip), Cover crop ET (ETcc), Vine ET (ETc), Irrigation (simulated or actual), Runoff, and soil moisture (SM, on the 2nd y-axis). The second figure graphs the daily LAI, Final Kc, and leaf water potential (LWP). You can change the values of input parameters to examine effect on water balance. You can examine the effects of different climates by linking to other climate data, or the effects of different irrigation strategies by altering data under ìActual Irrigation.î The parameter description sheet, CIMIS sheets, and yearday converter are read-only.

Specific equations and model logic can be seen by selecting the appropriate column or cell in the Block Worksheet. VSIM assumes that the user has a basic working knowledge of Microsoft Excel 2000 or later.

Citations

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith, 1998. Crop evapotranspiration ñ guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56.

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Saxton, K.E., W.J. Rawls, J.S. Romberger, and R.I. Papendick, 1986. Estimating generalized soil-water characteristics from texture. Soil Sci. Soc. Amer J. 50(4):1031-1036.

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