POSTER SUMMARY

MODELLING TRASH MANAGEMENT AND ITS IMPACTS: METHODOLOGY

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Abstract

A stand-alone sugarcane trash model, which is to be incorporated into the Canesim crop simulation model, has been developed. The objective of this poster is to present and discuss the approaches for modelling the trash dynamics and the effects of trash on soil-water balance and crop growth conditions. In principle, the model can also be used to address residues from other crops.

The model uses the state-variable approach, with a time step of one day. Model inputs are initial trash mass and thickness, specific surface area and daily weather data. The trash is modelled as a two-layered profile, with different dynamic characteristics for each layer. Trash decomposition rate is calculated as a function of temperature and water content; settling as a gradual change in trash density towards an equilibrium value. For the water balance, the model takes into account the effect on rainfall interception, using equations based on trash area index (P, an analogue of leaf area index); the effect on evaporation is taken according to a Beer’s law equivalent, as a negative exponential function of P; and calculation of runoff is based on the approach used in the ACRU model. A tentative empirical approach is followed for modelling soil and trash temperature.

Results of sample runs are presented to illustrate effects on individual and integrated processes. Suggestions for future research and development are outlined.

Keywords: modelling, sugarcane, green cane harvesting, trash blanket

Introduction

Good simulation modelling is necessary to quantify and evaluate the costs and benefits of trashing / burning. A standalone trash simulation model has been developed, and is to be integrated into the Canesim crop simulation model (Singels and Donaldson, 2000). This poster describes the methodologies used to model changes to the trash blanket over time, as well as its effects on temperature and the water balance of the soil. Model output is illustrated with results of sample runs performed on the BT1 burning/trashing trial (van Antwerpen *et al*, 2001). Model performance is illustrated by van den Berg and Jones (2006). The model is currently in a test phase, which might lead to further refinements.

Overview of the model

The model follows a state variable approach, with a daily timestep (see e.g. van den Berg, 2005). For each iteration of the simulation loop, daily weather information is read, and trash decomposition and settling rates are calculated and integrated. Trash of a certain mass and density is applied at the 'end' of a simulated day at a given 'age'. Trash applied is divided into two layers. Bottom layer thickness is kept constant (at 5cm) by feeding trash from the top layer to the bottom layer (as this layer decomposes and settles), until the top layer disappears. A simple canopy, using Canesim algorithms (Singels and Donaldson, 2000), was built into the model to assess the effects of the trash layer in the presence of a crop. These effects are determined simultaneously and include soil/trash temperature, runoff, infiltration, evaporation, plant water uptake, and drainage.

Change in trash mass and density

Settling

Settling is a phenomenon whereby the density of the trash blanket increases as a result of physical disturbances by gravity, wind, rain, vehicles, animals, and so on, and the decrease in size of trash pieces as they decompose. These effects are captured as a coefficient of time, using the following equation:

$$s = \alpha_i * \left(\rho_{i,equilibrium} - \rho_{i,t}\right) \tag{1}$$

Where s is the rate of settling, α is a coefficient of settling (day^{-1}), $\rho_{i,equilibrium}$ is the maximum equilibrium density the trash can achieve (kg.cm^{-1}.m^{-2}), $\rho_{i,t}$ is the density of the trash layer at time t, and i is the layer number. The trash bottom layer is permitted to settle to a higher equilibrium density than the top layer (effectively increasing the rate of settling in the bottom layer).

Decomposition

Decomposition is determined following the approach described by Thorburn *et al.* (2001). The per-layer rate of change in mass over time (dm_i/dt, kg.kg^{-1}.day^{-1}) as a result of decomposition is calculated as:

$$\frac{dm_i}{dt} = F_{i,temperature} * F_{i,moisture} * M_{decomp} * m_i \tag{2}$$

where M_{decomp} (kg.kg^{-1}.day^{-1}) is the maximum rate of decomposition under optimal conditions, m_i is the mass of trash layer I, and $F_{i,temperature}$ and $F_{i,moisture}$ are coefficients (between 0.0 and 1.0) describing the effects of temperature and moisture conditions respectively:

$$F_{i,temperature} = \frac{T_i}{T_{optimal}} \tag{3}$$

and

$$F_{i,moisture} = \theta_i/\theta_{i,DUL} \tag{4}$$

Where $\theta_{i,DUL}$ is the water holding capacity ('drained upper limit') of the trash layer i (mm), θ_i is its actual water content, T_i is its temperature (ºC) and $T_{optimal}$ is the optimal temperature for decomposition.

The bottom layer tends to be more moist because the top trash layer insulates against evaporation from the bottom layer, increasing the rate of decomposition in this layer. This, combined with the faster rate of settling in the bottom layer, captures (much of) the 'contact' effect proposed by Thorburn *et al.* (2001).

Effects of trash

Rainfall interception

Results of Thompson (1965) show that the maximum amount of rain that can be intercepted by a trash layer during a rainfall event (λ_{max}, mm) is less than proportional to the amount of trash; and that, rather than intercepting all rainfall until λ_{max} is reached, actual interception, λ_a, approaches λ_{max} asymptotically with increasing rainfall R (mm/event). These phenomena can be explained by the formation of preferential channels in the trash reducing interception. They are described by the following equations, which were derived from Thompson's (1965) data.

$$\lambda_{max} = P * MAX\left(0.,MIN\begin{pmatrix}\left(\theta_{top,DUL} + \theta_{bottom,DUL}\right) - \left(\theta_{top} + \theta_{bottom}\right), \\ 0.308 * e^{-0.026*P} + 0.02\end{pmatrix}\right) \tag{5}$$

$$\lambda_a = \lambda_{max} * \left(1. - e^{-1.*\varphi*R}\right) \tag{6}$$

where P is the 'trash area index' (m^2/m^2) and φ is a regression parameter. Equations (5) and (6) are applied for the combined (top+bottom) trash layer and for the top layer separately. The difference gives rainfall interception by the bottom layer.

Evaporation

The effect of trash on evaporation from the soil is calculated according to a Beer's law equivalent, in a similar manner to that suggested by Scopel *et al.* (2004):

$$E_{soil} = E_{ref} * e^{-1.*\varepsilon * P} \tag{7}$$

Where E_{soil} (cm/day) is the maximum evaporation from the soil; and ε is an extinction coefficient. Maximum evaporation from the trash bottom layer is calculated similarly; maximum evaporation from the top layer is the difference between this and E_{soil}. The actual evaporation from the soil is calculated as a function of the number of days without rain (as in Canesim). Actual transpiration from each trash layer is assumed to be equal to the maximum as long as water is available.

Runoff

Runoff (stormflow, S, mm/day) is based on equations described by Schmidt *et al.* (1998) and Lumsden *et al.* (2003) for the ACRU model (Schulze, 1995):

$$S = MAX\left(\left(\left(R - I_a\right)^2 / \left(R - I_a + S'\right)\right), 0.\right) \tag{8.1}$$

$$S' = \left(w_{saturated} - w\right) * y_s \tag{8.2}$$

$$I_a = C_{iam} * S' \tag{8.3}$$

$$C_{iam} = 0.2 + \left(0.2 * \left(1. - e^{-P*1.5}\right)\right) \tag{8.4}$$

where C_{iam} is the so-called 'coefficient of initial abstraction', y_s is a measure of the depth of soil which affects stormflow (35 cm), and R is the amount of rainfall for this day. I_a is the 'initial abstraction' (Schulze, 1995). $w_{saturated}$ and w are the saturated and actual water content of the soil respectively.

Trash/soil temperatures

Observations from trashing trials (e.g. Thompson, 1965; personal communication[1]) suggest that daily averaged soil temperatures under trash are generally lower than without trash, except in autumn/early winter; and with less pronounced fluctuations from one day to another. In the absence of a detailed heat conductance characterisation of trash and soil under different conditions, a pragmatic approach was followed to take these effects into account:

$$T_{bottom,today} = (1. - A) * (T_{top,today} - G) + A * (0.2 * T_{mean} + 0.8 * T_{bottom,yesterday}) \tag{9}$$

where

$$G = A * T_{\max diff} \tag{10}$$

and

$$A = 1. - e^{-1.*\beta*h_{top}} \tag{11}$$

where $T_{bottom,today}$ (ºC) is an 'effective temperature' of the soil/bottom trash layer, used to calculate the effect of trash on time to germination and emergence (and decomposition of the bottom layer); $T_{maxdiff}$ is the maximum difference between air temperature and $T_{bottom,today}$; β (cm^{-1}) is a measure of the insulation of the trash material; T_{mean} is the long-term mean average air temperature, and h_{top} (cm) is the thickness of the top trash layer.

Model parameters

A list of model parameters used is given below. These were obtained or derived from literature cited, limited field observations, as well as values inferred from preliminary runs.

$T_{optimal}$	35.0 ºC
M_{decomp}	0.016 $kg.kg^{-1}.day^{-1}$
$\rho_{equilibrium,bottom}$	0.3 $kg.cm^{-1}. m^{-2}$
$\rho_{equilibrium,top}$	0.05 $kg.cm^{-1}. m^{-2}$
ε	0.5
φ	0.17
β	0.4 cm^{-1}

Discussion

Results (van den Berg and Jones, 2006) suggest that the model performs well for conditions at Mount Edgecombe. Refinements may be required, but simplifications will always be needed, either to keep implementation manageable, or because input data are difficult or impossible to acquire. The current parameter set is of mixed quality. Field experiments at several sites throughout the industry are currently being conducted or planned to provide data for testing in different environments and to obtain an improved set of widely applicable model parameters.

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