MODELLING SOIL AND MANAGEMENT EFFECTS ON HERBICIDE RUNOFF FROM DRYLAND AGRICULTURE

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Abstract
Regular detection of residual herbicides such as Atrazine and Metolachlor in streams highlights the need to better understand and manage pesticides at the paddock level to minimise off site transport in runoff. Modelling can provide a risk assessment of the potential for off site losses over a range of soil and management conditions. This paper describes incorporation of a pesticide transport model into Howleaky? a physically based daily time step hydrologic and erosion model.

The model was calibrated to results from an Atrazine transport study on Black Vertosols on the eastern Darling Downs and was then used to test a range of management scenario's. It is demonstrated that observed data from a range of sources can be integrated to provide a predictive tool for testing soil and agricultural management effects on water quality outcomes, specifically for quantifying the risk of transport of pesticides in runoff.

Additional Keywords: Atrazine, Howleaky?, pesticide runoff

Introduction
Residual herbicides, including Atrazine, are detected in up to 90% of all stream water samples taken in highly developed agricultural areas (CBWC, 1999). To address this issue requires a better understanding of management options at the paddock level to minimise off site transport in runoff.

Field studies at a range of scales provide an understanding of the transport process and pathways for pesticide losses from paddocks. However this data is expensive to collect and it is often impractical to compare management strategies over a range of soils and climatic conditions. Also the runoff risk is intrinsically complex due to the decay of the pesticide concentration in the soil after application and the sporadic occurrence of runoff events over time. Simulation models can extend observed data to provide a risk assessment of the potential for off site losses over a broad range of scenarios.

Materials and Methods
Howleaky? is a physically based daily time step model, focusing on hydrology and erosion at the paddock scale (Rattray et al. this conference). It uses a similar approach to the Productivity Erosion Functions for Evaluating Conservation Tillage (PERFECT) (Littleboy *et al.*, 1992). A major strength of Howleaky? is a transparent and simple to use interface. A pesticide model was added to Howleaky? that tracks dissipation of pesticide in the soil and estimates pesticide concentration in runoff, partitioned between soluble and sediment bound phases. The major factors affecting transport potential are the application rate and half-life of the pesticide and its sorption capacity. A brief description is provided of the parameter inputs to the model, the algorithms used and the outputs generated.

Pesticide dissipation
Howleaky? calculates the daily concentration of the pesticide in the surface 25mm of soil (or a depth chosen by the user). Dissipation of the pesticide is modelled as a first order decay function (Equation 1, Leonard *et al.*, 1987, Silburn 2003) based on the half life the pesticide in days ($t_{1/2}$). Default half lives for a range of pesticides are provided with Howleaky? but can be modified by the user.

$$C_t = C_0 * e^{-k\,(t)} \quad (\text{mg kg}^{-1}) \qquad \text{Equation 1}$$

where, $k = 0.693 / t_{1/2}$ and, C_0 and C_t represent soil concentration at application and time t (days) after application respectively. At the moment, only soil applied pesticides are considered, though banding and incorporation can be considered.

Pesticide loss in runoff
On any day that runoff occurs the pesticide concentration is calculated for both the soluble (C_w) and sediment bound (C_s) phase (Leonard *et al.*, 1987; Silburn, 2003). The soil concentration available for runoff, C'_{av}, is

calculated from C_t and the sorption coefficient (K_d) to account for leaching from the surface before runoff (Leonard *et al.*, 1987). Defaults values for pesticide sorption and the extraction coefficient (β) are again provided with Howleaky?.

Based on Leonard *et al.* (1987), runoff concentration of pesticide in water phase (μg/l) is

$$C_w = (C'_{av}\ \beta)/(1 + K_d * \beta) \quad \text{Equation 2}$$

And concentration of pesticide bound to sediment (mg kg^{-1})

$$C_s = (C'_{av} * K_d * \beta)/(1 + K_d * \beta) \quad \text{Equation 3}$$

To get to a total concentration of pesticide C_{ro} in runoff (μg l^{-1}) the two concentrations are added together

$$C_{ro} = C_w + (C_s * SC) \quad \text{Equation 4}$$

Where, SC is the sediment concentration in g l^{-1}

Pesticide loads
In many cases it is the load of pesticide (g/ha) exported over a season, or average annual loads, that will be of interest for comparison of management alternatives. Howleaky? provides estimates of the load of pesticide exported in the soluble phase (C_w * volume of runoff), the sediment bound phase (C_s * sediment export rate) and in total.

Results and Discussion

Calibration
Measured soil parameters were used where possible and selected hydrologic and erosion parameters were calibrated against data from water balance and erosion trials. Crop parameters for sorghum were calibrated against the Agricultural Production Simulation Model -APSIM model (McCown *et. al.*, 1996). A study on a Black Vertosol (Rattray, unpublished data) was used to determine parameters for Atrazine. The study monitored Atrazine dissipation in soil and runoff concentration through a summer season. Model fits are presented in Table1. Calibration resulted in a set of parameters that are consistent with previous studies for Australian conditions (Kookana *et al.*, 1998; Silburn 2003). Howleaky? was used to regress observed and predicted concentrations of Atrazine in the soil and in runoff. The model was able to adequately represent the measured dissipation and transport of Atrazine.

Table 1. Calibration fits for observed and predicted Atrazine soil and runoff concentrations

	N	Slope (O:P)	R^2
Soil concentration (mg kg^{-1})	6	0.93	0.99
Runoff Concentration (ug l^{-1})	6	0.91	0.93

Modelled scenarios
Using the calibrated model a number of scenarios were tested for annual sorghum cropping, including soil type (hydrology and erosion), timing of application (hydrology) and tillage management (erosion).

Soil type
Three soils were compared; a Vertosol, a Sodosol and a Ferrosol, representing a soil more prone to runoff and with lower hydraulic conductivity (Sodosol) and one with higher conductivity and less likely to runoff (Ferrosol) (YeeYet and Silburn, 2003).

Figure 1 shows that in terms of water balance, the Sodosol has low drainage and high runoff and erosion. The Ferrosol has high drainage and low runoff and erosion, and the Vertosol is intermediate. This analysis indicates that the relative ratio of Atrazine load in runoff is Sodosol>Vertosol>Ferrosol.

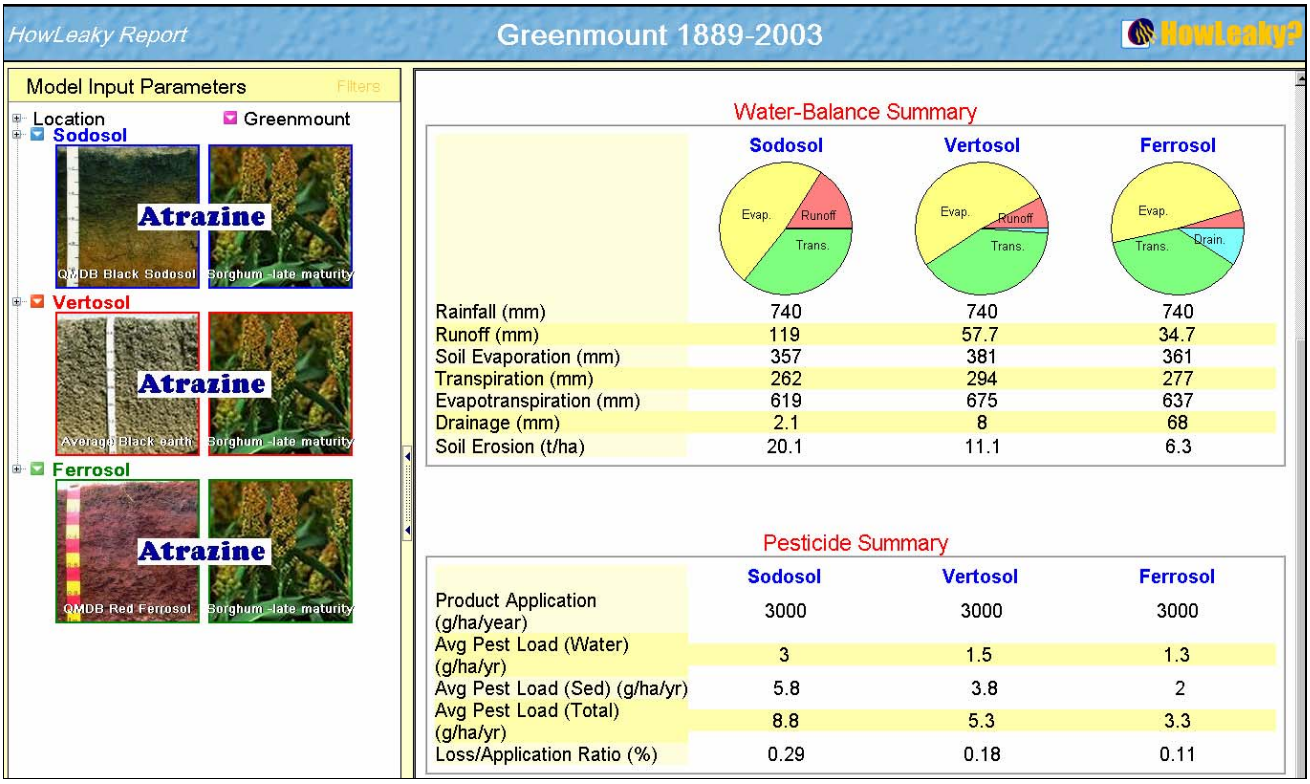

Figure 1. Howleaky? report screen shot showing the effect of soil type on the water balance, erosion and transport of Atrazine. The soils from right to left are Sodosol, Ferrosol and Vertosol.

Timing of application

Howleaky? was used to explore the impact of timing of application on export potential. The scenario uses a Vertosol soil and 100 years of climate data for Greenmount, south-east Queensland. Figure 2 shows Atrazine losses in runoff for a range of application times. The normal application period from mid September through to the end of the year is the highest risk period, as it coincides with a period of high runoff spanning October to February. There is lower risk leading up to this period that could provide a window of opportunity to use Atrazine more safely.

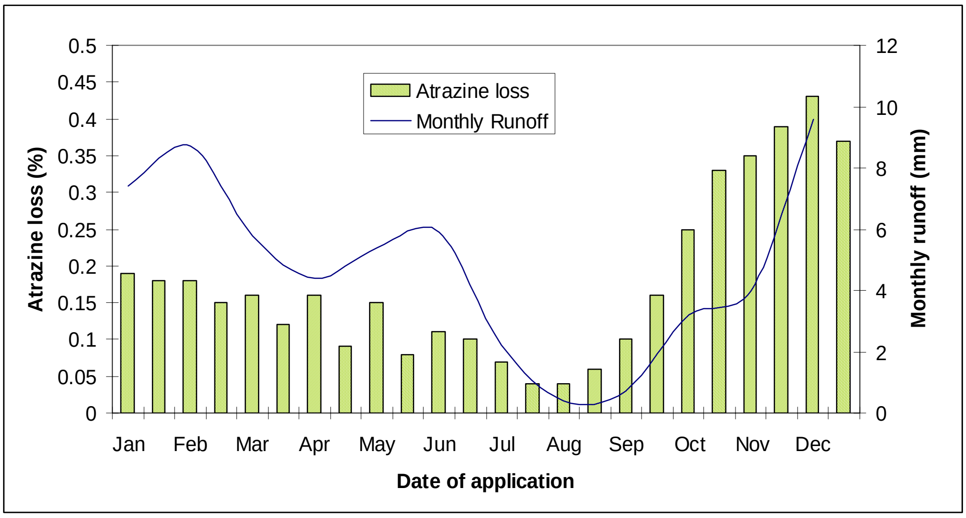

Figure 2. Atrazine lost as a percentage of total application rate by date of application, plant date October 15.

Tillage management

Two tillage scenarios for sorghum were studied - conventional tillage (CT) and zero tillage (ZT) (**Figure 3**). ZT has lower erosion but higher runoff and drainage. The lower erosion results from higher average cover levels, while the higher runoff and drainage is due to lower evaporation. While the amount of Atrazine lost is slightly lower in

ZT, the most interesting aspect of the scenario was that the major transport pathway for ZT was in the soluble phase while in CT the major pathway was Atrazine bound to sediment. This is an interesting result and warrants further field studies to confirm the effect of tillage on herbicide transport. The use of opportunity cropping management combined with ZT could reduce the runoff potential and hence reduce the Atrazine lost off site.

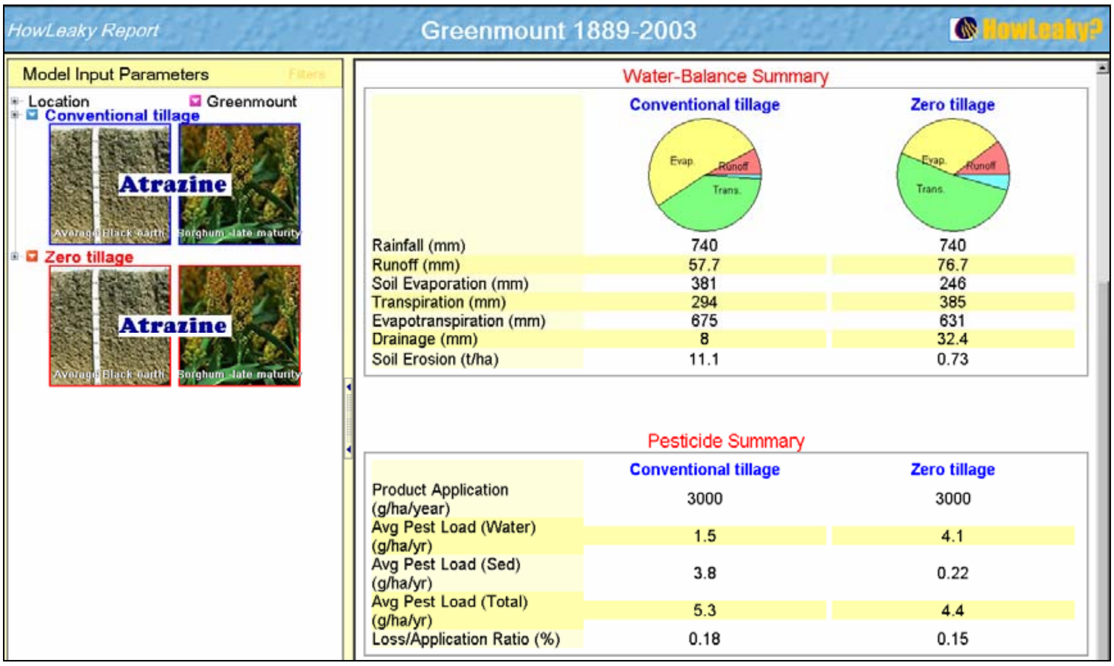

Figure 3. Howleaky? Report screen shot showing zero tillage and conventional tillage effects on herbicide transport.

Conclusions

The Howleaky? pesticide model provides a simple tool for risk assessment of off-site runoff losses over a range of soil and management scenarios. The model is physically based and represents major processes of crop development, water balance and erosion on a daily time step. The pesticide model incorporated into Howleaky? tracks pesticide soil dissipation and transport in runoff (partitioned between soluble and sediment bound phases). Limited calibration of the model demonstrated an ability to adequately represent these processes.

Supporting material

Further description of Howleaky? is available from the following website and a beta version is available for download. http://www.apsru.gov.au/apsru/Products/HowLeaky/index.html

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