Assessing water quality from farms – how much detail is required for a model to be useful?

David M Freebairn[1], Justin Cutajar[2], Mark Silburn[3]

1 RPS Australia East, PO Box 1559, Fortitude Valley 4006 david.freebairn@rpsgroup.com.au
2 RPS Australia East, PO Box 1559, Fortitude Valley 4006 justin.cutajar@rpsgroup.com.au
3 Dept. of Environment and Heritage Protection mark.silburn@dehp.qld.gov.au

Abstract

Agriculture is being implicated in declining water quality and its impact on natural assets such as the Great Barrier Reef and the Murray-Darling river system. With a paucity of empirical data to support impacts of practice change, water-balance simulation models are used to extrapolate empirical data. These models are used routinely to synthesis data from experimental studies and then used to extrapolate to a range of land use and soil types well beyond experimental conditions. A common challenge for modellers is: how best to describe a land use system in terms of model parameters.

This paper describes the impact of input detail on predictions of runoff, soil loss and water quality. We find there is scope for using models that describe land use systems and soil types that are less demanding then a literal interpretation of system conditions. Two applications of a model are used to demonstrate this proposition. Greater detail in a model or its inputs does not necessarily result in greater confidence in estimates. A model with fewer inputs can be easier to set-up, diagnose and apply. If there are few trade-offs in simplicity, there are likely to be efficiencies to data collection and model application.

Introduction

Agriculture is increasingly being expected to demonstrate its environmental credentials to governments and the community. As an example, sugar cane, grain and horticulture producers and graziers within the Great Barrier Reef (GBR) catchments are being encouraged to adopt practices that aim to reduce sediment, nutrient and pesticide loads reaching the lagoon by 20-50% within a target date.

While farmers have made many changes in agronomy in order to improve water use efficiency and soil stability, we have little basis for demonstrating in quantitative terms that there has been positive progress in water quality outcomes. Indeed, with greater use of fertiliser and pesticides there is a community perception that contamination of the environment has increased. High rates of adoption of new technologies such as conservation tillage provide evidence that farmers are adaptive and open for improvement (D'Emden and Llewellyn 2006). Empirical evidence of improved water quality is scarce because field studies are expensive and require several years to collect representative samples of climate given the episodic nature of runoff and pollutant movement.

Water balance models are a standard tool for estimating hydrology and water quality attributes of land use system, often relying on limited studies to "calibrate" the model. A key step in calibrating a model is determining how best to describe system conditions encountered in the real world. Where does the user source sensible parameter values to apply in a model?

This paper describes the impact of using a range of input detail on model performance. Two key inputs will be explored; the level of detail in soil water description and vegetation description.

Methods

Vegetation description for grazing study.
In order to explore the impact of level of vegetation description on model estimates of runoff and soil loss for grazing systems, the Howleaky model (V5.37.06, McClymont et al. 2011) was applied to data from the Mt Mort pasture study conducted by the Queensland Department of Natural Resources and Mines (1991–2000) (DM Silburn pers. Comm., Rattray et. al 2006). Runoff and soil loss were measured on three land

management practices (Grazed, Exclosed and Bare soil treatments) at "Old Hidden Vale", Mt Mort, 27 km SSE of Gatton in southern Queensland.

Three levels of vegetation and soil description were applied to simulate runoff and soil loss at Mt Mort (Figure 1):

- A time series of measured green and residue covers and optimised soil descriptions for each treatment (a literal re-enactment of the experiment);
- The above vegetation description and a site average soil description; and
- A generic mean monthly green and residue cover distribution reflecting pasture growth and residue for each treatment and a single soil description as above.

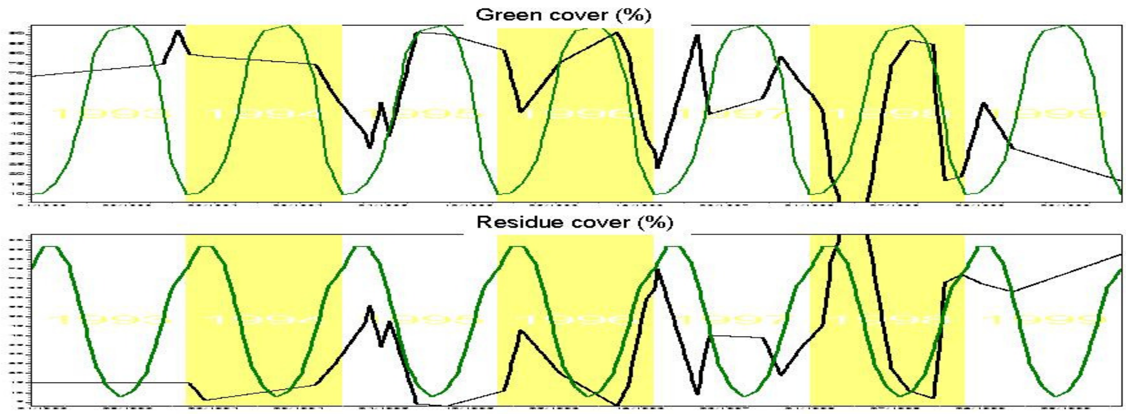

Figure 1: Two levels of cover description for the exclosed treatment used in testing Howleaky: measured time series of observed cover (black line); and a generic seasonal distribution which captures typical seasonal variation (green line). Green and residue cover are both described.

Soil description for cropping study

In order to explore the impact of level of soil description on model estimates of runoff and soil loss in cropping systems, three levels of detail of soil water description were used to simulate a winter cropping regime near Wallumbilla in south western Queensland (Freebairn et. al 2009). Two contrasting tillage - fallow stubble cover regimes are used to demonstrate hydrology and water quality responses to fallow management conditions.

Plant Available Water Capacity (PAWC) and internal drainage are derived from wilting point, drained upper limit and total porosity of soil layers. Air dry and saturated content are used to describe evaporation store and deep drainage respectively.

Soil is described using three levels of detail shown in Figure 2:

- six soil layers with all four parameters for each layer, (n=24 where n=number of parameters);
- four soil layers, (n=12); and
- A pseudo three layer soil specified by: available soil water range of the surface layer; "evaporation depth"; and rooting depth (n=3).

The third soil description method ignores soil water below wilting point and represents a very simplistic view of soil water stores.

Approximately 5-12 other variables are required to describe evaporation, runoff and drainage processes. The three soil descriptions used here were constructed to have similar PAWC values. Hydrology, erosion and water quality estimates are used to compare the results for the various levels of input.

Results

Vegetation descriptions for grazing

Table 1 presents observed and predicted runoff and soil loss for three grazing treatments, each with three levels of detail in system description. The model was able to predict the impact of management on hydrology and erosion with reasonable reliability and estimates for the three levels of description are similar. Figure 3 presents a cumulative time series of runoff for the data summarised in Table 1.

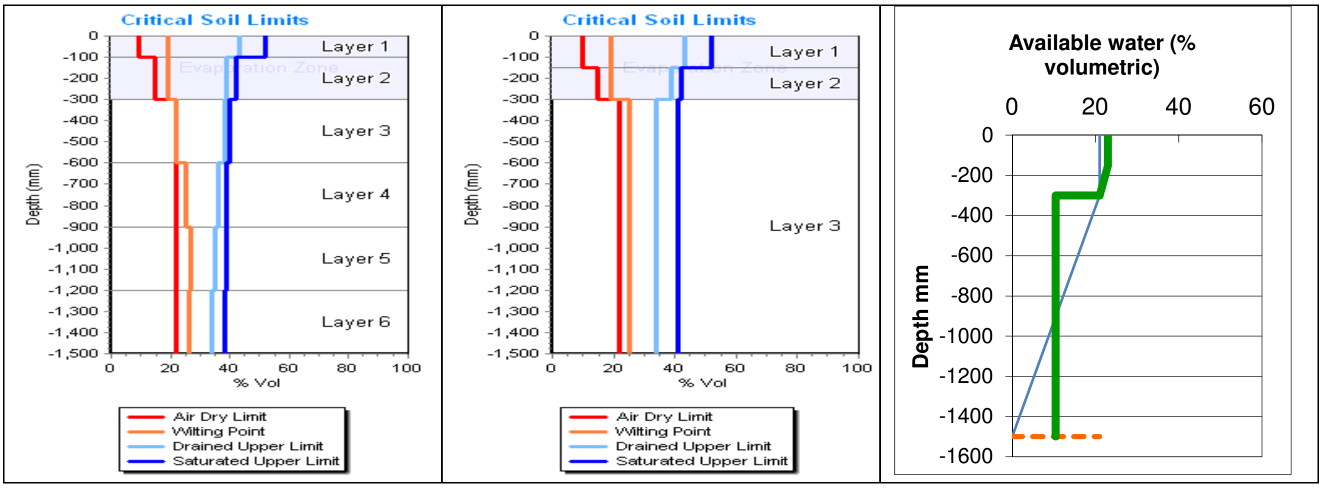

Figure 2: Three levels of soil water description for a brown sodosol near Wallumbilla: a full description with six layers (ApSoil profile No. 064); the same soil with 3 layers; and the much simplified soil water description based on three input values.

Table 1: Summary of Observed and Predicted Average Annual Runoff and Soil Loss for the Mt Mort Grazing Trial (1993-1999) with Three Levels of System Description.

Description of Management system and model parameterisation	Observed		Predicted	
	Runoff (mm)	Soil loss (t/ha)	Runoff (mm)	Soil loss (t/ha)
Level 1 model description (time series of measured green and residue cover and individual soil type)				
Bare	136	46	159	50
Grazed	22	0.5	18	0.7
Exclosed	3	0.06	4	0.1
Level 2 model description (generic time series of green and residue cover and site soil type)				
Bare	136	46	147	65
Grazed	22	0.5	15	0.4
Exclosed	3	0.06	12	0.2
Level 3 model description (generic time series of green cover, residue cover and soil type)				
Bare	136	46	142	54
Grazed	22	0.5	20	0.7
Exclosed	3	0.06	17	0.2

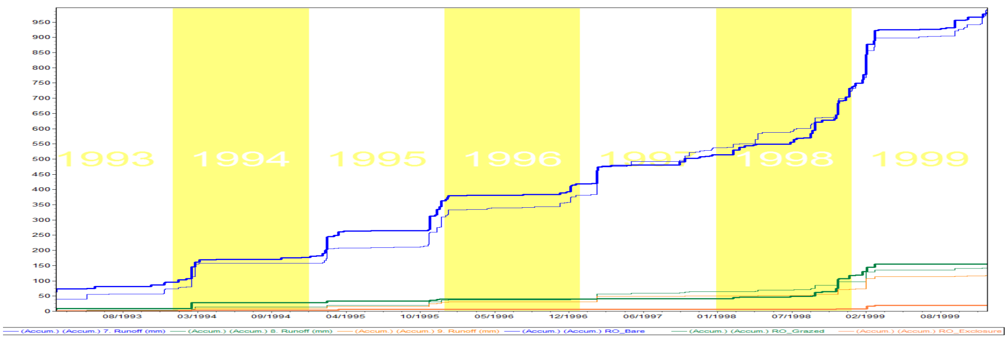

Figure 3: Simulated (bold lines) and measured cumulative runoff (mm) for three grazing treatments: bare (blue); grazed (green); and exclosed (orange) at Mt Mort, QLD (1993 - 1999).

Wallumbilla–cropping

The impact soil description on runoff, soil loss and sediment concentration estimates for cropping under two levels of soil management is presented in Table 2. Soil with six or three layers resulted in similar hydrology, erosion and sediment estimates while the simplified soil water description estimated slightly higher runoff. In terms of estimating differnces between management practices, all three soil descriptions provide similar estimates in terms of absolute values and relative rankings.

Table 2: Summary of Runoff, Erosion and Event Mean Sediment Concentration for Two Cropping Systems with Three Levels of Soil Description

Soil description 'n' refers to the number of parameter values in each description	**Runoff (mm)**	**Hill slope soil loss (t/ha)**	**Sediment Event Mean Concentration (g/L)**
High tillage, low residue retention			
Full soil description, 6 layers n= 32	48	5.2	1.5
Partial soil description 3 layers n=19	47	5.4	1.1
Simple soil description n= 10	69	8.2	1.2
Low tillage, high residue retention			
Full soil description, 6 layers n= 32	65	0.27	0.06
Partial soil description 3 layers n=19	64	0.34	0.05
Simple soil description n= 10	85	0.64	0.08

Conclusion

One conclusion from these two case studies is that while there may be differences in estimates of hydrology, soil loss and water quality from a model with a range of detail in system description, the differences between model estimates are small compared to difference in hydrology and water quality associated with soil management. It is unlikely that simplified model inputs will result in serious errors in estimates of hydrology, soil loss or water quality.

A generic set of model parameters is likely to be more useful and transferable than a parameter set that describes an experiment explicitly, especially since vegetation patterns from an experiment are unlikely to be repeated and soil types are spatially variable.

This paper does not propose that model inputs should be simplified *per se* but it does suggest that we can be more pragmatic in describing systems at least in terms of vegetation and soil water holding properties. Vegetation can be described by a generic green and residue cover pattern (mean monthly values) while soil water description requires a reasonable estimate of PAWC. One advantage of using water balance as a foundation for estimating water quality is that these models provide realistic estimates of water excess (runoff and deep drainage) and timing of excesses using qualitative assessments of soil properties, vegetation patterns and weather data.

We have found that if soil PAWC can be estimated from texture and rooting depth with a description of the soils propensity to surface crust, combined with a simple description of vegetation, estimates of hydrology and water quality responses to management can be achieved for a wide range of environments with reasonable confidence and efficiency.

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