Assessing field sediment exports of northern Victoria farming systems using HowLeaky2008 model

Olga Vigiak[A], Alice Melland[B], Dan Rattray[C], Anna Roberts[A] and Jane Whitford[A]

[A]Department of Primary Industries, Future Farming Systems Research Division, Rutherglen Centre, RMB 1145 Chiltern Valley Road, Rutherglen, VIC 3685, Australia, Email olga.vigiak@dpi.vic.gov.au
[B]Teagasc, Environment Research Centre, Johnstown Castle, Wexford, Co. Wexford, Ireland.
[C]Conics Consultants, PO Box 1185, Toowoomba, QLD 4350, Australia.

Abstract
Australian agriculture is under pressure to reduce sediment exports and improve stream water quality. However data on soil losses of different land management is lacking, thus potential benefits of adopting Best Management Practices cannot be quantified. In this study we assessed field soil losses of farming systems of North Central Victoria by using the HowLeaky2008 model. HowLeaky2008 is a one-dimensional farm system model that simulates the effect of soil and land management on daily water, sediment and nutrient exports. HowLeaky2008 was applied to current and alternative land management options in the Avon Richardson catchment, which is typical of the Wimmera-Mallee region of Victoria. Simulated long term average soil losses were similar to erosion rates previously assessed with ^{137}Cs techniques. Modelling suggests that changing from minimum to zero tillage can reduce sediment exports by 40-75% in cropping land; and switching from annual to perennial pastures or lucerne can reduce sediment exports by over 80%. Highest erosion rates and potential for reducing sediment exports were on duplex soils followed by Kandosols and Red or Grey Vertosols. The HowLeaky2008 model proved useful to quantify the relative efficacy of farming practices that improve the environmental sustainability of agricultural enterprises.

Key Words
HowLeaky2008, soil loss, land management, farming systems, Victoria, Avon Richardson catchment.

Introduction

Water quality in northern Victorian rivers is often poor, due to high turbidity and nutrient content. For public investment to reduce the impacts of agriculture on water quality effectively, a clear understanding of sources of sediments is required. In addition, quantifying the potential benefits of adopting Best Management Practices (BMP) compared with current practice is also required if on-farm investment is to be made. However, data on sediment exports of different land management and BMPs are currently lacking. Given the lack of field quantification of soil erosion in much of Victoria, in this study we pursued a modelling approach to investigate the relative impacts of current farm systems on field soil losses, and identified opportunities for reducing sediment exports. HowLeaky2008 (McClymont *et al.* 2008) proved to simulate well soil water content in crops and pastures of south-eastern Australia (Melland *et al.* submitted) and was selected for this study. The aim of this study was to assess the impact of land management on field sediment exports for the farming systems of the Avon Richardson catchment of north central Victoria, which can be considered typical of the Wimmera-Mallee region of Victoria, an area affected by severe water quality issues.

Methods

HowLeaky2008 model

HowLeaky2008 is a one-dimensional farm system model that simulates the effect of soil and land management on daily water surplus, sediment and nutrient exports. Soil losses are calculated according to:

$$E = (fCOVER\ LS\ K\ P\ Q/10)\ SDR \quad (1)$$

where E is the soil loss in t/ha, $fCOVER$ is a function of vegetation cover, LS, K and P are the topography, soil and protection factors of the Revised Universal Soil Loss Equation (RUSLE, Renard *et al.* 1996), and Q is the volume of runoff (mm). The main difference between equation (1) and the RUSLE approach is that the erosion agent is runoff instead of rainfall. SDR is the sediment delivery ratio; a value of 0.1 can be considered suitable for Australian conditions and was used throughout this study. Runoff is calculated using a modified USDA Curve Number approach and is a function of rainfall, soil water content, surface cover and surface roughness. Curve Number is maximum on bare soil (CN-bare), and declines linearly down to a minimum when vegetation cover reaches 80% or higher (CN-80).

Table 2. Howleaky2008 parameters for the hydrologic soil groups defined in the Avon Richardson catchment. GV = Grey Vertosols; GV_HS = Grey Vertosols, hard-setting; GV_hvy = heavy Grey Vertosols; RYC = Red or Yellow Chromosols, hard-setting; RS_notHS = non hard-setting Red Sodosols; RS_HS = hard-setting Red Sodosols; RedV = crusting Red Vertosols; SK = shallow Kandosols.

	GV	GV_HS	GV_hvy	RYC	RS_notHS	RS_HS	RedV	SK
Soil depth (mm)	1500	1500	1250	1500	1500	1500	1500	700
Soil PAWC (mm)	158	150	108	169	126	132	156	107
Max drainage (mm/d)								
- layer 1	24	12	24	30	240	30	24	72
- layer 3	4.8	4.8	2.4	12	12	12	4.8	48
CN-bare	75	75	75	87	85	85	75	75
CN-80	55	55	55	52	55	55	55	55
USLE K (t/ha/EI30)	0.15	0.15	0.15	0.4	0.3	0.4	0.25	0.5

Study area

The Avon-Richardson catchment is an endorheic basin that extends over 3300 km^2 of the Wimmera region of south-east Australia. Three agro-climatic zones are distinguished: grazed uplands in the south (average rainfall approximately 500 mm/y), mixed farming (i.e. combination of grazing and cropping) in the mid-catchment (average rainfall approximately 450 mm/y), and flat croplands in the north (average rainfall approximately 400 mm/y). Current grazing management consists mainly of set stocking on annual pastures (AP), whereas perennial pastures (PP) occupy approximately 10% of grazed land. In the mixed farming areas, 40% of the land is used for cropping, and 60% for pastures. In the flat croplands, 4-year rotations of canola-wheat-barley-legume (CWBL) are common. Due to recent drought, a 3-year rotation inclusive of bare fallow (wheat-barley-fallow, WBF) has re-commenced in all agro-climatic zones. Soils are mainly deep and clayey, with uniform or duplex soil profile. Published soil surveys and local knowledge were used to group soils with similar hydrological behaviour: hard-setting Red Sodosols, non hard-setting Red Sodosols, hard-setting Red or Yellow Chromosols, Grey Vertosols, heavy Grey Vertosols, hard-setting Grey Vertosols, crusting Red Vertosols, and shallow Kandosols (Melland *et al.* 2008).

Soil parameterization

Soil parameters define partitioning of water into infiltration or runoff, water losses by evapotranspiration, movement of water in the soil column, and water losses by percolation below the root zone. Most soil parameters were set according to a national databases of soil properties (Melland *et al.* 2008), with some exceptions. CN-bare and CN-80 were set as per Owens *et al.* (2003). The soil column is divided into three layers through which water moves in a cascading bucket system at maximum daily drainage rates (mm/day). These rates were based on Yee Yet and Silburn (2003) soil surface characteristics (hard-setting or not), and texture and structure of the soil profile. Table 1 indicates the most important soil parameters that affect runoff and soil loss simulation.

Model testing

The HowLeaky model has been extensively tested in Queensland, but in Victoria only its water balance has been tested (Melland *et al.* submitted). Previously published long term (about 40 years) erosion rates were assessed for several Victorian sites using the ^{137}Cs technique (Lorimer *et al.* 1996). Five of these sites were close to the Avon Richardson catchment and HowLeaky 2008 was applied to them using the soil hydrological group of Table 1 that was closest to site description, and appropriate cropping or grazing land use.

Results and discussion

Comparison of soil loss predictions with literature data

Howleaky2008 soil losses for cropping land were very close to the long-term net erosion rates assessed by the ^{137}Cs study (Table 2). However, HowLeaky2008 predictions were higher for the grazed sites. It is possible that Howleaky2008 overestimates erosion in grazed land or that Lorimer *et al.* (1996) underestimated erosion. The ^{137}Cs study used different regression equations to assess erosion under cropping or grazing conditions; the same difference in ^{137}Cs levels leads to a calculated erosion rate for cropping land that is 13 times greater than for grazed land. Higgitt (1995) found that the use of the two equations was not well justified. We therefore calculated the erosion rates for the grazing sites also using the cropping land equation. Results are shown in brackets in Table 2. Howleaky2008 soil losses are much closer to these estimates than to the original study of Lorimer *et al.* (1996) and are in reasonable agreement for the St Arnaud site. There was still poor prediction from Howleaky2008 for the Stawell site; Lorimer *et al.* (1996)

Table 2. Comparison of field soil loss estimated with HowLeaky2008 and ^{137}Cs erosion rates published for sites near the Avon Richardson catchment in Victoria. Source (Lorimer *et al.* 1996).

Location	Annual rainfall (mm)	Site description	^{137}Cs erosion rate (t/ha/y)		HowLeaky2008	
			Net†	Max	Simulated soil group	Soil loss (t/ha/y)
Horsham	420	Cropping, fallow every 3-5 years; grey cracking clays; slope 1.5%	0.52	16	GV_HS	0.32
Charlton	400	One crop every 4 years; red duplex soil; long gentle slopes of 3-5%	0.90	5.15	RS_HS	0.71
Colbinabbin	500	Mixed cropping and grazing; red sodic soil (dr3.42); slope 2%	1.05	2.51	RS_HS	0.85
St Arnaud	584	Annual pasture; grey stony loams and red duplex soils; slopes 5-7%	0.28 (1.40)*	1.74 (6.32)*	RS_HS or SK	1.79 (RS_HS) 0.74 (SK)
Stawell	584	Annual pasture; loam/sandy loam topsoil with high rock content; slope 15%	0 (0.55)*	1.70 (7.12)*	SK	2.63

† Net erosion rates account for soil loss or gain along the transect. Max erosion rates indicate the maximum erosion rate assessed along the transect; * Values in brackets show erosion rates estimated with the equation for cropping land.

however report that they had expected higher erosion rates for this site, but outcropping bedrock and high infiltration in the upper slopes may have restricted erosion. Although Howleaky2008 model testing was limited for the number of sites, soils and land use conditions, the results increase the confidence in model capability to assess soil losses in Victorian farming systems.

Land management options to reduce soil losses

The HowLeaky2008 model was applied to assess average annual soil loss (t/ha/y) for current land management and alternative options identified as suitable for the catchment. Perennial pastures (PP) in the grazed uplands, or lucerne in the mixed systems were selected as alternatives to annual pastures, and a zero tillage 4-year rotation (CWBL_0till) was selected for the cropping land. Field soil loss depends on topographic settings; to allow comparison of different soils, slope was set to 9% and field length was set to 22.1 m, so that the *LS* factor of equation (1) was equal to 1. In annual pastures, soil loss ranged from 0.3 to 1.5 t/ha/y; it was lowest in heavy Grey Vertosols and highest from Red/Yellow Chromosols (Figure 2).

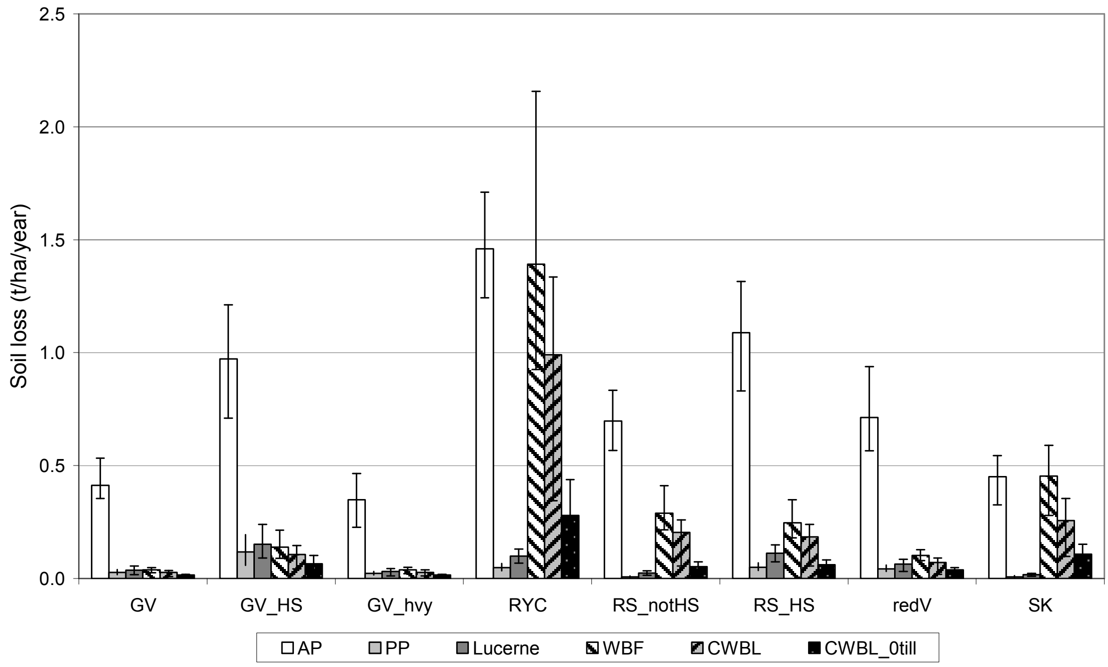

Figure 2. Soil loss (t/ha/year) under current and alternative land management systems estimated with Howleaky2008. Bars indicate min and max response across the Avon Richardson catchment climate zones.

By contrast, soil losses were always less than 0.15 t/ha/y under perennial pasture or lucerne. In cropping land, the 3-year WBF rotation generated most soil loss, at rates of 0.3 (heavy Grey Vertosols) to 3.7 t/ha/y (Red/Yellow Chromosols). Soil losses in the 4-year CWBL rotation were 25-45% lower (0.25-2.6 t/ha/y) than WBF. If zero tillage was adopted in crop land, soil losses under the 4-year rotation (CWBL_0 tillage) would reduce to 0.1-0.8 t/ha/year and would be particularly effective on red duplex soils (Red Yellow Chromosols and Red Sodosols). Estimated soil losses were similar to erosion rates measured in New South Wales under pastures (0.2-0.4 t/ha) and crops (1.5-8 t/ha) (Edwards and Zierholz 2007). Soil losses of Figure 2 do not account for topographic settings. Long fields and steep slopes multiply soil losses according to the *LS* factor. For example, in the Avon Richardson slopes are commonly as long as 100 m; at slopes of 2.7% soil losses would be halved, at 5% soil losses would be approximately equal to Figure 2, but at 10% soil losses would be 2.3 times these Figures. Vertosols occur mainly in flat areas and soil losses are of little concern, but duplex and Kandosols, which occur in the hills, may generate large soil losses.

Conclusions

HowLeaky2008 soil losses for the Avon Richardson catchment were comparable to ^{137}Cs estimates for nearby sites and observed values in NSW indicating that the model can be used to simulate Victorian farming system conditions. Model simulations showed that changing from minimum to zero tillage can reduce soil loss by 40-75% in cropping land; switching from annual to perennial pastures or lucerne could reduce soil loss by over 80% in grazing land. Highest soil losses were from duplex soils and the adoption of BMPs would have the largest impact in reducing sediment export. Further experimental work to verify the model simulations would be useful.

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