Defining tradeoffs between farm profit and natural resource indicators in grain-grazing systems

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Abstract

Natural resource indicators are used by catchment management organisations (CMOs) as targets for land use management. However, the nature of the tradeoff function between natural resource management (NRM) outcomes and whole-farm profit is ill-defined, varying between regions and according to the particular NRM indicator considered. Defining the function will assist CMOs and farmers to evaluate the achievability of particular targets, and help determine the size of economic incentives required to offset any expected loss in farm profit associated with meeting targets. We addressed this issue by modelling representative farm businesses in two mixed farming regions (southern NSW and the central wheatbelt of WA). The APSIM and GRAZPLAN farming systems models were linked and used to generate values of five NRM indicators (leakage, nitrate leaching, bare ground, soil organic carbon change, acidification) for a wide range of crop-pasture rotations. Predicted long-run NRM indicator values were incorporated into MIDAS and optimisations, constrained to meet various NRM targets, were run. For some circumstances and indicators, the resulting tradeoff functions were relatively flat; a wide range of enterprise mixes can lead to the same NRM outcomes but significant gains in the indicators may not be possible using current rotation options. For others, significant improvements could be achieved but at a substantial loss in whole farm profit (through the selection of less profitable rotations). This analysis demonstrates an approach by which biophysical simulation models of the farming system can be linked to linear-programming representations of farming enterprises, and provides a method for deriving objective relationships between NRM targets and economic performance.

Key Words

Profit, natural resource indicator, tradeoff, grain, graze, economics, model

Introduction

Natural resource indicators are used by catchment management organisations (CMOs) in Australia as targets for land use management. However, the nature of the tradeoff function between natural resource management (NRM) outcomes and whole-farm profit is ill-defined. Defining the function will assist CMOs and farmers to evaluate the achievability of particular targets, and help determine the size of economic incentives required to offset any expected loss in farm profit associated with meeting targets. More generally, it will also allow for quantification of the NRM impact of broadacre farming and the scope for more positive NRM outcomes through changes in land use and management.

This paper brings together two modelling approaches to address the challenge of defining NRM-profit tradeoffs. Dynamic biophysically-based simulation models of agricultural systems, such as APSIM (Keating *et al*. 2003) and GRAZPLAN (Donnelly *et al*. 2002), can produce estimates of production, soil states and processes in relation to weather and management and are commonly applied at point (i.e. paddock) scale. Whole-farm linear programming models, such as MIDAS (Kingwell and Pannell 1987), represent the biological, physical, technical and managerial relationships of a mixed farm that is representative of production systems within a defined region. The MIDAS model allocates available resources in order to maximise the objective function of whole-farm profit, subject to resource, environmental and managerial constraints.

In this paper we use the biophysical models to derive values for two key NRM indicators (leakage, bare ground) under a range of land uses and use these in MIDAS to explore the tradeoffs between profit and the indicators when subject to a range of constraints. The analysis was conducted in two contrasting mixed farming regions to explore potential regional differences in the tradeoffs.

Methods

Regions and farming systems

Versions of MIDAS have been developed for each of the southern mainland states of Australia. Whilst the general structure of the different versions is similar there are differences in activities and parameter values that reflect the inter-regional variation in climate and production systems. Characteristics of the models for the central wheatbelt of Western Australia (CWB) (see Byrne *et al*. 2008) and the Murrumbidgee region (Bathgate, unpublished) of southern NSW (MBD) are summarised in Table 1.

Table 1: Key features of regions and MIDAS versions used in the analysis.

	Central Wheatbelt, WA	Murrumbidgee, NSW
Farm Area (ha)	2000	1000
Land Management Units	*1.Poor sands* *2.Average sandplain* *3.Good sandplain* *4.Shallow duplex* *5.Medium heavy* *6.Heavy valley* *7.Sandy surfaced valley* *8.Deep duplex*	1.Non-arable land 2.Grey soil 3.Light red soil 4.Heavy red soil
Rotations	Continuous pasture Pasture/cereal Pasture/canola/cereal Continuous cereal Cereal/pulse Canola/cereal/pulse Lucerne/cereal Lucerne/cereal/canola Lucerne/cereal/pulse/cereal	Lucerne/canola/cereal/pulse Lucerne/canola/cereal Lucerne/cereal/pulse Lucerne/cereal Annual pasture/canola/cereal/pulse Annual pasture/canola/cereal Annual pasture/cereal/pulse Annual pasture/cereal Cereal/canola/pulse Cereal/pulse
Yields – range (t/ha)	Wheat: 0.9 – 2.4 Canola: 0.8 – 1.1 Lupins: 0.5 – 1.5	Wheat: 2.2 – 4.3 Canola: 1.1 – 2.1 Lupins: 1.1 – 2.1
Stocking rate (DSE/pasture ha)	7 – 8	11 – 12

Annual rainfall (mm)	350 – 400	400 – 500
Growing season for annual plants	10 May – 10 Oct	6 May – 3 Nov
Per cent rainfall received April-Oct	80	57

Simulations for NRM indicators

APSIM and GRAZPLAN biophysical models were linked and simulations were conducted for all possible rotations of crops and pastures on all soil types listed in Table 1. Rotations were simulated over 100 years of historical daily climate at both locations using realistic management settings extracted from MIDAS (e.g. N fertiliser rates, stocking rates, flock structure, grazing management). Simulated yields and pasture utilisations were checked against those in MIDAS and were generally realistic. For each rotation x soil type combination, long-term mean values of the NRM indicators were calculated for: water leakage (mm/year) and nitrate leaching (kg N/year) below the root zone, ground cover (live and dead plant cover), rate of change in soil organic carbon in the 0-10 cm layer and lime equivalents required to maintain a net proton balance (a measure of the rate of soil acidification). We present here only the results for ground cover and leakage. Ground cover is expressed either as the mean daily proportion of bare ground (CWB) or the proportion of days where groundcover is less than 50% (MBD).

Whole-farm optimisations

Values of the NRM indicators for each rotation and soil type were entered into MIDAS. The following sensitivity analyses were then run:

- Holding the value of the indicator constant at a range of levels and optimising for whole farm profit. Plotting the value of optimum profit against each NRM indicator level enabled the profit-NRM indicator response to be described.
- Holding the percentage of the farm under cropping constant at a range of levels and deriving the NRM indicator obtained when whole-farm profit was optimised. By plotting the resulting NRM indicators against percentage crop, the influence of enterprise mix (crop vs. livestock) on NRM indicators was examined.

Results and Discussion

Table 2 shows mean values for one indicator (groundcover) by soil type for the most common rotation selected for that soil type.

Table 2: Mean value for groundcover by soil type for the most common rotation selected for each soil in the most profitable system as predicted by MIDAS. Ground cover is expressed either as a mean daily annual percentage of bare soil (CWB) or proportion of days in the year where ground cover is less than 50% (MBD).

Soil type	*Most common rotation selected*	*Bare ground*
	Central Wheatbelt WA	
1.Poor sands	Continuous annual pasture	78%
2.Average sandplain	Wheat, barley, lupin	70%

3.Good sandplain	Continuous annual pasture	77%
4.Shallow duplex	Wheat, wheat, field peas	58%
5.Medium heavy	Continuous annual pasture	59%
6.Heavy valley	Wheat, wheat, field peas	57%
7.Sandy surfaced valley	Wheat, wheat, field peas	56%
8.Deep duplex	Continuous annual pasture	77%
	Murrumbidgee, NSW	
1.Non-arable land	Continuous annual pasture	2%
2.Grey soil	5 lucerne, 2 wheat, barley	22%
3.Light red soil	5 lucerne, wheat, canola, wheat, barley	28%
4.Heavy red soil	5 lucerne, wheat, canola, wheat, lupins, barley	21%

The most profitable rotation selected on each soil type varied from continuous annual pasture, to crop-dominant rotations, to those including lucerne (Table 2). Ground cover, as an example of a NRM indicator, varied across soil types. At CWB, continuous annual pasture versus crop-based rotations had more average annual bare ground. At MBD, crop-based rotations had similar bare ground, much more than that on non-arable land.

The first set of runs enabled us to examine the tradeoff with profit as different NRM targets are set for the farm. For some indicators, such as bare ground, profit changed markedly in response to varying the target value (Fig. 1). At CWB (Fig. 1a), except for high leakage values (> 20mm), any reduction in the target was accompanied by marked loss in profit (i.e. a win-lose). At MBD (Fig. 1b), a reduction in the leakage target was accompanied by a gain in profit (i.e. a win-win) up to a tipping point at about 40 mm, beyond which reductions in profit were required to effect further reductions in leakage.

Improvements in mean bare ground between 80 and 60% were possible without much change in profit at CWB (Fig. 1a). In contrast, at MBD (Fig. 1b), concurrent improvements in bare ground and profit were not possible, with a halving of profit for where the percent time below 50% groundcover decreased from 20 to 2%.

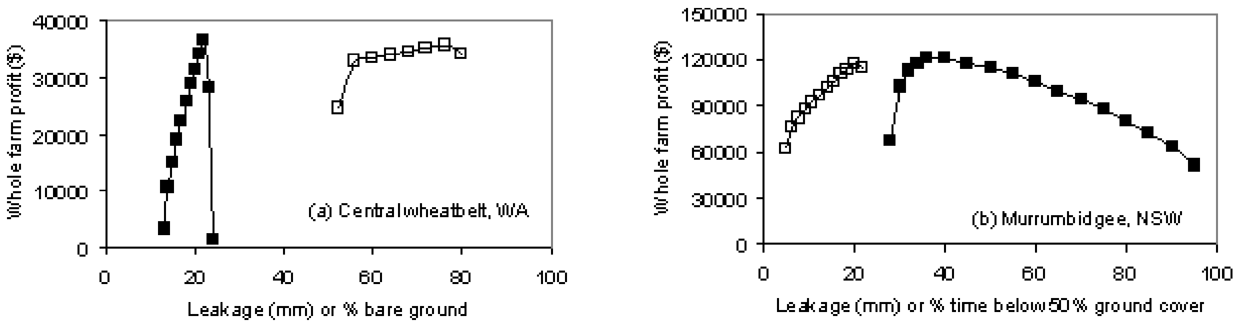

Figure 1. The relationship between optimised whole-farm profit ($/year) at set values of whole-farm averages of leakage (n, mm/year) and bare ground (o) on one example soil type for (a) Central Wheatbelt WA and (b) Murrumbidgee MIDAS farms.

Enterprise mix, expressed as area of the farm under cropping, had little effect on leakage at CWB (Fig 2a), due to the dominant effect of the substitution between annual pastures and grain crops, which have similar water use. Reductions in leakage would only have been possible if greater areas of a perennial pasture such as lucerne were selected as percent cropping was reduced. However, lucerne was not available for selection by the CWB model resulting in a flat response of leakage to profit. In contrast, more lucerne was selected at MBD as area of cropping fell, resulting in less leakage (Table 2, Fig. 2b).

In both farms, bare ground was remarkably unresponsive to area cropped, indicating that wide combinations of crop and pasture production result in similar groundcover outcomes (Fig. 2a,b).

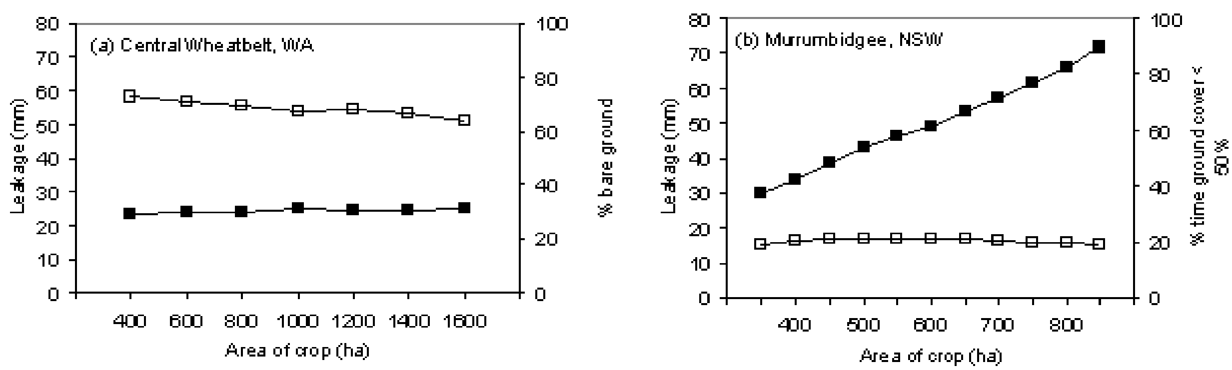

Figure 2. The relationship between NRM indicators leakage (n, left axis) and ground cover (o, right axis) and amount of the farm under cropping when optimised for whole-farm profit at set values of area of cropping for the (a) Central Wheatbelt (farm size of 2000 ha) and (b) Murrumbidgee (farm size 1000 ha) MIDAS farms.

Conclusion

This analysis is the first of its type to combine biophysical data on NRM indicators within a whole-farm economic model. It reveals a number of points:

- Win-wins are possible in the system where gains in the indicator (e.g. less leakage) are matched by improvements in whole-farm profit.
- Tradeoff situations are also apparent and in the case of leakage the ability to improve the NRM indicator is dependent upon the availability and profitability of lucerne. In some cases substantial profits will have to be foregone to reach NRM targets.

- NRM indicators vary in terms of their responsiveness to enterprise mix, with groundcover less responsive than leakage.

These analyses will be useful in the quantification of the NRM impact of broadacre farming and the scope for more positive NRM outcomes through changes in land use and management. More complex analyses will be required to consider optimisation where more than one NRM indicator is being considered

Conclusion

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