The profitability of grazing crop stubbles may be over-estimated by using the metabolisable energy intake from the stubble

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Abstract

Grazing crop stubbles may affect soil health, and the productivity of subsequent crops, but the costs associated with this practice are highly variable and not easily compared against the value of feed provided to livestock. To compare whole farm profit and water use efficiency (WUE) with and without grazing stubbles we created a mixed enterprise farm model using the APSIM and GRAZPLAN biophysical simulation submodels. We hypothesised that grazing crop stubbles would increase farm profit by an amount equivalent to the value of the metabolisable energy (ME) consumed by sheep when they grazed the crop stubbles. Representative mixed farms where sheep were or were not allowed to graze crop stubbles were compared for two locations in the wheatbelt of Western Australia (Cunderdin and Geraldton) at two stocking rates. Across locations and stocking rates, the value of the ME intake from crop stubbles (determined on an equal $/ME basis to supplementary feed) was $39/ha, compared with increase in the farm gross margin of $18/ha, for simulations where stubble grazing was permitted. A primary reason for this difference was that sheep utilised less of the annual and permanent pastures when stubbles were grazed. Therefore, the value of grazing crop stubbles to the profitability of the farm enterprise was overestimated by the ME value of the intake. Owing to reduced consumption of grain by livestock, whole farm water use efficiency of protein production was increased by 15% when grazing of crop stubbles was permitted. This study shows that results of simple, intuitive methods to calculate the value of crop stubbles in whole farm systems should be viewed with caution.

Introduction

The practice of not grazing crop stubbles has received attention in the wheatbelt of Western Australia because there is uncertainty whether the benefits of grazing to livestock and crop production exceed penalties to subsequent crops and soil characteristics (Flower and Braslin

2006). In some farming systems, crop stubbles are considered an important part of a suite of options to maintain a seasonal supply of feed for livestock. Crop stubbles are often available for grazing at times of the year when feed is scarce (Moore *et al.* 2009). Grazing crop stubbles can also reduce the problems associated with a high stubble biomass during the establishment of a subsequent crop (Moore and Lilley 2006), and allow livestock to utilise spilt grain and unwanted green summer plants. On the other hand, there is evidence that trampling by livestock may present a significant cost to crop production through the removal of cover increasing erosion, damage to soil physical properties causing reduced water infiltration and increased cultivation costs (Proffitt *et al.* 1993; Radford *et al.* 2008), thus reducing WUE. The impacts of grazing stubbles on soil characteristics and crop yields are variable, and not necessarily negative (Quiroga *et al.* 2009), but are strongly influenced by farm management practices and soil type (Vanhaveren 1983; Proffitt *et al.* 1995; Robertson *et al.* 2009). To evaluate the true costs and benefits of grazing crop stubbles, a whole farm analysis is necessary.

An estimate of the value of crop stubbles to farm profit can be made by calculating the metabolisable energy (ME) of the stubble biomass and then determining the cost to provide an equivalent amount of energy by feeding a supplement. This calculation requires several assumptions. First, there should be no alternative forage available for grazing simultaneous to the stubble, so that the marginal cost of providing additional feed (Ewing *et al.* 1989) is high. This is likely to be the case for much of southern Australia where there is a Mediterranean-type climate and crop stubbles are usually available at a time where the livestock feed supply is in ME deficit (Moore *et al.* 2009). Second, the calculation assumes that the energy spent grazing the crop stubble is the same as if the livestock were being fed a supplement. However, this assumption may not be accurate if producers seek to restrict animal movements to achieve efficiency gains when livestock require supplementary feeding (e.g. confinement feeding). Additional energy for locomotion during grazing periods may comprise as much as 35-40% of maintenance energy requirements (Standing Committee on Agriculture 1990).

In this study we use a mixed crop and livestock simulation model to compare farm profit and water use efficiency (WUE) when crop stubbles are grazed with when stubbles are excluded from grazing. The simulation was designed to evaluate net value of crop stubbles to the seasonal livestock feed budget. We hypothesised that the increase in farm profit would be equivalent to the value of the ME consumed by sheep grazing the crop stubbles.

Methods

Simulation analyses

To compare whole farm profit and WUE with and without grazing stubbles we created a mixed enterprise biophysical farm model using the CSIRO Common Modelling Protocol (Moore *et al.* 2007; Lilley and Moore 2009). The simulation described a mixed cropping and sheep meat/wool enterprise, designed to be comparable to a wheatbelt farm in Western Australia. The modelled enterprise comprised 7 x 200 ha paddocks in a 7 year crop and pasture rotation sequence (annual pasture, wheat, wheat, canola, lupin, wheat, wheat), 3 x 200 ha paddocks assigned to a permanent pasture (containing lucerne) and 2 x 5 ha feedlot paddocks (one feedlot for maintaining ewes when other forage options were exhausted, and one feedlot for finishing lambs). The sheep enterprise was based around prime lamb, ewe and wool production from a self-replacing Merino flock.

Two locations were selected, representing the central (Cunderdin) and northern (Geraldton) wheatbelt of Western Australia. These sites were selected to represent a large part of the mixed farming region of Western Australia and because these areas have relatively short growing seasons, so the value of out-of-season feed should be high. Historical weather data for these sites were obtained as Patched Point Datasets from the SILO database (http://www.longpaddock.qld.gov.au/silo, verified 3 August 2009). Simulations were run from 1950 to 2007; the first 8 years of each simulation were excluded from the analysis to remove any effects of the initial conditions. Multiple rotation farm systems and tactics for managing crops, pastures and livestock were described using rule-based coding in the AusFarm software (http://www.grazplan.csiro.au, verified 17 August 2009). Two stocking rates (Medium and High) were compared at each location: 5.8 and 11.7 DSE (dry sheep equivalents)/winter-grazed ha at Cunderdin and 8.1 and 16.2 DSE/winter-grazed ha at Geraldton. The term 'winter-grazed' refers to the area of the farm that was left uncropped and reserved for grazing at the time when crops were grown.

Stubble grazing

Simulations were run to compare the effects of grazing of crop stubbles or not. The simulation allowed grazing of stubble residues, unharvested grain and volunteer summer weeds. When grazing of crop stubbles was permitted, stubbles were made available for grazing immediately after crops were harvested and stubbles were given priority above other sources of forage for grazing by all adult ewes. Sheep younger than 1 year old (lambs) were not given access to crop stubbles. Volunteer annual pasture species in the model were allowed to grow following any rain events and were grazed if they were available. Unharvested grain (available for grazing) was set at 4% of yield for all crops. For the purpose of the model, all groups of sheep were combined and grazed each stubble paddock together, and all sheep were removed from the stubble together and moved to the next available paddock. Livestock were relocated from stubbles to a new forage source when one of the following conditions were met; i) the average body condition score of the leanest subgroup was less than 1.5, ii) the stubble had been grazed for 21 days, iii) ground cover in the stubble paddock decreased below 65% or iv) average sheep liveweight decreased more than 0.5 kg below liveweight at introduction to the stubble paddock. The simulation included a subset of soil chemical, physical and surface residue effects on soil water balance during the grazing of crop stubbles, with consequential effects on the potential yields of subsequent crops. It was assumed that grazing of stubbles had no effect on soil bulk density, infiltration rate or penetration of plant roots into the soil.

Gross Margin

Farm and enterprise based (grain and livestock) gross margins were determined as variable revenue minus variable cost. Revenue from grain, livestock and wool sales ($/ha) was calculated as the product of yield and price, using a 5-year (2004 – 2008) average for Australian commodity prices (ABARE 2008). Prices used in the model were wheat, $270/t, canola, $420/t, lupins, $230/t, ewes $0.77/kg liveweight, lambs $1.67/kg liveweight and wool, $8.20/kg clean. A 45% dressing percentage was assumed to convert carcass prices to liveweight prices. Variable costs for crop and livestock production were taken from gross margin calculations published for the eastern wheatbelt in 2005 by the state government of Western Australia (http://www.agric.wa.gov.au/PC_91745.html?s=1001, verified 19 June 2009).

Water use efficiency

For the purposes of this study, WUE is defined as the net amount of protein produced per unit of rainfall. This allowed direct comparisons of WUE between crop and livestock production across different locations and management scenarios. Whole farm protein production was used in preference to 'dollar water use efficiency' (Millar *et al.* 2009) because higher profit may be achieved at the expense of net farm protein production, for example, increased usage of supplementary feed to support a higher stocking rate. WUE was calculated per mm of rainfall as follows:

$$WUE = (Protein_{grain} + Protein_{meat} + Protein_{wool} - Protein_{supplementary\ feed}) / (annual\ rainfall \times farm\ area)$$

Assumed values for protein content of products were: wheat 12%, lupins 30%, canola 30%, supplementary feed 15.6%, meat 7.2% of liveweight, clean wool 80%.

Economic value of stubble for livestock

The economic value of stubbles for livestock production was determined by three methods. For simulations with and without stubble grazing permitted, we compared the value of i) farm gross margin, ii) the extra cost of supplementary feeding if crop stubbles were not used for grazing and iii) the value of the ME intake of livestock grazing crop stubbles, on an equivalent price per unit energy basis as supplementary feed.

Results

When grazing of crop stubbles was permitted, the simulation allocated sheep to graze crop stubbles for 90 and 94 days annually at Cunderdin and Geraldton when stocking rate was medium, and for 61 and 64 days when stocking rate was high. Across sites and stocking rates, the value of the ME intake from crop stubbles was more than double the increase in farm gross margin (39 *v* 18 \$/ha; Table 1). Farm gross margin decreased by \$15/ha at Cunderdin and \$20/ha at Geraldton when crop stubbles were excluded from grazing. Grazing crop stubbles increased profitability more at the high stocking rate, compared with the low stocking rate, at Cunderdin. However, there was no effect of stocking rate on the overall value of grazing stubbles at Geraldton. The value of grazing crop stubbles calculated using the ME intake of stock was 40% higher than when calculated based on additional supplementary feeding costs, and two times the value of the increase in farm profit. Some of the cost of providing extra supplementary feed when crop stubbles were not grazed was recouped in the system, as supplementary feed costs were 44% higher than the loss of profit. The revenue from livestock decreased by \$5/ha when stubble grazing was permitted, which was partly due to a 5% decrease in the liveweight of lambs sold.

When stocking rate was medium, the proportion of annual pasture that was utilised decreased from 46 to 42% when sheep were permitted to graze stubbles and the number of days grazing annual pasture decreased from 143 to 120. When stocking rate was high, utilisation of annual pastures did not change in response to stubble grazing. Utilisation of permanent pastures decreased when stubbles were grazed for both medium (26 to 23 %), and high (42 to 39%) stocking rates.

WUE increased by 15% when crop stubbles were grazed (0.25 *v* 0.28 kg protein/mm.ha; Table 1). WUE was reduced by 57% at the high stocking rate when stubble grazing was excluded, mostly due to an increase in supplementary feed requirement causing a decrease in net farm protein production. The annual minimum ground cover, averaged across the farm, decreased by 4.8 percentage units when crop stubbles were grazed.

Insert Table 1

Cumulative distributions of the change in farm profit by grazing crop stubbles are displayed in Figure 1. The value of grazing crop stubbles varied considerably between years, ranging from -$25 to $110 at Cunderdin and -$40 to $101 at Geraldton. At Geraldton the profitability of grazing crop stubbles was more variable at the high stocking rate, with a decrease in profit in 28% of years compared with 10% of years at the medium stocking rate. Inspection of years where profit was reduced when crop stubbles were grazed revealed that there was no single contributing factor. When a loss of profit occurred by grazing crop stubbles this was the result of impacts of grazing stubbles on livestock production, subsequent crop yield, or both.

Insert Figure 1

Discussion

The contribution of grazing crop stubbles to farm profitability was not equivalent to the value of ME intake from the stubbles or the cost of providing additional supplementary feed, so our hypothesis was rejected. A primary reason for this was that sheep utilised more of the annual and permanent pasture biomass when no stubble grazing was allowed. Lower profit from grazing crop stubbles than was predicted by stubble ME intake suggests that stubbles were either not used, or available to be used, optimally in the model. That is, the provision of crop stubbles did not directly replace supplementary feeding of livestock. Despite the marginal cost of supplementary feeding generally being high when crop stubbles are available (Ewing *et al.* 1989; Moore *et al.* 2009), grazing crop stubbles did not reduce the need for supplementary feeding as effectively as might be expected because in 'good' seasons other forage options (dry annual pasture and permanent pasture) were available concurrently with the crop stubbles.

In this study, crop stubbles were grazed conservatively because livestock were not permitted to lose more than 0.5 kg of weight while grazing on stubbles. The profitability of grazing crop stubbles depended on the grazing rules used in the model, and the effect of changing these rules is likely to affect the value of crop stubbles determined in the simulations. For example, if the sheep grazed the stubbles for a longer time, increased liveweight loss in ewes and lower utilisation of other forage options may have affected profitability differently, with different interactions across sites and stocking rates. The feeding value of crop stubbles varies widely, and the intake of sheep has been reported to range from 4.4 to 9.8 MJ/sheep.day depending on the crop type, grazing intensity and whether green summer plants have grown in the stubble (Mulholland *et al.* 1976). Improved management of feed demand and supply, allowing tactical decision making and response to seasonal stubble conditions, may have improved the efficiency of utilising crop stubbles in this study. However, trade-offs between livestock production, stubble utilisation and the utilisation of other fodder options may prevent simultaneous gains across these profit drivers.

Revenue from livestock production decreased by $5/ha when crop stubbles were grazed, which was another contributing factor to lower value of grazing crop stubbles compared to what was predicted using ME intake from stubbles. The decrease in liveweight of lambs sold when crop stubbles were grazed indicates that grazing pregnant ewes on crop stubbles adversely affected lamb production, in comparison to their counterparts fed grain in a feedlot. Direct effects were not possible as lambs were not permitted to graze stubbles. Effects of animal nutrition during pregnancy on the growth of offspring occurs by a range of mechanisms (Bell 1984; Martin *et al.* 2004). In the AusFarm model, foetal liveweight and survival of newborn lambs are linked to the condition of the ewe (Freer *et al.* 1997). Differences in condition score between ewes grazing stubbles and fed a supplement during pregnancy may have contributed to the differences in lamb production.

Greater reliance on other pastures when crop stubbles are not grazed may transfer grazing pressure, and the risk of overgrazing and soil degradation, to other parts of the farm. In this study, the minimum annual ground cover, averaged across all paddocks, was about 5 percentage units lower in simulations without stubble grazing because livestock spent a higher proportion of their time grazing annual pastures where surface residues are consumed and break down more quickly compared with crop stubbles. Therefore, to avoid overgrazing pasture paddocks when crop stubbles are not grazed, there may be a greater need for management interventions such as confinement feeding of livestock (Milton 2003; Lilley and Moore 2009).

Whole farm WUE was determined using net annual protein production to compare efficiency between simulations and enterprises. Reduced supplementary feeding and higher pasture utilisation were drivers of improved WUE in the simulations. Overall, grazing crop stubbles increased WUE because the contribution of reduced supplementary feeding was greater than the decrease in pasture utilisation. Conversely, increasing stocking rate reduced WUE because the WUE penalty by increased supplementary feeding was greater than the increase in pasture utilisation at the higher stocking rates. In this model, the value of all protein biomass produced was considered to have the same value for WUE. In reality, the type of protein produced per unit water may be important in determining WUE. Livestock protein has a higher commercial value, and biological value, on a per kg basis compared with grain protein.

Although the impacts of livestock on soil condition are not fully represented by our model, the management rules used in this study were selected to represent a moderate level of stubble utilisation, which reduced the possibility that livestock impacts on soil (e.g. surface compaction) would have had large effects on subsequent crop yields. The complex interactions that exist between the grain and livestock enterprises modelled in this simulation show that simply estimating stubble ME values or additional supplementary feeding costs may not be useful to determine the value of crop stubbles to farm profitability, and the type of modelling approach should be selected carefully. The selection of issue-specific modelling approaches has been reviewed by Bell *et al.* (2008).

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Tables and Figures

Table 1. Annual whole farm gross margin and water use efficiency with or without stubble grazing (SG) and values representing the profitability of grazing crop stubbles at two locations and two stocking rates

	Gross margin ($/ha)[#]		Change in profit ($/ha)	Reduced supplement cost ($/ha)	Stubble ME value ($/ha)	Water use efficiency (kg protein/mm.ha)	
	No SG	SG				No SG	SG
Cunderdin							
Low stocking rate	185	195	10	15	27	0.35	0.38
High stocking rate	151	172	21	31	36	0.15	0.21
Geraldton							
Low stocking rate	265	285	20	24	40	0.37	0.39
High stocking rate	232	253	21	35	52	0.12	0.17
Mean	208	226	18	26	39	0.25	0.28

[#]Values of $/ha were calculated using total farm area

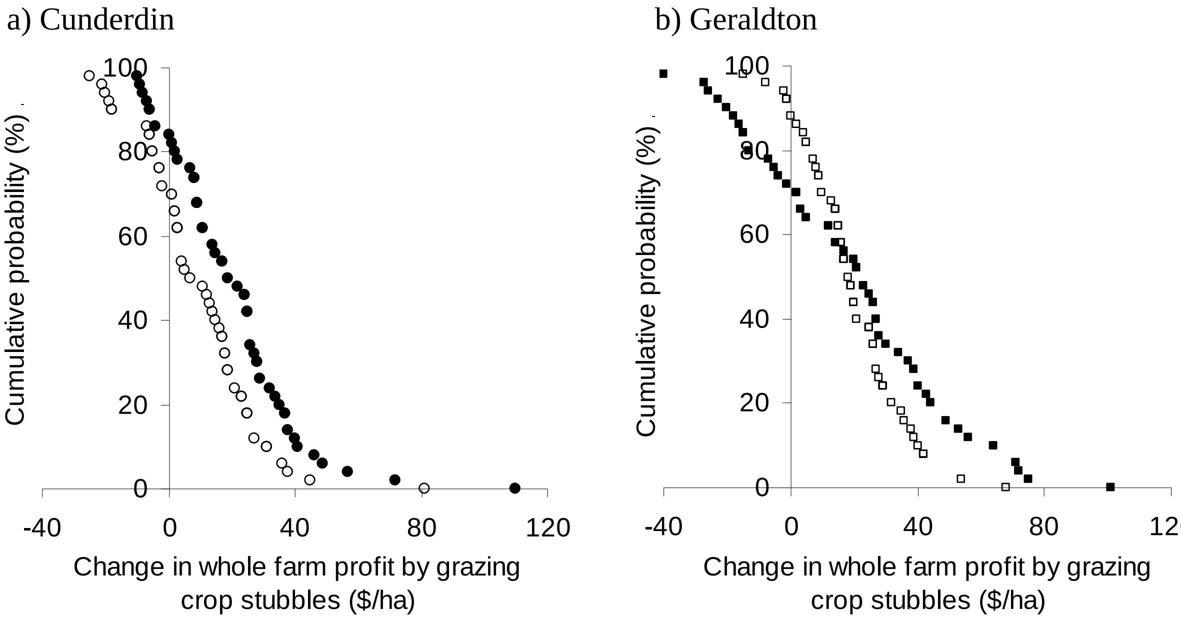

Figure 1. Simulated cumulative distribution of the change in farm profit ($/ha) when crop stubbles are grazed at a) Cunderdin and b) Geraldton at medium (open symbol) and high (closed symbol) stocking rates. Each curve is composed of 50 seasons.