Pasture Cropping-Integrating Livestock and Crop Production for Sustainable Management of Rangelands in South East Australia

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The 21st International Grassland Congress / 8th International Rangeland Congress took place in Hohhot, China from June 29 through July 5, 2008.

Proceedings edited by Organizing Committee of 2008 IGC/IRC Conference

Published by Guangdong People's Publishing House

Pasture cropping-integrating livestock and crop production for sustainable management of rangelands in south east Australia

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Key words : intercropping , pasture regeneration , farming systems , perennial pastures

Abstract Pasture cropping (PC) is an intercropping technique that was developed by farmers in the Central West region of New South Wales , Australia to retain perennial grasses for summer/autumn grazing . Winter cereal crops are sown directly into summer growing (C4) native pastures (e .g . *Bothriochloa macra* and *Paspalidium jubiflorum*) to exploit their complementary growth phases . The experiment examined the production and environmental differences between grazing pasture (PA) , PC and no till (NT) wheat cropping . PC yields were significantly lower than NT and were limited by nitrogen . There was only a minimal reduction in the density and basal area of perennial grasses from PC compared to PA . Gross margin increased from PA to PC to NT , but higher returns were associated with higher annual volatility .

Introduction

The farmer s story The pasture cropping concept was developed in Australia 15 years ago by Colin Seis , an innovative farmer . Colin s family have run their property Winona for nearly 80 years and in that time they developed the farm using introduced perennial grasses , subterranean clover (*Trifolium subterraneum*) and superphosphate fertiliser until about 30 years ago . Each paddock was stocked more or less continually with high stocking rates and substantial inputs were required to maintain production . At that time pastures were quite degraded and dominated by annual grasses and weeds . There was substantial economic pressure involved with continually resowing introduced pastures , and the annual application of superphosphate fertiliser , so Colin made a choice to change . Firstly , he reduced inputs , and then introduced short-duration high intensity grazing . Finally , pasture cropping was an opportunistic attempt to improve farm productivity .

Colin s first attempt at pasture cropping involved sowing a crop of oats (*Avena sativa*) into a dormant stand of summer growing (C4) native grass , dominated by *Bothriochloa macra* , as an inexpensive method of producing winter forage . This turned out to be very successful and it was evident that the crop could be harvested for grain . Over following years , other crops such as cereal rye , wheat and lupins were trialled and the system was developed . Economically , the system has performed as well as , or better than , others on the property . Crop production costs are generally lower as there is less fallowing and land preparation required compared to conventional cropping systems . In addition , up to an extra six months of grazing can be achieved .

In addition to increased profitability the system has delivered some unplanned environmental benefits . It was observed that the pasture cropping process stimulated the recruitment of perennial grasses , substantially enhancing native grass population and diversity . As a result Colin pasture crops a paddock for one to two years , to rejuvenate the pasture , before returning it to grazing for 5 years . His aim is to achieve 100% ground cover 100% of the time , in both cropping and grazing phases , by retaining perennial native grasses . Soil structure has improved , with soil organic carbon levels rising from 2% to 4% from 1997 to 2007 and Winona is a much more profitable and healthy farm .

The science behind the system Grassland and soil degradation are substantial problems in agricultural systems in southern Australia . Degradation is exhibited by a reduction in the level of perennial grasses (exotic or native) , a shift to a less desirable composition or a loss of production and ecosystem function (Kemp and Dowling 2000) . Reseeding is the most common form of reclamation , although it has high costs associated with inputs and short term loss of production . Management strategies that enhance the recruitment and regeneration of perennial grasses without removing land from production , and / or have low costs , are the key to economic regeneration of degraded land . Retaining perennial grasses in production systems can limit many sustainability problems such as soil erosion , rising water tables that cause dryland salinity and reduce nitrogen leaching .

Intercropping or sod seeding winter cereals into perennial pastures has been used within Australia for a long period of time (e . g . Colman 1966 ; Cook 1980 ; Humphries *et al* . 2004 ; Michalk and Witschi 1977) . Pasture cropping is a form of relay intercropping where two or more crops are grown simultaneously for part of their life cycle (Andrews and Kassam 1976 ; Vandermeer 1989) . Generally winter cereal crops are sown directly into summer growing (C4) native pastures (e .g . *B . macra* and *Paspalidium jubiflorum*) to exploit their complementary growth phases and to reduce direct competition (Figure 1) . Essentially a productive cereal crop is replacing annual grass weeds . While a lack of fallowing can reduce the accumulation of nitrogen (N) and water over summer , and reduce crop yield , the reduced N and associated soil disturbance may result in native grass regeneration in the following summer due to reduced annual weed competition and a seedbed provided within drill rows .

This study aimed to determine the production and environmental benefits of pasture cropping compared with cropping or grazing alone .

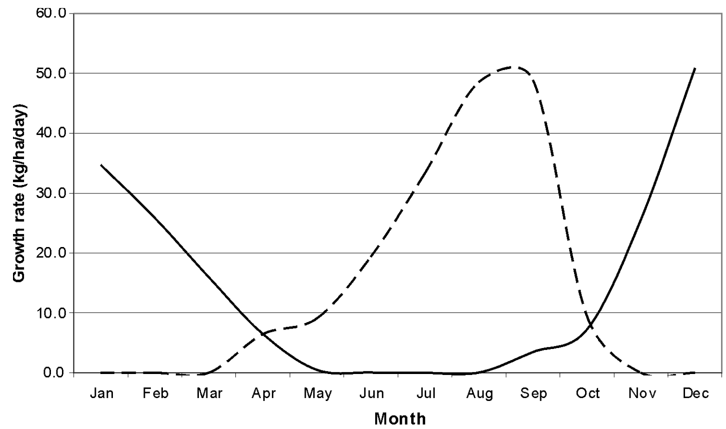

Figure 1 *Average growth rates for* B . macra *(solid line) and an annual pasture/cereal species (dashed line) at Wellington derived from the Sustainable Grazing Systems Pasture Model (www .imj .com .au/sgs) from 1998 to 2004 .*

Methods The experiment was located at the Wellington Research Services Centre (WRSC , latitude : -32 .5059S ; longitude 148. 9708E) , NSW , Australia . The site is gently undulating (300m a .s .l) , with red dermosol soils (Isbell 1996) . The mean annual rainfall is 618 mm , evenly distributed throughout the year . Mean maximum daily temperature is 22 .8℃ ranging from 31 .2℃ in January to 14 .1℃ in July . Mean minimum daily temperature is 10 .5℃ ranging from 17 .5℃ in January to 3 .4℃ in July (Table 1) .

The trial was run on a *B . macra* dominant pasture (25 plants/m^2) , that also contained significant proportions of annual grasses , legumes , broadleaf weeds and other native perennial grasses (e .g . *Austrodanthonia* sp . and *Elymus scaber*) . The site had been infrequently cropped or fertilised over the past 30 years , but had been pasture cropped with oats in 2004 , prior to the experiment . Three treatments were established and run for the duration of the experiment : Pasture Cropping (PC) , No Till cropping (NT) , and Pasture (PA) . The preparation for PC prior to sowing involved grazing to reduce pasture biomass , and application of 135g/L paraquat + 115g/L diquat 24 to 48 hours before sowing to control emerging annual weeds . Post emergence , grass and broadleaf weeds were controlled as required using herbicides that did not damage perennial grasses (e .g . Chlosulfuron) . NT had two glyphosate fallow sprays through summer and a knockdown herbicide prior to sowing that maintained a bare fallow in 2006 and 2007 . As the experiment began in April 2005 , there was only a short fallow period before sowing in that year for NT . All crops were sown with 60 kg/ha of wheat (*Triticum aestivum*) , in one pass to minimise soil disturbance . PC had 50 kg/ha (2005) and either 50 or 100 kg/ha (2006 and 2007) of DAP fertiliser applied at sowing while NT received 100 kg/ha each year . PA had no herbicide , sowing or fertiliser , but was grazed at the same time as PC .

Plots were 50 by 18m in size and were replicated in 3 blocks . Pasture composition and ground cover were monitored at 3 monthly intervals . Pasture composition was determined using the BOTANAL procedure (Tothill *et al* . 1992) in 20×0 .1 m^2 quadrats per plot (10 spaced 5m apart across each diagonal) . Perennial plant demography was measured in autumn at two fixed quadrats (0 .5 m^2) per plot each year . Soil nitrate was monitored in the top 10cm of the soil prior to sowing and at 10cm intervals in the top 100cm in winter 2007 .

Plots were harvested using a small plot header in 2005 and 2007 , while crop biomass was determined by randomly cutting 3 representative 1m^2 quadrats per plot in 2006 when drought prevented conventional grain harvesting .

Gross margin (GM) analysis incorporating both cropping and grazing enterprises was carried out on the three treatments for each year using 2007 costs and prices (www .agric .nsw .gov .au/reader/budget) . Grazing gross margins were developed from the average pasture biomass per ha available during the grazing period (all year for PA ; from beginning of the year to sowing for NT and PC) , divided by an average sheep consumption of 0 .8 kg/head/day , divided by 365 days to obtain a stocking rate per hectare . This value was then multiplied by $16 .86 (GM per head for a 21 micron merino wether enterprise) to obtain a GM/ha for the grazing portion of the three systems . Crop GM/ha was determined by subtracting sowing costs (seed , herbicide and fertiliser) and harvesting costs (harvesting , cartage , levies and insurance) from income derived from crop yield . Note that in 2006 no crop yield was obtained in NT and PC and all treatments were grazed .

Analysis of variance (ANOVA) (Genstat 10 , Lawes Agricultural Trust Rothamsted) was carried out on wheat yield ; total biomass and biomass components (litter , crop , perennial grass , annual grass , legume and other species) ; ground cover ; *B* .

macra plant numbers and basal area ; and soil nitrate .

Results

Seasonal conditions Rainfall was above average in 2005 due to substantial rain in the second half of the year , but the late break delayed sowing until 24/6/05 (Table 1) . 2006 was an extremely dry year with only 302 mm of rainfall , of which 71 mm fell in the crop growing period (sown 22/6/06) and crops were grazed instead of harvested . In 2007 , rainfall was above average from April to June (sown 25/5/07) , but substantially below average for the remainder of the crop growing season .

Table 1 *Monthly rainfall 2005-2007 (mm) and mean annual (1946-2004) rainfall (mm) and temperature (℃) for WRSC .*

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2005	39 .1	41 .9	26 .6	7 .0	0 .9	102 .4	61 .0	37 .6	114 .7	85 .3	113 .6	38 .0	668 .1
2006	40 .6	81 .6	14 .2	20 .8	1 .0	29 .0	51 .8	9 .6	6 .4	3 .2	13 .2	30 .8	302 .2
2007	13 .4	31 .2	75 .0	50 .0	74 .6	122 .2	22 .6	29 .4	1 .0	0 .0	41 .6+	n/a	461+
Mean	64 .8	60 .1	50 .6	43 .6	48 .1	40 .3	46 .6	49 .1	44 .3	63 .6	57 .1	49 .9	617 .9
T_{max} (℃)	31 .2	30 .2	27 .5	23 .2	18 .5	14 .9	14 .1	15 .7	19	22 .7	26 .4	30	22 .8
T_{min} (℃)	17 .5	17 .4	14 .9	10 .9	7 .5	4 .6	3 .4	4 .2	6 .6	9 .9	12 .7	15 .9	10 .5

Pasture Production and Demography Mean biomass of litter , crop , perennial grass , annual grass , legume and other species , and ground cover for the 3 treatments (Figure 2) , showed that maximum biomass obtained on NT and PC was due to the crop , with significantly more crop on NT ($P<0.001$) . Annual grasses and other species made increasing contributions to total biomass in PA . While overall there was significantly more litter on NT and PA compared to PC ($P<0.001$) , by the end of 2007 there was no significant difference between the treatments . Perennial grasses were mainly evident through summer and were effectively removed in NT by 2007 , were greatest on PA overall ($P<0.001$) , but were still maintained on PC . Ground cover was maintained at over 80% on PA for most of the experiment , but was significantly lower on NT and PC ($P<0.001$) . In late 2007 , ground cover was significantly greater on PC compared to NT ($P<0.001$) .

There was no difference in the number or basal area of *B . macra* plants in 2005 (prior to sowing) in any treatment (Table 2) . *B . macra* plants were completely removed from NT by 2006 but were retained at similar levels in PC and PA . Between 2006 and 2007 older plants tended to decrease and seedlings to increase in both PA and , particularly , PC although the differences were not significant . The basal area of adult plants was significantly lower ($P<0.05$) in PC compared to PA in 2006 , but there was no difference by 2007 .

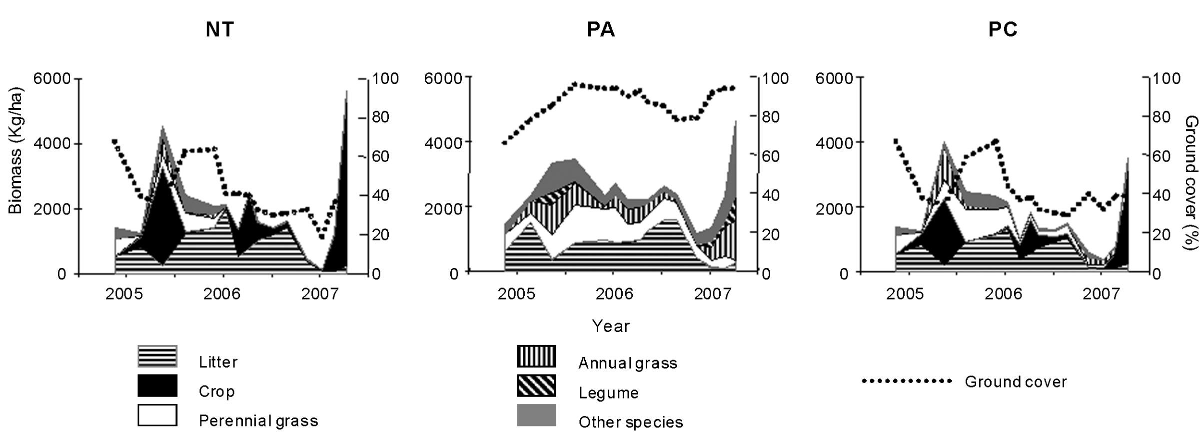

Figure 2 *Mean biomass of litter , crop , perennial grass , annual grass , legume and other species , and ground cover for NT , PA and PC .*

Table 2 *Mean adult B. macra plants and seedlings (plants / m^2) and adult plant basal area (cm^2/ plant) measured in autumn annually in PA, PC and NT (l.s.d. P<0.05).*

Year	Treatment	Adult	Seedling	*Total*	Adult Basal Area
2005	PA	-	-	30	36.6
	PC	-	-	28	35.2
	NT	-	-	20	45.1
	l.s.d.	-	-	*ns*	*ns*
2006	PA	27	4	31	47.2
	PC	22	6	28	19.3
	NT	0	0	0	0
	l.s.d.	*7.58*	*4.77*	*9.83*	*15.61*
2007	PA	22	6	28	30.9
	PC	15	11	26	19.7
	NT	0	0	0	0
	l.s.d.	*18.20*	*6.41*	*12.83*	*14.59*

Nitrogen There was a substantial difference in the level of nitrate in the top 10cm of the soil between treatments prior to sowing in 2006 and 2007 with highest levels in NT and lowest in PA (Table 3). Nitrate in PC was similar to PA in 2006 and to NT in 2007. Nitrate gradients measured to a depth of 100cm in winter 2007 showed similar relativities between treatments, with actual differences most apparent between 30 and 80 cm (Figure 3). There was a strong linear relationship between crop yield and available N in the top 10 cm (mineral N at sowing plus N added in fertiliser) across all treatments in 2005 ($R^2 = 0.95$). Multiple regression analysis with nitrate 0-10cm and 10-80cm described 81% of the variation in crop yield across all treatments in 2007.

Table 3 *Nitrate (mg/kg) in the top 10 cm measured prior to sowing (2005-2007) in PA, PC and NT (l.s.d. P<0.05).*

Treatment	2005	2006	2007
PA	8.8	8.2	23.7
PC	9.5	10.5	40.0
NT	10.9	35.0	52.0
l.s.d	*ns*	*10.7*	*13.7*

Crop Production Grain yield was significantly higher in the NT compared to the PC treatment in 2005 (P<0.001; Table 4). There was a higher crop biomass in 2006 (P<0.001) and grain yield in 2007 (P<0.01) in the NT treatment, with no difference between PC treatments with either 50 or 100 kg/ha of DAP fertiliser.

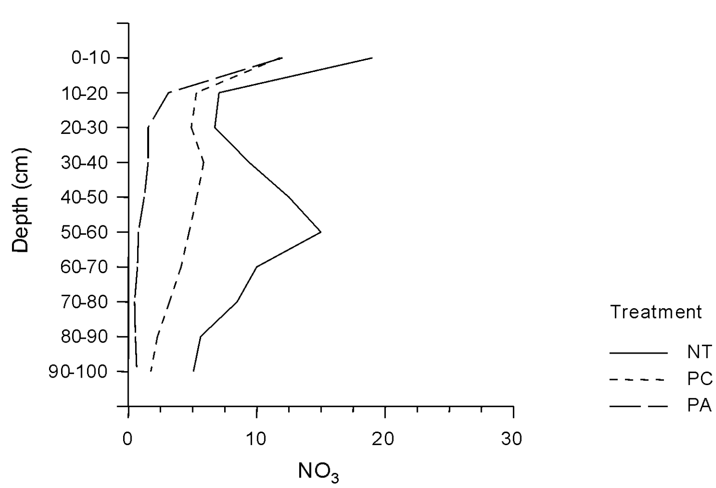

Figure 3 *Nitrate (mg/kg) measured at 10cm intervals to a depth of 100cm in PA, PC and NT.*

Table 4 *Grain yield (2005 and 2007) and crop biomass (2006) measured in NT and PC treatments in B. macra dominant pasture (l.s.d P<0.05).*

Treatment	Fertiliser	2005	2006	2007
	(kg DAP/ha)	Grain (t/ha)	Crop biomass (t/ha)	Grain (t/ha)
NT	100	1.7	1.6	2.7
PC	50	1.2	0.6	1.4
PC	100	-	0.7	1.5
	l.s.d	*0.13*	*0.21*	*0.47*

Gross margin (GM) analysis Over the three years of the experiment on average GM /ha increased from PA to PC to NT (Table 5). Higher returns were associated with higher annual volatility in gross margins. In 2006 crop growth was extremely poor due to very low rainfall and crops were grazed instead of harvested resulting in negative returns for cropping enterprises. Stubble was grazed in the NT treatment throughout the experiment.

Table 5 *Crop, grazing and total GM ($/ha) for NT, PC (50 kg/ha of DAP) and PA.*

Year	NT			PC			PA
	Crop GM	Grazing GM	Total GM	Crop GM	Grazing GM	Total GM	Total GM
2005	195.37	50.70	246.07	118.70	48.44	167.14	64.03
2006	-147.24	48.15	-99.09	-83.78	58.43	-25.35	71.25
2007	326.15	10.51	336.66	124.36	25.64	150.00	60.63
Average	124.76	36.45	161.21	53.09	44.17	97.26	65.30

Discussion The region in which pasture cropping was developed has a-seasonal rainfall that can sustain summer pasture and winter crop growth. In this region conventional farming systems have a fallow period through summer and autumn to store moisture and nutrients for the following winter crop. It was hypothesised that soil moisture would be limited in a pasture cropping system by pasture growth through summer, but data collected in this project (not shown) indicated that this was not the case in this experiment. While soil moisture may have determined differences in grain yield between years, differences in yield between NT and PC systems appeared to be explained primarily by differences in soil N. The site had a history of low fertiliser use which, together with a high density of perennial grasses actively growing through summer, reduced the accumulation of N in the profile of the PC treatment. Lower N levels substantially reduced crop biomass, even when 100 kg/ha DAP was applied to both PC and NT treatments.

Despite the capacity for N to limit production, PC was more profitable than grazing alone over the experimental period, though not as profitable as NT. However, returns from NT were highly variable which presents a challenge to farmers who are trying to maintain a cash flow. Pasture cropping reduced variability in returns due to both an increased contribution from livestock and the saving in crop establishment costs in the dry year 2006. The system also provides flexibility in decision making, an important adaptive advantage in an increasingly variable climate, since the decision to crop can be delayed until just before planting without any forgone production or financial outlay.

Even through the extremely dry years of this experiment, recruitment of *B. macra* was sufficient to replace mortality caused by the cropping process. However, the cropping process reduced the basal area of perennial grasses particularly in 2006, possibly exacerbated by a relatively aggressive sowing method used in 2005 that was rectified in following years. Summer-autumn rainfall was also well below average in each year of the experiment (59% - 2005, 48% - 2006 and 13% - 2007) further limiting the contribution of perennial grasses to the production system. The possibility of rejuvenating pastures without removing them from production attracts farmers to this technique. The system can reduce the risks associated with ground preparation and pasture establishment that is required in conventional crop – pasture rotations.

Most farmers practice this technique in degraded pastures that have a lower proportion of perennial grasses than the experimental site, and a history of higher fertiliser use, which reduces the large influence that N played in this experiment. Our experience of pasture cropping on degraded lucerne paddocks indicates little difference in crop yields between conventional and pasture cropping. In similar circumstances farmers also are finding smaller differences in crop yield between conventional and pasture cropping and that yields are more likely to be moisture driven, improving the relative profitability of pasture cropping when inputs are equal. Pasture cropping is estimated to have been adopted by over 1000 farmers throughout eastern, southern and western Australia and has the capacity to improve the sustainability of large areas of cropping and grazing land.

Acknowledgements The authors would like to acknowledge the contribution made by Daryl Cluff in developing the pasture cropping system in collaboration with Colin Seis. Funding was provided by NSW Department of Primary Industries and Grain & Graze, a national mixed farming systems research program supported by a collaborative partnership between Grains Research and Development Corporation, Meat and Livestock Australia, Australian Wool Innovation Limited and Land & Water Australia. Regional partners in this project include STIPA Native Grasses Association, Central West Conservation Farmers and Central West Farming Systems.

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