Crop yield, pasture yield, and environmental impact of pasture cropping with sub-tropical perennials.

Phil Ward[1,2], David Ferris[2,3], Roger Lawes[1,2], Nicola Palmer[1,2], Shayne Micin[1] and Phil Barrett-Lennard[2,4]

[1] CSIRO Sustainable Agriculture Flagship, www.csiro.au Email phil.ward@csiro.au
[2] Future Farm Industries CRC, www.futurefarmcrc.com.au
[3] Department of Agriculture and Food Western Australia, www.agric.wa.gov.au
[4] AgVivo

Abstract
Pasture cropping is a term applied to a farming system in which annual crops and summer-active pastures are grown concurrently. This system is becoming more common in the Northern Agricultural Region of Western Australia on sandy soils of marginal cropping capacity. A trial was established in 2008 20 km south-west of Moora, in which Gatton panic, Rhodes grass, or Siratro were grown either as pastures or as pasture-cropped plots. 'Crop only' plots were also included. Crops were barley in 2009 and 2011, and lupins in 2010, but the lupin crop failed due to dry conditions. In 2009, barley yield was significantly reduced in the Rhodes grass (3.0 t/ha) and Siratro (3.0 t/ha) plots compared with the 'crop only' (3.7 t/ha) plots, but barley yield in the Gatton panic plots (3.3 t/ha) was not significantly affected. There was no significant difference in yield in 2011, with yields averaging 3.3 t/ha. There was also no significant difference in total pasture production between 'pasture cropped' and 'pasture only' plots, although pasture growth in the pasture-cropped treatments was delayed until crop maturity. The impact of pasture on crop yield was smaller than anticipated, due to barley being highly competitive during the grain-filling period. Possible hydraulic redistribution in the perennial pasture may also play a role in limiting competition effects.

Key Words
Sub-tropical pasture, companion cropping

Introduction
In the Northern Agricultural Region (NAR) of WA, sandy soils of low fertility are relatively common. These soils usually support sparse annual pasture, and are occasionally cropped. The generally low water holding capacity, productivity and ground cover on these soils predisposes them to wind erosion, groundwater recharge and associated dryland salinity.

Many farmers in the region are establishing sub-tropical perennial grasses on these marginal sandy soils, in an effort to stabilise the soils and provide out of season fodder for grazing enterprises (Lawes and Robertson, 2008). Because the sub-tropical perennials become dormant during the winter, there might also be scope to grow a crop whilst maintaining summer ground cover. This practice is known as pasture-cropping. Perceived benefits of pasture-cropping include increased flexibility of production from marginal soils (can be grazed, harvested for grain or both), whilst reducing the risk of dryland salinity and soil erosion. However, there could be competition between the pasture and crop components for water and nutrients. The level of competition is likely to be greatest during grain filling, as the pastures will be actively growing in the warmer temperatures, and the annual crop will have not yet senesced.

In this research we test several different sub-tropical species (Gatton panic, a tufted grass; Rhodes grass, a creeping grass; and Siratro, a perennial legume) for their suitability for pasture cropping on the marginal sandy soils in the NAR of WA. This paper deals with crop yield, pasture yield, ground cover and aspects of the water balance in both pasture only and pasture-cropped plots, compared with crop-only plots.

Methods
Agronomy
A site was selected about 20 km south west of Moora on a deep sandy soil. Perennial pastures Gatton panic (*Megathyrsus maximus*), Katambora Rhodes grass (*Chloris gayana*) and Aztec Siratro (*Macroptilium atropurpureum*) were sown in September 2008 in plots of 6m x 30 m. Row spacing was 36 cm for Siratro and Rhodes grass, and 36 or 72 cm for Gatton panic, and there were 14 different treatments in total with three replicates (Table 1). Pasture growth was assessed at 6-week intervals by cutting at a height of 5 cm. Crops of Buloke barley were sown in 2009 and 2011 in the 'crop only' and 'pasture cropped' plots. Lupins were sown in 2010, but the crop failed due to dry seasonal conditions and poor crop establishment. A

knockdown herbicide (Sprayseed 1 L/ha, 2009 & 2010; Glyphosate 1 L/ha 2011) was applied to all plots prior to seeding and broadleaf weeds controlled in-crop (Barracuda, 2009; 2,4-D amine, 2011).

Soil Moisture

Neutron Moisture Meter access tubes were installed in selected treatments (Table 1) in March 2009, and measurements of soil moisture were performed at approximately 6-week intervals from June 2009. Deep drainage beyond a depth of 3.0 m was calculated from rainfall (measured on-site with a tipping-bucket rain gauge), ET_0 (Allen *et al.* 1998) and change in soil moisture storage.

Table 1. List of treatments at the Moora pasture cropping site. * indicates treatments where Neutron Moisture Meter access tubes were installed.

Treatment Code	Treatment description
CNH*, CNL	Crop only, with 80 kg N/ha (CNH) or 50 Kg N/ha (CNL)
G36*	Gatton panic only, 36 cm row spacing
G36NH*, G36NL	Gatton panic 36 cm, pasture cropped with 80 (G36NH) or 50 (G36NL) kg N/ha
G72	Gatton panic only, 72 cm row spacing
G72NH, G72NL	Gatton panic 72 cm, pasture cropped with 80 (G72NH) or 50 (G72NL) kg N/ha
R36	Rhodes grass only, 36 cm row spacing
R36NH, R36NL	Rhodes grass 36 cm, pasture cropped with 80 (R36NH) or 50 (R36NL) kg N/ha
S36*	Siratro only, 36 cm row spacing
S36NH*, S36NL	Siratro 36 cm, pasture cropped with 80 (S36NH) or 50 (S36NL) kg N/ha

Ground cover

Ground cover was assessed in April 2011 from digital photographs. Photos were taken from a height of approximately 1.5 m vertically downward, and covered a ground area of approximately 2 m^2. The proportions of bare ground, dry residue, and green leaf were measured with ImagePro Plus 7.0.

Results and Discussion

Crop and pasture growth

Growth of all pasture species was heavily dependent on seasonal conditions, as previously noted by Lawes and Robertson (2008). Of the three pasture species, Rhodes grass was the fastest to establish, and produced significantly more biomass than Siratro or Gatton panic throughout 2009 (Figure 1). Siratro produced the least biomass throughout the measurement phase, largely due to poor establishment (about 1 plant/m^2), although reasonable growth was measured in May 2010 and again in March 2012. Inclusion of a crop in the pasture significantly reduced pasture biomass during the crop growth season in all three years. However, outside the crop season (e.g. March 31 2010 and March 16 2012), pasture production was significantly ($p \leq 0.004$) greater in the pasture cropped plots than in the pasture only plots. Addition of extra nitrogen to pasture cropped plots (the NH treatments) produced a significant ($p = 0.016$) difference in pasture growth only in November 2010. At this time, pasture growth was increased by 22% for Gatton panic, 60% for Rhodes grass, and 67% for Siratro, but values were low compared with maximum production levels. It seems that higher N availability may help the pasture to grow faster as it comes out of dormancy.

Table 2. Barley yields (t/ha) in 'crop only' and 'pasture cropped' plots.

Treatment	Barley yield 2009	Barley yield 2011
CNH	3.3	3.4
CNL	2.8	2.7
G36NH	2.4	3.3
G36NL	2.6	3.3
G72NH	2.6	3.1
G72NL	2.8	3.3
R36NH	2.7	3.7
R36NL	2.5	3.5
S36NH	2.8	3.0
S36NL	2.9	3.4
LSD	*0.6*	*0.6*

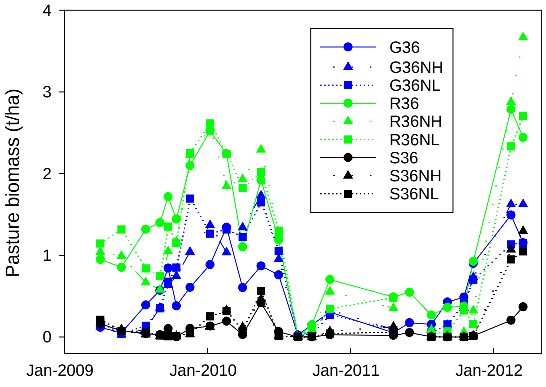

Figure 1. Pasture biomass in 2009 and 2010 for Gatton panic (blue), Rhodes grass (green) and Siratro (black).

Crop yield for lupins in 2010 was not measured due to crop failure under the very dry conditions. In 2009, barley yield was slightly depressed in the pasture cropped plots compared with the crop only plots, particularly under high nutrition (Table 2; Ferris *et al.*, 2010), possibly due to increased competition from the pasture. In 2011, crop yields were similar in all plots, despite relatively dry seasonal conditions during spring (44 mm in September and 37 mm in October). The good yields were possibly due to better nitrogen and water cycling in the 'pasture cropped' plots offsetting the impact of competition for water. In previous research with cereal crops sown into lucerne stands (Ward et al., 2004), the median decrease in crop yield was of the order of 40-50%, so yield decreases in this study were much lower.

Soil water content

As expected from previous research with lucerne and sub-tropical grasses (e.g. Ward *et al.* 2006; 2008), soil water contents under the perennials were about 100 mm lower than under the 'crop only' plot for the summer and autumn periods (Figure 2). The 'pasture only' treatments were more effective in scavenging subsoil moisture than their pasture-cropped counterparts in both summer periods (2009/10 and 2010/11), indicating that the presence of the crop does impact on root growth and water uptake by the pasture plants. Even in the top 1.2 m of soil, water uptake by the pasture was earlier in the pasture-cropped treatments, again indicating the impact of competition from the crop. Siratro was less effective than Gatton panic, largely due to the very low density (about 1 plants m^{-2}) achieved in the Siratro pasture.

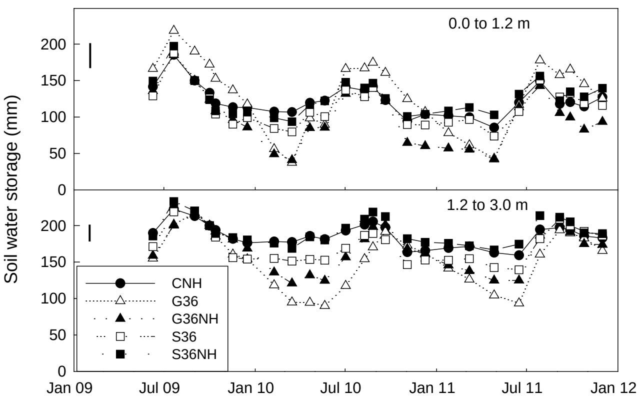

Figure 2. Soil water storage under crop only, pasture only, and pasture cropped treatments for the top 1.2 m soil (top panel) and 1.2-3.0 m soil (bottom panel). The bar indicates the LSD value.

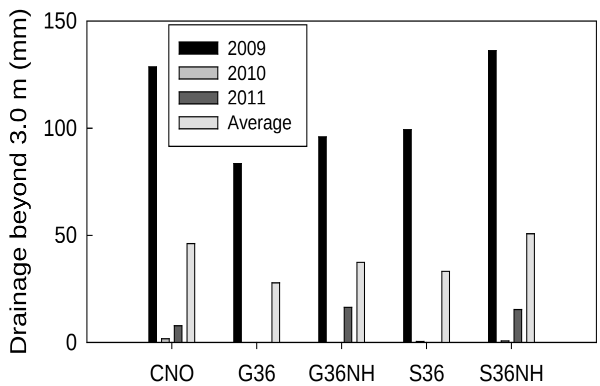

Figure 3. Deep drainage for various crop, pasture and pasture-crop treatments for 2009, 2010 and 2011.

Soil water in the top 1.2 m of soil was similar during the winter growing season for all treatments (Figure 2), although soil water tended to be higher for the Gatton panic treatment. This could be due to hydraulic redistribution as shown for other panic grasses by Sekiya *et al.* (2011), and further research will be undertaken to investigate this. In the work of Sekiya *et al.* (2011), panic grasses were proposed as a means of 'irrigating' crops grown alongside using sub-soil moisture below the crop root zone. However, crop yields from the panic plots in our experiment were generally no higher than yields from other plots.

Groundwater recharge

Deep drainage beyond 3.0 m was highest in 2009 (average 109 mm) and substantially lower in 2010 and 2011 (0.6 and 7.9 mm respectively) (Figure 3). Drainage under the Gatton panic treatments (pasture and pasture-cropped) and the Siratro pasture was significantly lower than the crop only treatment in 2009. Averaged over all three years, drainage was significantly lower relative to the crop treatment for the Gatton panic pasture, but not for any of the other treatments. Modelling with LeBuM (Ward 2006) suggests that long-term average annual drainage on an acid loamy sand at Moora could be reduced from 75 mm to 32 mm by the incorporation of Gatton panic as a pasture, and reduced to 44 mm by pasture-cropped Gatton panic. This represents a reduction in potential groundwater recharge of 41-58%.

Ground cover

In April 2011, following very dry summer conditions (29 mm rainfall from December 2010 to March 2011), there was little green leaf in any of the treatments (Figure 4). Despite this, the proportion of bare soil in the Rhodes grass treatments was significantly smaller than for many of the other treatments. Although there was no significant difference between crop plots and Gatton panic plots in bare soil percentage, we anticipate that differences will be expressed in seasons better suited to summer forage growth. Rainfall for December 2011 to March 2012 was 106 mm, but ground cover in April 2012 was not available at the time of writing.

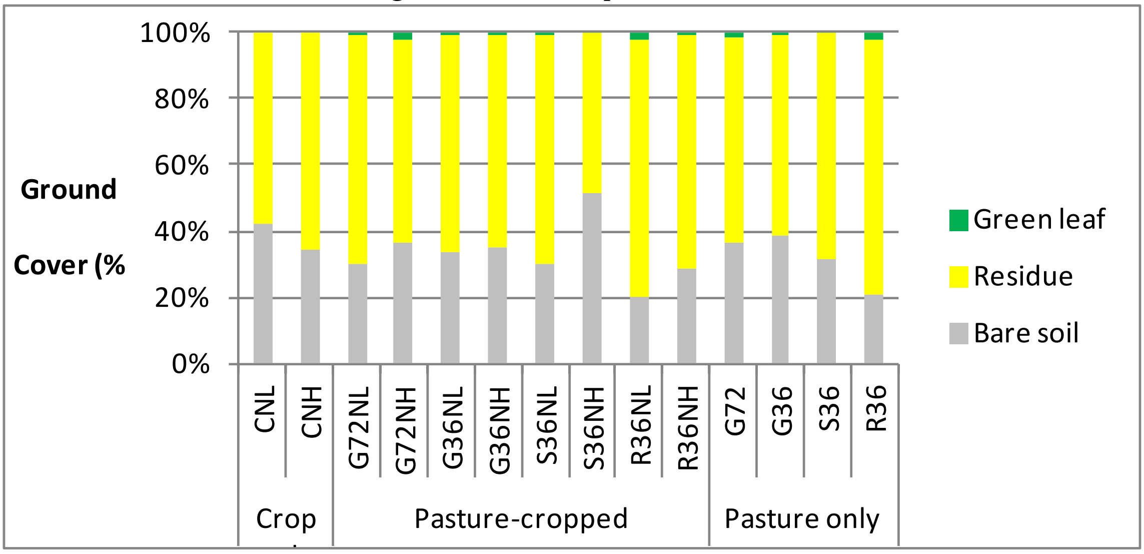

Figure 4. Proportions of green leaf, residue and ground cover for various treatments in April 2011.

Conclusions

Sub-tropical pastures can successfully be grown in the Northern Agricultural Region of the Western Australian Wheatbelt, and can be incorporated into pasture cropping systems. Rhodes grass was quick to establish, produced more dry matter than Gatton panic and Siratro, and had minimal impact on crop yield, but questions remain about digestibility and drought tolerance. Its creeping growth habit is a positive for erosion control, but poses challenges for some crop management operations. All perennial pastures tested here had positive impacts on dryland salinity risk through their deep-rooted scavenging of soil water.

Acknowledgements

Chris Vanzetti generously allowed us to onto his farm to conduct the trial, and was instrumental in site selection. Bec Parsons, Chris Herrmann and Jake Joyce all gave technical assistance, and the DAFWA Geraldton RSU managed and maintained the trial. This research was funded by the GRDC through the Future Farm Industries CRC as part of the Evercrop Project (P2 FP09).

References

Allen, R.G., Pereira, L.S., Raes, D., Smith, M., 1998. Crop evapotranspiration - Guidelines for computing crop water requirements. FAO.

Ferris, D.G., Ward P.R. and Lawes R., 2010. Buloke barley yield when pasture-cropped across subtropical perennial pastures. Agribusiness CropUpdates.

Lawes, R. and Robertson, M. 2008. Seasonal variability of Rhodes grass production in the northern West Australia wheatbelt. *In* "Global Issues. Paddock Action." Edited by M. Unkovich. Proceedings of 14th Agronomy Conference 2008, 21-25 September 2008, Adelaide, South Australia.

Sekiya, N., Araki, H., Yano, K., 2011. Applying hydraulic lift in an agroecosystem: forage plants with shoots removed supply water to neighboring vegetable crops. Plant and Soil 341, 39-50.

Ward, P.R., Bellotti, W., Butterly, C., Crawford, M., Dolling, P., Fedorenko, D., Fettell, N.A., Gaydon, D.S., Harris, R., Hirth, J., Honeysett, B., Latta, R.A., Lyons, A., Peoples, M.B., Robertson, M., 2004. High water-use farming systems that integrate crops with perennial pastures. In: Ridley, A., Feikema, P., Bennett, S., Rogers, M.J., Wilkinson, R., Hirth, J. (Eds.), Salinity Solutions: Working with Science and Society. CRC for Plant-Based Management of Dryland Salinity: Perth., Bendigo, Victoria.

Ward, P.R., 2006. Predicting the impact of perennial phases on average leakage from farming systems in south-western Australia. Australian Journal of Agricultural Research: Aust. J. Agric. Res. 57, 269-280.

Ward, P.R., Micin, S.F., Dunin, F.X., 2006. Using soil, climate, and agronomy to predict soil water use by lucerne compared with soil water use by annual crops or pastures. Australian Journal of Agricultural Research: Aust. J. Agric. Res. 57, 347-354.

Ward, P.R., Knight, S. and Barrett-Lennard, P. (2008) “Production and water use by sub-tropical grasses in south-western Australia”. International Salinity Forum, Adelaide, April 2008.