Wheat yield benefits from fallow due to stored soil water and nitrogen.

Imma Farre[1], Michael Robertson[2] and Doug Abrecht[3]

[1] Department of Agriculture and Food Western Australia, Baron-Hay Ct, South Perth, WA, Australia 6151. Email imma.farre@agric.wa.gov.au
[2] CSIRO Ecosystems Sciences, Private Bag 5, PO Wembley, WA, Australia 6913
[3] Department of Agriculture and Food Western Australia, Northam, WA, Australia, 6401

Abstract
The practice of fallowing, by omitting a year of cropping, is regaining attention in the wheatbelt of Western Australia due to the high occurrence of dry seasons in recent years and the belief that fallow can improve soil water accumulation. We evaluated the benefits of fallowing using the APSIM-Wheat crop simulation model for two locations, three soil types and two levels of nitrogen fertilizer. In the absence of fallowing, the simulated long-term (105 years) mean yields were in the range of 1.3 to 2.4 t/ha across locations and soil types. The long-term mean wheat yield benefit to fallowing was 0.2-0.3 t/ha in shallow soil, 0.4-0.5 t/ha in duplex soils and 0.5-0.9 t/ha in clay soils. Despite the fact that the current perception is that the yield benefit from fallow comes from water stored, we found that in low rainfall environments in Western Australia, the stored soil water was only responsible for half of the yield response to fallow, and that the other half of the yield response to fallow was due to extra soil nitrogen available to the wheat after fallow.

Key Words
Modelling, yield response, simulation model, soil water, soil nitrogen

Introduction
Recently, the practice of long fallowing, by omitting a year of cropping, has received renewed attention from farmers. This is particularly so in the low and medium rainfall areas of the Western Australia agricultural zone, due to two main drivers. The first driver is the reduction in sheep numbers in the farming system (Curtis, 2009), associated loss in pasture area and therefore reduced options to control weeds in the out-of-crop phase of the sequence. The second driver is a shift towards drier seasons that is associated with the drying trend in rainfall for much of the central and northern agricultural zone of WA during the last 30 years (Smith *et al*., 2000; Farre and Foster, 2009), and less reliable cropping and increasing reliance on crops to grow on stored soil moisture, as opposed to in-crop rainfall (Moeller *et al*., 2009). A number of farmers are now practising fallowing more widely on their farms and have seen impressive yield benefits to subsequent crops during the last decade of drier-than-average rainfall (Oliver *et al*., 2010). Nevertheless, it is difficult to determine whether the benefits are due to season, management, disease, weeds or nutrition.

Simulation modelling analysis can be used to understand the interactions between season, soil type, rainfall location and management on the responses to fallowing. Understanding the factors that determine the responses to fallowing will allow farmers to determine the benefits and risks from fallowing. The aims of this work were to assess: 1) the yield benefit from long fallow for different soil types in the medium and low rainfall area of the central wheatbelt of WA and, 2) how much of the yield benefit is attributable to water or nitrogen accumulation during the fallow period?

Material and Methods
The validated crop simulation model APSIM-Wheat (v.7.3) (Keating *et al*., 2003) was used to analyse the long-term yield benefits from long fallow. The simulation experiments included two sequences: (1) a traditional continuous wheat system (W–W), interspersed with a short summer (November–April) fallow and, (2) a fallow–wheat system (F–W),where there was a long (18 month) period of no cropping along with no disturbance of previous crop residues between the harvest of one wheat crop and the sowing of the next. Long-term simulations for the period 1906-2010 were run for two locations in the central wheatbelt of Western Australia (Table 1): Cunderdin, in the medium rainfall zone (mean May to September rain 250 mm), and Merredin, in the low rainfall zone (mean May to September rain 207 mm). Rainfall averages for annual, pre-season, growing season and end of season for the long-term period 1906-2010 and for the last decade are shown in Table 1.

Three soil types from the APSOIL database were used for the simulations: shallow, duplex and clay. These soils are part of the generic soils for WA and are representative of the major soils in the area. Plant available water capacity (PAWC) and maximum crop root depth were, respectively: 34 mm and 0.6 m in the shallow soil; 90 mm and 2.0 m in the duplex soil; and 134 mm and 2.0 m in the clay soil.

Simulations were performed for two nitrogen fertilizer treatments, one was the current practice for the area with nitrogen amounts typically low (N Current = 20 kg N/ha at sowing plus 40 kg N/ha four weeks after sowing), the other was a high nitrogen treatment so that nitrogen was not limiting in the good seasons (N High= 90 kg N/ha at sowing plus 90 kg N/ha four weeks after sowing). Crop management was simulated to reproduce best management practices in each rainfall zone. Soil nitrogen was initialized to 50 kg/ha at the beginning of the first year of the two year rotation, so that the soil N at sowing in the wheat following the long fallow accounted for the N mineralised and accumulated in the soil during the fallow period.

Table 1. Locations used in the simulation analysis and rainfall means (mm) for annual, pre-season (Jan-Apr), growing season (May-Sep) and end of season (Oct-Dec) over the last 105 years (1906-2010) and for the last decade (2001-2010).

Locations	Lat	Long	Years	Annual rainfall Jan-Dec	Pre-season rainfall Jan-Apr	Growing season rainfall May-Sep	End of season rainfall Oct-Dec
Merredin	-31.48	118.28	1906-2010	325	73	207	46
			2001-2010	305	82	177	47
Cunderdin	-31.66	117.25	1906-2010	361	70	250	60
			2001-2010	299	66	193	40

Results and discussion

The long term wheat yields of wheat after wheat under current N management ranged from 1.3 to 2.4 t/ha across the two locations and the three soil types (data not shown). The average yield increase of wheat after fallow compared to wheat after wheat ranged from 0.2 t/ha on a shallow soil to 1.2 t/ha on a clay soil (Table 2). There was little difference between the yield response to fallow in the last decade compared to the long-term (Table 2).

Table 2. Average yield response to fallow (t/ha) for the last 105 years (1906-2010) and for the last decade (2001-2010) for two locations and three soil types under the N current treatment.

			Soil	
Locations	Period	Shallow	Duplex	Clay
Merredin	1906-2010	0.17	0.48	0.88
	2001-2010	0.04	0.37	0.81
Cunderdin	1906-2010	0.26	0.36	0.53
	2001-2010	0.16	0.46	0.87

Under current N practices, the wheat after fallow stored between 50 and 71 mm more of soil plant available water on 1st May than the continuous wheat in the duplex and clay soils. In contrast, in the shallow soil the wheat-fallow sequence did not accumulate more water than the wheat-wheat sequence. There was little difference between the two locations and between the two periods studied (Table 3).

In Merredin, the amount of N in the soil, expressed as kg/ha N, at May 1 in the wheat following fallow ranged on average between 114 and 135 kg/ha N on the soils studied. At the same date, the soil N in the wheat crop following wheat ranged between 44 and 71 kg/ha N in the three soils. The increase in stored soil nitrogen under fallow compared to continuous wheat ranged from 40 to 70 kg/ha N. There was little difference between the two locations and between the two periods studied in stored soil nitrogen (Table 3).

The yield response to fallow, expressed as the difference between the wheat yield after a long fallow and the yield of wheat following wheat, varied from year to year. As the model does not include pests or diseases, the simulated yield response to fallow was due to water and nitrogen accumulation during the 18 months fallow period. Under the high N treatment, the N was considered to be not limiting and therefore the fallow response was attributed to water accumulation during the fallow period (circles in Figure 1). Under the high N treatment, the fallow response was greater in years with lower growing season rainfall, where the stored soil water could be used for the wheat crop after fallow. In the high N treatment, the average yield response to fallow for Merredin on a clay soil was 0.4 t/ha.

Table 3. Average increase in stored soil water (mm) and average increase in stored mineral soil nitrogen (kg/ha) under fallow compared to continuous wheat at the start of the season (1st May) for the last 105 years and the last 10 years. Results for two locations and three soil types under current N practices.

Locations	Period	Increase in stored soil water (mm)			Increase in stored mineral soil nitrogen (kg/ha)		
		Shallow	Duplex	Clay	Shallow	Duplex	Clay
Merredin	1906-2010	6	50	60	41	66	62
	2001-2010	4	52	66	33	64	63
Cunderdin	1906-2010	5	51	58	35	62	58
	2001-2010	6	60	71	45	72	68

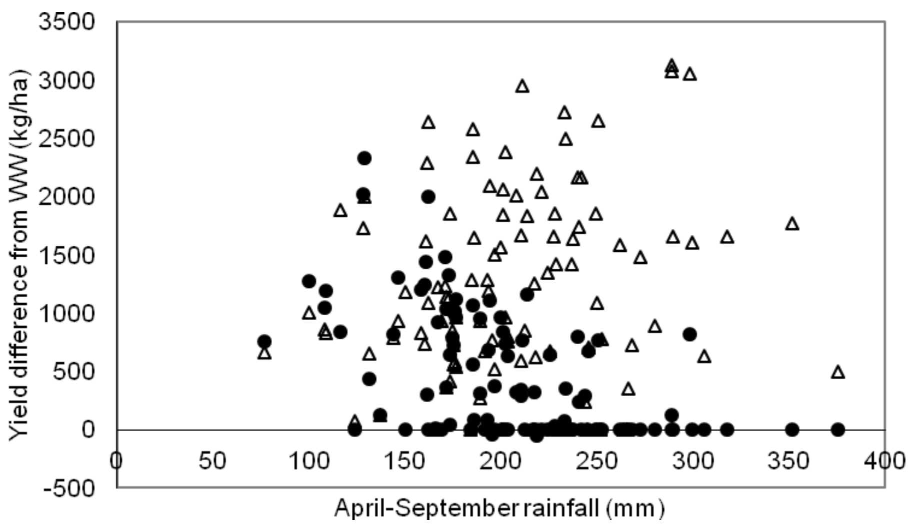

Fig. 1 Wheat yield response to fallow, expressed as yield difference between the yield of wheat after fallow and yield of wheat after wheat, in Merredin on a clay soil under N High (circles) and N current (triangles) practices.

Under current N practices, N is often limiting and the fallow response can be attributed to water and nitrogen accumulation during the fallow period (triangles in Fig. 1). The fallow response under current N practices varied from year to year, but it tended to increase with growing season rainfall, because wetter years can use the extra N accumulated during the fallow period as well as using the extra water. Under current N practices, the N accumulated during the fallow period contributed to yield in years where there was enough soil water available. Under current N practices, the highest yield responses to fallow occurred in general in years with high growing season rainfall, high soil stored water, higher soil stored nitrogen and low out of season rainfall. Years with very low growing season rainfall had in general low yield responses to fallow. In the current N treatment, the average long-term yield response for Merredin on a clay soil was 0.9 t/ha.

Under the high N treatment, the average long-term yield response to fallow was half that under the current N treatment (Table 4) on the duplex and clay soils.

Table 4. Response of simulated wheat yield (t/ha) to fallow over 106 years (1906-2010) at Merredin and Cunderdin in Western Australia on three soil types and two N treatments (N current and N high).

Locations	N treatment	Soil		
		Shallow	Duplex	Clay
Merredin	N current	0.17	0.48	0.88
	N high	-0.01	0.19	0.44
Cunderdin	N current	0.26	0.36	0.53
	N high	0.02	0.11	0.21

Conclusions

Under current N practices, the long-term mean wheat yield benefit to fallowing was lower in shallow soil (0.2-0.3 t/ha) than in duplex or clay soils (0.4-0.9 t/ha). The yield benefit to fallowing under the N current treatment, where N is typically low, was attributed to the combination of both water and nitrogen accumulated during the fallow period. Under the high N treatment, the average long-term yield response to fallow was half that under the current N treatment on duplex and clay soils. Despite the fact that the annual and growing season rainfall was significantly lower in the last decade, there was little difference between the yield response to fallow in the last decade compared to the long-term.

Despite the fact that the current perception is that the yield benefit from fallow comes from water stored, in our study we found that in low rainfall environments in Western Australia, the stored soil water was only responsible for one half of the yield response to fallow, and that the other half was due to extra nitrogen in the wheat after fallow.

References

Curtis, K, 2009. Recent Changes in the Australian Sheep Industry (The Disappearing Flock). Department of Agriculture and Food Western Australia, 15 pp.

Farre and Foster, 2009. Wheat yields and future climate in Western Australia. Climate 21 Conference http://www.agric.wa.gov.au/PC 92242.

Keating, B.A., Carberry, P.S., Hammer, G.L., Probert, M.E., Robertson, M.J., Holzworth, D., Huth, N.I., Hargreaves, J.N.G., Meinke, H., Hochman, Z., McLean, G., Verburg, K., Snow, V., Dimes, J.P., Silburn, Wang, M.E., Brown, S., Bristow, K.L., Asseng, S., Chapman, S., McCown, R.L., Freebairn, D.M., Smith, C.J., 2003. An overview of APSIM, a model designed for farming systems simulation. Eur. J. Agron. 18,267–288.

Moeller, C., Asseng, S., Berger, J., Milroy, S.P., 2009. Plant available soil water at sowing in Mediterranean environments—is it a useful criterion to aid nitrogen fertiliser and sowing decisions. Field Crops Res. 114, 127–136.

Oliver, Y.M., Robertson, M.J., Weeks, C., 2010. A new look at an old practice: Benefits from soil water accumulation in long fallows under Mediterranean conditions. Agr. Water Manag. 90, 291-300.

Smith, I.N., McIntosh, P., Ansell, T.J., Reason, C.J.C., McInnes, K., 2000. Southwest Western Australian winter rainfall and its association with Indian Ocean climate variability. Int. J. Climatol. 20, 1913–1930.