Modelling the profit and risk outcomes of a range of soil water thresholds and cropping area intensities – a whole-farm approach

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Abstract

For this study, APSFarm was used to quantify the effect of planting 'rules' involving i) the minimum quantity of soil water at planting (soil water threshold) and ii) the maximum area planted for each crop at the planting event. These options mimic farmer attitudes to quantity of stored soil water at planting and intensity of cropping. Simulations were conducted for a high rainfall zone (Dalby) and a lower rainfall zone (Goondiwindi). Greater net profit was achieved by using the lowest soil water threshold (50 mm) and by planting a greater proportion of the farm (80%) in the longer term at both sites. At Goondiwindi, both 50mm and 100mm would be appropriate soil water thresholds. At Dalby, profit was insensitive to soil water threshold up to 150mm but may benefit from increased intensity of area planted. These results demonstrate the 'next step' in farming systems analysis with modelling whole-farm scenarios which is closer to real-world farms.

Key Words

Simulation, rotation APSIM, APSFarm, frequency, profit

Introduction

Two important decisions are made by growers at the commencement of a cropping season: i) whether to plant with the available stored soil water or wait for further storage and, ii) if the decision to plant is made, what proportion of the area should be cropped or fallowed. These questions are particularly relevant to cropping areas in Queensland, Australia that rely on stored soil water, have considerable flexibility in crop type and crop sequence and can practice 'opportunity cropping' (Moeller *et al*. 2009).

In recent times, low crop yields have occurred in areas that were previously considered 'safe' farming areas and were attributed to low levels of stored soil water (Hayman *et al.* 2002). Increased cropping intensity, instigated via larger areas planted results in fewer long fallows, lower yields of individual crops but can result in greater overall profit (Freebairn *et al*. 1997). Previous studies have been conducted on a paddock basis. However, this study had the dual advantage of being able to quantify the importance of stored soil water and intensity of area planted on whole farm profit, whilst incorporating constraints that are present on real farms such as machinery work-rates, labour supply and other fixed costs. APSFarm is a dynamic simulation model that extends the APSIM model to a whole-farm level. It can simulate economic, financial, environmental impacts of alternative allocations of land, labour, time, water, livestock, machinery, and finance resources (Rodriguez *et al.* 2007).

The aim of this study was to compare the effect of increasing the intensity of cropping via decisions related to the minimum soil water threshold after which planting will occur and the proportion of the farm that is planted at each planting event. Two case-studies were conducted using farm financial structures and a crop rotation that was typical of farms in their respective low and high rainfall zones. The hypothesis of this study was that implementing lower minimum soil water thresholds and higher areas planted would increase profit but may increase risk of negative returns.

Materials and Methods

Simulations using APSFarm were conducted over 40 years for two, typical, cropping-only farms in south Queensland (Table 1). The farm structures were developed with advice from local consultants. The areas in which the farms are located experience different rainfall quantity and seasonality.

The cropping system comprised a flexible rotation including wheat, sorghum and chickpea with whole-farm and agronomic parameters listed in Table 2. The controlling rules that initiated planting in the simulations were factorial combinations of:

i) Minimum soil water thresholds at planting of 50 mm, 100 mm, 150 mm or a full profile of plant available soil water and

ii) Maximum proportion of the farm area planted to wheat or sorghum crop at each available planting opportunity, of 40% or 80%. Thus, when all other planting rules were satisfied, and fallowed paddocks were available, planting could occur until the maximum of either 40% or 80% of the total area was reached. The maximum area of chickpea was left constant at 20% to reflect a conservative approach to disease control.

Table 1. Main whole-farm parameters used in the APSFarm model

?**Factor**	Goondiwindi	Dalby
Farm area (ha)	3000	1000
Land value ($/ha)	1300	5000
Property value ($m)	3.9	5
Overhead costs ($/yr)	146 000	240 000
Tractors	250 kW + 170 kW FWA	240 kW FWA
Planter	12 m	9m
Spray rig	27 m	27 m self-propelled
Soil PAWC (mm)	174	332
Machinery loans	7% over 5 years	
Prices ($/t):	Wheat $280/t, Sorghum $160/t, Chickpea $500/t	

Table 2. Main agronomic model parameters derived from local agronomic advice used in the model

Factor	Sorghum	Wheat	Chickpea
Planting windows	15 Sept to 15 Feb	26 Apr – 9 June (late)	15 May – 31 May
Planting rain	20 mm over 4 days	Not req’d	Not required
Fertiliser (top-up to)	85 kgN/ha	85 kgN/ha	Not required
Cultivar	Medium	Early, mid or late	Standard
Density (pl/m^s)	4.5	100	30

Results and Discussion

Effect of soil water threshold on profit and risk

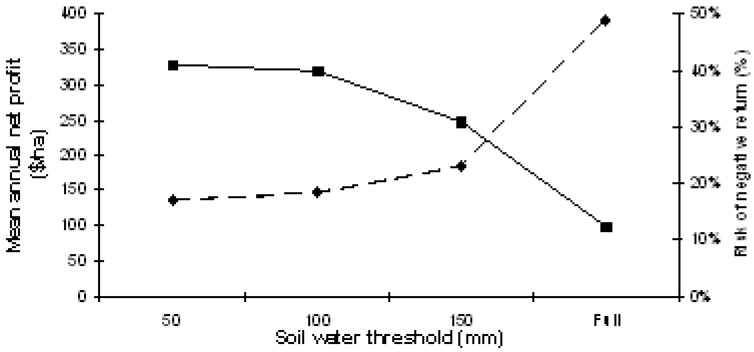
Higher minimum soil water thresholds at planting progressively reduced mean annual net profit and increased the risk of negative returns at both sites (Figure 1). At Goondiwindi there was negligible decrease in profit from the 100 mm soil water threshold rule compared to 50 mm but profit decreased significantly at higher soil water thresholds (Figure 1a). Thus in the long-term, either soil water threshold would appear to be appropriate. At Dalby, mean annual net profit was insensitive to soil water threshold up to 150 mm (Figure 1b). This reflects the higher rainfall received at this site.

The mean risk of negative returns was minimised with the lowest soil water thresholds. This reflects the long-term outcome but will not necessarily apply to crops in a single year that is planted with low stored soil water. The higher frequency of cropping outweighs individual annual effects.

The highest soil water threshold, which was a complete recharging of the soil profile before planting, significantly reduced the mean net profit and increased the risk of negative returns at both sites. The reduction in profit and increased risk of negative returns was largely a result of reduced number of crops planted (data not shown).

Combined effect of area planted and soil water threshold

The simulation indicated approximately $40/ha greater profit using the more ‘aggressive’ (80%) area-planting rule and this was reasonably consistent across the soil water thresholds at each site (Figures 2a and 2b). In combination with the soil water threshold, changing from a 100 mm, 40% area combination to a 50 mm, 80% area combination increased profit from $302/h to $345/ha. Profit was increased with the 80% area planted because of a greater total number of crops. The average annual number of crops planted was increased by 20%. Thus, whilst there is potential to increase profit in the longer-term, the trade-off is a higher cropping frequency which may put pressure on management factors such as timeliness of weed control, labour requirements and machinery required to plant larger areas quickly.



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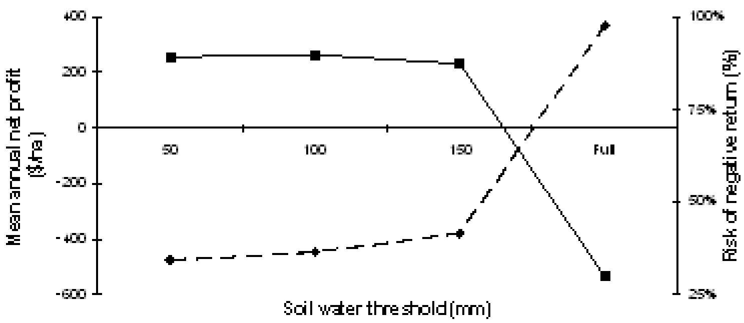

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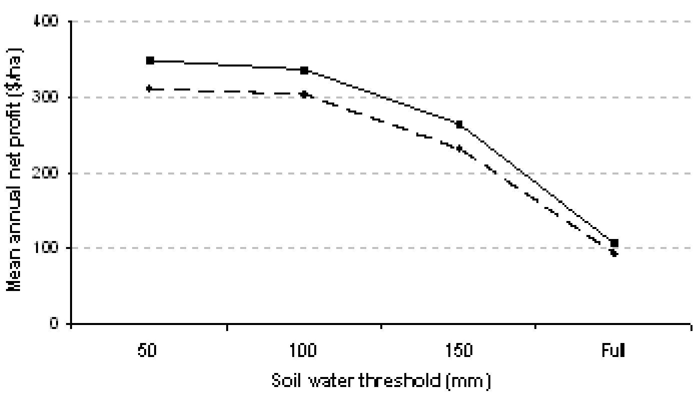
Figure 1. Effect of soil water threshold on mean annual net profit (—) and risk of negative profit (− −) of farms using the modelled rotation at a) Goondiwindi and b) Dalby in south Queensland for the period 1969 to 2009. The data is the mean of the two area planted treatments.



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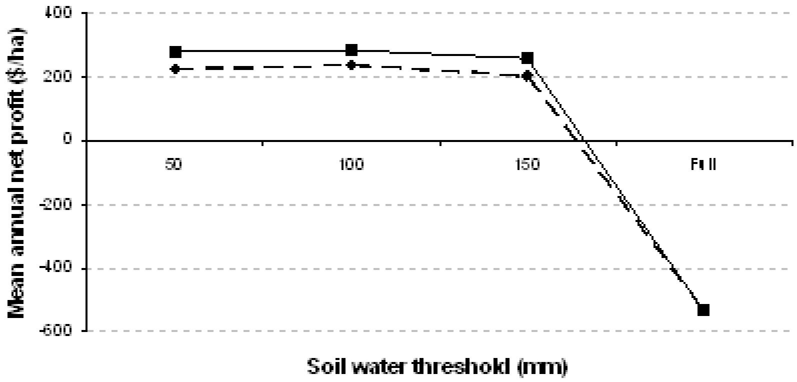

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Figure 2. Effect of area planted and soil water threshold on mean annual farm profit for a) Goondiwindi 1969 to 2008 and b) Dalby 1969 to 2008. Maximum area planted options of 80% (—) and 40% (− −) are shown.

Discussion and conclusion

This study has provided insights into the long term effects of a range of minimum soil water thresholds and maximum area planted rules for planting for s typical farm in that region and in areas of contrasting rainfall environments. In the long-term, there is a potential profit advantage from implementing the most aggressive planting rules employing minimum soil water thresholds and maximum areas planted. In the long-term the risk of negative returns is not increased by these strategies providing no other management problems are created.

However, there are trade-offs that must be taken into account. Individual crop yields are more likely to be lower with a low soil water threshold. There are tools available to provide such insights. Several consecutive low-yielding years may put pressure on farm equity and this may be an unacceptable risk to some farmers. Cropping frequency will be increased by low soil water thresholds and high proportion of area planted. This may put pressure on other management inputs such as timeliness of operations, weed control, labour requirements and machinery work capacity. Hence it is likely that farmers will opt for more conservative soil water thresholds and in some instances, cropping intensity.

A more conservative area-planted strategy may be more appropriate during dry periods and this can be examined using the APSFarm program. If climate change results in lower rainfall, analyses with altered rainfall files and/or more recent climate history, will provide insights into potential strategies. A wider spectrum of rainfall districts would broaden the conclusions regarding these long-term impacts.

A farmers' decision regarding the impact of the soil water at planting and area planted will always be a balance between the risk of achieving profitable yields for the next crop, balanced with a longer term strategies regarding thresholds for stored water and cropping intensity. This study provides input into the longer term strategies in the context of typical whole farms. The analysis could be expanded to other areas and for other input factors contained in the APSFarm modelling platform such as machinery.

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