Farming system resilience - system risks and sustainability. How much rain is needed to hit a soil water trigger for sowing in different soils and conditions? Risk and double cropping after sorghum

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Take home message

- Soil water triggers for sowing are valuable but must be matched to your environment and risk profile
- Fallows can be wasted opportunities, or valuable buffers to reset the farming system
- The greater the soil water holding capacity the more aggressive (lower plant available water) the sowing trigger can be
- Resilience in a farm business comes in many forms and strategic soil water triggers are only one avenue.

Introduction

What is resilience?

There are many forms of resilience in business, but in short it all revolves around surviving the ups and downs. In farming, the reliance on nature creates situations that can't be controlled so resilient systems have strategies or rules that help manage the risk. How conservative or aggressive the rules are depends on the individual, the enterprise and the situation. Risk is personal and different situations or different parts of a business can invoke different risk strategies. For this reason, it is not possible to present a farming strategy that will suit all situations, businesses, or grain crops. It is also difficult to focus an investigation on individual cropping strategies applied to individual paddocks when you are unaware of a whole farms' portfolio of crops, systems and enterprises. However, for the purposes of this paper, we review soil water triggers as one means of informing decisions and hence reducing the risk of those decisions.

Making decisions

The management of risk and the ability to be resilient, be that in the financial, biological, nutritional, or personal side of a farm business, depends on decisions. Every decision has a cost - the trick is to ensure the benefits outweigh the costs. This is not going to happen all the time, but the more knowledge you have about the consequences of different decisions and the ability to look at historic data beyond our own lived experiences, the more informed the decision maker will be.

The use of soil water triggers to plant crops in the northern grain zone

Over the last 30 years, the use of simulation modelling and other extension tools have demonstrated how knowing, or estimating, the amount of soil water at sowing can indicate the probability of crop success. This approach has been successful in helping growers consider the risks associated with planting a crop when there is limited water stored in the profile. It has also, following particularly dry times, been used to follow a more conservative strategy of waiting until the profile is near full to plant crops. A question often asked, particularly in the drier, more westerly areas of the northern grain's region, is it better to grow fewer crops on good soil water (i.e., include more and longer fallows) or is it better to have lower yielding crops more often (fewer fallows). Until now, much of the data used in tools such as the rainbow charts (Whish et al., 2008, Whish et al. 2014) comes from simulation studies of a single crop grown with a range of initial soil waters (Figure 1). These tools work well, but invoke a new question, if I have an 80% chance of getting 2.5 t if I sow on 100 mm, why wouldn't I wait until I have 150mm of stored soil water and have an 80% chance of getting 4.5t? Then how long would it take to get that extra 50mm? How much yield potential is lost waiting? Finally, the systems question, how often following a long fallow from wheat will I have 150mm?

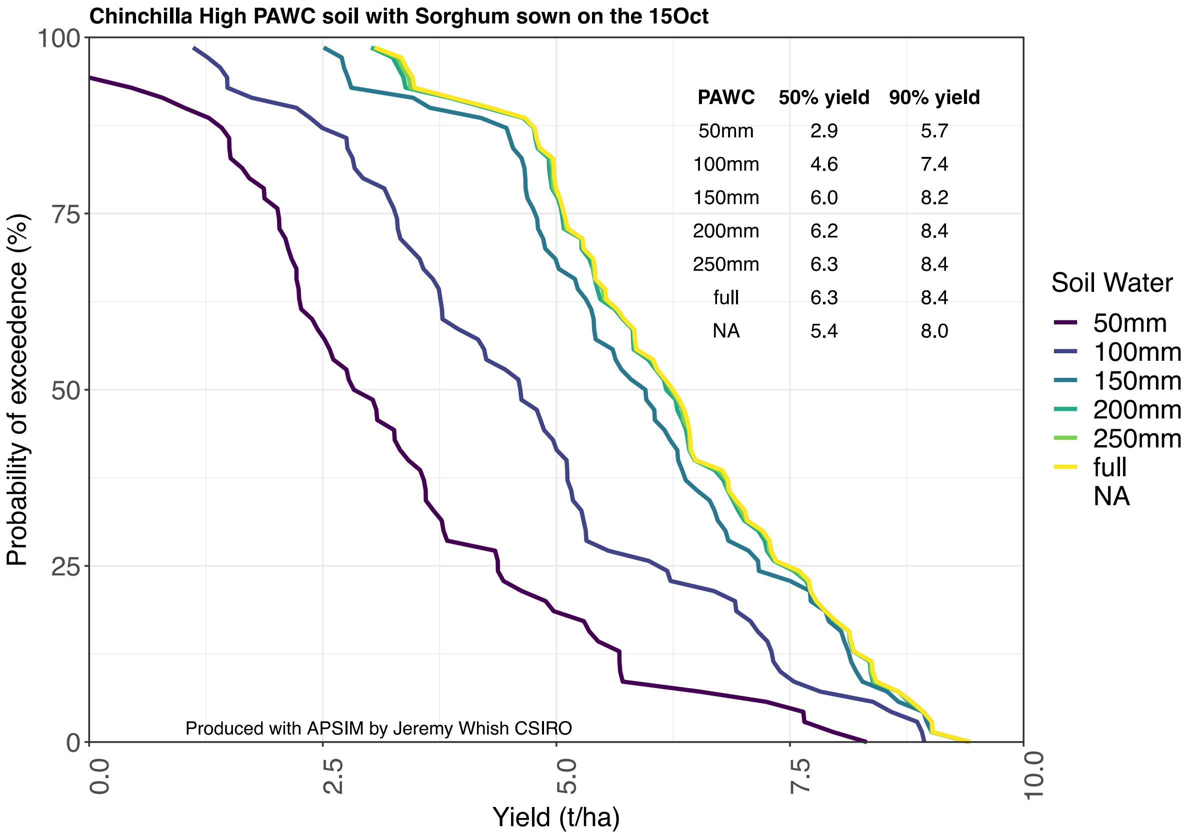

Figure 1. An example of a rainbow chart for sorghum sown on the 15th of October on a Brigalow soil with a plant available water holding capacity of 260 mm at Chinchilla

To answer the systems question and help examine the consequences of these decisions, a range of simulation studies have been prepared. All studies have their limitations and what we are presenting will apply differently in different areas or even for different people. It is not designed to be a recipe, but to show what happens in a particular environment when different rules or strategies are followed. The aim is to offer people different options that they can use to satisfy their own risk profiles. But most importantly the aim is to help people understand their environment and allow them to make more informed decisions about cropping intensity within their system.

Simulation analysis

The risk of double cropping chickpea after sorghum

Double cropping chickpea after sorghum has often been promoted as a good practice to reduce the number of long fallows in a rotation and increase the cropping intensity. In areas that tend to receive late summer or autumn rainfall, sowing pulses on a long fallow can cause waterlogging and reduce yield potential. In these environments sowing chickpea as a double crop after sorghum takes advantage of the late season development and late season water demand of chickpea to maintain yield potential. Provided sufficient rainfall occurs during the cooler low chickpea growth period. In other environments the sorghum crop removes any soil water buffer forcing the chickpea crop to survive on rainfall alone. Double cropping chickpea is probably a poor decision in these environments, especially when the high price of chickpea management is considered. How do you know if your cropping system is well matched to your environment?

Matching the cropping system to the environment at Miles

To assess how the cropping system in Miles, for example, matches the environment a simple simulation study has been constructed. In this study, the same set of crop options will be examined in three different ways. Firstly, we use a fixed rotation (called 'Fixed') where three crops are sown in 3 years (sorghum then double crop chickpea, short fallow to wheat and long fallow back to sorghum). The decision to plant a crop is based on rules and sowing triggers (Table 1). In the Fixed treatment, if the sowing rules are not met during the sowing window, the crop is sown at the end of the window so that a crop is always sown. This is described as the 'must sow' rule.

The second sequence is the Flexible (called 'Flex') sequence. This sequence is the same as the Fixed rotation for the 'must sow' rule applied to the sorghum and wheat phase, but chickpea is only sown if the soil water conditions are satisfied. This means that if a sowing opportunity is not achieved chickpea is skipped and the rotation continues onto a long fallow back into wheat. This is described as the 'opportunity sow' rule.

The third sequence is the free sequence (called 'Free'). Here, any crop can be sown whenever the rules allow (i.e., all crops are sown with the 'opportunity sow' rule; Table 1). In this situation, the only limitation to a crop being sown are the sowing rules. This means that a true sequence is not followed, but it highlights what opportunities exist to increase intensity and the costs of these increases. This approach is a good way to see how often an environment can support a double cropping option and if the double cropping option should be considered regularly or only opportunistically when the environmental signals allow.

The Fixed, Flex and Free sequences were each simulated for a 64-year period using historical weather data at Miles.

In keeping with the request from the updates committee we have conducted this analysis on three different soil types, which have been selected as close to the local area as possible. These soils are: a Brigalow type Grey Vertosol with a plant available water holding capacity (PAWC) of 250 mm, a Brigalow Belah type Grey Vertosol with a PAWC of 160 mm and finally, a red Sodosol with a PAWC 120 mm.

Table 1. Summary of the different management rules applied to the scenario analysis

System Code	Crops	Rules	PAW mm
Fixed	Wheat	Must sow	110
	Chickpea	Must sow	100
	Sorghum	Must sow	120
Flex	Wheat	Must sow	110
	Chickpea	Flexible	100
	Sorghum	Must sow	120
Free	Wheat	Last not winter cereal	110
	Chickpea	2 crop break	100
	Sorghum	2 in row	120

In general, across the three different rotation approaches the more PAWC the soil can hold, the greater the potential returns. This is an uncontrollable variable as you generally can't increase soil water holding capacity, and so is included as part of the environment. For simplicity, discussion in the remainder of the paper will focus on the soil with intermediate PAWC (Brigalow Belah type Grey Vertosol with160 mm PAWC).

The Fixed rotation had a crop sown at every point of the sequence with the same number of crops sown over the 64-year period (22 crops each). This sequence gave the lowest returns and had 17 percent of crops returning a negative gross margin (Table 2).

If we look at the Flex rotation that only sowed chickpea when the sowing trigger was met, 10 fewer crops were sown, yet the average annual income improved by $18 dollars/ ha (Table 2).

The Free rotation applied the 'opportunity sow' sowing rule to all crops, and as a result over the 64 years sowed 1 additional crop compared to the Fixed system. However, annual returns were increased by $96, while the risk of negative gross margins increased by only 2% (Table 2). This highlights the value of having robust sowing rules and following them. The idea that seed won't grow in the shed, so you may as well plant it has a cost, and in this analysis, we have only considered the general gross margin cost of the failed or negative gross margin crops, not the cost of logistics, stress and overheads that are also associated these crops.

However, despite the Free sequence having a greater return, it was not significantly more aggressive than the Fixed rotation and not significantly more risk adverse than the Flex rotation with less than 10% of crops having a negative gross margin. Clearly the 'opportunity sow' decision rules worked in this example, but where were the gains and losses made?

Table 2. A comparison of the mean annual gross margins for each system after 64 years and an estimate of the risk required to achieve them

Treatment	Soil PAWC	No. Crops sown	Mean annual gross margin ($/ha/yr)	Percent crops with negative gross margin (%)	Intensity (crops/yr)	Return on investment ($/$)
Fixed	120	66	279	29	1	0.60
Flex	120	54	293	20	0.86	0.70
Free	120	60	396	7	0.95	0.87
Fixed	**160**	**66**	**401**	**17**	**1**	**0.90**
Flex	**160**	**56**	**418**	**7**	**0.88**	**1.04**
Free	**160**	**67**	**497**	**9**	**1.05**	**1.04**
Fixed	250	66	553	15	1	1.22
Flex	250	56	578	4	0.88	1.41
Free	250	67	671	1	1.05	1.41

Still focusing on the 160mm soil, the Flex rotation planted the lowest number of chickpea crops (Table 3) but had the highest average annual returns for them (Table 4). The Free rotation reduced the number of chickpea and wheat crops compared to the Fixed rotation, but increased the number of sorghum crops (Table 2). This shifting from a 33% summer, 66% winter sequence in the Fixed rotation to 48% summer 52% winter in the Free sequence, may be due to our rules that allowed for two sorghum crops to be sown in a row and it may not suit the portfolio across a whole farm. However, it does raise the question if there are more opportunities for summer crops that are currently not being considered?

Table 3. The number of individual crops sown in each rotation over the 64 years of simulation.

Treatment	Soil PAWC	Chickpea	Sorghum	Wheat
Fixed	120	22	22	22
Flex	120	11	22	22
Free	120	18	28	15
Fixed	**160**	**22**	**22**	**22**
Flex	**160**	**12**	**22**	**22**
Free	**160**	**17**	**32**	**18**
Fixed	250	22	22	22
Flex	250	12	22	22
Free	250	20	33	14

Table 4. The number of individual crops sown in each rotation over the 64 years of simulation.

Treatment	Soil PAWC	Chickpea	Sorghum	Wheat
Fixed	120	291	452	68
Flex	120	657	429	95
Free	120	498	476	202
Fixed	**160**	**409**	**536**	**221**
Flex	**160**	**816**	**517**	**253**
Free	**160**	**520**	**503**	**382**
Fixed	250	546	758	303
Flex	250	1021	729	394
Free	250	721	629	557

Matching cropping intensity to the environment using clearly definable rules such as soil water triggers is one way to reduce risk and improve the resilience of a farming enterprise. In the example of the low 120 mm PAWC soil, the cropping intensity was reduced by the Free sequencing approach, suggesting that resources within this environment are limiting and that without the buffering capacity of a higher PAWC soil, a lower intensity strategy should be followed. This can be created by increasing the trigger values for the individual crops.

Conclusion

The purpose of this paper is not to promote a sequence or a practice for any particular soil type within the Miles region. What we have tried to demonstrate is the value of matching your soil water trigger for sowing to your risk profile, and your targeted sequence of crops to the environmental potential of your paddock. Every decision has a cost: in the example presented, the strategy of sowing all crops on a trigger and having a structured set of rules improved overall returns. However, this came at a cost, with more lower valued sorghum crops sown, which in turn, resulted in fewer, but more profitable wheat and chickpea crops. Over any period, there is a finite supply of resources, so the trick is to make the best use of them without knowing what to expect next. The tools presented here have been developed as part of the northern farming systems project and our aim is to use them with growers and consultants to refine and explore options within their own region. Over the next 3 years it is hoped to run a series of workshops that will allow a more personalised exploration of system ideas using these tools. Finally, this paper has focused on the soil water decision; in other work we have focused on the sowing date and crop choice decision. For these decisions, we have observed how delays in sowing have reduced yield potential, but these delays were not due to uncontrollable climatic factors as in this paper but were due to logistics and the trade-off between efficiency and capital outlay.

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