Identifying high value tactical livestock decisions on a mixed enterprise farm in a variable environment

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Summary

Context: Australia is renowned for its climate variation featuring years with drought and years with floods, which result in significant production and profit variability. Accordingly, to maximise profitability, dryland farming systems need to be dynamically managed in response to unfolding weather conditions.

Aim: The aim of this study is to identify and quantify optimal tactical livestock management for different weather-years.

Method: This study employs a whole farm optimisation model to analyse a representative mixed enterprise farm located in the Great Southern region of Western Australia. Using this model, we investigate the economic significance of five key livestock management tactics. These include, timing of sheep sales, pasture area adjustments, rotational grazing, crop grazing and sheep nutrition adjustments.

Key results: The results show that, on the modelled dryland mixed enterprise farm in the Great Southern region of Western Australia, short-term adjustments to the overall farm strategy in response to unfolding weather condition increase expected profit by approximately 16%. Each tactic boosted profit by between $7,704 and $53,171. We outline, however, several complexities that farmers must consider when implementing tactics.

Conclusions: The financial gains from short-term tactical management highlight their importance and farmers' need to develop and apply those skills. The tactical skills promote business resilience and adaptability in the face of climate uncertainties.

Implications: The study highlights the economic value of dynamic livestock management in response to climate variations, offering farmers in the Great Southern region the means to underpin profitable and sustainable farm practices.

Introduction

Climate variation is a constant challenge to managing mixed enterprise farming systems in Australia; with the incidence of drought especially complicating sheep management when feed and water supplies become increasingly scarce and expensive. To handle climate variation, farmers can alter their "big-picture" strategic management to set up a more versatile and diversified enterprise mix of their farm business (Azam-Ali, 2007, Kandulu et al., 2012). However, Kandulu et al. (2012) suggest that in many locations a sole focus on diversification does not wholly mitigate the financial effects of climate variation. An alternative management method, applicable by farmers to manage their external variations, is to implement short term tactical adjustments in response to unfolding conditions (Anderson et al., 2020).

Tactical management is most valuable within systems where farmers have a wide portfolio of tactics for use in response to an external change (Cowan et al., 2013). This is the case in mixed farming systems where there are many livestock tactics that can be implemented throughout the year in response to unfolding weather conditions, including sale or purchase of stock, adjustment of stock liveweight targets, adjustment of grazing management, adjustment of pasture area and pasture manipulation (Young et al., 2022). In mixed crop and livestock businesses, farmers can adjust enterprise allocation, their interactions and relevant tactics to better suit unfolding climate conditions. The efficacy and value of this suite of adjustment or tactics is commented upon by Pannell et al. (2000) who discuss the inclusion of risk attitudes and production and price risk in farm analyses. They conclude that the most important aspect of risk management is a farmer's short-term tactical responses to variation in weather and prices.

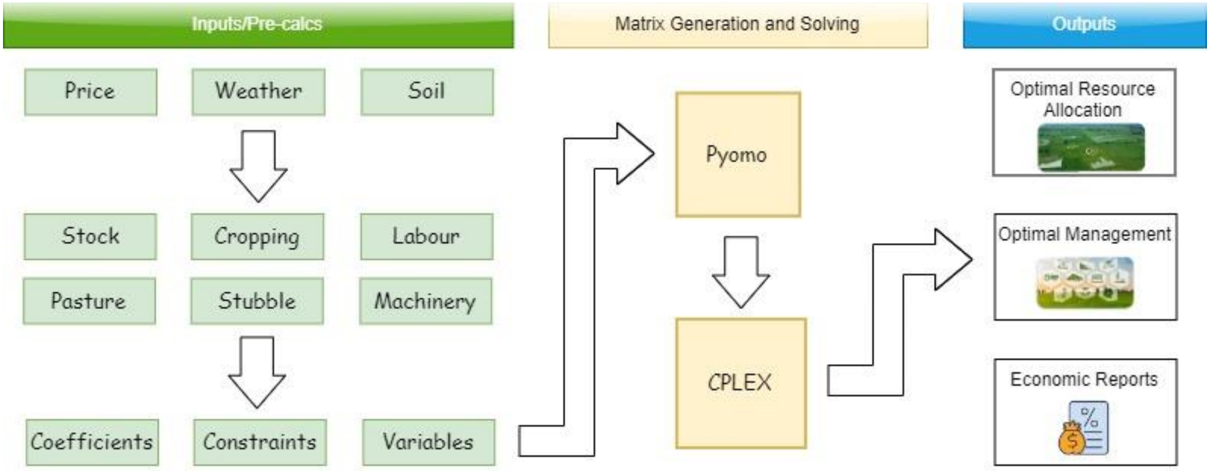
In this paper, we apply a whole farm optimisation model that firstly represents year-to-year variation and secondly includes an extensive array of tactical management options tailored to that variation. The model is used to identify and quantify optimal tactical livestock management for different weather-years.

Methods

Model description

The whole farm model called **A**ustralian **F**arm **O**ptimisation Model (AFO) is applied in this study. AFO is a whole farm linear programming model that supersedes the popular MIDAS model (Kingwell and Pannell, 1987, Pannell, 1996, Kopke et al., 2008, Bathgate et al., 2009, Kingwell, 2011, Young et al., 2011, Thamo et al., 2013, Young et al., 2020). A brief summary of the model is provided below. For a more thorough description see the model's documentation: https://australian-farm-optimising-model.readthedocs.io/en/latest/index.html.

Figure 1: Visual representation of AFO



The model represents the economic and biological detail of a farming system, including modules for rotations, crops, pastures, sheep, crop residues, supplementary feeding, machinery, labour and finance. Furthermore, it includes land heterogeneity by considering enterprise rotations on a range of soil classes/land management units (LMU). AFO was selected as an appropriate tool to evaluate optimal tactical livestock management in a mixed enterprise, broad acre farming system for several reasons. First, it includes year-to-year climate variation and a large relevant range of tactical management options including; adjusting the number of stock, altering rotations, altering stock liveweights, selling livestock, altering supplementary feeding, manipulating grazing timing and intensity, deferring pastures, and crop grazing. Secondly AFO leverages powerful algorithms to efficiently identify the optimal management for a given farm system. Finally, AFO also has detailed feed budgeting modules that help identify the optimum utilisation of feed sources across the whole farm.

Overview of the farm system

AFO was calibrated to represent a typical farm in the medium rainfall zone of the Great Southern region of Western Australia.

The Great Southern region in Western Australia is characterised by winter-dominant rainfall (400–650 mm) and a 6-month growing season that supports a mix of cropping and livestock enterprises. Weather variance in the region was approximated by eight discrete states of nature (see Table 1). Soil data representing the land management units are defined in and other key features of the modelled farm are shown in Table 3. The standard prices for wool, meat and grain used in the analysis were based on the 70th percentile prices received over the last 13.5 years for wool, 18.5 years for meat and 14 years for grain (Source: Mecardo, 2023) Table 4 and Table 5.

Table 1: Summary information for each weather-year represented in the Kojonup version of the AFO model.

Code for weather -year	Definition of each weather-year	Probability of occurrence	Growing season rainfall	Crop yield scalar[4]
z1	Early break[1] with follow up rains and a good spring[3].	24%	447	1.2
z2	Early break with follow up rains and a poor spring.	20%	346	1.0
z3	Early break that turns out to be a false break[2] but is followed by a good spring.	8%	416	1.22
z4	Early break that turns out to be a false break and is followed by a poor spring.	4%	294	0.87
z5	Medium break with follow up rains and a good spring.	14%	448	1.05
z6	Medium break with follow up rains and a poor spring.	16%	392	0.83
z7	Late break with follow up rains and a good spring.	4%	477	0.95
z8	Late break with follow up rains and a poor spring.	10%	337	0.65

[1] Early break (i.e. start of the growing season): before the 5th May; Medium break: between the 5th May and 25th May; Late break: after the 25th May.

[2] False break: pasture feed on offer reaches 500 kg/ha followed by 3 weeks of no growth.

[3] Good spring: above the median (86 mm) rainfall for September and October; Poor spring: below the median rainfall.

[4] Yield scalar is the relationship between yield in the given weather-year and the average yield. This was calculated using the output of APSIM modelling using Kojonup climate and soil data from 1970 - 2019.

Table 2: LMU definitions for a typical farm in the Great Southern region of Western Australia.

Soil class	Description	Arable %	Grazing area (ha)
Deep sands	Deep sands but not waterlogged. Over mottled clay.	100	150

Sandy gravels	Gravels and sandy gravels to 50 cm over clay or gravelly clay.	80	1230
Sandy loams	Sandy loam, loamy sand over clay rock outcropping in landscape.	80	750

Table 3: Key features of the modelled farm.

Farm size (ha)	2130
Time of lambing	'Spring' lambing (lambing starts mid July)
Pregnancy scanning management	Scanning for pregnancy status only
Sheep liveweight	Nutrition profile is optimised by AFO
Sheep genetics	Medium frame merino
Standard reference weight (kg)	55
Fibre diameter (μ)	20
Canola yield (t/ha)[1]	
Roundup-ready	2.6
Standard (non-GM)	2.2
Wheat yield (t/ha)[1]	4.5
Barley yield (t/ha)[1]	5.0
Oat yield (t/ha)[1]	4.5
Hay yield (t/ha)[1]	8.0
Lupin yield (t/ha)[1]	2.5
Faba bean yield (t/ha)[1]	3.0

[1] Reported yield is on LMU 4 (best-performing areas of the farm) in a canola–cereal or pulse-cereal rotation weighted across all weather-years.

Table 4: Meat and wool prices in the analysis (before fees). Source: Mecardo (2023)

Prime Lamb [1] ($/kg)	Store lamb [2] ($/kg)	Export wether [3] ($/hd)	Breeding ewe [4] ($/hd)	Mutton ($/kg)	Wool [5] (c/kg)
6.98	6.24	112	127	4.87	1432

[1] 18 kg carcass weight Merino prime lamb, maximum age is 15 months with a 10% discount after 12 months of age.

[2] Lambs younger than 15 months sold to other graziers.

[3] Wethers sold to the export market. No sales between May and July inclusive.

[4] 5.5 yo Breeding ewes in condition score 3. There is a 10% premium for ewes sold at 19 mo or younger.

[5] Fleece price (c/kg) for clean 20 micron wool.

Table 5: Grain prices in the analysis (before fees). Source: Mecardo (2023)

Canola ($/t)	Wheat ($/t)	Barley ($/t)	Oats ($/t)	Lupins ($/t)	Faba bean ($/t)

566	301	283	235	305	350

Tactics examined

Farmers have a large array of tactics they can apply as the year unfolds and many of these are represented in AFO. However, in this study we only examine some of the more common livestock tactics and so focus on the following tactics:

i) Sale quantity and timing – additional classes of sheep can be sold or retained in response to the unfolding years condition.

ii) Pasture area and rotation – the area of pasture can be adjusted based on the time of break and pasture can be established in paddocks with different land use histories that impact germination (e.g. continuous pasture has a higher germination than pasture following multiple years of crop).

iii) Grazing management – depending on the unfolding year stock can follow different grazing management (e.g. pasture can be deferred for longer in weather-years in which pasture growth is limiting).

iv) Crop grazing – crops can be grazed early in the growing season when pasture is limiting or to allow pasture to be deferred.

v) Stock nutrition profile – animals can gain more weight in a good year and lose more weight in a poor year.

Results

Value of tactics and strategic impact

Dynamically managing farming systems in response to unfolding weather conditions increases expected profit by $128,000 (16%) (Table 6). Tactical management has a large impact in early break years that have no follow up rain (z2 and z3) (Table 6). This is largely because in the Great Southern region of Western Australia false breaks do not affect crop production (Table 1). However, pasture production during the false break period is significantly reduced. Thus, tactical adjustments have the potential to significantly boost profit in those years.

A farm managed with a full complement of tactics has a different overall strategy to a farm managed with minimal tactics. For example, with tactics, the optimal overall stocking rate is increased by 30% (Table 7). Thus, the change in profit reported in Table 6 is not necessarily a reflection of the importance of including tactics in a given weather-year. For example, other results (not included here) show that the value of tactics in z7 is $90,000 (105%). Utilising tactics in z7 (a poor weather-year) allows the profit to remain similar whilst the strategic stocking rate is increased.

All tactics have a significant impact on farm profit (Table 8). However, due to interactions between the different tactics, the exact value depends on the complement of tactics being applied.

Table 6: Weather-year profit with full tactics versus minimal tactics.

Weather-year	Full tactics ($'000)	Minimal tactics ($'000)	Change $'000 (%)
Expected [1]	904	776	128 (16%)
z0	1,345	1,164	181 (16%)
z1	990	872	118 (14%)
z2	1,068	767	301 (39%)
z3	370	106	264 (250%)
z4	931	876	56 (6%)
z5	624	527	98 (19%)
z6	836	778	59 (8%)
z7	187	183	4 (2%)
Minimum [2]	186	105	81 (44%)
Maximum	1,344	1,164	180 (13%)

[1] Weighted average of weather-years

[2] Minimum & maximum profit across the weather years

Table 7: Summary of farm strategy with full tactics and minimal tactics.

	Full tactics	Minimal tactics
Profit ($'000)	903.5	775.7
Stocking rate (DSE/winter grazed ha)	18.6	14.3

Supplement fed (t)	937.3	829.8
Pasture area (%)	35.6	39.2
Cereal area (%)	39.4	38.7
Canola area (%)	25.0	22.1

Table 8: The expected change in profit of including and excluding each tactic individually.

	Crop Grazing ($'000)	Pasture grazing ($'000)	Rotation ($'000)	Stock sale ($'000)
All in [1] - remove each tactic	$53	$17	$28	$14
All out [2] - add each tactic	$27	$44	$30	$8

[1] Calculated by a model with all tactics included, then each tactic removed individually.

[2] Calculated by a model with all tactics excluded, then each tactic added individually.

Key tactical decisions

In early break years it is optimal to increase the canola area by up to 55% and in late break years it is optimal to decrease canola area by 55% (Table 9). All of the tactical rotation adjustments occur on the productive soils (LMU 3 and LMU 4). Sandy soils (LMU 2) are never tactically adjusted and always remain in continuous pasture (Table 9). The difference in rotation selection based on the presence or absence of follow up rains in early breaks shows that in years with an early break it is optimal to delay the rotation decision on a proportion of the area until follow-up rains are received. The results in this paper only report the changes in land use area on each soil type. However, the adjustments are fine-tuned based on the rotation history. This is accounted for in AFO, but for simplicity we have not reported the full rotation changes.

Under minimal tactics, all pasture is grazed at a similar intensity and all paddocks have a similar level of FOO. Optimal management employs rotational grazing, grazing low FOO paddock lightly to maximise growth (Figure 2). In early break weather-years it is optimal to graze pastures heavily early and then defer them by grazing crops.

The optimal level of crop grazing correlates with the break of season timing, where early break seasons have the highest level of crop grazing (Table 10). After an establishment period, crops can be grazed. However, it is optimal to further delay grazing to increase relative availability of the feed. At low FOO levels the relative availability of pasture is low, which reduces intake and nutritive feed values for sheep. At low nutritive value the yield penalty outweighs the value of grazing. Hence, in late break and false break years, some of the crop available for consumption is not grazed (Table 10). Crop grazing is economical even in favourable weather-years because the stocking rate is increased, which outweighs the negative impact of yield loss.

The majority of sales that differ based on weather-year conditions are related to stock less than 18 months of age. Additionally, there are some smaller tactical sales of sheep that include the oldest age group of ewes. Adjusting only the youngest and oldest age group of animals allows the breeding strategy to remain constant, suggesting that destocking of ewes in a poor year is not profitable due to the opportunity cost caused by being understocked in the subsequent years. The farm strategy (minimal tactics) is to sell the heavy proportion of wethers at 8 months of age and the remainders after the second shearing at 18 months of age (Figure 3). With tactical management included the general strategy is similar however, in years with a false break or a poor spring, a large proportion of the wethers are sold after shearing at 5.5 months of age. Additionally, in years with a false break, a greater proportion of wethers are sold at 8 months of age.

Implementation of these short-term tactical management increases the optimal winter stocking rate (Table 11), whilst reducing supplement fed per DSE in five out of eight weather-years (Table 12).

Table 9: Optimal land use choice on each LMU for each weather-year.

Weather-year	Pasture (ha)			Cereal (ha)			Canola (ha)		
	LMU2	LMU3	LMU4	LMU2	LMU3	LMU4	LMU2	LMU3	LMU4
Expected[1]	150	108	500	0	720	119	0	402	130
z0	150	95	424	0	537	100	0	598	227
z1	150	95	424	0	537	100	0	598	227
z2	150	107	475	0	612	209	0	511	67

z3	150	107	475	0	612	209	0	511	67
z4	150	132	620	0	920	84	0	178	46
z5	150	132	620	0	920	84	0	178	46
z6	150	99	506	0	956	182	0	175	62
z7	150	99	506	0	956	182	0	175	62
Minimal tactics[2]	64	498	271	86	424	315	0	308	164

[1] Weighted average of weather-years

[2] All weather-years are the same without tactics

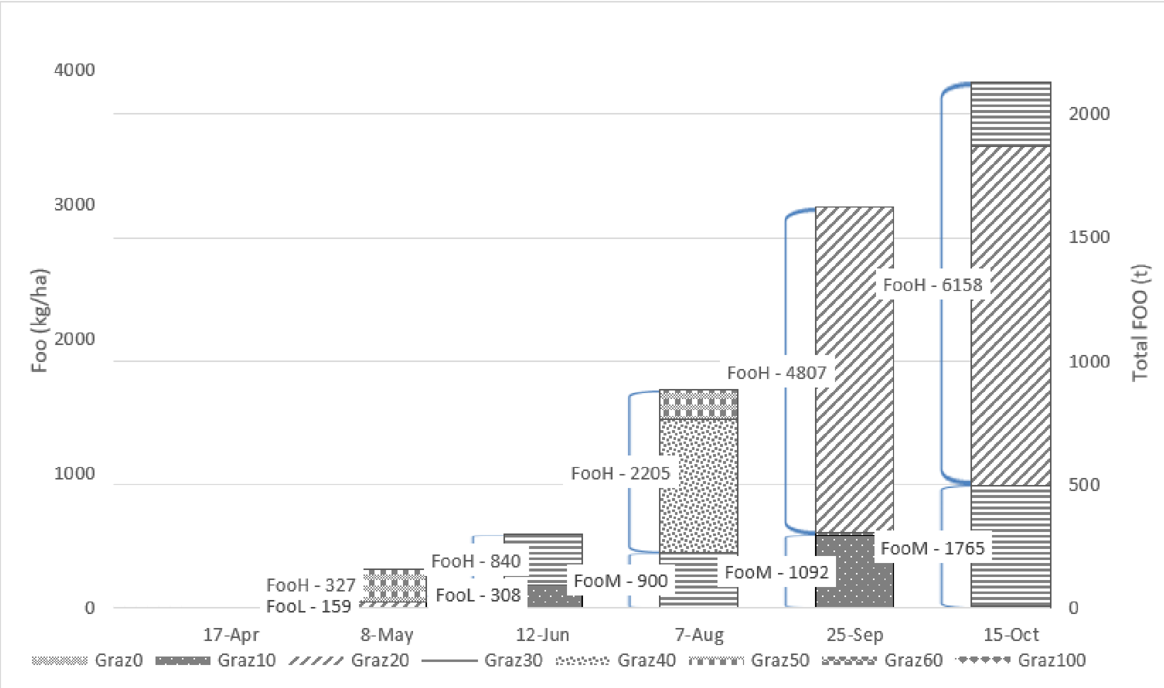


Figure 2:Full tactics green pasture grazing summary for LMU4 and z4. The columns indicate both the total FOO and FOO per hectare at the specified date. The data labels indicate the FOO per hectare of each FOO level. The shaded segments indicate the grazing intensity where Graz100 means grazing all the available feed (including the growth).

Table 10: Tonnes of crop grazing in each weather-year.

Weather-year	Crop consumed (t)	Available proportion consumed (%)
Expected[1]	386	85%
z0	543	100%

z1	543	100%
z2	395	89%
z3	395	89%
z4	329	100%
z5	329	100%
z6	4	4%
z7	4	4%
Minimal tactics [2]	0	-

[1] Weighted average of weather-years

[2] All weather-years are the same without tactics

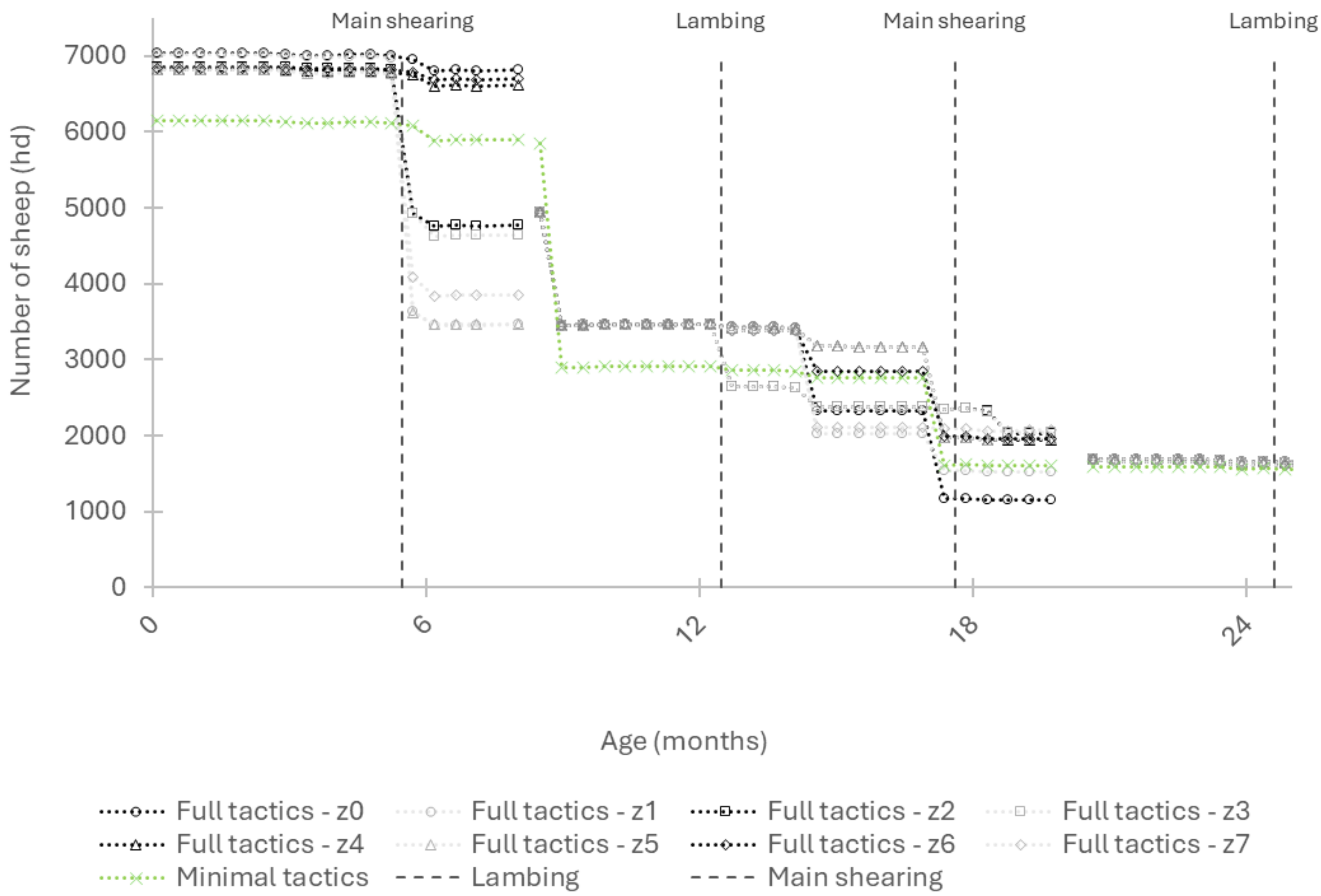


Figure 3: Sheep numbers by age group in each weather-year. Note: There is a gap in the graph at 8 months and 20 months which is the beginning of the next year at which point all weather years have the same opening numbers and they can then diverge again.

Table 11: Winter stocking rate in each weather-year

Weather-year	Stocking rate (DSE/WgHa)
Expected[1]	18.6
z0	21.1
z1	21.1
z2	18.3
z3	18.3
z4	15.3
z5	15.3
z6	18.0
z7	18.0
Minimal tactics[2]	14.3

[1] Weighted average of weather-years

[2] All weather-years are the same without tactics

Table 12: Supplement fed in each weather-year with full tactics vs minimal tactics.

	Full tactics		Minimal tactics	
Weather-year	Total (t)	Kg/dse	Total (t)	Kg/dse
Expected[1]	1053	80	963	82
z0	1173	87	1065	90
z1	889	69	620	53
z2	1010	78	1255	107
z3	1614	122	1989	171
z4	898	68	795	68
z5	1011	77	963	83
z6	1095	84	782	67
z7	1173	87	1065	90

[1] Weighted average of weather-years

Conclusion

Short-term adjustments to the overall farm strategy in response to unfolding weather condition can result in substantial improvements in expected profit on dryland mixed enterprise farms in the Great Southern region of Western Australia (by approximately 16%). Benefits stem firstly from capitalizing on knowledge about the profitability of different decision tactics tailored to the unfolding weather conditions. Secondly, the benefits accrue from more optimally selecting the underlying farm management strategy of the farm business. Deterministic models and even stochastic models which do not include activities for tactical adjustments miss this key feature of the system and may incorrectly identify optimal activities.

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