Farming Systems trial machinery

Ben Jones *(Mallee Focus and BCG)*

Aim

To see how different the machinery requirements are in different farming systems.

Take home messages

- *Different farming systems can have similar timeliness requirements during critical periods and are likely to need similar capacity machinery*
- *There are substantial differences in annual hours and hectares accumulated for different machines in different systems*
- *These are likely to lead to big differences in the costs associated with machinery in different systems.*

In 2002, Fiona Best (BCG) surveyed the BCG Farming Systems trial champions to develop a machinery inventory for a hypothetical 1500ha southern Mallee farm representing their systems (Best 2002). Flushed with success from the 2000 and 2001 seasons, and hoping for better days ahead, the machinery choices of some champions could only be described now as 'optimistic'. In 2009, with a good record of what had been done at the Systems trial over many years (since 1999), we are in a position to ask 'what machinery would be required to farm these systems?' Although farmers have many different operations on a farm and ways of managing machinery, by taking a consistent approach we aim to highlight the differences in requirements for machinery that are related to the systems themselves.

Method

For a description of the Farming Systems trial, refer to the article 'Farming Systems trial economics 2008'.

Machinery requirement

Each farming system was assumed to take place on a 'representative' 2000ha farm (400ha per plot on the Systems trial). The diary of operations on each plot was summarised into a number of operations (cultivate, harrow, sow, spray) per month. This was used to develop a set of constraintss (area per hour = speed, width) that the machinery chosen for each system had to meet.

For tillage and harrowing, a month was assumed to be 20 days of 12 hours of tillage or six hours a day harrowing, mostly incorporating trifluralin. The sowing day was assumed shorter to account for filling (ten hours). Effectively, this means that any month's operations could be done in three weeks, a month allows for some breakdown and poor weather.

For spraying, it was assumed that there were fewer opportunities per month (ten days in winter, allowing for wind, rain and frost, and 15 days in summer, allowing for wind), and fewer hours (4 per day in summer, due to low Delta T, and 6 per day in winter, due to low temperature).

For harvest, a longer month was assumed, 25 days with ten hours a day of work, and total tonnes of grain to be harvested added as an additional constraint (in the economic analysis, unloading was also included as a source of fuel consumption, but was not included in the ten hours per day here).

Tractor capacity and fuel consumption

The power requirement for an implement in a particular operation was determined according to Papworth's (2004) tables for primary and secondary tillage, harrowing and banding knives (assuming 30.5cm width). These were generalised for any depth and speed by fitting power in kW/m as a function of depth (mm) and speed (km/h). The fitted equation was:

Power (kW/m) = constant + 0.0021 x depth + 0.107 x speed + 0.00959 x depth x speed

where constant = 0.8 for primary tillage, -1.0 for secondary tillage, and -0.55 for knife point sowing at 12 inch (30.5cm) spacing.

Air carts and fans, and boomsprays, were assumed to require 15 kW power to drive and pull them (Papworth 2004).

Tractor drawbar power and fuel consumption were obtained from the Nebraska tractor test data compiled by R Grisso (http://filebox.vt.edu/users/rgrisso/Pres/Nebdata_07.xls). It was assumed that each farm would use a second-hand 4WD tractor of 20 percent more power than required for the highest demand operation (usually sowing for the No-Till and Reduced Till systems or primary tillage for the Fuel Burner and Hungry Sheep systems), and a smaller second-hand FRONT WHEEL ASSIST (FWA) or 2WD tractor for spraying. Fuel efficiency at 50 percent power in Nebraska tests has typically been 80 percent of fuel efficiency at maximum power, and it was assumed that fuel efficiency for power levels in-between could be interpolated linearly. Even if the power requirement was less than 50 percent, for fuel consumption calculations it was assumed that the tractor always operated at least at 50 percent power.

Results

Tillage

Most tillage occurred in the Fuel Burner system, between September and May (Table 1). There has been less tillage in recent years. The Fuel Burner needed to till up to four plots per month, whereas the Hungry Sheep tilled three at most, and Reduced Till two. Both Fuel Burner and Hungry Sheep harrowed up to six times a month with trifluralin application (occasionally once before to level). There were relatively few tillage operations in the Reduced Till system, and it was assumed that sweeps would be fitted to the sowing bar when tillage was required in this system, rather than keeping a special-purpose machine.

Table 1. Tillage operations in the Farming Systems trial, 2003-2008.

Operation	Year	J	F	M	A	M	J	J	A	S	O	N	D
Fuel Burner													
Cultivate Primary	2003	4										1	
	2004									1		1	
	2005		2								2		
	2006		2			1							
	2007				2								
	2008	2		3									
Cultivate Secondary	2003		4		4								1
	2004	1	1							2		1	2
	2005			3							1	2	
	2006					1							
	2008			1									
Harrow	2003					3							
	2004					3							
	2005						1						
	2006					5							
	2007				6					1			
	2008					1							
Hungry Sheep													
Cultivate Primary	2003	1		3									1
	2004												2
	2005		2										
	2006					1							2
	2007				2								
	2003			1									
	2005			2									
Harrow	2003					6							
	2004			1									
	2006					1							
	2007				2	1							
	2008					1							
Reduced Till													
Cultivate Primary	2003		2										
	2004											1	
	2005		1										
Cultivate Secondary	2004												1
	2005			1									

Sowing

The Fuel Burner and Hungry Sheep systems had relatively drawn-out sowing periods (Table 2), occasionally sowing forage (Hungry Sheep) or vetch (Fuel Burner). In 2003, the Fuel Burner also pre-drilled fertiliser. Hungry Sheep and Reduced Till almost always sowed all five plots, but no more than four in any one month. In Reduced Till, sowing dates are spread as a risk management feature (with early sowing and short-season, late-sown varieties), whereas in Hungry Sheep the forage plot is always sown early, and sowing of the last plot is sometimes delayed to manage feed in years where the forage plot is not yet established. The No-Till system should, in theory, be doing more dry-sowing, but in practice sowing has been delayed due to concerns over weeds. In recent years, fertiliser rates have not been high and currently a two-bin air-cart would be adequate for all systems.

Table 2. Sowing operations in the Farming Systems trial, 2003-2008.

Operation	Year	J	F	M	A	M	J	J
Fuel Burner								
Sow	2003				1	4	4	
	2004			1			3	
	2005						3	
	2006					4		
	2007			1		4		
	2008				1	3		
Hungry Sheep								
Sow	2003					1	3	
	2004			2			3	
	2005		1				4	
	2006					5		
	2007			1		4		
	2008			1		4		
No-Till								
Sow	2003				1	3	1	
	2004					4		
	2005						4	
	2006					4		
	2007					4		
	2008					4		
Reduced Till								
Sow	2003				1	3	2	
	2004					2	2	
	2005					2	3	
	2006					4		
	2007					5		
	2008					4		

Spraying

Spray equipment has been used more in the September-April months in the No-Till and Reduced Till systems (Table 3). All systems apart from Hungry Sheep have, at some time, had to spray all five plots within a month. In 2007, No-Till and Reduced Till systems chose to split knockdown and trifluralin sprays at sowing, hence two sprays per plot. Rather than increasing spray capacity, it was assumed this was managed by longer hours, but if it became a regular occurrence it would be necessary to look at higher capacity spraying or regular use of contract spraying.

Table 3. Spraying operations in the Farming Systems trial, 2003-2008.

Operation	Year	J	F	M	A	M	J	J	A	S	O	N	D
Fuel Burner													
Spray	2003					3		1	4	1			
	2004					1	2	5					
	2005		2				2			3			
	2006					3			1		1		
	2007				4	5	4	2	1		1		
	2008		3		1	3		4	1				
Hungry Sheep													
Spray	2003					3		3	1				
	2004							2	3				
	2005	2	2				4		4		1		
	2006					4							
	2007				2	6	2	1	1				
	2008					4	1	1	1				
No-Till													
Spray	2003		5			4	1	3	1	1			
	2004					2		5	1				5
	2005		3				4		5	3		1	
	2006		1			4				2			
	2007				5	8	4	3	1				
	2008		5			4	1	3	1				
Reduced Till													
Spray	2003		1	3		3	2	3	3				
	2004						2	2	1				4
	2005		1	2		2	3	1	2	1			
	2006					4			1	1			
	2007				5	10	3	3	3				
	2008		5			4	1	2	1				

Translation to implement width

The greatest requirement for tillage was in the Fuel Burner system (four plots per month, Table 4), which for a 2000ha farm and the working hours constraints led to a 6.7m implement width at minimum. The minimum width for a sowing implement in Hungry Sheep or Fuel Burner was 8.0m, given a higher potential sowing speed (because soil throw is not an issue), which makes using 30ft (9.1m) implements possible in these systems. In this analysis, it was assumed that given the relatively small additional cost and widespread availability of 40ft (12.2m) implements and low-medium power 4WD tractors, farmers would choose to use these (although the relative merits could be tested in a further analysis). For tillage, it was also assumed that different implements were used for primary (eg. chisel) and secondary (eg. cultivator) tillage. The reduced sowing speed in the No-Till and Reduced Till systems meant implement widths of at least 10.0m (33 foot) were required, again a 40ft implement was specified. Tillage was achieved in the Reduced Till system by putting sweeps on the No-Till seeder.

Sprayers in nearly all systems (Table 4) had to be at least 22.2m (73ft), but in the Hungry Sheep system, given less frequent spraying, could be 17.8m (59 feet). Initially, given the widespread availability of 100ft (30.5m) boomsprays, it was assumed that farmers would prefer them, new in the case of Reduced Till and No-Till systems (which rely more on spraying), and second-hand for the Fuel Burner system, and 80ft (24.4m) second-hand for the Hungry Sheep system.

Table 4. Translation of operations per month to minimum implement width for a 2000ha farm, given constraints on working hours and speed.

	Constraints	Area	Working hours		Min.	At max.	Min.
	Plots per month	ha	Days	Hrs/day	area ha/hr	speed km/hr	width
Tillage							
Fuel Burner	4	1600	20	12	6.7	10	6.7
Hungry Sheep	2	800	20	12	3.3	10	3.3
Reduced Till	1	400	20	12	1.7	10	1.7
Harrow							
Fuel Burner	6	2400	20	6	20.0	15	13.3
Hungry Sheep	6	2400	20	6	20.0	15	13.3
Sow							
Fuel Burner	3.5	1400	20	10	7.0	10	7.0
Hungry Sheep	4	1600	20	10	8.0	10	8.0
No-Till	4	1600	20	10	8.0	8	10.0
Reduced Till	4	1600	20	10	8.0	8	10.0
Spray							
Fuel Burner	5	2000	10	6	33.3	15	22.2
Hungry Sheep	4	1600	10	6	26.7	15	17.8
No-Till	5	2000	15	4	33.3	15	22.2
Reduced Till	5	2000	15	4	33.3	15	22.2

Choice of tractor

The final selections of implements are listed in Table 5. These lead to the power requirements in Table 6. The maximum power requirement (176-178 drawbar horsepower) was similar in all systems and occurred in primary tillage in Hungry Sheep, Fuel Burner and Reduced Till, and sowing in No-Till. Note that power requirement for no-till sowing is very sensitive to depth; power requirement would be much more with deeper tillage below the seed. Drawbar horsepower (measured in Nebraska tests) is typically about 85 percent of quoted engine horsepower, hence all systems require about 210hp – a large FWA or small 4WD tractor. In the analysis, a second-hand tractor similar to a CaseIH 9230 (quoted 235hp) is used in all systems. A generic second-hand 120hp tractor has been assumed for spraying and could also be used for harrowing. Smaller tractors or other types of vehicles could be used for spraying.

Table 5. Final choice of implements, speeds and depths for different farming systems.

Operation	Implement (s)		Speed	Depth km/hr	Power function mm kW/m
		Fuel Burner			
Cultivate Primary	12m s/h chisel plough		10	75	Primary tillage
Cultivate Secondary	12m cultivator w/ air kit		15	50	Secondary tillage
Harrow	18m prickle chain		15	25	
Pre-drill	12m cultivator w/ air kit	2 bin air-cart	12	50	Secondary tillage
Sow	12m cultivator w/ air kit	2 bin air-cart	12	50	Secondary tillage
Spray	30.5m s/h boomspray		15		
		Hungry Sheep			
Cultivate Primary	12m s/h chisel plough		10	75	Primary tillage
Cultivate Secondary	12m s/h cultivator w/ air kit		15	50	Secondary tillage
Harrow	18m prickle chain		15	25	
Sow	12m s/h cultivator w/ air kit	2 bin air-cart	12	50	Secondary tillage
Spray	24.4m s/h boomspray		15		
		No-Till			
Sow	12m no-till bar	2 bin air-cart	10	75	Sow 0.305 knife
Spray	30.5m new boomspray		15		
		Reduced Till			
Cultivate Primary	12m no-till bar		10	75	Primary tillage
Cultivate Secondary	12m no-till bar		15	50	Secondary tillage
Harrow	18m prickle chain		15	25	
Sow	12m no-till bar	2 bin air-cart	10	75	Sow 0.305 knife
Spray	30.5m new boomspray		15		

Table 6. Power requirement and work rate for operations in the different farming systems.

System	Drawbar power kW	Area rate ha/hr	Min. tractor DB power* hp
Primary tillage			
Fuel Burner	111	12.0	178.0
Hungry Sheep	111	12.0	178.0
Reduced Till	111	12.0	178.0
Secondary tillage			
Fuel Burner	95	18.0	152.6
Hungry Sheep	95	18.0	152.6
Reduced Till	95	18.0	152.6
Harrowing			
Fuel Burner	32	27.0	52.1
Hungry Sheep	32	27.0	52.1
Reduced Till	32	27.0	52.1
Pre-drilling			
Fuel Burner	89	14.4	142.8
Sowing			
Fuel Burner	89	14.4	142.8
Hungry Sheep	89	14.4	142.8
No-Till	109	12.0	176.1
Reduced Till	109	12.0	176.1
Spraying			
Fuel Burner	15	45.8	24.1
Hungry Sheep	13	36.6	20.9
No-Till	15	45.8	24.1
Reduced Till	15	45.8	24.1

** Min. tractor drawbar power is drawbar power in kW, divided by 0.7457 (converts to hp), multiplied by 1.2 (adds 20 percent margin).*

Harvest

A similar analysis was undertaken for harvester width and capacity, initially assuming a minimum yield (15km/h speed). All systems, except Reduced Till, harvested four plots at most (Table 7), and at 15km/h could harvest the area in the time given with a fairly small front width. The main constraint was a good year (Table 8), which between 2003 and 2008 yielded at most 2.25t/ha average across all plots in a system (No-Till in 2005). Assuming an average minimum speed of 6km/h, the minimum harvester width (to complete harvest in 25 ten-hour days) was 10.7m (35.1ft) for all systems except Reduced Till, which was 13.3m (43.6ft). The feed rates were well within the capacities of headers with those front widths. In the analysis it was assumed that farmers would choose machines that would just cope with a 'good' year (eg. Case IH 2188, 9.1m front, 20t/hr maximum feed rate, for all systems except Reduced Till, which would be Case IH 2388, 10.7m front, 27t/hr maximum feed rate) and work longer or employ a contractor if a better year came along.

Table 7. Translation of maximum harvest area to minimum header width for a 2000ha farm, given constraints on working hours and speed.

System	Constraints	Area	Working hours		Min.	At max.	Min.
	Plots per month	ha	Days	Hrs/day	area ha/hr	speed km/hr	width
Fuel Burner	4	1600	25	10	6.4	15	4.3
Hungry Sheep	4	1600	25	10	6.4	15	4.3
No-Till	4	1600	25	10	6.4	15	4.3
Reduced Till	5	2000	25	10	8	15	5.3

Table 8. Translation of maximum average yield and harvest area to minimum front width for a 2000ha farm, given constraints on working hours and speed.

System	Yield constraint		Time-constrained		Minimum average speed km/hr	Required width m
	Max. yield t/ha	Total t	Feed rate t/hr	Area rate ha/hr		
Fuel Burner	2.00	3200	12.8	6.4	6	10.7
Hungry Sheep	2.00	3200	12.8	6.4	6	10.7
No-Till	2.25	3600	14.4	6.4	6	10.7
Reduced Till	2.15	4300	17.2	8	6	13.3

Annual machine hours per area

The four systems often required similar machines because of timeliness, but because of different patterns of use throughout the year, tended to have quite different average use when estimates of working hours and total areas were made from actual operation records and yields at the Systems site, 2003-2008 (Tables 9 and 10). The Fuel Burner and Hungry Sheep systems made much greater use of the primary tractor, and less of the spray tractor. The relative position of the different systems was similar to the original analysis, but there were fewer hours for the primary tractor and more for the spray tractor, especially in the No-Till and Reduced Till systems. Drier seasons have had a big impact on primary tractor use, particularly for the Fuel Burner system (less tillage, reflected in lower areas covered than originally estimated, Table 10). This analysis also estimates faster speeds for secondary tillage than in the original.

Table 9. Estimates of average annual machine hours for the different systems applied to a 2000ha farm (left side), and the estimates from the 1500ha farm used in the original analysis (right side).

System	Average annual machine hours					
	Current analysis (2000ha)			Original analysis (1500ha)		
	Primary tractor	Spray tractor	Header	Primary tractor	Spray tractor	Header
Fuel Burner	331	85	111	637	79	106
Hungry Sheep	222	88	118	311	91	157
No-Till	133	124	145	182	155	215
Reduced Till	168	111	146	256	75	185

Table 10. Estimates of average annual hectares worked in particular activities for the different systems applied to a 2000ha farm (top), and the estimates from the 1500ha farm used in the original analysis (below).

Machine	Hectares worked per year (average, 2000ha farm)			
	Fuel Burner	Hungry Sheep	No-Till	Reduced Till
Seeding/tillage	4884	3205	1658	2255
Harrows	1320	946		
Boomspray	3828	3152	5705	5240
Original estimates of hectares covered (1500ha farm):				
Air seeder and bar	6993	3418	1575	2563
Boomspray	4085	4008	7639	4434

Interpretation

Although the four systems are quite different in their approaches, they translate to quite similar requirements for machinery. All need quite similar seeders, sprayers and, in the case of Fuel Burner and Reduced Till, harrows (Table 4), because at various times they need to do similar amounts of seeding and spraying in a similar time period. There was some variation between systems in tillage requirements, but because the seeder is one tillage implement (primary or secondary), which in turn sets the tractor capacity available for any other tillage, in practice it is more acceptable to use tillage implements that match the tractor, even if they are larger than required to meet time considerations.

Farmers also have the opportunity to match level of investment in a machine to the amount of time required. A second-hand machine may be acceptable for an activity that is not done often, or one that is not time-critical, where some level of breakdown can be tolerated. This analysis provisionally specifies new implements (boomspray and bar, but not air-cart) for the No-Till and Reduced Till systems, and a new bar for the Fuel Burner system, but second-hand gear everywhere else. Later analyses could compare the relative merits of new and second-hand for each implement in the different systems, for example a no-till chisel plough conversion could easily be used in the No-Till and Reduced Till systems.

Application

Farming systems can have quite different use patterns for machinery but, when timeliness is key, similar requirements for machinery capacity. Farmers will already have a good understanding of where the key 'bottlenecks' are in their machinery inventory, but need to be wary of the possibilities of problems if they change system. Changing climate patterns could also change the emphasis on particular implements. Future changes in the trend (hopefully wetter) could see farmers struggling to gear up to match the work requirement!

References

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