National Centre for Engineering in Agriculture
University of Southern Queensland
Toowoomba

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Energy and Carbon Accounting Case Study on Keytah (NEC0901)

Craig Baillie

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KEYTAH ENERGY USE CASE STUDY

Background

Keytah is an irrigated cotton and grains farming operation west of Moree in Northern NSW. The total area of the property is 24 000 hectares of which 10 400 hectares is irrigated cotton, grown in rotation with wheat. During a normal season only half of the irrigated area is cropped at any one time with the other half maintained as a bare fallow. The farming system includes a summer cotton crop, planted in October and followed by a winter wheat crop planted in May and harvested in November. After the winter wheat crop a fallow of approximately 12 months takes place before cotton is replanted back in October. The farming system incorporates 60” beds where cotton is usually grown in two rows 30” apart or more recently in a single row where water supplies are limiting. In comparison the wheat is grown in 4 rows on the same 60” beds at a spacing of 15”. Regardless of the planting system adopted different plant lines are maintained between the summer and winter crop options. All tractors have been extended to operate on 120” (i.e. 3 m) centres.

In a normal irrigation season Keytah relies on 7 to 7.5 ML/Ha of water for irrigation which is applied by surface (furrow) irrigation and two lateral move irrigators. Water is sourced from the Gwydir and Mehi Rivers and is pumped into on farm storages before being distributed to the field for irrigation. In response to limited irrigation supplies (1 ML/Ha) in 2007 / 2008, a radical change in farming practices is currently being pursued to establish and produce a cotton crop. Previously the variation in soil properties across the farm has been identified via an EM survey. This survey was conducted when the soil was relatively close to field capacity. In an attempt to identify fields which had adequate soil moisture for planting cotton, an EM survey of the farm was again conducted to identify areas of high soil moisture content. The EM survey identified 2 fields side by side where one field had an estimated increase in soil moisture of 40% soil moisture. This increase in soil moisture was attributed to no tillage over the fallow period.

Introduction

Having identified the significance of the tillage operations on soil moisture radical changes to the farming system are being investigated to virtually eliminate tillage operations. These changes also include the incorporation of surface irrigation fertigation in lieu of applying a base rate of fertiliser via a deep ripping (primary tillage) operation. In addition to the observed benefits of soil moisture other potential benefits include:

i) greater control of when to plant, therefore maximising the crop potential and other farm resources i.e. labour and machinery;
ii) a reduction in fuel (energy) use on farm and cost savings
iii) a reduction in the associated greenhouse gas emissions (GHGs).

The benefits described above are evaluated in the following report to more broadly assess the impact of reduced tillage practices at Keytah.

Figure 1 Wheat stubble amongst zero till cotton on 60" rows

Figure 2 Wheat stubble following harvest

Methodology

To assess the benefits of farming system changes in terms of energy and GHG emissions, 3 scenarios were developed from actual crop history data and evaluated using the energy assessment software, EnergyCalc. EnergyCalc is a decision support software tool developed by the National Centre for Engineering in Agriculture to assess total on farm energy use and the associated GHG emissions. The three scenarios that were developed to assess farming practices on Keytah included:

i) a benchmark of energy use from 2000,
ii) current practices or reduced tillage and
iii) progression towards zero till farming methods

Each scenario was developed from previous farm records of field K8 (in 2000) and current crop records of K8 and C16 (reduced tillage) and K13 and C17 (towards zero till). Farm practices were also confirmed via an initial site visit.

Defining farm inputs
Once specific practices were defined for each of the farming system scenarios, practices were linked to specific machinery / tractors on farm. Performance data for these machinery operations was determined from Nebraska tractor test data which identified engine power (KW). Fuel consumption data was determined using EnergyCalc and based on the relative load of different farming operations in terms of heavy, medium and light.

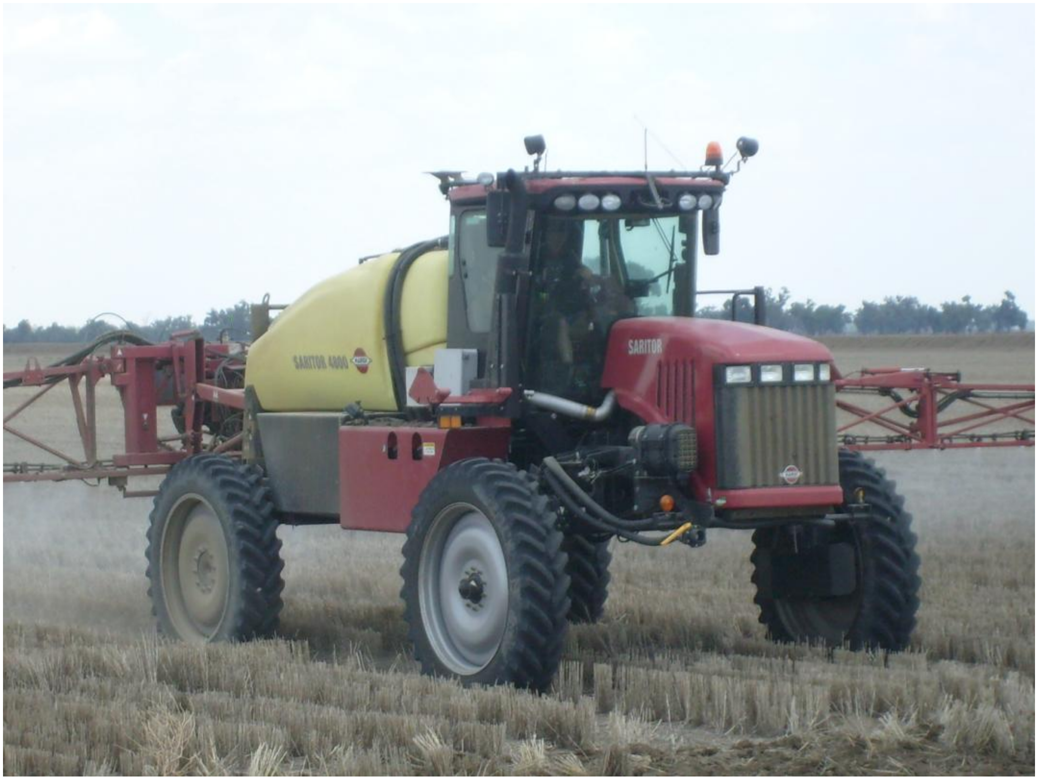

Figure 3 Herbicide application in fallow

Field work rates were also determined from tractor speed and machinery widths. Tractor speeds were assumed to be 6, 8 and 10 Km/hr for heavy, medium and light loads. Field inefficiencies (15%) due to turning were also taken into account.

In cases where machinery data could not be obtained i.e. spraying and harvesting, previously collated data was used. Fuel consumption due to pumping of irrigation water was determined from pump and engine specifications (i.e. 26” Chinese pump; Cat C-10 engine).

Figure 4 Pump Station on Keytah (1 of 26)

Standard Energy

Total energy was calculated in EnergyCalc from diesel use. EnergyCalc assumes a diesel heat content of 38.6 MJ/L of fuel. For example:

$$\text{Total (primary) energy use (GJ)} = 0.0386 * \text{Total diesel use (L)}$$

Greenhouse Gas Emissions

GHG emissions (kg CO_2) are determined in EnergyCalc by assuming an emission factor of 74.9 kg CO_2 / GJ which is equivalent to 2.9 *litre of diesel. For example:

$$\text{GHG emission (kg } CO_2\text{)} = 2.9 * \text{Total diesel use (L)}$$

Note that the above calculation includes only the direct greenhouse gas emissions from direct energy use and does not include emissions due to soil disturbance and fertiliser.

Results & Discussion

A summary of the results are presented in Tables 1 and 2 which identify the total energy, cost per hectare and GHG emissions of the three scenarios. Energy use is further broken down into key processes within the crop production system, presented in table 2.

Table 1. Energy implication for different farming systems

	Total Energy (GJ/Ha)	# Energy Costs ($ / Ha)	GHG Emissions (kg of CO2)	Since 2000
2000 Benchmark	16.32	402	6377634 (1226 kg/Ha)	
Reduced Till	14.33	353	5599958 (1076 kg/Ha)	-12%
Towards Zero Till	12.44	306	4861566 (935 kg/Ha)	-24% *(-13%)

Table 2. Breakdown of Energy Use

	Preparation	Planting	In Season	Irrigation	Harvest	Post Harvest
2000 Benchmark	34%	2%	5%	45%	12%	2%
Reduced Till	19%	2%	6%	52%	13%	8%
Towards Zero Till	7%	2%	6%	60%	16%	9%

Energy and GHG Implications

A benefit of 12% energy savings was observed through reduced tillage operations, compared to the 2000 benchmark. This is consistent with expected savings of 10% due to the adoption of minimum tillage. This figure however is sensitive to the frequency of laser levelling operations which was assumed to occur every 5 years in the 2000 benchmark system. Due to the adoption of GPS auto steer topographic information (i.e. field levels) can be obtained during the cropping season and laser levelling is now focussed to when and where drainage issues start to emerge (i.e. less frequent and on parts of a block).

As the farming system moves towards zero till, a further energy saving of 13% has been identified. In relation to the 2000 benchmark this equates to a total reduction in energy (diesel) of 24% and an estimated cost saving of $496 643 across Keytah (assuming fuel price of $0.95 / L; cropped area of 5200 Ha).

Current energy use on farm (reduced and towards zero till) ranged from 14.33 – 12.4 GJ/Ha and is consistent with previous work in the cotton industry which identified a maximum of 15.2 GJ/Ha. Similarly energy costs \$306 - \$353 / Ha (\$310/Ha) and GHG emissions 935 – 1076 kg CO_2 (1404 kg CO_2) were consistent with previous work.

Within the farming system the most significant users of energy were previously in preparation and irrigation. Progressively through the implementation of reduced tillage practices the proportion of energy for preparation has reduced while irrigation has increasingly represented a greater proportion of the total energy on farm. It is important to note that these percentages represent relative difference within the farming system while the amount of energy for irrigation has remained the same overtime in this analysis. Given that irrigation represents the greatest proportion of energy use on farm future efforts to reduce on farm energy should be focused in this area.

Other Issues (fertigation)
To facilitate the adoption of zero till at Keytah, surface irrigation fertigation is currently being explored to eliminate heavy primary tillage operations which in the past have been used to drill / deep rip fertiliser into the soil profile. The fertigation system consists of a large tank containing liquid nitrogen based fertiliser (i.e. N26) that is dispensed into the head ditch throughout the irrigation event. N26 is applied into the head ditch at a constant flow rate (via a constant head device) where water is then applied to the field via siphon fed furrows.

Figure 5 Fertigation installation

Given that fertigation is the most significant difference between the zero till scenario and the other scenarios, the likely nett difference in GHG emissions needs some consideration. In particular potential differences in nitrous oxide emissions that result from fertiliser applied via tillage operations versus fertigation. The generation of nitrous oxide in the farming system is due to denitrification associated with surface irrigation events. The relative importance in nitrous oxide as a greenhouse gas is due to its potency, which is approximately 300 times greater than CO_2.

For the purposes of this study the net difference between fertiliser applications is inconclusive due to a number of factors which include:

- Lack of fundamental work that has monitored GHG emission from tillage based fertiliser application vs fertigation
- Other complexities i.e. organic carbon content would appear to control the rate of nitrous oxide production from denitrification (therefore zero till may in fact have more of an effect due to increased organic C)
- Current deep ripping / drilled fertiliser applications would appear to be inefficient from a nitrogen placement point of view (i.e. fertiliser is applied via cross ripping with no relationship to the eventual plant line)
- In other industries (i.e. sugarcane) nitrogen losses are more sensitive to the relative amount applied not the application method.

Given these uncertainties there is potential to explore nitrous oxide emissions much further through research and development. The priorities include:

- Optimisiation of application methods (ice tillage and fertigation based)
- Monitoring GHG emissions from different farming systems and fertiliser
- Monitoring the relative sensitivity of different application methods.

Conclusions

From an assessment of energy use on Keytah, the following conclusions can be made:

- Significant improvement in energy use has occurred over time due to changes in farming practices. Based on 2000 figures a total improvement of 12 % has been made with potential for a further 13% through zero till. This represents a total cost saving of $496 643.

- Energy useage on Keytah is consistent with previous work in the cotton industry particularly for enterprises where pumping large volumes of irrigation water occurs. To demonstrate the significance of irrigation based energy requirements, Keytah has 26 pumps (~350 HP) that collectively operate for 26000 hours annually

- Having pursued reduce tillage operations over the last 9 years on Keytah, irrigation has been elevated in terms of its relative status as an energy user on farm. This would suggest that irrigation is the next step in investigating further energy conservation and cost reduction (although current tillage strategies need to be bedded down). It is important to note that already there is some consideration of this through the conversion of diesel motors to LPG.

- This study is a desk top study of energy use on farm and there are further opportunities to collect more accurate and detailed information on energy use which will inform specific opportunities to improve mechanical efficiencies (ie fine tune practice as opposed to a change of practice).

- At an industry level further R&D is required to support measurement of inputs (energy) and outputs (emissions)

Attachment A - Practices for Farming System Scenarios

Table 3. Benchmarked Practices 2000

Process	Practice	No. Passes	Operation	Fuel Use per pass (L/Ha)	% Energy
Preparation	Discing	3	Tillage	12	9%
	Regrade (annual cost; every 5 yrs)	1	Tillage	30	7%
	Deep Ripping	1	Tillage	18	4%
	Lister – Bed Forming (apply N)	1	Fert	20	5%
	Ripper (apply MAP)	2	Fert	7	3%
	Cultipacker	1	Tillage	4	1%
	Spraying (Herbicide) - Raptor	7	Spraying	3	5%
Planting	Plant Cotton (MaxEmerge)	1	Planter	5	1%
	Aerial Spray (Herbicide)	1	Spraying	0.035	0%
	Chains	1	Tillage	4	1%
In Season	Inter-row Cultivation (clean furrows)	2	Tillage	6	3%
	Shielded Spray (Herbicide)	1	Spraying	3	1%
	Boom Spray (Insecticide)	2	Spraying	3	1%
	Aerial Spray (Insecticide)	9	Spraying	0.035	0%
	Aerial Spray (Defoliation)	2	Spraying	0.035	0%
Irrigation	Irrigation (7 ML / Ha)	2.5	Irrigation	77	43%
Harvest	Cotton Picker	1	Harvesting	45	10%
	Module Builder	1	Harvesting	5	1%
Post Harvest	Mulcher	1	Crop Dest	7	2%

Table 4. Reduced Tillage Practices

Process	Practice	No. Passes	Operation	Fuel Use per pass (L/Ha)	% Energy
Preparation	Deep Ripping	1	Tillage	18	5%
	Lister – Bed Forming (apply N)	1	Fert	20	5%
	Ripper (apply MAP)	1	Fert	7	2%
	Spraying (Herbicide) - Raptor	7	Spraying	3	6%
	Cultipacker	1	Tillage	4	1%
Planting	Plant Cotton (MaxEmerge)	1	Planter	5	1%
	Boom Spray (Herbicide – Roundup)	1	Spraying	3	1%
In Season	Inter-row Cultivation (clean furrows)	1	Tillage	5	1%
	Boom Spray (Herbicide – Roundup)	2	Spraying	3	2%
	Boom Spray (Insecticide)	3	Spraying	3	2%
	Aerial Spray (Insecticide)	8	Spraying	0.035	0%
	Aerial Spray (Defoliation)	2	Spraying	0.035	0%
Irrigation	Irrigation (7 ML / Ha)	2.5	Irrigation	77	52%
Harvest	Cotton Picker	1	Harvesting	45	12%
	Module Builder	1		5	1%
Post Harvest	Root Cut	1	Crop Dest.	7	2%
	Mulcher	1	Crop Dest	7	2%
	Ripper (Pupae Bust)	1	Tillage	16.5	4%

Table 5. Towards Zero Till Practices

Process	Practice	No. Passes	Operation	Fuel Use per pass (L/Ha)	% Energy
Preparation	Spraying (Herbicide) - Raptor	6	Spraying	3	6%
	Spread Fertiliser	1	Fertiliser	3	1%
Planting	Plant Cotton (MaxEmerge)	1	Planter	5	2%
	Boom Spray (Herbicide – Roundup)	1	Spraying	3	1%
In Season	Inter-row Cultivation (clean furrows)	1	Tillage	5	2%
	Boom Spray (Herbicide – Roundup)	2	Spraying	3	2%
	Boom Spray (Insecticide)	3	Spraying	3	3%
	Aerial Spray (Insecticide)	9	Spraying	0.035	0%
	Aerial Spray (Defoliation)	2	Spraying	0.035	0%
Irrigation	Irrigation (7 ML / Ha)	2.5	Irrigation	77	60%
Harvest	Cotton Picker	1	Harvesting	45	14%
	Module Builder	1	Harvesting	5	2%
Post Harvest	Root Cut	1	Crop Dest.	7	2%
	Mulcher	1	Crop Dest	7	2%
	Ripper (Pupae Bust)	1	Tillage	16.5	5%