2017

Case Study Farm 6 - Mackay

Turf Queensland

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RURAL WATER USE EFFICIENCY
IRRIGATION FUTURES
Improving irrigation management for a profitable and sustainable future

False positives can increase water use.

Introduction

The efficient and profitable production of turf grass involves several farm management practices that directly and indirectly influence productivity, energy and water use.The introduction of precision agriculture techniques and sophisticated technologies, as well as adopting modern management practicescan help to improve production, but getting the balance right does not always come easy.

Figure 1: Lateral move irrigator on Case study Farm 6.

An irrigation system involves many components, each influencing the efficiency of the whole system, correcting one issue or changing one component without considering the system as a whole can compound problems and mask other issues. Assessing an irrigation system and the associated management practices can help to identify any hidden issues that are affecting productivity and what options or actions can be taken to increase productivity and efficiency while reducing costs. Without an understanding of how all factors affect production, the right decision at the wrong time can create a false positive.

This case study discusses how assessing the irrigation system and management practices can highlight inefficiencies, expose underlying problems, and identify good practices, as well as increase productivity.

Project outline

The project North Queensland Rural Water Use Efficiency - Irrigation Futures (NQ RWUE-IF) is a collaboration between the Queensland Government and Turf Queensland. The aim of the project was to provide training, information and support to Turf producers while assessing their farm practices and implementing alternative practices to improve water use efficiency, reduce input costs and increase productivity.

The efficiency of the irrigation system and how irrigation is scheduled are two main influencing factors of water and energy use, however other factors and management practices will also have an indirect influence on productivity and input costs. For example, soil type and condition, water quality, fertilise use and application, and the type of electricity tariff used.

A baseline cost of inputs for production was developed by assessing all farm management practices and influencing factors. An irrigation specialist was engaged to evaluate the irrigation system and identify upgrade options. A second irrigation system assessment was conducted approximately 12 months later after upgrades to the irrigation system. Soil and water tests were conducted to identify any influencing environmental factors affecting production. A target area within the main production zone was chosen to represent the farm with all water use, energy use, fuel use, maintenance, labour, harvest yield, harvest waste and any other management practices recorded between November 2015 and December 2016. The data obtained was used to determine key influencing factors that could be altered or managed to increase production efficiencies. Two harvest periods, one before and one after any upgrades or changes was used to develop productivity indicators for comparison. Productivity indicators used are

- Irrigation energy efficiency calculated as kilo-watts-hours per megalitre of water pumped (kWh/ML)
- Water use efficiency measured as megalitres of water used per hectare (ML/ha)
- Increase in yield calculated as square metres of turf per harvest (m^2/harvest)
- Economic benefit measured as net cost of production per square metre of turf produced ($/$m^2$)

Case Study Farm

Overview

This family owned and operated farm is located in the Mackay region on a sandy clay loam surrounded by sugar cane farms. Currently 19 hectares of the 60 hectare farm is used to produce three varieties of turf. Sugar cane Mill Mud, a by-product of sugar cane crushing, is used as a soil supplement and to replenish the soil in production areas. On average two to three complete harvests per year, each taking three to four months from harvest to harvest, are achieved depending on weather conditions and market demand.

The farm has a water allocation of 100 mega-litres per year, but due to the regular rainfall in the region they rarely exceed 50% of their allocation. The turf is irrigated with a six span Reinke lateral move irrigator using a diesel hydraulic drive and supplied by the original single speed bore pump commissioned in the early 1980's. A second pump of similar size and age that draws water from a one mega-litre dam is used as a backup supply. The bore pump and lateral move irrigator has been customised, maintained or repaired as needed but no major upgrades had been done to the system.

The irrigation schedule was develop from the growers' experience, visual inspection of the turf and a manual rainfall gauge. Other turf maintenance procedures e.g. mowing, fertiliser application, and pest or disease control, are conducted using visual cues or seasonal changes.The grower has refined farm management practices over the years to improve production efficiency but has not conducted any formal evaluation of operational procedures. Neither had any measurement of harvest waste or monitoring of harvest yield been implemented.

Farm assessment

The initial farm assessment was conducted between February and April 2016. The irrigation system was evaluated, the electricity tariff assessed, irrigation water and soil samples were taken for analysis, and daily management practices recorded. These results were used to determine the best options for the farm to improve productivity.

Irrigation system

The 12 year old Reinke centre feed lateral move irrigator is supplied water by a Southern Cross L series, turbine pump through approximately 1,100 metres of 150mm CL 9 PVC pipe and a 200 metre long lay-flat connecting hose. The irrigator was designed for a flow rate of 17.2 litres per second at 120 kPa (17.4 psi) pressure and is fitted with Nelson #23 D3000 static sprays designed to be pressure regulated at 42 kPa (6 psi).

The system has been customised over the years as per irrigation equipment supplier recommendations in an attempt to increase uniformity of application and reduce water pooling on the surface. No irrigation system assessments had been conducted until this project. Customisation included changing sprinkler drop heights to two different heights, and replacing the individual sprinkler pressure regulators to higher rated units (138 kPa/20 psi) in an attempt to compensate for pressure variations in the system.

The old worn bore pump, although appropriate when commissioned, does not match the operating parameters (flow rate or pressure) the irrigator requires. A bleeder system or manual water by-pass valve, feeding the onsite dam, is used to adjust flow rates and operating pressures. A flow rate of 20.8 litres per second and an operating pressure of 125 kPa at the irrigator was recorded during assessment. A high pressure difference between the pump and irrigator of approximately 460 kPa was recorded. This suggested pressure loss due to increased pipe friction caused by the high flow rate or a leak in the underground supply pipe. Several rubber seals (grommets) and flexible fittings in the system had developed leaks,further adding to water and pressure loss. Regular manual adjustment to the by-pass value was required when triggering an irrigation to compensate for flow rate fluctuations and the pressure loss between the pump and irrigator.

Irrigation system recommendations

The ideal upgrade for this farm is to replace the old bore pump and pipe work with a new multi-stage variable frequency drive pump system and a larger main supply pipe to match the irrigator operating specifications and provide capacity for future expansion. However, due to the age of the bore, the casing and bore head must be evaluated for damage and structural integrity before installing a new pump system. Other recommendations included

- Reconditioning the existing bore pump to improve energy and pumping efficiency.
- Resetting sprinkler heights back to the designed height or to suit the sprinkler configuration used.
- Repair leaks in the system to reduce pressure and flow rate fluctuations, and reduce water loss.
- Install an inline filter to remove the debris that blocks the sprinklers or increase the sprinkler maintenance schedule to reduce sprinkler blockages.
- Replacing the sprinklers with new multi-trajectory sprinklers appropriate for the wind conditions on farm and design parameters of the lateral move irrigator.
- Replace the lay-flat supply hose with a solid or fixed diameter poly hose to reduce the friction losses in the supply pipe.

Upgrades implemented

- Due to the condition of the bore casing and the costs involved, upgrading the bore pump was not done, instead the existing pump was reconditioned to increase pumping efficiency.
- Replaced pump regulator/pressure valve and install pressure gauge at irrigator for a more accurate pressure adjustment during irrigation events.

- Change sprinkler drop heights to original design specifications for the sprinklers used.
- Replaced or repaired rubber grommets and flexible fitting to stop water leaks and reduce pressure losses.
- Conduct sprinkler inspection and cleaning prior to an irrigation event and flush the irrigation system regularly to remove any debris that can cause blockages.

The other recommendations of replacing the sprinkler pack and the lay-flat supply hose has been investigated and will be implemented as products and funding become available.

Energy assessment

The irrigation pump energy use and the electricity tariff were assessed to determine opportunities to reduce costs through selecting the best tariff (based on historic usage) or managing the irrigator usage to suit the tariff.

Recommendation

- Upgrade pump set and supply pipe to a more efficient system will reduce energy use considerably.
- Investigate changing electricity tariff to another irrigation specific tariff.
- Change irrigation schedule to take advantage of Tariff off-peak rates.
- Awareness raising, through education/training, use scheduling tools to refine the irrigation scheduling to reduce irrigation costs.

Changes made

The existing irrigation pump was reconditioned instead of being replaced, which has improved pumping efficiency by 7%, but pump energy use was still considered higher than expected. The second assessment calculated energy use at 484 kWh per ML of water pumped. Based on tariff 66 energy costs of $0.185/kWh (excluding gst), this energy usage equates to a pumping cost of $89.54/ML. The biggest proportion of this loss is pipe friction loss at 337 kWh per ML due to the high flow rate of 24 L/s. Installing a new poly hose would reduce friction losses and could reduce pumping costs further by an estimated $40/ML. Ongoing upgrades are planned to lower operating pressure and flow rateback to the design specification to reduce pipe friction losses and energy use.

The investigation of electricity tariffs identified two potential tariff options. The alternative electricity tariffs considered did offer lower costs per kilowatt-hour during off-peak times but with a considerably higher peak usage rate charged if irrigation occurred outside of off-peak hours. Also these tariffs are listed as Transitional, meaning they will becoming obsolete in June 2020. The costs of transferring to a transitional tariff and upgrading the power meter as required did not provide sufficient energy cost saving before the June 2020 termination date. Instead it was decided that greater cost savings could be achieved with changing irrigation scheduling to utilise the off-peak rates of the existing tariff.

Irrigation scheduling techniques

The irrigation schedule was developed by the grower from years of experience and visual cues. A standard irrigation schedule of 8 mm per irrigation, four to five times per week was established. Irrigation frequency and duration was adjusted depending on market demand, seasonal temperature changes and rainfall. An average irrigation event would be triggered during the day and take 12 hours to complete. In times of high market demand or hot weather the irrigator could run for 24 hours. The primary factors that influenced irrigation scheduling was the time it took for the lateral move irrigator to complete an irrigation event and the drying time needed between irrigation and harvest. In some cases water pooling on the surface due to excess irrigation restricted harvesting. No other method or tools were used to determine the irrigation schedule.

Irrigation scheduling recommendations

The surface pooling of irrigation water indicates that the soil may be compacted and water absorption is poor, or the irrigation application volume is greater than the infiltration rate of the soil. Recommendation included

- Assess soil condition and infiltration rate
- Aerate production area to increase water absorption
- Incorporate the use of irrigation scheduling tools to change the focus of irrigation scheduling from a set timed base schedule to either a daily turf water use or soil moisture content method.

Figure 4: Oregon Scientific WMR89 electronic weather station.

Figure 5: Wind sensor and rain gauge installed two meters high with no obstructions to ensure accurate readings.

Changes implemented

The production area was aerated at the beginning of the project and soil tests conducted. No major issues with the soil condition was identified and water infiltration is being monitored in relation to changing irrigation management practices. After the initial farm assessment, the Scheduling Irrigation Diary (SID App) and a Delta-T soil moisture probe was introduced to change the focus from a timed base irrigation schedule to a root zone soil moisture and seasonal turf water use focus. A low cost wireless weather station was provided and installed to monitor the micro-climate of the farm and provide actual rainfall and evapotranspiration (ET) data for use with irrigation scheduling tools. Training and data interpretation was provided for both scheduling tools as well as how managing root zone moisture can reduce water use by maintaining optimum soil moisture and increase nutrient availability, while reducing water and energy use.

Figure 2: SID App landing page

The 'SID App' is a free phone application to help irrigators make informed decisions about when and how much to irrigate. It estimates moisture lost from the soil based on real time daily rainfall and evapotranspiration data obtained from the Bureau of Meteorology or entered by the farm manager from the on-site weather station. It uses this data to calculate the volume of irrigation required to replace the estimated moisture loss.

The Delta-T soil moisture probe is a handheld insertion probe that measures the percentage of moisture in the top 100 mm of the soil profile. Although turf can have a root depth greater than 300mm, discussions with turf producers suggest the top 100mm has the greatest influence on turf production. Using the Delta-T soil moisture probe to refine the irrigation schedule will allow more precise manipulation of soil moisture and nutrients within this limited root zone.

Figure 3: The Delta-T Soil Moisture Kit.

In the short-term using either device in conjunction with the onsite weather station will help to identify daily soil moisture loss, and estimate daily crop water use. In the long-term they can help to identify seasonal soil moisture variations and the soil water holding capacity (full point), wilt point, recharge point (irrigation trigger), and soil infiltration rate. Recording the data daily will help to develop a seasonal soil moisture map that can be used to adjust the irrigation schedule according to changes in environmental conditions, management practices or turf health.

"Having been supplied with a moisture monitoring device has also been a valuable tool in developing our watering [irrigation] schedule."

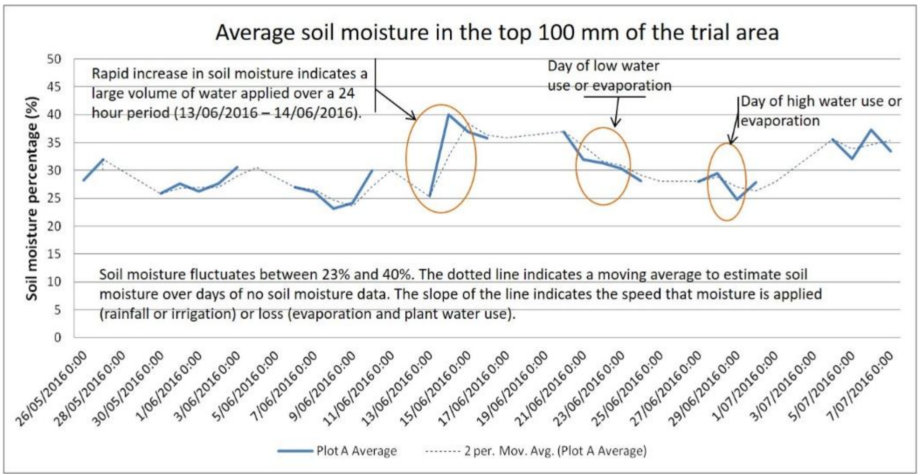
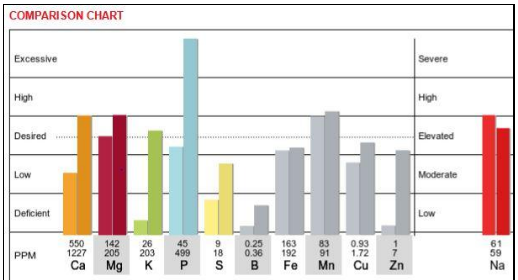


Figure 6: An example of soil moisture data recorded in the trial area.

Soil Tests

Four (4) soil samples across the production area and one of the Mill Mud were taken for analysis. Results showed all soil samples were slightly acidic with deficiencies in calcium, potassium, sulphur, boron and zinc. All soil samples indicated elevated or high levels of sodium. The Mill Mud sample had a neutral pH (6.7) and desirable to excessive concentrations of nutrients with low sodium levels.The addition of the Mill Mud is providing a nutrient supplement, which reduces the need for additional fertiliser applications. Only specific nutrient deficiencies need to be targeted, for example, the sulphur and boron.



KEY ELEMENTS

	IDEAL	MRN AVG NO MM AVERAGE	MRN AVG WITH MM AVERAGE
Organic Matter (humus)		1.38	2.90
pH		5.57	5.80
Total Exchange Capacity		7.20	11.56
Ca	68-72%	39.72%	45.37%
Mg	13-16%	16.87%	16.14%
K	3-5%	0.98%	2.39%
Na	<3%	3.84%	3.22%
H	4.50%	30.73%	25.63%
Other	5%	7.86%	7.24%

Figure 7: A comparison of average nutrient concentrations for soil samples without Mill Mud (left columns) and with Mill Mud.

Recommendations from the analysis included, appropriate applications of calcium, magnesium, potassium, phosphorus, and minor nutrients over several months to return the soil to a nutrient balance that doesn't rely on Mill Mud. This will increase nutrient availability, improve soil health, and improve uniformity of turf growth throughout the year. Fertiliser type and application rates need to be determined in relation to turf nutrient requirements, the irrigation application rate and soil infiltration rate to ensure optimum nutrient retention within the root zone for turf uptake.

Furthermore, sodium levels in the soil should also be monitored regularly either with soil tests or using an EC meter. Although soil sodium levels are not a major concern, an increase in sodium levels due to drought or a change in irrigation water quality could elevate sodium levels to a point that can interfere with turf root development.

"Initial soil testing done showed up what was lacking in our soil nutrients and the effect soil amendments may also have in grow/harvest/waste outcomes. This also gives us a better idea of any additional fertilizer required between plant/harvest period and the ability to maximise usage in this area. "

Water tests

The irrigation water quality was classified as good, relatively neutral (pH 6.5) and no major concerns for irrigating turf. Most quality indicators were within acceptable levels except bicarbonates (HCO3 134 ppm; ideal <120 ppm) and sodium (Na 56 ppm; ideal <50 ppm), however the electrical conductivity (EC = 0.75 dS/m) and the adjusted Sodium Absorption Ratio (SARadj = 2.48) indicate these were not an issue. The water is considered to be slightly precipitating, meaning there is a chance that the sodium irons could cause calcium to precipitate out of the water to block emitters and irrigation equipment.

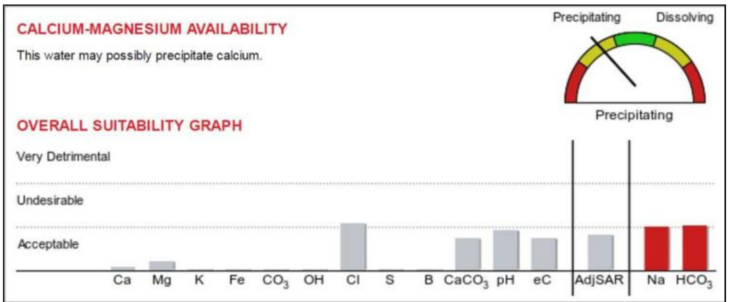


Figure 8: water analysis results showing the levels of nutrients and ion concentrations in the irrigation water.

No water amendments were needed but it was suggested that bicarbonates, sodium and chloride concentrations be monitored yearly and especially during periods of drought or reduced rainfall. If bicarbonate concentrations rise above 200 ppm, iron and manganese uptake is reduced causing plant growth problems. Sodium concentrations greater than 70 ppm and chloride concentrations above 140 ppm in irrigation water can become toxic to most plants and has the potential to affect the soil structure. Monitor the EC and SAR values as an indicator of change, if EC level increase above 0.8 dS/m or the SARadj value increases considerably (above 6) a specialist should be consulted to discuss treatment options.

Results of hardware and management practice changes on productivity

Irrigation system

Implementing the low cost changes to the irrigation system has reduced operating costs and increased operating efficiencies. Fixing leaks, reconditioning the bore pump, and replacing pressure gauges for more accurate pressure regulation, has improved pumping efficiency and reduced pump energy costs. Combined pump efficiency has increased by 7%, energy use to pump a mega-litre (kWh/ML) has reduced by 8.8% saving at least $20 per mega-litre at peak tariff times (see Table 1).

Table 1: Changes in irrigation system efficiencies from first assessment to second assessment.

	1st ASSESSMENT	2nd ASSESSMENT	DIFFERENCE	COMMENTS
Irrigation target	10.1 mm	9.8 mm	- 0.3 mm	Designed target 8 mm
Coefficient of Uniformity (%)	76.8	68.1	- 8.7	A decrease in CU% due to increase friction loss, incorrect pressure regulators, and worn sprinklers.
Combined pump efficiency	35.5%	42.5%	7%	Pump + motor efficiency
kWh/ML	531	484	47	An 8.85% per mega-litre saving
kWh/ML/m	7.7	6.4	1.27	Benchmark 5kWh/ML/m
$/ML	$83.10 off-peak $235.01 on-peak	$75.75 off-peak $214.21 on-peak	$7.35 $20.80	An average of 8.8% saving in the pumping costs ($/ML)

However, these improvements have now revealed that the previous condition of the irrigation system and the customizations done over the years had managed to bring the system into a relatively efficient balance that was masking the actual issues. Returning the system to original design parameters now highlights that many of the issues experienced can be attributed to incorrect pipe sizes and an oversized pump. The previous inefficiencies and water leaks were actually beneficial as these effectively bleed off excess pressure and reduced the flow rate. What was seen as the cause of the inefficiencies is now seen as the result of other issues hidden by the customizations. Although the efficiencies has been achieved, the system operates at a flow rate 28% above design specifications causing greater stress on the system, increased pipe friction losses and energy use. This is indicated by the coefficient of uniformity (CU%) being reduced from 77% to 68% after the system improvements.

The ideal upgrade for this farm is to replace the old irrigation pump with a more efficient pump system and upgrade the main water supply pipe, but this would require an upgrade to the bore itself as the metal casing of the bore is breaking down. A new bore or bore casing is required to avoid rust particles from damaging a new pump system. The cost of installing a new bore and pump system is beyond the financial capabilities of the farm at this time. Instead replacing the existing lay-flat supply hose with a standard 140mm poly hose to reduce pipe friction losses will save a further 237 kWh/ML in energy. Also replacing the old worn sprinkler nozzles and re-installing the original sprinkler pressure regulators will help to return the irrigator back to the original design specifications and provide more efficient operation of the irrigator until a new bore and pump set can be installed.

> *"The trial has now showed us the friction loss component of our irrigation system is a major cause of our irrigation inefficiency. Pump distance can't be avoided; however the improved efficiency of a hard hose as opposed to a soft hose was never pointed out at planning stage. If this had been pointed out at the time of planning, purchase and installation the more efficient option would have been installed."*

Irrigation schedule

The greatest savings achieved on this farm have been through changes to the irrigation schedule. A better understanding of how each component of the irrigation system affects the overall efficiency, water use and energy efficiency, has led to changes in system maintenance and management. Furthermore an understanding of managing soil moisture and nutrients within the root zone has led to a change in irrigation scheduling practices. Irrigation scheduling has changed from a predetermined set time basis to a root zone soil moisture focus. Using the Delta-T soil moisture probe as a check mechanism of soil moisture in conjunction with monitoring daily weather conditions and tracking moisture loss with the SID App has helped to refine the irrigation schedule.

Irrigations are now determined with the irrigation scheduling tools and vary according to turf water use and climatic conditions. A standard weekly schedule now consists of one or two top-up irrigations of 4 mm to 6 mm at night during the week and longer (10+ mm) irrigations on the weekends. Total irrigation applied during the first growth/harvest period was 70 mm (108 hours) while total irrigation applied during the second growth/harvest period was 43 mm (67.5 hours). This will vary with the change in seasonal weather conditions but this new schedule has provided added benefits such as

- No surface pooling as the irrigation application rate is similar to the soil infiltration rate
- Less water lost due to wind drift and evaporation when irrigating at night.
- Less hesitation to trigger an irrigation event during the day if needed due to the savings already achieved.

Water Use

For the first harvest period 8.1 mega-litres (0.426 ML/ha) of irrigation was applied and for the second harvest period 5.8 mega-litres (0.305 ML/ha) of irrigation was applied. Rainfall for both harvest periods was

below the seasonal average by 20% and 28% respectively. Although there was a water saving of 2.3 mega-litres between harvest periods, water use for both harvest periods is considered to be higher than the calculated water use using the irrigator design specification. A further saving of 1.6 mega-litres could be achieved with the planned upgrades to the irrigation system. Currently due to the higher operating pressure and flow rate, there is an excess of water being pumped that needs to be blead off into the dam to reduce pressure and flow at the irrigation cart. Addressing the issues of incorrect pipe sizes and installing a pump system suited to the irrigator specifications will provide greater water savings again and increase irrigation efficiencies further.

Table 2: Water and Energy use difference for the two harvest periods.

	PRE-CHANGES	POST-CHANGES	DIFFERENCE
Water use (ML)	8.1	5.8	2.3 (28%)
Electricity use (kWh)	4298	2828	1470 (34.2%)
Irrigator fuel use (L)	44	28	13 (32%)

Energy Use

An energy saving has been achieved in both electricity used for pumping and the fuel used by the motor to drive the hydraulics on the irrigator. Under the new irrigation schedule electricity costs for the second harvest period was reduced by $1091, and fuel costs reduced by $46. Fuel costs associated with maintenance tasks has also been reduced but are incorporated in the input costs for that task, see table 3.

With a new understanding of electricity tariffs the farm manager now records irrigation data and monitors energy use regularly. He estimates the changes implemented have the potential to save up to $10,000 in electricity costs per year. A re-assessment of tariffs will be conducted when the irrigation pump is replaced or new farm use tariffs are offered.

> *"As a direct result from the study we have made changes to our irrigating times to take advantage of off peak energy costs savings pointed out to us. This change will probably equate in dollar savings to the business of approx $8,000 - $10000 per water year (or until the energy provider removes this particular tariff)."*

Table 3: Input costs for two harvest periods showing the savings due to upgrades.

INPUTS#	1st HARVEST	2nd HARVEST	DIFFERENCE
Irrigation cart fuel	$147	$101	-$46
Bore pump power	$1534	$443	-$1091
Mowing	$298	$255	-$43
Maintenance*	$211	$211	
Fertiliser	$249	$214	-$35
Aeration*	$26	$26	
Pest & Disease control	$416	$66	-$350
Harvest	$2209	$2604	+$395
Total input costs =	$5088	$3920	-$1168
Turf cut (waste)	9360 m2 (6.8%)	11296 m2 (1.5%)	+1938 m^2
Cost ($/m2) =	$0.55/$m^2$	$0.35/$m^2$	0.20/m^2

All costs have been calculate using net variable costs and are rounded to the nearest dollar.Variable costs are non-capital items, such as labour, water, nutrients and electricity (the amount spent varies with production levels, species and the efficiency with which inputs are used).

* Maintenance and aeration cost are equal for both periods to account for a yearly tractor service, replacing mowing blades, and yearly aeration of production area.

Productivity improvements

The upgrades and management changes undertaken during the project has resulted in a reduction of input costs of $1168 between the two harvest periods and an increase in productivity of $0.20 per square meter, see table 3. Turf quality has increased and waste at harvest decreased with the change in management practices. Waste losses at first harvest were 6.8%, which was reduced to 1.5% for the second harvest resulting in an increase in saleable turf of 5.4% or 2361 m^2 per year. At a cost of $4.71 per square meter this effectively provides an increase in income greater than $11,000 per year. The saving made during this project has resulted in most efficiency targets being achieved (see table 4).

Table 4: A summary of efficiency improvements achieved due to the project.

ACTIVITY	TARGET	ACTUAL IMPROVEMENT
Water use improvement	15% or 1ML/Ha	28%
Energy use improvement	25%	16.5%
Fertiliser use improvement	12%	50%
Productivity improvement	10%	22%
Yield (Waste reduction) improvement	5%	5.4%

Furthermore, due to the assessments, support and savings achieved by the RWUE project the farm manager has now developed a 3 to 5 year transitional plan to continue upgrading equipment that is limiting productivity. In parallel to equipment upgrades, there are now plans to expand the farm to take advantage of costs savings gained so far. This will include:

- Replacing the current lay-flat hose with a solid poly-pipe to reduce friction losses and energy used further.
- Install an in-line filter on the supply line to reduce sprinkler wear and blockages.
- Replace the sprinkler pack and sprinkler regulators on the irrigator to more efficient low pressure sprinklers.
- Install diversion pipes on the irrigator to stop water draining into the wheel tracks causing wheel slip.
- Repair/replace existing bore and installing a new multi-stage VFD pump set to increase irrigation efficiency and provide the capacity for expansion.
- Prepare another 20 hectare for expansion and engage an irrigation specialist to design a second travelling irrigator.

> *"Being part of this project has highlighted the poor condition our irrigations system was in......, that the current pump is the wrong pump for the irrigator and will not be appropriate for the planned expansion. Also through discussions with [the project team] has shown that a better understanding of electricity tariffs and irrigation scheduling can reduce production costs considerably"*

Conclusion

The farm manager found the irrigation, soil and water assessments, irrigation scheduling tools, and weather station provided by the project to be highly valuable. Some efficiencies attributed to the project were an increase in the irrigation system efficiency and the identification of hidden limiting factors, a reduction in irrigation energy use, a greater understanding of production factors influencing productivity, and the inclusion of better record keeping as part of general farm practices. The use of soil moisture monitoring and harvest waste monitoring were new concepts but have highlighted how productivity gains can be made

through the adoption of more efficient management practices. Both are now accepted as an ongoing part of farm management.

The greatest outcome from the project has been from educational awareness developed during the project. A new understanding of efficiency measures and irrigation scheduling techniques, and the influence they have on productivity has provided a new direction for the farm. Previous increasing production costs were limiting upgrade options but now a three to five year upgrade and expansion plan has been develop following the principles outlined in the project. The influence of this project will continue beyond the project completion.

> *"The trial for us has been invaluable in showing up our inefficiencies and also recognising things that we are doing well in relation to our productivity. Data collection is something we now program into [our] daily farming routine to enable us to monitor how we can achieve more efficient and desirable outcomes...... Was a great trial to be part of."*

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Queensland Government

Department of Natural Resources and Mines

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