2017

Case Study Farm 5 - Townsville

Turf Queensland

Introduction

The efficient and profitable production of turf grass involves several farm management practices and environmental factors 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 practices can help to improve production, but without an understanding of all influencing factors, getting the balance right does not always come easy.

An irrigation system is made of many components, each influencing the efficiency of the whole system, but an efficient irrigation system is only one part of turf production. A well-managed irrigation system operating at optimum performance cannot compensate for poor water quality or soil health. Conducting soil and water tests as part of a farm assessment will identify any nutrient or salinity issues that may limit production. Understanding how soil and water quality affect turf production can help to refine management practices to reduce the impact of salinity on production.

In this case study, due to a prolonged drought, rising salinity, the introduction of water restrictions, and the suspension of turf production during the project, we discuss turf production in a high saline environment and how the effects on production can be controlled by adjusting the irrigation schedule and management practices.

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 identifying alternative methods to improve water use efficiency, reduce input costs and increase productivity.

The efficiency of the irrigation system and how irrigation is scheduled was the main focus of the project, however other environmental factors and management practices was also investigated to determine their influence on productivity, input costs, and water and energy efficiency. These included, 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. 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 over a twelve month period. The data obtained was intended 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 turf farm established in 1997 in the Townsville area produces three turf varieties, greenlees park couch, carpet grass, and empires zoysia over 16.2 hectares. On average two to three complete harvests per year are achieved depending on weather conditions and market demand. Sugar cane Mill Mud, a by-product of sugar cane crushing, is used to replenish the soil in production areas and as a supplement for fertiliser.

There are two separate production areas on this farm but only the 4.5 hectares irrigated by a three span Pierce centre pivot irrigator installed in 2010 was the focus of the project. The centre pivot is supplied water from the nearby dam using a dedicated single speed Davey 7.5 kW pump and is independent from the rest of the farm. The dam is filled from an adjacent bore using a 5.5 kW bore pump.

The irrigation schedule was develop from the growers' experience, industry training aids, visual turf inspection and data from a manual rain gauge. A standard timed irrigation schedule is used to apply 15 mm of irrigation per week. 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 assessment of the centre pivot irrigator identified the system was in good condition for its age and there was limited upgrade options available. The main recommendations included

1. Installing a Variable Frequency Drive (VFD) pump controller to reduce the operating pressure from 200 kPa down to design specifications of 120 kPa. This will reduce pipe friction and pumping costs.
2. Service or replace the end gun as overall system performance or Coefficient of Uniformity (CU) is reduced from 91% to 83% due to an inefficient end gun. The end gun efficiency should be reassessed after reducing the operating pressure back to design parameters. Replacement could be a new low pressure multi-trajectory end spray system.
3. Implement the use of irrigation scheduling tools, e.g. SID App or Soil moisture probe, to adjust irrigation duration and frequency to match turf water use.
4. Change electricity tariffs or change the irrigation schedule to take advantage of off-peak rates for irrigation.

Irrigation energy use

The assessment identified that changing from the current Tariffs 20 (general supply) to a lower cost tariff there was a potential to reduce irrigation pumping costs by $450 to $2400 per year. However there are several issues that need to be considered before changing tariffs and any change should not be entered in to without understanding the differences and consequences of changing tariffs. There are a variety of domestic, industrial and commercial tariffs available with some being specifically for irrigation or farm use. Each tariff will have different use conditions, time of use, or blocks of kilowatt hours that attract a different cost. Choosing the wrong tariff or not operating within the conditions could result in a higher cost. Also many electricity tariffs are considered obsolete by electricity suppliers and once a business changes from an obsolete tariff there is no going back.

An alternative option to changing tariffs is to understand the conditions of your current electricity tariff and adjust the irrigation schedule to take advantage of any lower off-peak pricing. Irrigating during off-peak periods will also help to reduce the evaporation of moisture from the production area. Increasing the efficiency of an irrigation system and refining the irrigation schedule will help to maintain irrigation events within the off-peak period and reduce operating costs. This many not provide a large reduction in electricity use but can offset the cost of irrigating during high cost periods.

Water test results

The water analysis indicated the irrigation water is alkaline (pH 8.3) with a high bicarbonate (HCO_3) level of 311 ppm, high sodium (Na) content of 116 ppm, an EC of 0.91 dS/m, and an adjusted Sodium Absorption Ratio (SAR_{adj}) of 6.42, refer Table 1 and Figure 1. In general, bicarbonate concentrations greater than 200 ppm can cause plant growth problems, and interfere with the uptake of iron and manganese. Sodium concentrations greater than 70 ppm in irrigation water can become toxic to most plants, has the potential to affect the soil structure, and cause calcium to precipitate out of the water interfering with irrigation equipment and blocking emitters. EC levels greater than 0.7 dS/m can affect plant production and reduce yields. The SAR value, an indicator of the relative proportion of sodium ions to calcium and magnesium in the water, is used to predict the potential for sodium to accumulate in the soil. A SAR values above 6 is considered a slight to moderate hazard to 2:1 clay soils and can affect salt sensitive plants.

Table 1: Comparison of measured and ideal water quality indicators.

Test Parameter	Measured	Ideal
pH	8.3	~7
Bicarbonate (HCO_3)	311	<120
Sodium (Na)	116 ppm	<50 ppm
Electric Conductivity (EC)	0.91 dS/m	<0.8 dS/m
Sodium Absorption Ratio (SAR)	6.42	<6

A study by Bennet and Raine 2012[1] on using saline-sodic irrigation water suggest the EC and SAR values can be used to predict the effect of saline irrigation of soil structure. The values recorded (EC 0.91 dS/m &SAR_{adj} 6.42) indicate that the soil is just within the range to cause soil structure damage. The extent of damage is dependent on soil type and volume of rainfall received. Continued drought conditions or an increase in sodium concentrations may cause major soil structure issues such as reduced drainage and aeration, and change the soil chemistry so nutrients will not be retained in the root zone. Sodium concentrations need to be monitored regularly and a sodium treatment plan for the dam, or the implementation of a saline irrigation management plan, should be considered.

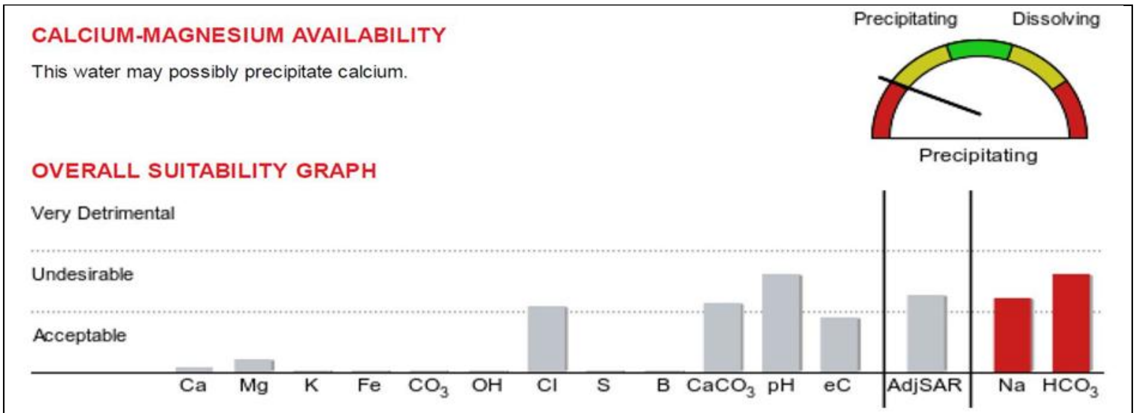

Figure 1: A summary of water quality indicators for Case study farm 5.

[1](Bennet and Raine 2012, Using marginal quality saline-sodic irrigation water sustainably)

Soil test results

Soil test results indicated the soil type and structure was consistent across the irrigation area with reasonable levels of magnesium, manganese, and copper. Calcium levels fluctuated in all samples and were below desired levels. Potassium and phosphorus was considered to be low or deficient. All soil samples indicate a deficiency in zinc, which could potentially be the limiting nutrient for turf production. The addition of the 'Mill Mud' provides a supplemental source for most nutrients and increases phosphorus and potassium to desired levels. Calcium concentrations are still considered to be low (approx. 36% base saturation) while the ideal base saturation for calcium concentration is 68% - 72%.

All four soil samples show severe levels of sodium ranging from 124 ppm to 380 ppm or an averaged base saturation of around 15%, the ideal base saturation for sodium is less than 3%. The averaged soil conductivity of the four soil samples without Mill Mud is 0.23 dS/m. The mill mud sample has moderate levels of sodium (22 ppm) and conductivity (0.14 dS/m) which alone would not be considered an issue but due to the high concentrations of sodium already in the soil, sodium levels in the mill mud should also be monitored. When nutrient concentrations are averaged with and without mill mud, zinc is still considered to be deficient with boron and calcium levels low. The addition of the mill mud does reduce the sodium level slightly but is still considered to be severe, see Figures 3 and 4. To return the soil to a nutrient balance, appropriate applications of calcium, potassium and phosphorus is required over time. These recommendations do not include the turf nutrient requirements, which should be considered when calculating fertiliser application and frequency.

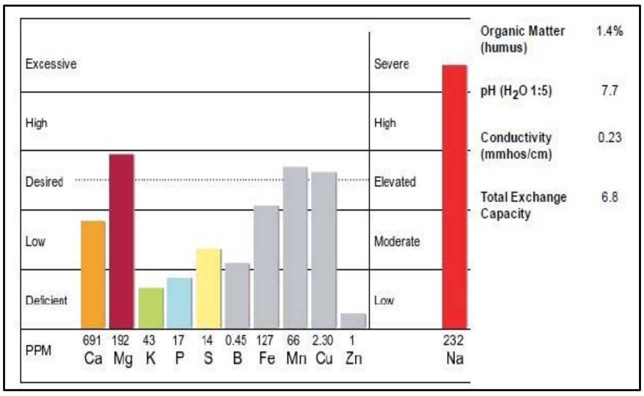

Figure 2: Average nutrient concentrations of four soil samples without the addition of Mill Mud.

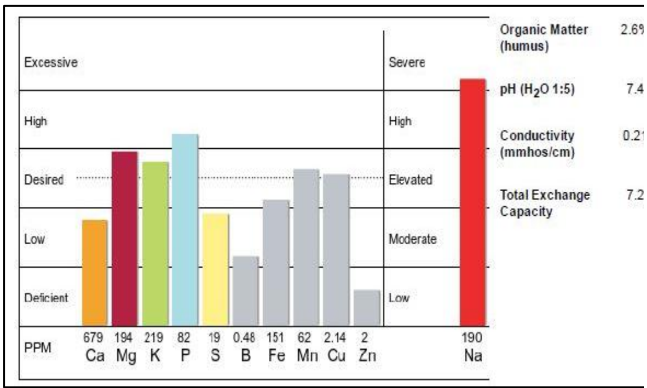

Figure 3: Average nutrient concentrations of four soil samples with the addition of Mill Mud.

High sodium levels in both the irrigation water and soil samples suggest there is a potential to cause salinity stress in the turf, which can reduce plant growth and vigour. High concentrations of sodium in the soil can displace calcium and/or potassium ions causing them to be leached below the root zone. Soil structure is degraded by high sodium concentrations and can lead to reduced permeability and aeration. Plants can experience a physiological drought (osmotic stress) even with increased irrigation because the salt can eventually burn the root system or increase the osmotic pressure required by the turf to extract water and nutrients from the soil. The nutrients and organic matter provided by the Mill Mud has helped to reduce the severity of irrigating with high saline water, but an increase in salinity levels could cause long-term damage to the soil and reduce turf

production. A saline irrigation management plan should be implemented to ensure salinity levels within the root zone are controlled within acceptable levels for optimum production.

Irrigation scheduling

Ideally the irrigation schedule should apply the irrigation at a rate that is equal to or less than the soil infiltration rate (how quickly the water is absorbed) to minimise nutrient leaching while maintaining the optimum soil moisture. Realistically, irrigation scheduling is a compromise between plant water requirements, soil types, the application efficiency of the irrigation system, and climate variation. Another issue that needs to be consider is the shallow root zone targeted in turf production. Established turf can have a root depth greater than 300mm but discussions with turf producers suggest the top 100mm have the greatest influence on turf production. To manipulate soil moisture and nutrients within this limited root zone requires an efficient irrigation system tuned for optimum performance and an irrigation schedule that considers all influencing factors.

Using an irrigation scheduling tool such as the Delta-T soil moisture probe (supplied) can also help with refining an irrigation schedule by estimating changes in soil moisture over time to develop a soil moisture map. In the short-term a soil moisture probe can be used to identify soil moisture within the top 100 mm of the root zone to estimate daily crop water use and moisture evaporation. In the long-term it 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. Incorporating the use of an insertion EC meter to monitor salinity levels in the irrigation water and root zone can provide a warning mechanism if salt content increases to dangerous levels. Although taking regular soil moisture and EC readings can be time consuming at first, once a soil moisture map has been developed and EC fluctuations are known, monitoring can be reduced to periods when there is major changes in environmental conditions, management practices or turf health.

The EC of the irrigation water is an indicator of the levels of salts in suspension. It does not identify any specific dissolved salts or the effect they have on the soil and crop, but is used to calculate a leaching fraction and indicate water quality. For example, freshwater rivers can have an EC between zero and 0.8 dS/m. EC readings between 0.31 dS/m and 0.78 dS/m are acceptable for turf grass irrigation[2].

Developing a saline irrigation management plan

A saline irrigation management plan is similar to developing an irrigation schedule but includes triggering prolonged irrigations to specifically 'flush' salts from the root zone. A basic saline irrigation schedule will consist of several short irrigation events to allow moisture and nutrients to remain in the root zone followed by a prolonged irrigation event to flush salts below the root zone. Prolonged irrigations should be used cautiously as these will also flush/leach nutrient below the root zone. Developing a saline irrigation schedule that reduces nutrient leaching and controls salinity may take time but can help to maintain soil moisture, nutrient availability, and reduce water use while managing salts within the root zone.

[2]PennState College of Agricultural Sciences, http://plantscience.psu.edu/research/centers/turf/extension/factsheets/water-quality#EC

To develop a salinity irrigation management plan requires the understanding of several parameters including -

- Soil infiltration rate
- Soil water holding capacity at saturation
- Electrical conductivity (EC) of the irrigation water
- The target EC of the soil
- The leaching fraction required

The soil infiltration rate is a measure of the rate water moves or percolates down through the soil profile. Knowing this allows the irrigation application rate to be matched to the soil infiltration rate. This will reduce surface pooling or runoff, and allow control of nutrients leaching through the root zone. The infiltration rate will not change unless there is a change to the soil structure, e.g. increased compaction or reduced aeration.

The soil water holding capacity is when the soil is saturated and leaching to lower depths begins. This can be determined with the use of a soil moisture probe by recording moisture levels before and during irrigations. Soil moisture will increase until a constant moisture is reached, this is the soil saturation point. Monitoring soil moisture over time and comparing moisture loss to evaporation will also allow plant water use to be estimated. The data can be used to develop an irrigation schedule that provides optimum moisture content while managing salinity and water use.

The target EC of soil is the salinity levels that is acceptable for production. This is either expressed as the salinity of drainage water or as an acceptable percentage loss in harvest yield. Soil EC is also affected by fertiliser application, therefore soil salinity measurements should be taken before and after the application of fertilisers to provide a soil base-line EC point. Monitoring EC at regular intervals after fertiliser application can also provide an indication of nutrient leaching and fertiliser scheduling.

A leaching fraction is the amount of water that must be applied in excess of irrigation requirements to ensure salts are leached from the root zone, rather than concentrating at the surface. To calculate a leaching fraction the EC of the irrigation water and the target soil EC is required. For this farm the averaged soil EC of 0.23dS/m should be used as the target EC to maintain current soil conditions.

The main issue that confounds developing a salinity irrigation management plan is that during times of drought the EC of the irrigation water can be higher than the EC of the soil. In this situation there are few simple inexpensive options that can be implemented to reduce increasing soil salinity.
Some options would be to dilute the irrigation water with lower EC water, use a salt tolerant turf variety, apply gypsum to the production area to displace and leach the salt out of the root zone, or maintain production practices as is and monitor salinity levels. A turf specialist experienced with using high saline irrigation water should be consulted to determine the best option for the farm especially if drought conditioned prevail or sodium levels in the irrigation water increase quickly.

Conclusion

Suspending turf production may have been the best decision for this farm in the long-term due to the high salinity levels recorded in both the soil and irrigation water. Continued irrigation without implementing a saline irrigation schedule may have cause major damage to the soil structure and the existing turf roots.

When the drought breaks, restrictions reduced and the farm starts producing again the water and soil quality should be retested and the irrigation schedule adjusted to suit changing conditions. How long it will take for this farm to return to full production will depend on rainfall, soil health and water quality. The high levels of salinity in the irrigation water and soil samples adds an extra layer of difficulty to developing an irrigation schedule. It may require ongoing monitoring and adjustments over several growing periods to identify the most water efficient irrigation schedule to suit the changes in production and climate variations.

To reduce any future impact of salinity on turf production it is highly recommended that a soil moisture probe and EC meter are used in conjunction with a saline irrigation management plan.

More information about interpreting water and soil analysis or irrigating with saline water can be found at

https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/managing-water-resources/interpreting-water-analysis

https://publications.qld.gov.au/storage/f/2013-12-19T04%3A10%3A23.754Z/salinity-management-handbook.pdf

http://www.dpi.nsw.gov.au/agriculture/soils/salinity/salinity-and-crops/saline-irrigation

Acknowledgments: We would like to thank all the turf producers who participated in this project and the following people for their support and input into this case study

- David Hunt, researcher and author
- Jim Vaughan, QTPA
- Steve Attard, AgriTech Solutions
- NuTurf Solutions

This pilot farm case study is published by Turf Queensland as part of the Rural Water Use Efficiency Irrigation Futures project delivered through collaboration with the Queensland governments Department of Natural Resources and Mines.

Queensland Government

Department of Natural Resources and Mines

RURAL WATER USE EFFICIENCY IRRIGATION FUTURES

Improving irrigation management for a profitable and sustainable future