Environmental Assessment of the Australian Turf Industry

Hort Innovation Project no. TU16000

Benchmarking Report 2018

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Benchmarking Summary

The Environmental Assessment of the Australian Turf Industry is directed to examine the environmental performance of the turf industry. A key component of this is the measurement of efficiencies of processes used to grow turf.

This report provides an analysis of process efficiency data gathered from 30 Australian turf growers for the operating years 2015-16 and 2016-17. The rationale behind this work was to gather useful efficiency data that growers can use to track their own position and continue to run benchmarks on their improvement path. Input efficiencies have been measured in terms of the square meters of turf produced so that the turf growers can be directly compared.

The efficiency data we collected was for inputs such as fertilisers, water and energy. We also collected some output data, particularly production and Greenhouse emissions. The latter was calculated from intensive studies of six turf growers and published industry factors. This data has been compared with other horticulture industries where practical and where information is available.

Turf is successfully grown under a wide range of climates and soil types in Australia. Turf as a typical intensive horticulture product uses high quantities of fertiliser, and less of chemical applications, to enhance growth and protect the turf from pests and diseases. This leaves farm management with a task of making the most of the materials used and managing the risk of excess chemicals entering the environment.

This study has shown that there is a wide range of application practices, with some in significant excess to the turf needs. This presents an opportunity for those growers to consider their practices and modify their farm management.

This study has also shown that all turf growers were able to provide a carbon positive product with net sequestered carbon dioxide averaging 1.6 kg of CO_{2eq} per square meter of turf produced[1]. By estimating the total area under turf in Australia at 4,400 Ha, the net sequestered carbon dioxide by the turf industry is approximately 48,000 Tonne of CO_{2eq} per year.

Comparisons with vegetable growing and vineyards showed that the turf industry has about the same efficiency of water delivery, but uses more water and energy than the vegetable and grape growers per tonne of plant matter produced. Cultivation and irrigation systems are equivalent to the vegetable industry, the difference is possibly in the extra work required in mowing and turf harvesting.

The benchmarks presented in this report provide an overview of the turf industry's performance efficiencies that are directly related to its environmental performance. However, these performance KEPIs do not necessarily directly provide environmental impacts of the industry as these are dependant on particular locations and loss mechanisms.

[1] Sequestration of one kg CO_{2eq} is the equivalent of one kilogram of carbon dioxide removed from the atmosphere

Limitations:

This report has been prepared by Infotech Research in accordance with its contract with Hort Innovation. The data presented has been gained in cooperation with the participating turf growers and site testing data. Modelling has been used to develop estimates of material flows through the turf farm.

There are variations in soil types, climate and operations which have been examined at most farms. This introduces an uncertainty in some of the data. There was also a variation in the amount and quality of the data provided by the growers. We cannot guarantee the accuracy of the information provided by the growers and suggest that before acting on the data presented herein the reader confirms the validity of their own data and checks it against the full sample.

This report is for public presentation and is the property of Hort Innovation. Individual performance data is the property of the particular turf farms, no turf farm has been identified in this report and individual data should not be presented in isolation without the express agreement of those turf farmers themselves.

Acknowledgements:

This study would not have been possible without the gracious and welcoming assistance of the thirty turf growers involved. Their patience and positive assistance in all aspects of the project is appreciated.

A special thank you is due to Joe Rogers from Lawn Solutions Australia who assisted us in getting the show on the road and introduced us to a lot of turf growers.

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Thanks are due finally to Byron De Kock from Hort Innovation for his calm direction as project manager (also to Dr. Brenda Kranz who successfully launched the project.)

Contents

Introduction and purpose

This study commenced in January 2017 after a revision to the original goals. The study aims to provide turf growers with useful efficiency benchmarks that relate to environmental outcomes. Growers who participated in the study can compare their farm's performance in relation to the others studied and examine their opportunities for improvement. Growers outside this study can undertake their own measurements and make the same comparisons.

Environmental impacts are the result of wastes entering the environment from human activities. Less wastes generate less environmental impacts and result in a more efficient and profitable activity.

Less Waste = Less Material Input and Lower Cost of Production =>> More Profit

The profit motive and environmental outcomes are aligned in this case.

We have assessed the turf farms to ascertain their position in relation to sensitive environmental receptors like residential developments, rivers and parklands that may be impacted by farm activities. We have looked at inputs and outputs from farm activities.

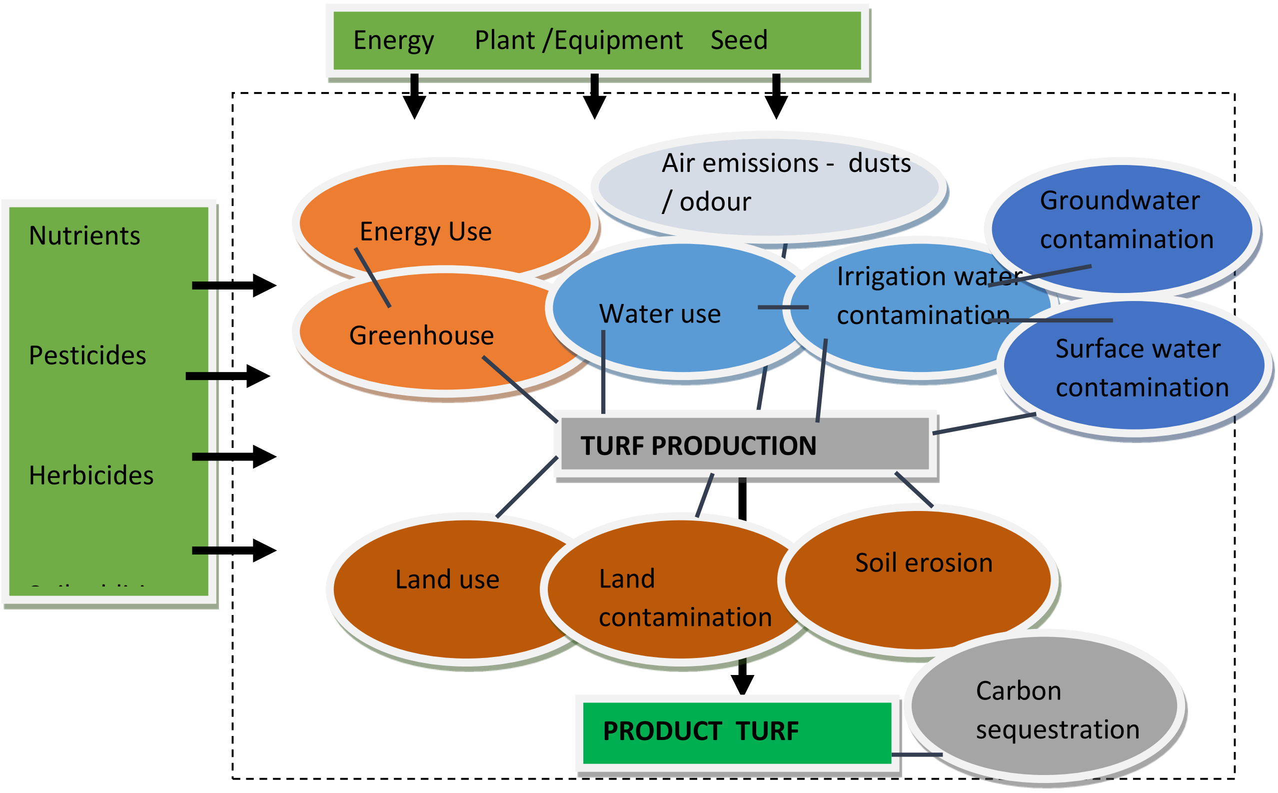

Diagram 1 – Input and output parameters examined

In practice it is much easier to measure inputs than outputs / wastes. This was the method of choice for this benchmarking study. Grower records were used to determine inputs of materials and energy. This was supplemented by examination of wastes, testing of waters and measurements of pump flows and energy consumption where practicable.

The sample

Turf growers' interest in the study was canvassed without any restrictions on size and location. The objective was to gain participation from growers in most states and to gain a cross section of small to large growers.

In total 30 responses have been provided and we have visited 28 of these growing sites to gather information. We believe that this is a reasonably representative set of growers from five of the six states (Tasmania was the one exclusion). In practice we found it necessary to visit the majority of growers to gain the most relevant data. We collected soil samples at 26 sites and irrigation water samples at 28 sites.

Six farms were more intensively evaluated in order to gain a better understanding of water, soil and nutrient flows. These learnings have been applied to the data from the rest of the farms to make estimate such as the composition of the plant tissue, losses of nutrients through erosion, leaching and volatilisation and to enable a calculation of the carbon balance (Greenhouse emissions).

What have we considered

When calculating farm efficiencies, and hence wastes from an input output analysis, we have used a standard for measurement of one square meter of turf produced. This enables comparison of growers of differing sizes. All input measures have been determined per square meter of turf production.

The key efficiency factors we have looked at are given in the following table.

Production (m^2/Ha)	Production efficiency m^2 per Ha under cultivation (100% efficiency = 10,000 m^2/Ha)
Pumping energy efficiency (kL/kWh)	Irrigation flow in kilolitres per kilowatt hour of energy consumed (electric pumps only)
Water use (Litre/m^2)	The number of litres of water irrigated per year for one square meter of turf produced
ML/Ha	The number of megalitres of irrigation water per Ha of farm
Fertilizer use (kg N/m^2)	Nitrogen application to the farm in kilograms divided by the production in m^2
(kg P/m^2)	Phosphorus application to the farm in kilograms divided by the production in m^2
(kg K/m^2)	Potassium application to the farm in kilograms divided by the production in m^2
Pesticide use (Formulated L/m^2)	Litres of pesticide and herbicide formulations per m^2
Energy use (Diesel L/m^2)	Litres of diesel used on the farm per m^2
(Electricity kWh/m^2)	Kilowatt hours of electricity consumed per m^2
(Total Energy MJ/m^2)	Total energy used (diesel plus electricity) in megajoules per m^2
Greenhouse emissions ($kgCO_{2eq}/m^2$)	Greenhouse emissions from energy and chemical products used on the farm per m^2
Net sequestered carbon in turf ($kgCO_{2eq}/m^2$)	Net Greenhouse emissions in the turf product per m^2

Table 1. Key Environmental Performance Indicators (KEPIs)

Further details on the method used to calculate these efficiency factors is provided in the Appendix: Method

In addition to these efficiency factors we have examined soil and water conditions, where possible. We also rated environmental risks in a qualitative manner in this report.

What did we find

In aggregation the efficiency figures for the 30 turf farms studied are given in the following table. These present median (most likely result) for the 30 farms. In most cases we determined these efficiencies per square meter of turf produced, using accounts for materials and energy used by the farm and dividing these inputs by the production.

Aggregated results	**2015-16**	**2016-17**	**Source**
Production (m^2/Ha)	5,990	6,655	Data provided[2]
Pumping energy efficiency (kL/kWh)		3.23	Measured
Water use (Litre/m^2)	1,098	1,013	Calculated
ML/Ha	6.7	6.1	Calculated
Fertilizer use (kg N/m^2)	0.043	0.051	Data provided
(kg P/m^2)	0.016	0.016	Data provided
(kg K/m^2)	0.018	0.024	Data provided
Pesticide use (Formulated L/m^2)	0.0018	0.0020	Data provided
Energy use (Diesel L/m^2)	0.11	0.14	Data provided
(Electricity kWh/m^2)	0.26	0.23	Data provided
(Total Energy MJ/m^2	5.2	6.5	Calculated
Greenhouse emissions (kgCO2eq/m^2)	0.50	0.52	Calculated
Net sequestered carbon in turf (kgCO2eq/m^2)	-1.63	-1.63	Modelled

Table 2. Median KEPIs across the 30 participating growers

The variation in these figures from the 2015-16 financial year to 2016-17, are indicative of the changes in conditions of the climate and the market in the case of production efficiency (m^2/Ha). The variation between turf growers is more pronounced, which is demonstrated later in this report.

Production data indicates the efficiency of production on an annual basis. The production (harvested turf) in square meters is given per Ha cultivated. This is between 60% and 67% of the area in 2015-16 and 2016-17 respectively. Production data can be a little misleading as some species of turf take 18 months to mature in lower longitudes and others have potentially two harvests within the one year.

Water consumption is expressed as megalitres per hectare (ML/Ha) as well as Litres per m^2 of product turf. The latter is a better measure of water efficiency, but will certainly depend on the mix of species grown as well as the climate for individual growers. The median water consumption was consistent from one year to the next at 1000 L/m^2 which is equivalent to 1000 mm of rain.

This data enabled us to calculate the total industry figures for Australia by using Turf Australia's estimate of the total area under turf in Australia of 4,400 Ha.

[2] Data was gathered from the turf growers accompanied by site inspections and soil and water sampling.

Parameter	Industry total	
Area under commercial turf	4,400	Ha
Production expected	29	million m^2
Water consumption	30,000	ML
Nitrogen applied in fertiliser	1,250	Tonne
Phosphorus applied	460	Tonne
Potassium applied	520	Tonne
Chemicals applied	52	kL
Diesel used	3,240	kL
Electrical energy used	7,700,000	kWh
Net Greenhouse emissions[3]	- 48,000	Tonne of CO_{2eq}

Table 3. Gross Australian turf industry estimates

Key figures for the turf industry are the production of 30 million square meters, consumption of 30 Gigalitres of water and the net saving of 48,000 Tonne of Greenhouse emissions at the farms.

Industry comparisons

How do these performance efficiencies compare with other horticultural industries? We have looked at available data mainly from the Australian Bureau of Statistics. In order to compare turf with other crops we have used the average turf yield of 1.41 kg of plant matter per m^2 and converted this to tonnes of plant matter to have a similar factor to the other industries for production.

Industry Comparisons[4]	Vegetables	Pasture	Vineyards	Turf[5]
Water use (ML/Ha cultivated)	6.5	3.9	10.4	6.1
Water use (ML/T)	0.13[6]	-	-	0.72
Pump efficiency (kL/kWh)	3.7	-	-	3.23
Energy use (MJ/T)	2,120	-	2,600	4,635
Diesel use (kL/T)	0.034	-	-	0.098
Electricity use (kWh/T)	194	-	-	165

Table 4. Cross industry comparisons

Turf farming has a similar water use per hectare to vegetable growing, consumes more water per hectare than pasture irrigation, but less than vineyards on average. This data is approximate and varies considerably with the climate and species being grown. Water use per tonne of turf plant produced is significantly greater than for vegetables on average due to the higher vegetable yields.

Energy use is greater on turf farms per tonne of plant matter produced (approximately double vegetable averages), which appears to be due to greater diesel consumption. Electricity use is lower for turf, as vegetable producers can run energy intensive cool stores as well as using electricity for water pumping.

[3] These Greenhouse emission calculations have not taken farm infrastructure into account.
[4] Data has been sourced from the ABS (2004-5). Vineyard data comes from (J.Russell, 2009) and the vegetable energy data is from (Cumming, 2014)
[5] Results from this study
[6] While vegetables are irrigated at about the same rate per hectare as turf, the vegetable yields are much greater than turf (average around 50 T/Ha)

The greatest electrical energy use on a turf farm is usually pumping water. Pump efficiencies were similar for turf and vegetable irrigation where there is a fair comparison available with similar pumping and water delivery systems in the two industries. Individual growers will have varying performance characteristics depending on the irrigation set up, high or low pressure, and the water source, bore water or surface water.

Efficiency Benchmark data

Production efficiency

Individual turf grower's production efficiency was calculated as square meters of turf produced per hectare from annual production data and the total farm area under turf. This is likely to vary from one year to the next as seasons and markets both change, so two years were evaluated to gauge this variation.

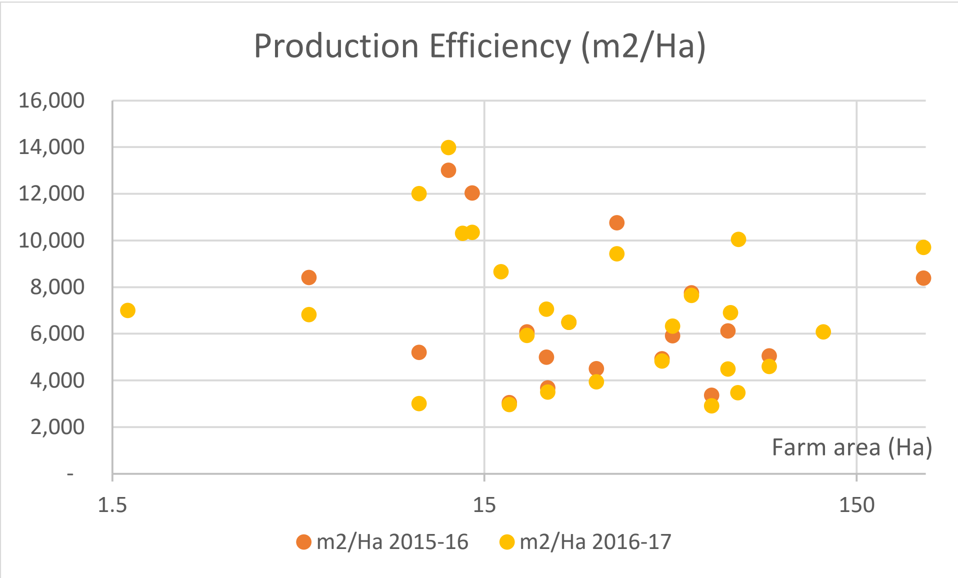

Chart 1. Production efficiency plotted against farm area in Ha

This performance can be determined as a percentage production efficiency by dividing these numbers by 100. In percentage terms, grower efficiencies varied from about 30% to 140% of the area farmed. This is a large variation, which was consistent from one year to the next for individual growers.

Errors are in the determination of the area under turf, as this may change with farm expansion or with paddocks being rested at times.

There did not appear to be a correlation between the production efficiency and the size of the farm as both the least and most efficient farms are at the lower farm sizes.

Turf varieties also impact on efficiency due to different cultivation systems, some leaving a strip of turf for regrowth and others harvesting 100% of the turf area.

Despite different varietal growth rates there is opportunity for the growers with lower production efficiencies to lift and increase their turf sales. A study of precision farming techniques showed an improvement for plots from 8,200 to 9,500 m2/Ha (Turf Queensland, 2015) in the Logan region of South east Queensland, which does enjoy the benefit of twice the sun exposure of the southern growing regions of Victoria.

Water consumption benchmarks

Metered water data was used if available. If growers did not meter water use, the pump efficiency was measured, as was the energy use, to calculate the amount of water pumped. This was then divided by the farm area to give the water usage per Ha.

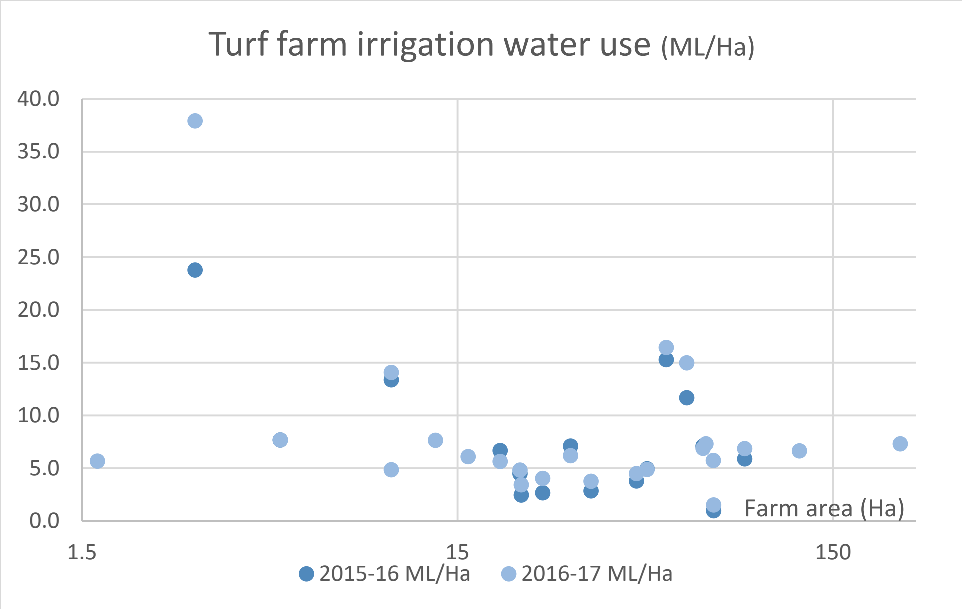

Chart 2. Irrigation water use per hectare plotted against farm area

The median water use for irrigation was 6.7 ML/Ha in 2015-16 and 6.1 ML/Ha in 2016-17. A few farms were significantly above this, but these were in hotter regions and/or had more porous soil structures.

There is a correlation between irrigation water use and rainfall during the growing season. Water balances carried out indicated that the total water input equated with the major loss mechanism of evapotranspiration. In some cases of high water use, loss through leaching was a significant water loss mechanism.

The major opportunities for performance improvement appeared to be the use of soil moisture meters to control irrigation scheduling, rather than turf appearance and using weather forecasts to plan irrigation.

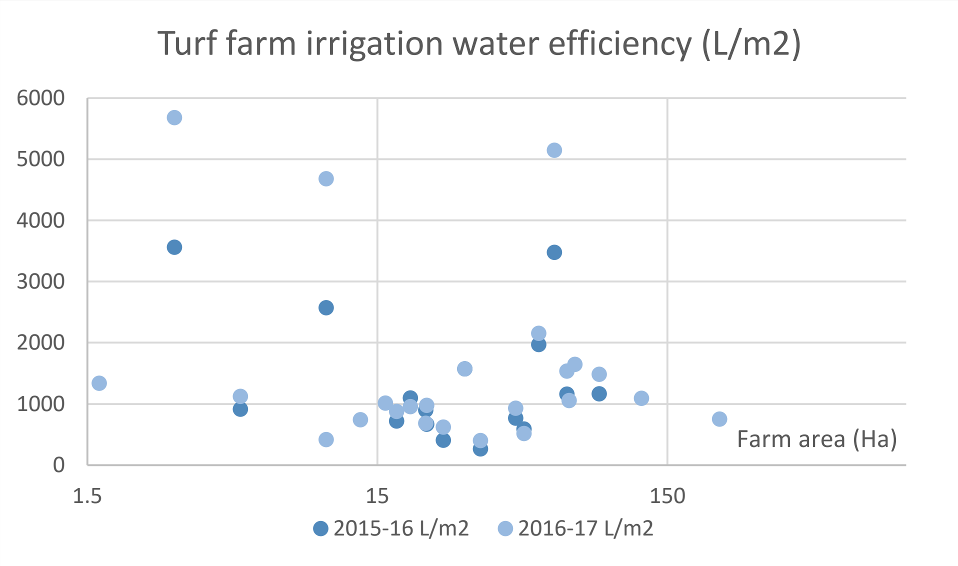

Chart 3. Irrigation efficiency plotted against farm area

The median water used per m2 of turf produced was 1,098 L/m^2 in 2015-16 and 1,013 L/m^2 in 2016-17. This corresponds to ~1,000 mm across the area harvested, or 700L/kg of plant matter harvested.

Variation in water efficiency is more pronounced when expressed in terms of production and there does appear to be a slight correlation between improved efficiency and increasing farm size.

Pump efficiency

Pump efficiency was measured opportunistically when pumps were operating during the inspection, and either meters were in place or the flow rates could be determined using an ultrasonic flow meter. Pump efficiencies for diesel pumps were calculated when diesel consumption and flow data were available, in a few cases only.

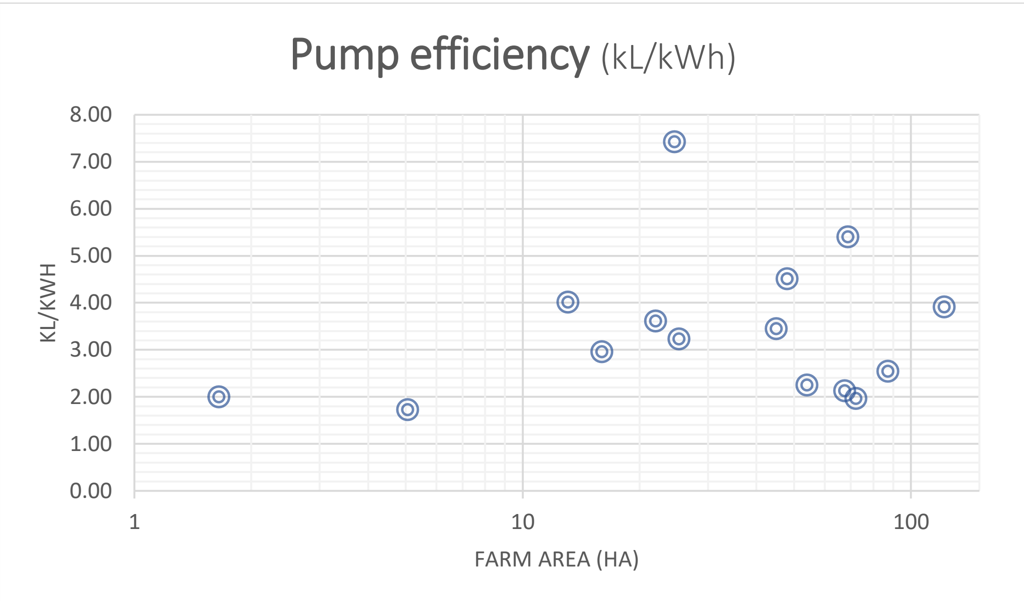

Chart 4. Pump efficiency plotted against farm area

The median pump efficiency was 3.2 kL/kWh and was measured for the 2016-17 year during site inspections. Other Australian studies have measured pump efficiencies at 2.9 to 3.6 kL/kWh (Turf Queensland, 2015).

The lower range of efficiencies were due to sub optimal pump set ups and static heads in pumping bore water to the surface. The requirements of high pressure irrigation systems also lead to lower pumping efficiencies.

Nevertheless, the range from 2 to 5 kL/kWh indicated that there is an opportunity to improve pumping systems and to save on energy costs for those at the low end of efficiency.

In most cases there is a variable demand on the pumps, which then generates variable efficiency. The grower can set the system up to be most efficient at the most common irrigation scenario, or include a variable speed drive, VSD, to the pump motor to allow for variation in flow demand. Six growers from 22 using electric pumps had installed VSD systems of pump control, thus avoiding the need of valves to choke flow rates.

Fertiliser application benchmarks

Nitrogen

Fertiliser application is a significant expenditure for turf farms that require it for good plant growth, making wastage expensive and providing a possible environmental impact to either surface or ground waters.

The nitrogen application to the whole farm was calculated by determining the total application of each fertiliser product and manures with the percentage of nitrogen calculated for each product. The total "N" in kg was calculated and then divided by the quantity of turf produced in that year. The application rate in kg (N)/Ha is determined by the product of the N (kg/m2) x Production in m2/Ha.

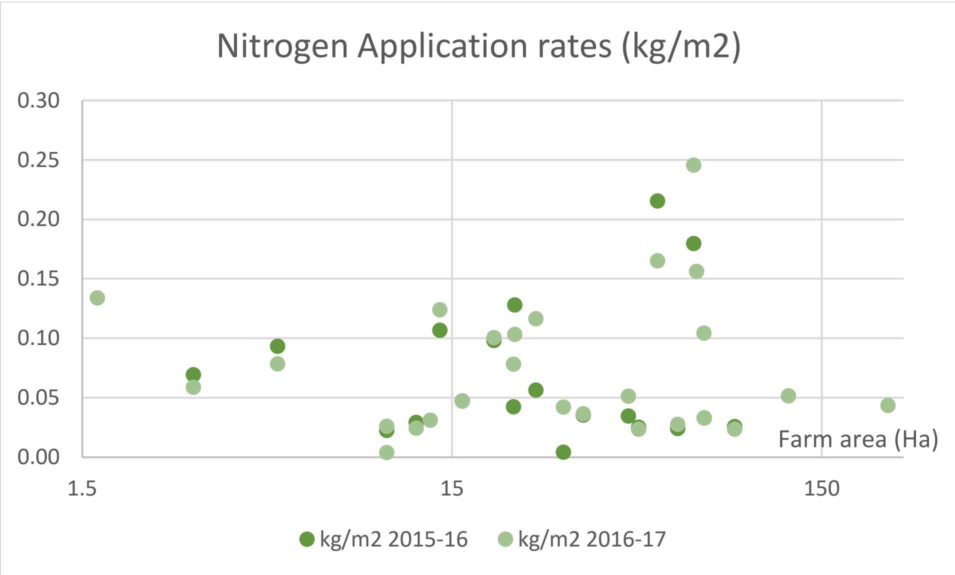

Chart 5. Nitrogen application per m2 of product plotted against farm size

The median N application efficiency was 0.043 Kg (N)/m^2 in 2015-16 and 0.051 kg (N)/m^2 in 2016-17. This corresponds to annual application rates of 430 and 510 kg (N) per Ha. The application rates varied from almost nothing to five times the median level, with a cluster of farms around 0.10 kg (N)/m^2.

All the applied N should end up in the turf product in an ideal scenario. However, at the median level of application and the measured average N content of the turf of 0.30%, approximately 8.3% of the applied N was recovered in the turf. Deficit fertilisation[7] could improve this, but the question is whether this is sustainable as the soil nitrogen stocks are being depleted.

What is considered as best practice depends on the unique circumstances of each farm. Although the measurement of nitrate was limited in the surface waters and not at all in the groundwaters, it appears that this sort of monitoring is a useful method of detecting losses of excess nitrogen (and other fertiliser elements).

In six of the farms this study undertook a soil depth profile of nitrate nitrogen to one meter. In most cases the nitrate levels were low, and they did not accumulate at deeper soil levels. A few farms had

[7] Deficit fertilisation uses a lower application than the turf needs so that soil nutrient reserves are drawn on.

run off catchments and the water tested in most of these cases did show nitrate and phosphate at elevated levels from runoff.

The conclusion from this data is that some farms are putting too much fertiliser as N onto the turf and have an opportunity to apply less.

Phosphorus

The same approach was taken to measure the phosphorus, as P applications, as a function of production.

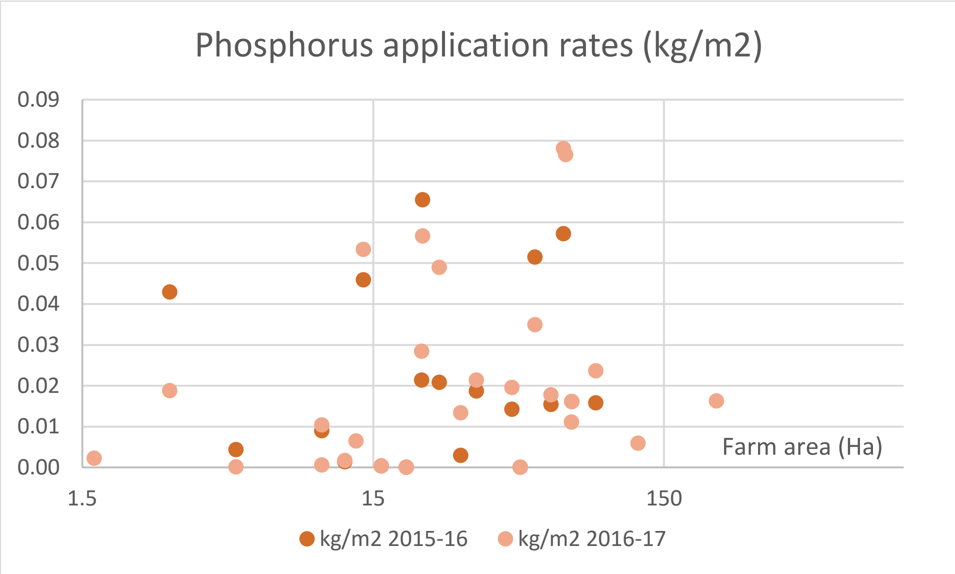

Chart 6. Phosphorus application per m2 of turf produced plotted against farm area

The median application rate for phosphorus as P was 0.016 kg (P)/m^2 in both years 2015-16 and 2016-17. In this case there was a fivefold variation in application rates. These rates are lower than nitrogen, as expected, but the variation indicates less active control of phosphorus by growers. Several growers were applying less than 0.002 kg (P)/m^2, most definitely a deficit situation where the soil stocks of P will be depleted.

The phosphate applied will probably attach to soil particles, at the soil pH encountered the phosphate will most likely be in an ionic form ($H_2PO_4^-$). In the intensively studied farms the phosphorus levels dropped with increasing depth to one meter.

Any excess in phosphate is likely to be adsorbed by the soil so that soil analyses should indicate the level of soil stocks and ability to reduce application rates to a sustainable level.

Potassium

Potassium application rates were expressed in kg/m^2 in the same way from farm fertilisation schedules, examining “K” content for each product and calculating the total potassium applied. The total potassium was then expressed as a rate per m^2 of turf produced.

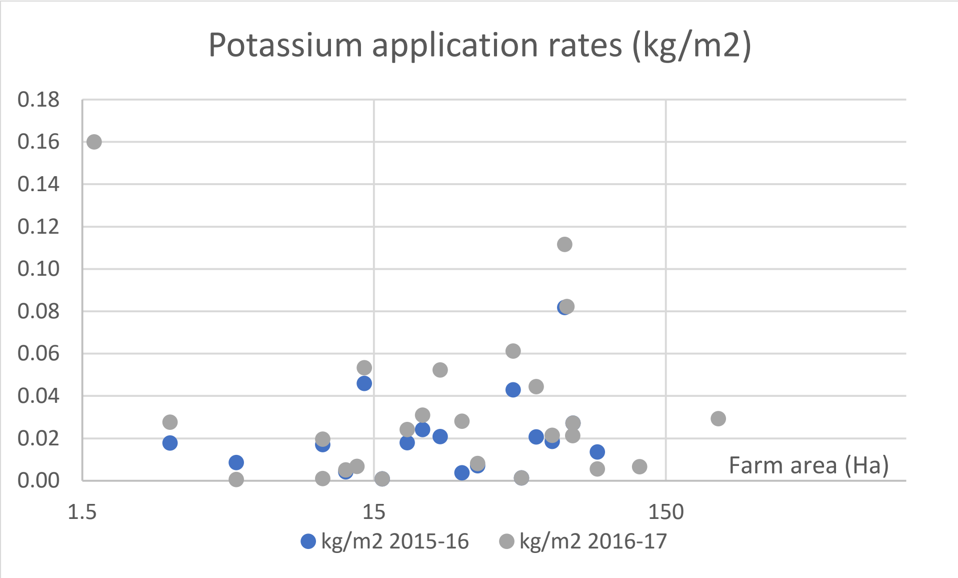

Chart 7. Potassium application rates in kg/m2 of product plotted against farm area

The median potassium application rate was 0.018 kg (P)/m^2 in 2015-16 and 0.024 kg (P)/m^2 in 2016-17. The variation between individual growers was ±100% with a few growers adding five times more potassium.

Losses of potassium are more likely as it is highly water soluble and will move with water flows.

Using the median potassium application figure for 2016-17 of 0.0124 kg(P)/m^2 and plant content of potassium average of 0.019 kg(P)/m^2 there is a small deficit that will come from potassium stocks in the soil. It appears that a “K” application rate of 0.02 kg(P)/m^2 is about the optimum sustainable rate of potassium application, assuming that there are no issues with water losses in run-off or leaching through the soil profile.

Potassium levels through the soil profile were examined in the six intensive grower studies. These all showed a degradation in level of potassium deeper into the soil.

Energy consumption

Turf farms used energy as diesel to fuel tractors and associated equipment (and in some cases to produce electricity). They also used electricity from the grid or generated on the farm. Some petrol may be used and some LPG for forklifts loading trucks, but these fuel uses were minor in comparison to the diesel and, as such, were not considered as part of this study.

Total energy was calculated for each year in megajoule (MJ), where the conversion factors are 3.6 MJ/kWh for electricity and 38.6 MJ/L for diesel fuel. These were added to give a total energy consumption for the farm.

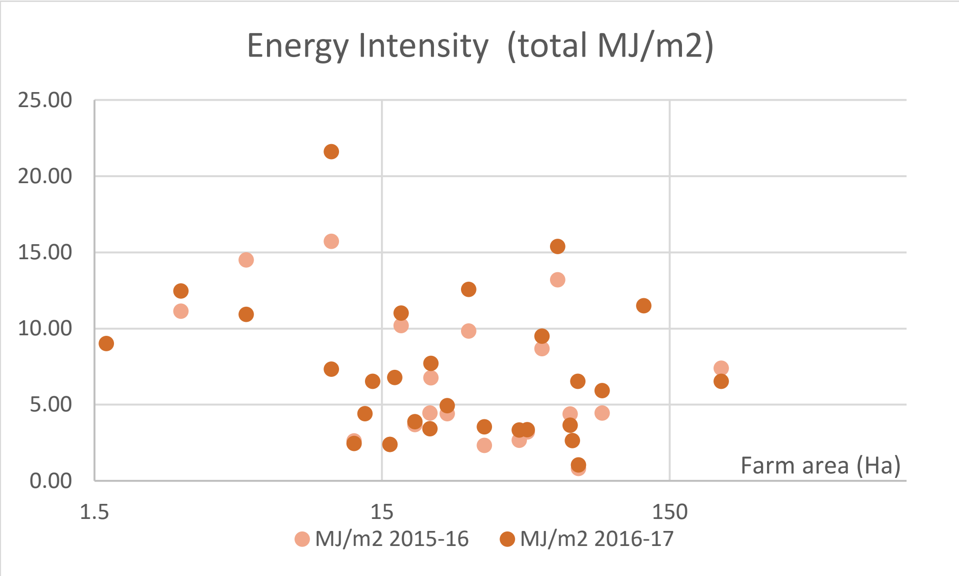

Chart 8. Energy intensity of farm practices plotted against farm area

The median energy consumption was 5.21 MJ/m^2 for 2015-16 and 6.54 MJ/m^2 for 2016-17 (a 25% increase year on year). The reason for this increase is unclear, but the increase was consistent in 80% of the growers surveyed. Variation about the median ± 4 MJ/m^2 with some growers in the 10 to 15 MJ/m^2 range (high energy users).

There appeared to be no correlation between energy use and farm size, with farms in the 20 to 70 Ha range exhibiting the lowest energy use as well as the highest.

The energy use was split between diesel fuel (mainly tractors) and electricity (mainly pumps). In terms of MJ, it was about 5:1 in favour of diesel. It should be noted that of the 30 participants only 20 provided data for energy use in 2015-16 while 28 provided data for the year 2016-17. Three of the extra eight ran diesel pumps for irrigation, which may have weighted the energy use toward diesel in 2016-17.

It should also be noted that diesel at $1.10 per Litre costs 2.9c/MJ, while electricity at $0.25/kWh costs 6.9c/MJ. However, electric motors are approximately 90% efficient, while diesel motors may only have an efficiency of 35%, pushing the cost of work done in favour of electricity over diesel. This suggests that any work in which electric or diesel are options should fall in favour of electricity. From this analysis farm work should be considering moving towards electrification over internal combustion engines.

Diesel

Diesel consumption efficiency was expressed as litres of diesel per m^2 of turf harvested for the years 2015-16 and 2016-17.

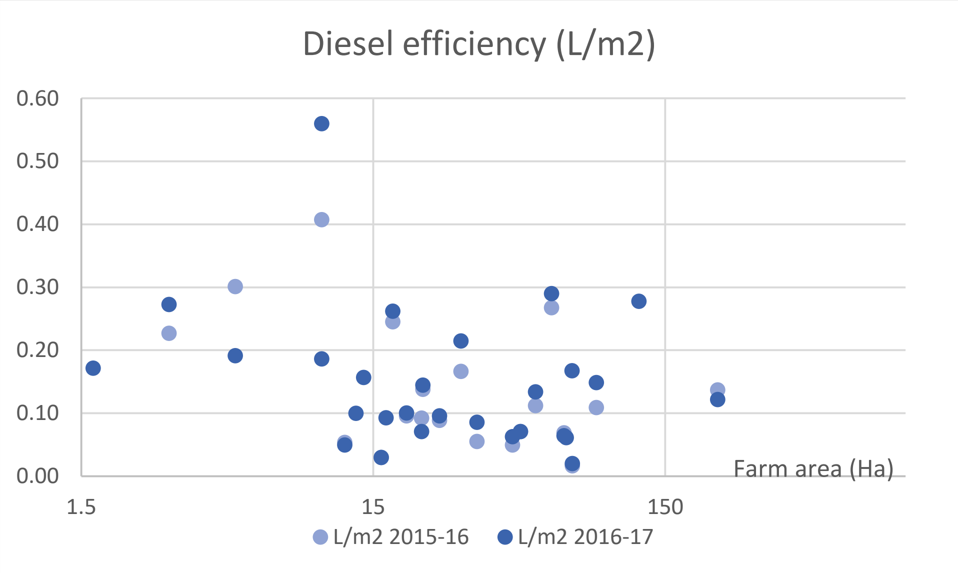

Chart 9. Diesel consumption efficiency plotted against farm area

The median diesel consumption per m2 harvested was 0.10 L/m^2 in 2015-16 and 0.13 L/m^2 in 2016-17. There was no obvious cause of the increase of 30% from one year to the next except the inclusion of another eight farms in the 2016-17 data. The variation from the median was almost ±100%, casting some doubt on the validity of the low usage data. High diesel users had diesel pumps in the main and there is a possibility of other uses of diesel becoming mixed into the farm use in some cases.

Best practice diesel consumption is not readily defined, as the consumption depends on the applications for which it is used. In some cases, diesel was used in gen sets to generate electricity for pumps, in others diesel pumps were used. All growing sites used diesel for tractors and associated mobile equipment.

It can be concluded that there is room for diesel usage efficiency improvement for those with a high diesel consumption level.

Electricity

Total electricity usage on the farms included pump stations (metered), sheds and farm offices. Frequently a farm house was included in this data, in these instances an allowance was made and a deduction for the assumed usage was made. The farm's total electricity consumption was then divided by the production to arrive at an electricity usage efficiency in kWh/m^2.

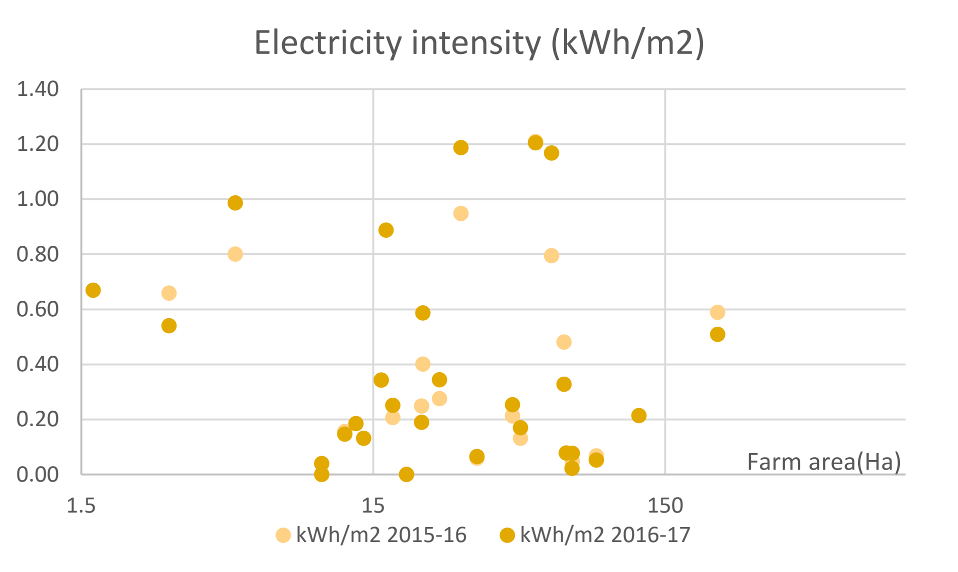

Chart 10. Electricity efficiency in kWh/m^2 plotted against farm area

The median electricity usage efficiency was 0.26 kWh/m^2 in 2015-16 and 0.23 kWh/m^2 in 2016-17, indicating a 12% efficiency improvement year to year. This may also be affected by the inclusion of more data in 2016-17 from growers than 2015-16.

There was a much greater range of electricity usage than diesel, with some farms using five times the median usage and others using practically no electrical energy, for instance the farms using gen sets.

Best practice is a more difficult concept to quantify for electricity than for diesel, as it depends on what the electricity is used for. Examination of operations showed a wide variation in technology efficiency and some farms had installed solar photovoltaic panels to reduce their dependence on the electricity grid. Solar PV systems have the potential to drop electricity usage to zero in some cases.

Greenhouse impacts

Greenhouse impacts were determined by modelling the carbon dioxide sequestration by the turf plant and subtracting the emissions caused by energy use[8], fertiliser[9] and chemical[10] use on the farm, to arrive at a net level of carbon sequestration. The model was produced from the intensive study of six farms, in which the product turf was analysed for carbon to determine the amount of CO_2 sequestered per m^2 of turf harvested.

The figures calculated are accurate for the six intensively studied farms, but varied considerably depending on the species of turf studied, the cultivation and the harvesting methods. This introduced an error of ±23% into the average carbon sequestered in a m2 of turf of 0.71 kg C/m^2.

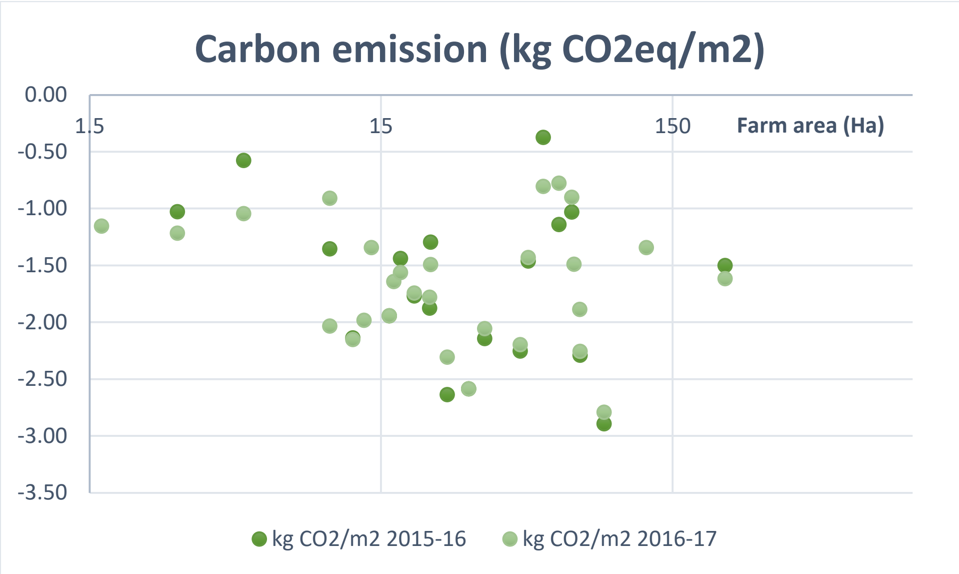

Chart 11. Greenhouse emissions (net sequestration) for turf produced

As shown on the chart all growers recorded a negative Greenhouse emission from their farm operations. This means that all were effective in producing a carbon positive product, although the degree of sequestration varied from 0.5 kg CO_{2eq} / m^2 to 2.9 kg CO_{2eq} / m^2.

The median carbon dioxide sequestration was 1.63 kg CO_{2eq} / m^2 in both years. The factors that feed into Greenhouse efficiency variations include production efficiency, energy efficiency, fertiliser and chemical efficiencies and irrigation efficiency. So that the Greenhouse result for a farm is the sum of the process efficiencies previously given.

Best practice is again a difficult concept to determine due to all the reasons provided, as well as the role played by climate. The regions with more sunshine will gain more photosynthesis and sequester more carbon dioxide than those with lower photosynthesis potential. In Queensland daily sun exposure is around 18 MJ/m^2-day, while New South Wales/Western Australia averages 15 and southern Victoria/Tasmania averages 9 MJ/m^2 (half that of Queensland). There is also a balance of

[8] Energy use was converted into Greenhouse emissions using the Australian Department of Energy and the Environment's Greenhouse factor report in 2017

[9] Fertiliser production and emission impacts were modelled from the intensive farm studies plus the emissions in fertiliser production and transport (factor used N kg x 5.6 = CO_{2eq} kg)

[10] Chemical use related Greenhouse emissions were estimated using an average of individual chemical determinations by Audsley et.al. at Cranfield University in 2009 (factor used 20.7 kg CO_{2eq}/kg chemical)

the hot and cool regions that require varying applications of water that costs energy and produces Greenhouse emissions on the farm.

Overall no specific factors could be determined that made a consistent impact on carbon sequestration per square meter across the turf farms studied. Farms that used lower energy levels and had higher production efficiencies showed higher levels of carbon sequestration.

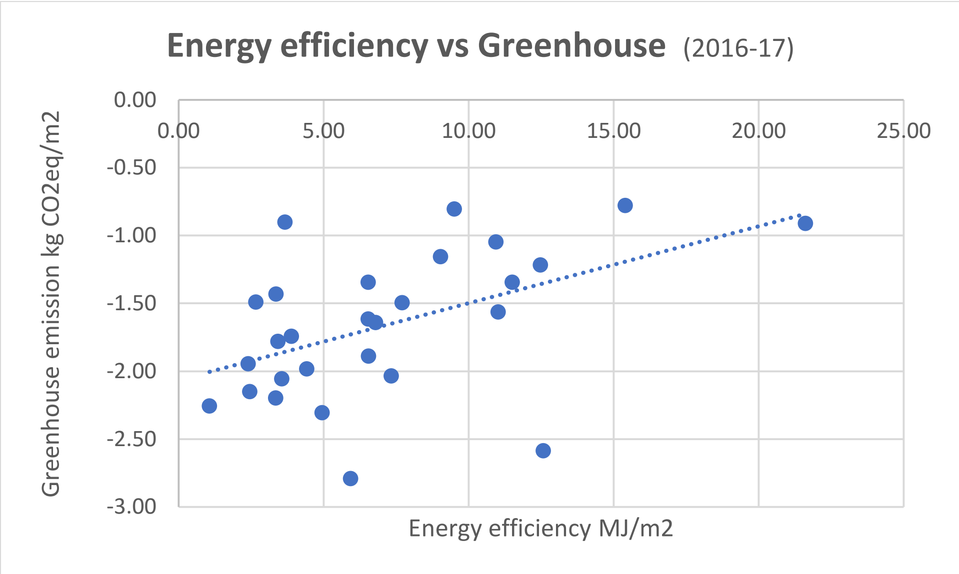

Chart 12. Effect of energy efficiency on Greenhouse emissions

Environmental Risk

Twenty eight turf farms were visited by the audit team that investigated environmental pollution risks. These risks were identified and given a qualitative assessment (high – medium – low risk) based on the potential pollution loads and the sensitivity of the receiving environment.

A full list of risks was qualitatively evaluated for each participating turf farm, the table gives an average view of the spread of these risks across the participants.

Environmental segment	**Risks averaged across the surveyed turf farms**					
Land	Erosion	Asbestos	Diesel spill	Chemical spill	Product losses	Salinity
Surface waters	Nutrients	Turbidity	Toxicity	Bacterial action	Persistent pollutants	
Ground water	Pesticides	Heavy metals	Salinity	Nutrients		
Air	Odour	Dust	Noise	Spray drift		
Wastes	Litter	Chemical drums	Turf wastes	Infrastructure	Machinery	Old batteries
Low-medium	Medium	Higher				

Table 5. Environmental risks for turf farms

High risks

The one consistently high risk for turf farms is the potential for chemical sprays to travel from farms to neighbouring properties. In areas where turf farms are close to residential areas this risk of spray drift is exacerbated. Similarly, rivers can be affected by spray drift impacting on aquatic bio systems.

Asbestos is a high risk in farms that have asbestos pipe works. This is common in New South Wales where irrigation mains were made from asbestos pipe. These are often old and when the pipes are disturbed farmers have the dilemma of what to do. To avoid a toxic legacy to future generations it is recommended that the asbestos be professionally removed from the property.

Medium risks

Consistent losses of top soil from the land from export in the turf is an issue for all turf farms. The average loss is 11.3 kg (soil)/m2 in the turf product that is equivalent to a loss of 6.5 mm of soil from the intensive studies. This may eventually affect the soil's fertility.

Diesel spills may contaminate the land and will often film over water surfaces, impacting the viability of aquatic life. Most of the farms had bunded their diesel tanks, but only a few had bunded the delivery area, which is most at risk from spills during refuelling.

Chemical spills present a similar risk to diesel, but the impact can be significantly worse on river ecologies. Most farms had a locked and bunded chemical store, but none were observed with a bunded mixing and fill area.

Surface waters can be at risk from run off containing fertilisers and silt from the farm's soils. This risk is particularly acute where erosion occurs during periods of high rainfall. A few farms had buffer regions around the turf to absorb run off, but most did not.

Groundwater is also at risk from fertiliser nutrients and water soluble chemicals applied to the farms. This risk needs to be managed where the soil porosity is high and water leaches quickly through the soil profile. This risk was evident where sandy soils were encountered. Nutrients were detected in some bore water samples, but it was not conclusive that the pollution was coming from the turf farm itself.

In some areas where groundwater is used for irrigation the aquifer itself may be at risk from overuse. Recharging the aquifer was a practice of one of the farms visited.

Wastes may have an environmental risk: empty chemical drums old batteries and old equipment can contaminate the land immediately around them. The contents of drums should be cleaned out and old equipment should be drained of oil before it is left unprotected.

Loss of nutrients to run off is a risk where piles of manure and other fertilisers are left near drains unprotected. Containment may be as simple as putting a tarp over the pile to reduce losses through erosion and run off.

Turf wastes is a risk mainly in terms of opportunity. These wastes can be recovered and used on the farm if there is protection against cross species contamination. Composting is an option that only a few farmers were practising.

Low risks

Low risks do not warrant expensive preventative actions to avoid them. These include dust generation and noise, as most farms were not very close to residential areas.

Erosion was a problem in a few farms and needed action to mitigate the effects. This can be alleviated by strategic plantings of suitable vegetation for the area to form a barrier to the flow of materials off farm. It has been reported that vegetation barriers will reduce nutrient losses to water ways if planted along the riparian zone (Lively, 2016).

Land salinity could also be a risk for those using saline bore water. This was not evident in soil samples taken for the participating growers, although some growers were using bore water with an EC > 1000 uS/cm.

Farm Condition

Farm conditions varied in every aspect, so that benchmarking was not possible. In most cases was a soil sample was taken and the irrigation water was tested. The basic elements of the soil fertility and suitability of water for irrigation are presented for most of the participating growers.

Soils

pH

The pH, cation exchange capacity and the organic content of the soils has been studied to give a broad understanding of the situation at this time. Soil samples were taken at four points (0 to 10 cm) on the farms and combined into one sample that was then sent to Phosyn Analytical Laboratories for analysis.

The soil pH given is for a soil water mixture of 1:5.

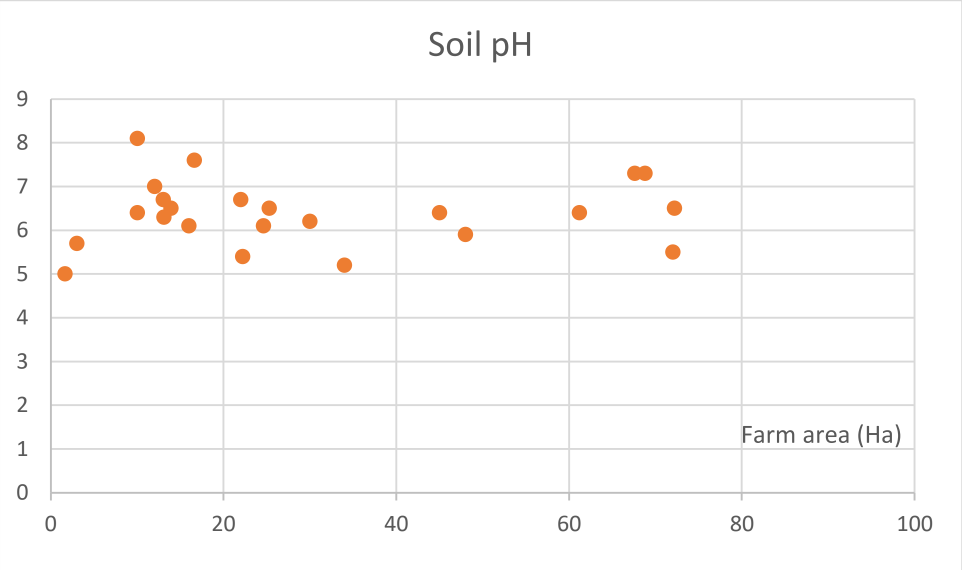

Chart 13. Soil pH for the participating growers plotted against farm area

The median pH from soil tests was 6.4, the range for these farms was 5.0 to 8.0 (which equals a H^+ concentration range of 1000 fold). This is a satisfactory pH for most plants and at this pH the H^+ ion does not dominate the soil cation sites. At lower pHs the H^+ ion is at a much greater concentration preventing the metallic nutrient cations from being as available to the plant.

At a pH of 5 or less there is a need to push the pH up usually with the application of agricultural lime.

Cation Exchange Capacity

This is a measure of the soil's capacity to hold metal ions like calcium, magnesium and potassium. A good range for the CEC is 10 to 40 milliequivalents per 100 g of soil.

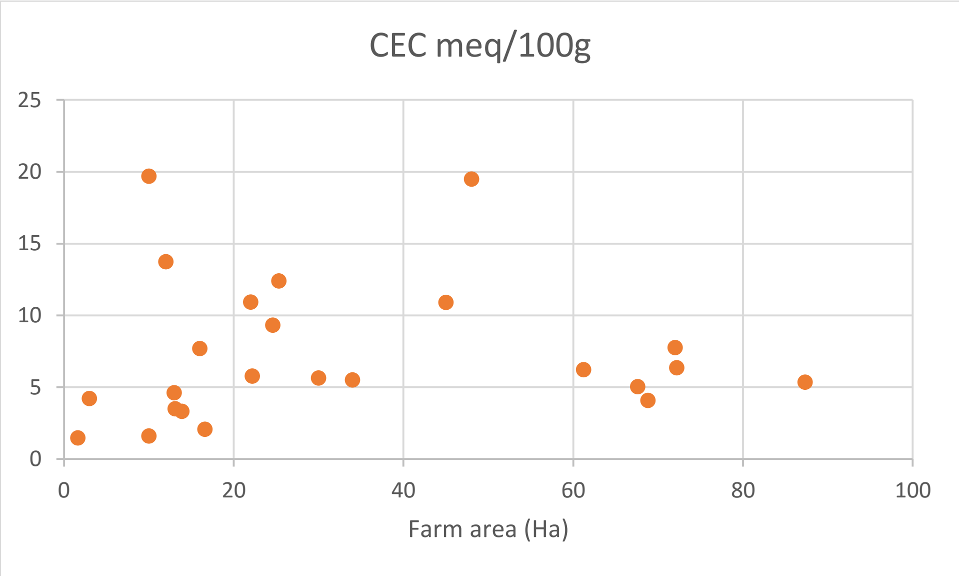

Chart 14. Cation Exchange Capacity (CEC) of growers' soils plotted against farm area

The median CEC for turf grower soils was 5.7 which is well below an optimal level for fertile soils. Only 20% of the soils tested had a CEC above 10. Some turf farms had established soil amendment schemes to increase the water holding capacity and CEC of certain areas in their farms with positive results.

Organic matter

Organic matter is a measure of soil biological activity that is aligned with soil fertility. Soil organic matter is a major storage of soil carbon (about 50%) and nitrogen (about 6%). A good range for organic matter is 3 to 8% of soil mass.

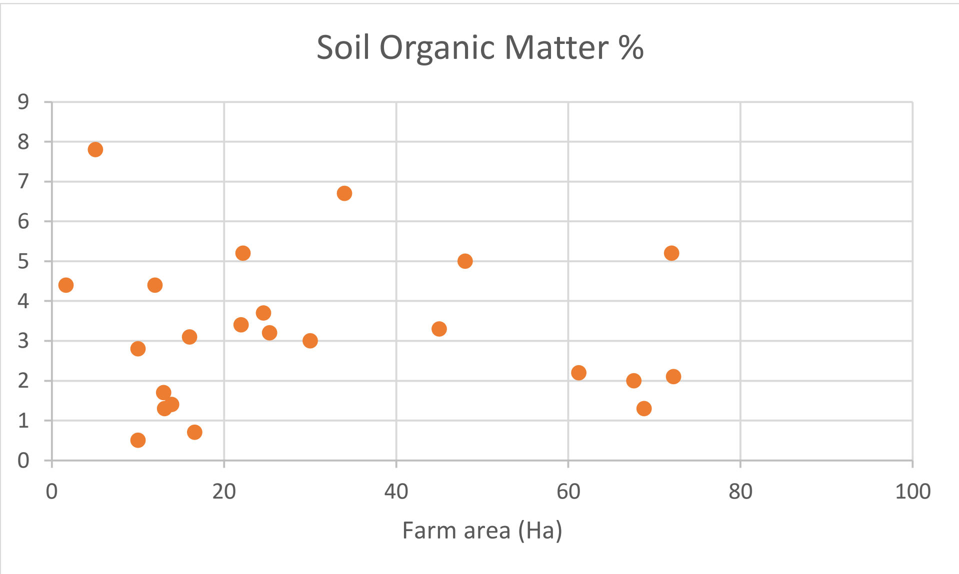

Chart 15. Soil organic matter plotted against farm area

The median level of organic matter in the participating turf growers was 3.2%, which is at the low end of the target range. 36% of the soils tested had less than 3% organic matter which affects the soil's resilience and stock of nutrients for plant growth, making turf growing a matter of applying most of the nutrients to the turf when they are needed.

There are many other elements that make up soil structure and need attention from turf farmers. This study has just shown the significant variation in a few indicators that are apparent in the turf growers' soils across Australia. These growers are successfully running turf farms with these differing conditions.

Irrigation Water

During farm inspections irrigation water supply was tested to see if it was suitable for irrigation. Tests were limited to pH, Electrical Conductivity (salinity), Nitrate/Nitrite and Phosphorus (free phosphate).

The desired water for irrigation is neutral in pH (~6-8), low in salinity (EC < 1,000 uS/cm), clear, non-turbid and free from toxins. In these tests these conditions were usually met by those using a river water supply, or dam water from run off, but the salinity criterion was often challenged by the use of bore water.

High salinity can adversely affect plant growth rates. This effect can start to kick in around 1,000 uS/cm, however, some of the turf species are quite salt tolerant. The salinity of the irrigation supply can affect plant growth but also lead to salinity build up in the soil if not managed adequately.

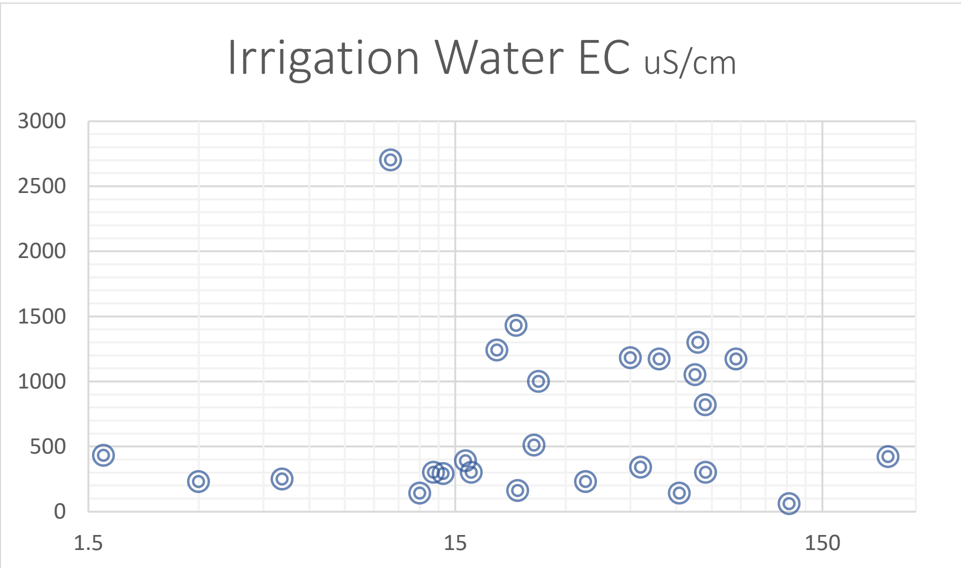

Chart 16. Irrigation water salinity (EC) plotted against farm area

The salinity of the irrigation supplies to the participating turf growers splits into two groupings: those that use river water with an EC < 500 and those that use bore or recycled water with an EC >1000 and one turf farmer using bore water at 2,700 EC.

The turf growers using bore water have to manage the irrigation schedule to prevent salinity build up in the soil and grow turf varieties that are not affected by the level of water salinity used. This was successful as none of the soils tested had a build-up of salinity. Neither was there a correlation between salinity in irrigation water and loss of farm productivity.

Farm waste

Farm waste is an indicator of environmental risk, so the majority of farm inspections included an examination of waste volumes and its management systems. Growers were given a list of wastes and an indication of the risk and effective management actions. There was not a quantitative assessment of waste management in this study that could be benchmarked.

There are a few points that can be made about waste management by turf growers, as follows:

1. Ubiquitous at most turf farms was a pile of turf wastes, often accompanied by broken pallets. These piles assumed significant proportions at some farms and occupied a lot of space. Consideration should be given to methods for reusing this waste, by composting or other treatment. This is a resource that is sitting often near a drain or a creek that ends up as silt.

2. Chemical drums and plastic containers were also abundant on most farms. If not rinsed out these containers are at risk of discharging remaining contents into drains leading to down stream toxicity. There should be a standard method used to clean out these containers and to store them for disposal.

3. Most farms have an equipment graveyard that can become a contaminated area as lubricants, oils and hydraulic fluids leak out onto the ground. At the least disused equipment should have all fluids drained from it before it is let out to pasture. Better management is required to remove this equipment from the farm.

4. Batteries present a disposal problem when they fail. They can leak acid and lead onto the ground if they are not stored in a contained environment. Even a tray put outside will quickly fill up with water and leakage will overflow onto the land.

5. Asbestos pipes from dug up mains were found on several farms. These have a risk of fraying and exposure to asbestos dusts for occupants. They should be contained to avoid the potential for dusts to develop and disposed to a licensed landfill as soon as possible.

Conclusion

There is a significant variation in the conditions under which turf is grown in Australia, from sand to heavy clay and from low to high levels of sunlight. These factors have led to significant variation in the performance efficiencies measured as benchmarks or key environmental performance indicators (KEPIs). This wide variation is common to other forms of horticulture in Australia.

The average performance of turf farms against other horticultural industries also indicates room for improvement in turf management, relative to vegetables and grapes. These forms of horticulture suffer from the production of plant matter that is not harvested and yet their consumption of water and energy is on a par or better than for turf.

The benchmarks for turf farm inputs of fertilisers, water and chemical applications do show opportunities for improvement by farms that perform below the median, while it is difficult to determine a level that could be termed best practice across Australia.

Energy benchmarking is confused by differing applications of diesel and electricity at farms, particularly with the mix of diesel and electric pumping systems used. Overall diesel represented 85% of total megajoule energy use on farm in 2016-17 and was the highest energy cost. The average diesel usage was 0.15 L/m^2 ±0.11 indicating a wide variation in usage. Electrical energy usage averaged 0.38 kWh/m^2 ±0.38 indicating an even wider variation.

The study did indicate strong net sequestration of carbon dioxide from the atmosphere for all of the participating turf growers. This had a median value of 1.63 ±0.54 kg CO_{2eq}/m^2 of turf harvested with the stronger performers around 2 to 2.5 kg CO_{2eq}/m^2. There is a relationship between energy and fertiliser efficiency and carbon sequestration rates and a certain way of improving the carbon footprint of the product is by using less energy and fertiliser.

The site inspections indicated that the growers were well aware of run off and loss of soils and had some protective measures in place. Soil erosion was modelled as moderate for the intensive farm investigations but more can always be done to protect sensitive receptors such as rivers and nearby residences.

The risk of spray drift into neighbouring properties was high of for some growers, but in most of these cases the growers had a schedule for spraying that took into consideration factors such as wind speed and direction.

Some of the growers had to irrigate with quite saline water that could affect plant growth rates and result in salt build-up in soil profiles. However, no salinity build-up was observed in the 26 soil samples taken indicating good control of irrigation practices by these growers.

Overall this study found that turf grown around Australia is done so responsibly with care for the environment. It is our intention to assist growers become more efficient, less wasteful and be able to improve their performance into the future.

Appendix – Calculation Methods

Production (m^2/Ha)	The area under turf was provided by the turf growers as was the annual production in square meters. The production efficiency was then calculated as the production divided by the farm area.
Pumping energy efficiency (kL/kWh)	Pump efficiency was calculated as the amount of water pumped in kilolitres divided by the energy required in kilowatt hours. This was only calculated where electrical pumps were used, and flow rates and energy consumption could be determined.
Water use (Litre/m^2)	The total amount of irrigation water used on the farm was either provided from meter readings or calculated from pump energy consumptions (electrical bills) and the efficiency determined. This value in litres was divided by the production in square meters to provide a water use efficiency in L/m^2.
ML/Ha	The same total for water use was divided by the farm area to give the megalitres per hectare efficiency factor.
Fertilizer use (kg N,P,K/m^2)	Fertiliser data was provided by the turf farmers schedules. The nitrogen, phosphorus and potassium concentrations were determined from product data. In the case of manures data was taken from a series of sources and averaged with the prime source (Griffiths, 2011). The total kilogram of N,P and K were calculated and divided by the total annual production in square meters to give the application efficiencies in kg/m^2.
Pesticide use (Formulated L/m^2)	Data on formulated chemical usage was provided by the turf growers. The litres of formulated products were determined and divided by the annual production in square meters.
Energy use (Diesel L/m^2)	Diesel consumption was provided by the turf growers in litres. This was totalled for the year and divided by the production as previously.
(Electricity kWh/m^2)	Electrical energy was summed from electricity bills for the farm meters. The total in kilowatt hours was then divided by the production to give an energy efficiency in kWh/m^2.
(Total Energy MJ/m^2)	Total energy was calculated as L(diesel) x 38.6 MJ/L (Department of Environment and Energy, 2017) + kWh (electricity) x 3.6 MJ/kWh to give a total MJ which was divided by production
Greenhouse emissions ($kgCO_{2eq}/m^2$)	Greenhouse emissions from farm operations were calculated from total energy use = L (diesel) x 2.67 $kgCO_{2eq}$/L and kWh (elec.) x state factor for Greenhouse emissions (Department of Environment and Energy, 2017). These emissions were totalled and divided by production to give the Greenhouse emissions efficiency in $kgCO_{2eq}/m^2$.
Net sequestered carbon in turf ($kgCO_{2eq}/m^2$)	The net sequestered carbon as $kgCO_{2eq}/m^2$ was calculated from the total average plant matter content of the turf x 0.5 (50% carbon) x the mass of CO_2 (44)/ mass of carbon (12). This was subtracted from the energy emission plus the fertiliser emissions calculated as kg (N) x 5.6 (Yara International)+ chemical emissions calculated from kg (active chemical) x 20.7 (Audsley, 2009). This total for emissions minus sequestration in kg is divided by production in m^2. (A negative number indicates net carbon sequestration from the atmosphere.)

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