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IRRIGATED PUBLIC OPEN SPACES

Using a lawn irrigation trial to find a balanced fertilisation/ watering approach for use in the wet-dry tropics

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ABSTRACT

Lawn irrigation trials were used to examine the effects of frequency and duration of watering, and fertiliser application, on local lawn grass species in Darwin, NT. The growth of local turf species was monitored with a view to suggesting best active irrigation practice for gardens and ovals in the greater Darwin and Palmerston region (a wet-dry tropical climate classification) to ensure reduced, and efficient, consumption of water. Six test plots on a well-established local public lawn were established, and irrigation and fertiliser application treatments were applied.

A contour survey was performed to measure slope, and to help quantify run-off losses; species identification was undertaken to establish existing conditions. Site investigation identified the soil colour, texture, saturated hydraulic conductivity, moisture content, bulk density, particle size distribution, and root zone depth at the plots. A local weather station was established to measure rainfall, temperature, relative humidity, solar radiation, wind speed, and evapotranspiration losses. Soil nutrient testing was performed to assay the chemical composition of the sub-surface soils in the rhizosphere. Grass growth and biomass development over time were used to find a horticultural regime best-suited to the irrigation of Darwin and Palmerston's public, open, green spaces.

The trial followed current principles of good irrigation practice and used an effective monitoring strategy to examine the growth rate of the grass (various species) throughout the dry season of 2016. The results provide valuable recommendations and supporting information enabling improved irrigation practice in the wet-dry tropics, with implications that go beyond water efficiency.

INTRODUCTION

Australia is one of the driest inhabited continents and is a highly urbanised society with around 89% of the population living in cities and towns (ABS, 2015). Climate change is threatening Australian urban water supplies through increasing evaporation and decreasing precipitation. The effects of the El Niño/La Niña Southern Oscillation, the Indian Ocean Dipole, and presence of the sub-tropical ridge, mean that Darwin (wet-dry tropical climate classification: Aw (Rubel and Kottek, 2010)), sits on the nexus between three large-scale global climate systems. This has implications for efficient water use and protection of future water security. Power and Water Corporation (PWC) are delivering a water-efficient message through their successful Living Water Smart campaign (PWC, 2016) and this irrigation trial aims to inform, and support the Living Water Smart message by enshrining best-use of irrigation water.

Darwin is a developing city: water demand has increased due to newly established suburbs. At present, the availability (storage) of water and the demand to supply ratio are satisfactory; however, future planning projections indicate that Darwin may need to improve its water management strategy to satisfy future demand.

Irrigation practice in Darwin consumes more water than in other jurisdictions in Australia. A possible reason for this may be that Darwin is the only capital city in Australia not to have been subjected to water restrictions. Accordingly (PWC, 2016) people living in Darwin use around 2.1 times as much water as people living in other Australian capital cities – approximately 454 kL *per* property *per annum,* against an Australian average of 213 kL *per* property *per annum* (PWC, 2013).

Over the last three years (2012-2015), water prices have increased by 73%, and PWC has spent $2.5 million *per annum* in electricity costs alone for pumping and treating water in Darwin. In the greater Darwin area, where dry conditions prevail for most of the year, a perception of a high rainfall wet season means that less attention is devoted (in the public's mind at least) to the region's water resources. This has sometimes led to a lack of public awareness as to how to vulnerable the water supply can be to the Darwin and Palmerston area.

Much of the high water consumption is accounted for by the irrigation of lawns (both public and domestic); improved irrigation practice will not only save water but will also reduce runoff, reduce leaching of essential nutrients, reduce pollution from the leaching of excess fertiliser and the potential eutrophication of receiving waters, prevent spread of non-native species and other propagules, seeds, and plant matter via drains and watercourses, reduce energy consumption. Significantly, up to 70% of water use in the region is outside the house and mostly on gardens (PWC, 2016). Unplanned irrigation is commonplace. The management of open green spaces must be in accordance with best practice guidelines. Codes of practice for irrigated public open spaces (IPOS) need to be followed more widely and scaled to domestic situations too. The less tangible side effects to over-irrigation include a greater rate of grass growth which imposes cost, energy and noise pollution burdens in the mowing and removal of grass clippings as municipal solid waste.

We remain attached to our lawns and this is understandable although future research is focussing on alternatives (Fairfield & Hasan, 2016). Therefore, best irrigation practices for local turf require *in situ* monitoring under controlled conditions, hence this horticultural irrigation/fertiliser application trial conducted on Charles Darwin University's Casuarina campus as the latest in a line of turf and irrigation trials undertaken in Australia (*inter alia* Short & Colmer, 2007).

METHOD

This section presents details of: site selection, species identification on the selected irrigation trial plots, the site investigation and laboratory soil testing undertaken to characterise the plot sites, the collection of environmental data pertaining to the plot sites, the combined fertiliser and water application regimes trialled, and finally the measurement of the rates of growth of the various grass species under each treatment regime.

Figure 1. Site location (blue rectangle) and weather station (red cross) at Casuarina campus, Darwin, NT, Australia, latitude 12° 22´ 13.64´´ S, longitude 130° 51´ 56.54´´ E, (Google Earth Pro, 20 May, 2015), eye altitude 189 m).

Site Investigation

An initial site inspection was undertaken to identify the most suitable area on Charles Darwin University's Casuarina campus (located 10 km north east of the Darwin CBD): requirements included access by foot, availability of water supply, and the ability to restrict other facilities management activity in and around the area. The selected site is shown in Fig. 1. The site measured 18 m × 3 m and was sub-divided into six plots (each measuring 3 m × 3 m), each of which was subjected to different irrigation/ fertiliser application regimes.

Site Survey

A GPS elevation survey was conducted to identify the site elevation and slope of the ground (a site as flat as possible was selected to minimise runoff interference between plots and to minimise runoff during irrigation).

6 sub-plots @ 3 m per sub-plot = 18 m overall length					
Plot 6	Plot 5	Plot 4	Plot 3	Plot 2	Plot 1
Fertiliser: 0 %	Fertiliser: 50 %	Fertiliser: 100 %	Fertiliser: 0 %	Fertiliser: 50 %	Fertiliser: 100 %
Water: 22 mm/wk	Water: 22 mm/wk	Water: 22 mm/wk	Water: 11 mm/wk	Water: 11 mm/wk	Water: 11 mm/wk

Figure 2. Sub-plot fertiliser and irrigation regime details: a fertiliser dose of 100 % equated to 72 kg ha^{-1} with watering to the equivalent depth (as shown) occurring on two days each week from 1700-1800 (ACST)

A contour survey identified a change in level of only 300 mm across the 18 m × 3 m site (see Fig. 2 for schematic showing layout of sub-divisions into 3 m × 3 m sub-plots).

As shown in Figure 2, three levels of fertiliser dose were used (none, 50 %, and 100 %) corresponding to the addition in liquid form by manual application of none, 36 kg ha^{-1}, and 72 kg ha^{-1}, respectively (see Section 2.4). Two levels of irrigation were applied (11 mm/week and 22 mm/week, respectively). As this was a preliminary trial, and of necessity, time-limited, only one replicate was available on an equal-sized block of land situated 150 m northwest of the site described (Figure 1). Unfortunately during the running of this replicate trial, the grass was cut at times outside the authors' control and as such the results are not reported here.

Two heliopaths for the southern hemisphere winter, and summer, solstices are shown in Figures 3a and 3b, respectively. The selected test plots were effectively in full sun from within 30 minutes of sunrise and until 30 minutes before sunset: they were not shaded by buildings, nor tree canopy cover, or other vegetation.

(a) Heliopath: noon, 21 June 2016 (Agafonkin (2016) SunCalc, http://suncalc.net)

(b) Heliopath: noon, 21 Dec. 2016 (Agafonkin (2016) SunCalc, http://suncalc.net)

Figure 3. Heliopaths at winter (a) and summer (b) solstices

Note: yellow lines mark sunrise, orange lines mark first daylight on the trail site, and red lines mark sunset.

Soil Testing

The irrigation principals governing lawn maintenance are directly influenced by the sub-soil properties which affect the amount of soil water storage, saturated hydraulic conductivity, and nutrient availability. These properties are important for determining the design irrigation depth. Therefore, soil tests (to AS 1289: Methods of testing soils for engineering purposes) were undertaken to determine the: gravimetric moisture content, *in situ* bulk density, saturated hydraulic conductivity (to water), porosity, specific gravity, particle size distribution (by dry sieving method), root zone depth, and the soil chemical composition (to allow the identification of bioavailable nutrients and to assist in specification of applied fertiliser dose levels)

Species Identification

To perform this irrigation trial, it was essential to identify the species of grass and plants present on the selected plot sites. The best time to undertake species identification was thought to be during the wet season (wet season onset being defined here as that date by which a cumulative total precipitation of 50 mm has been recorded after 1 September, at a given gauging station). An adjacent (now abandoned) test site was available at which native, and non-native, species had not been mown for more than four months, and this helped in the species identification. The Department of Land Management, Charles Darwin University, assisted with the identification and the following species were found on the plot sites: Bahia grass (*Paspalum notatum*), Carpet grass (*Axonopus affinis*), Gamba grass (*Andropogon gayanus*), Mission grass (*Pennisetum polystachion*), Feather Top Rhodes grass (*Chloris virgata*), Indian Bluegrass (*Bothriochloa pertusa*), Buffel grass (*Cenchrus ciliaris*), Pangola grass (*Digitaria eriantha*), Para grass (*Urochloa mutica*), Brazilian centro (*Centrosema brasilianum*), and Molasses grass (*Melnis minutiflora*).

Table 1. Maximum recommended irrigation requirements for lawns in Darwin (Cameron, 2006)												
Month	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Irrigation (mm/ week)	30	29	27	32	33	32	33	35	39	41	38	33

Environmental Data

Environmental factors were considered to identify the water loss due to evaporation and evapotranspiration. Therefore, environmental data were collected as follows: ambient temperature, relative humidity (by hygrometer method), precipitation, incident solar radiation, wind speed, amount, and rate of evaporation. A weather station (see Fig. 1) was established within 500 m of the test site in a secure location for this purpose with additional data available from the Bureau of Meteorology (Darwin Airport, Station No. 14015).

Fertiliser Application

The objective of the project was to monitor the effects of applied fertiliser rate on the growth rate of those grass species found on the selected test plots. Therefore, a fertiliser application strategy, involving different amounts of irrigation water was designed. A commonly available soluble fertiliser (mixed to 5 ml fertiliser *per* litre of potable water and with a mean average composition of 25:5:8.8 (N:P:K)) was applied with the full standard dose being 72 kg ha^{-1} (and *pro rata* for each plot, see Fig. 2).

IRRIGATION REGIMES

A water stress method was used to schedule irrigation based on previous recommendations by the NT Government (Cameron, 2006). The amount, in equivalent depth terms, on each sub-plot represented one-third, and two-thirds of the recommended monthly values for Darwin (Table 1), i.e., average irrigation depths of 11 mm and 22 mm per week were used (see Fig. 2).

Observation of Rates of Growth of the Grasses

Photographic measurement of grass growth and density (measured by green pixel value counts on the RGB image palette), and height measurements of the grass species were recorded on a weekly basis from 1 July (mid-dry season, onwards). For the photographic measurements a quadrat frame with a digital camera was used: the images were orthorectified, and typical changes in a given 1 m^2 quadrat are shown in Fig. 4.

(a) 2 weeks (mid-July) (b) 4 weeks (end July) c) 6 weeks (mid-August)

Figure 4. Changes in colour and vegetative cover with time: Plot 3 (no fertiliser, irrigation: 11 mm/week)

RESULTS AND DISCUSSION

From the test data, it was found that the ground was a clay loam texture intermixed with small gravel particles. During the excavation of the uppermost 150 mm depth of soil, the ground was found to be relatively dense (1810 kg m^{-3}) and hard which probably contributed to the shallow root zone (depth extent, approximately 125 mm to 150 mm, as estimated by visual inspection during shallow excavation). Due to the short root length, the grass species had less access to soil profile water (the mean average *in situ* gravimetric moisture content was 7.7 %) denoting unfavourable conditions for plant survival, and therefore, irrigation was the only source of water available to the species during the dry season. Additionally, adjacent to the test site, on rough, unimproved bush, it was found that Gamba grass (*Andropogon gayanus*) reaching a height of 2 m had a rooting depth of no more than 150 mm. Species on this site therefore depend on surface water irrigation. From soil testing on undisturbed soil cores, it was also found that the infiltration rate was high (5.40 mm h^{-1}) an the soil was also found, from dry sieving, to contain a significant gravel fraction (the percentages by mass retained on the 4.75 mm, 2.36 mm, and 1.18 mm mesh sieves were 31 %, 20 %, and 13 %, respectively). The water holding capacity of soil sample was also poor (the mean average porosity was 0.50).

The results of soil chemical assay led to the conclusion that the sub-soil was nutrient-poor. Key results (averaged, n = 4) arising from the soil chemical assay were as follows: pH (1:5 water), 6.7; pH (1:5 $CaCl_2$), 5.8; electrical conductivity (saturated extract) 0.5 dS m^{-1}; organic carbon, 2 %; nitrate nitrogen (NO_3), 4 mg kg^{-1}; ammonium nitrogen, 5.5 mg kg^{-1}; phosphorus (Colwell), 12 mg kg^{-1}; total cation exchange capacity, 9.4 $cmol^{(+)}$ kg^{-1}; and a calcium to magnesium ratio of 4.5.

From the middle of the dry season (1 July onwards), the species were regrown, from a browned, water-stressed condition, by applying 11 mm of irrigation water by hand-held hose to Plots 1 to 3, and 22 mm for Plots 4 to 6. Few of the species were observed to have regrown quickly and few of the species turned green even after the second week of irrigation. The fertiliser was only applied from Week 4 onwards, so as not to burn the species in their initial stages of growth. No starter fertilisers were used because the intention was to observe the effect of a common lawn fertiliser alone. After fertiliser application (note that fertiliser was only added to Plots 1, 2, 4, and 5), the growth of each grass species responded to a significant extent. Fig. 5 shows the growth on Plot 3 (no fertiliser: 11 mm/week irrigation).

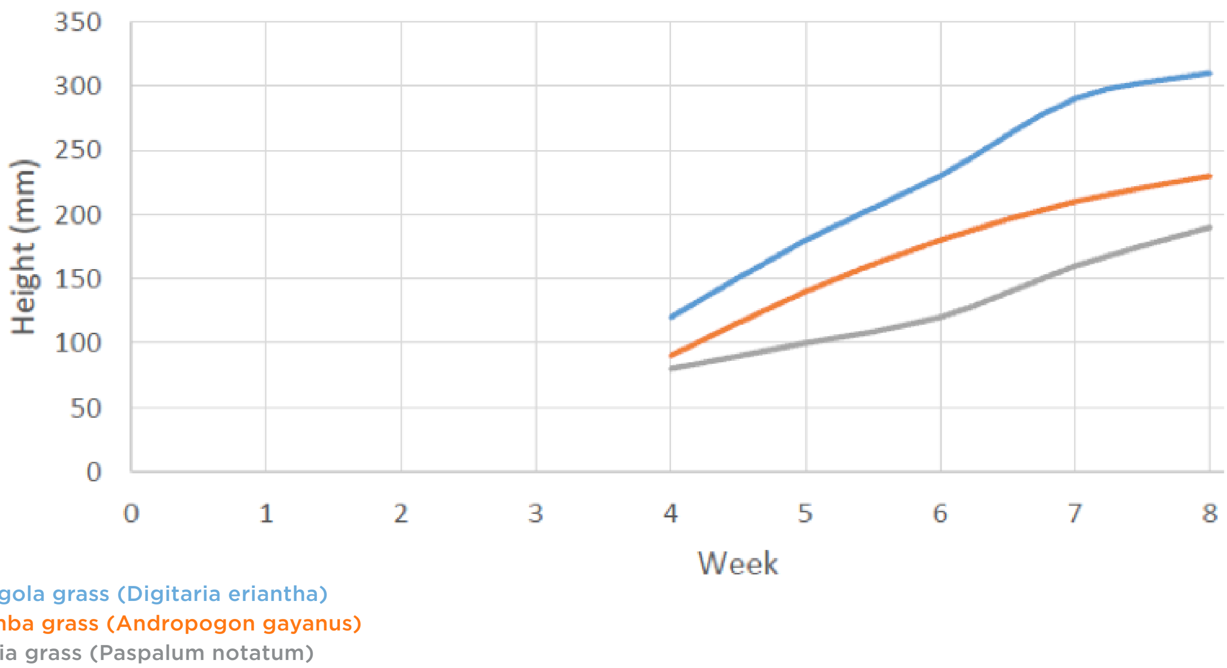


Figure 5. Changes in the height of three grass species (Plot 3: no fertiliser, irrigation: 11 mm/week)

A biomass analysis of Plots 3 and 6 (no fertiliser applied) showed that less biomass was produced relative to all other plots. Besides this, the height and density of the species were higher in Plots 1 and 4 (100 % fertiliser dose applied). The maximum green colour, as measured by visual inspection against Munsell colour charts and digital image analysis of the series of 1 m^2 images (Fig. 4), was reached in Plots 4 and 5 (100 % and 50 % fertiliser dose application with 22 mm *per* week irrigation, see Table 2).

At the end of the trial, the grass was hand-mowed, and the clippings collected from each plot and weighed to determine the amount of biomass produced per square metre (Table 2).

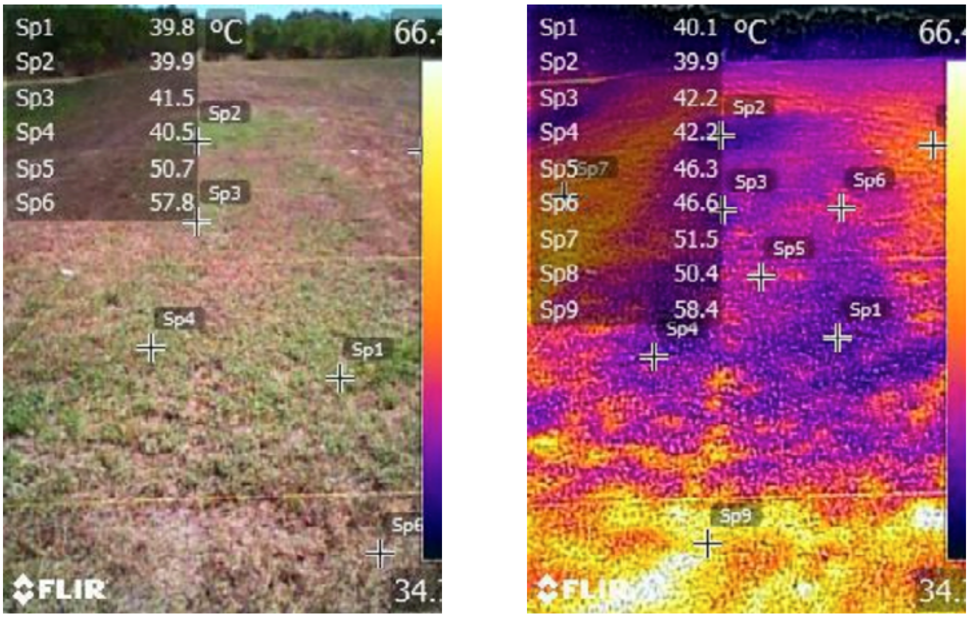
Over-irrigation tended to lead to the generation of a greater mass of clippings for disposal whilst colour measurements indicated good species recovery from dry starting conditions. In general, over-irrigation, and over-mowing, leads to an illusory greenness developed by over-rapid growth, coming at the expense of a loss of leisure time (in domestic circumstances at least) spent cutting the grass. Set against these data the key message was: cut less, water less, balance the amount of fertiliser, and save time, money, and energy.

The F: 100 treatments were less than 10 % different with regards biomass yield. Hence lower irrigation delivered an acceptable outcome; however zero fertiliser use reduced biomass yield by 50 % for each irrigation treatment.

As an aside, and cognisant of the contribution that less frequently mowed grass makes towards the amelioration of urban heat island effects, a hand-held thermal imaging camera was used to record the changes in temperature across the site in contrast to the adjacent, regularly mowed areas (Figure 6). Where the grass had been allowed to grow (Plots 1-6) the mean average surface temperature was 19.1 °C less than that of the over-mowed surrounding area (surroundings mowed fortnightly, no fertiliser or irrigation water was added to the surroundings during this trail). Note that these images were captured *before* irrigation and at Week 4 where the growth could hardly be described as lush. Leaving the grass to grow is perhaps even more conducive to increasing this temperature differential: essential in Darwin's climate. Upon irrigation, this difference increased to over 22 °C (data not shown). The possibility of less frequent mowing having public health benefits may be worth further research (CRC WSC, 2016) beyond the scope of this paper.

Table 2. Biomass in the form of weighed grass clippings

Plot no. F: fertiliser dose (%) W: irrigation (mm/wk)	1 F: 100 W: 11 mm/wk	2 F: 50 W: 11 mm/wk	3 F: 0 W: 11 mm/wk	4 F: 100 W: 22 mm/wk	5 F: 50 W: 22 mm/wk	6 F: 0 W: 22 mm/wk
Mass of clippings (kg)	1.230	0.930	0.680	1.320	1.080	0.620
Biomass yield (kg m^{-2})	0.137	0.103	0.076	0.147	0.120	0.069
Total mass (kg)		2.840			3.020	
Mean areal density (kg m^{-2})		0.105			0.112	



(a) Visible light image

(b) Longwave infrared (8 to 14 mm) image

Figure 6. General site over-view facing NW from the end of Plot 1 (a) visible light, (b) infrared radiation

Note: Sp n denotes a spot-temperature reading taken at the location indicated by the adjacent cross

CONCLUSIONS AND RECOMMENDATIONS

Plot 2 (irrigated to an equivalent depth of 11 mm *per* week, treated with a 50 % fertiliser dose, *i.e.*, 36 kg ha^{-1}) represented optimal conditions for grass growth at the selected test site with respect to height attained, appearance, and lower biomass produced as waste. These conditions saw the grasses reach heights of between 185 and 310 mm (depending upon species) thus generating only 0.103 kg m^2 of grass clippings in eight weeks of growth.

Water the grass less: this study trialled irrigation at one-third and two-thirds of previously recommended water volumes to no adverse effect with regard to species' visual appearance, height, rate of growth, or health. Provided that a careful balance of water and fertiliser is reached, then the use of lower volumes of water expended on irrigation will probably lead to: less runoff, less leaching of nutrient from pre-existing nutrient-poor soils, lowered risk of eutrophication of receiving waters caused by reduced leaching of fertiliser and reduced runoff to drains and watercourses.

Future research to extend this small-scale trial to full-scale (parks, ovals, *etc.*) is recommended. Future research into the frequency of mowing and quantification of the potential reduction in the mass of municipal solid waste generated in the form of grass clippings, and reduced energy consumption in the annual mowing operational cycle, are also suggested.

THE AUTHORS

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