ADELAIDE AIRPORT HEAT REDUCTION TRIAL

Greg Ingleton [1], Elsie Mann [2], Leigh Gapp [3]
1. SA Water, Adelaide, SA, Australia
2. Stantec, Adelaide, SA, Australia
3. Adelaide Airport Limited, SA, Australia.

CASE STUDY SUMMARY

A trial was established at the Adelaide Airport to quantify the benefits, including wildlife hazard reduction, environmental and economic benefits, that could be achieved through the irrigation of a 4 hectare parcel of the airside area. The trial has been underway for more than 2 years, with the monitoring showing a reduction in air temperature within the 4 hectare irrigation area of over 2 degrees Celsius on average, and above 3 degrees C on warmer days (i.e. days above 30 degrees C). A crop of lucerne was planted on part of the irrigation area to demonstrate the ability to grow commercial crops that will both cool the air, and provide a source of revenue. This information was used to undertake a financial and economic assessment based on the hypothetical expansion of the irrigation area to a 200 hectare plot. The benefits include those directly derived from the cropping, as well as the secondary benefits of cooling on other aspects of the airport operations, including passenger terminal energy use and aircraft performance. The breadth of benefits far exceeded our initial expectations, and whilst further work is required to quantify some of the assumptions made in the economic assessment, the results provided confidence to investigate expansion of the trial at Adelaide Airport and possible implementation at other airports and also public open space areas.

KEYWORDS

Airport irrigation, urban cooling, economic benefits

INTRODUCTION

Adelaide is a dry capital city with high to very high temperatures being reached during summer and early autumn. It is predicted that, as a consequence of climate change, there will be a significant increase in the number of days exceeding 40 degrees Celsius in the next few decades (CSIRO, 2015). The airport is brown for most of the year, as summer rainfall is minimal (average rainfall is 45mm in total for the three months of summer) and there is very little irrigation occurring on the airside area of the airport.

One significant issue facing airport operations is the risk of increased high temperatures impacting on aircraft performance. Using the highest modelled emissions scenario (Representative Concentration Pathways 8.5), Coffel and Horton (2015) state that for the Boeing 737-800, a common domestic jet used in Australia, the number of weight-restriction days will increase by between 50 - 200% in some major American airports after 2050. The risk of flight cancellations, when temperatures rise above the safe operating limits of aircraft, is also likely to increase. This was evident in Phoenix, Arizona in June 2017, when all flights out of one airport were cancelled for an entire day when the temperature rose above 49^{0}C. Over 50 flights were cancelled, creating issues for the airport, airline operators, and passengers (The Washington Post, 2017). The reduction in payload, plus potential cancellation of flights associated with increasingly high temperatures will have a significant economic impact.

Investing in opportunities to implement irrigation to reduce air temperature at airports could be a simple yet effective method to reduce the impact of increasing temperatures on aircraft performance and airport operations. The ability to cool via irrigation is not a new concept. This has been done in many open space environments, particularly urban parks and gardens. The cooling occurs due to the evaporation of moisture from the soil profile, along with the transpiration of moist air from the irrigated vegetation. Urban areas have been targeted for investment in irrigation to maintain green spaces due to the benefits to human health (Harlan and Ruddell, 2011), which range from reduction in heat-related illness, benefits from increased physical activity, enhanced air quality, improved mental health and social benefits. The benefits at a site like an airport would be different and warrant further investigation.

One argument against investment in irrigation for greening of open space is the cost to install, maintain and operate the irrigation infrastructure. This can be overcome at a site like an airport where land management is already relatively intensive, with well-defined objectives to manage risks to airport operation. Risk mitigation measures focus on reducing bird and other wildlife attraction, maintaining vegetative coverage to reduce the generation of dust, ensuring compliance with CASA requirements (e.g. maximum vegetation height), and not posing a physical risk to aircraft if they leave the runway or present any other risk to airport operations.

In 2015 a trial was established at the Adelaide Airport to determine the extent of cooling, and the subsequent benefits that could be gained through the irrigation of land on the airside area of the airport. The trial was established on a 4 hectare site, with a number of parameters being monitored both within and outside of the irrigation area. The information collected from this trial was then used to determine what benefits could be achieved for airport operations, airport aesthetics and the local environment.

CASE STUDY DETAIL

The trial commenced at the start of summer 2015, via a partnership between SA Water and Adelaide Airport. The trial aimed to identify the benefits of irrigating the airside area of the airport, with a view to ensuring that aviation safety risks can be managed and new risks are not introduced. The study had two key objectives: firstly, understanding the potential reduction in temperature resulting from irrigation of the airside area, and secondly, to investigate the benefits of low bird density ground covers which maintained cover year round.

Following the success of the first 2 years of the trial, SA Water and Adelaide Airport undertook further analysis to understand the financial and economic costs and benefits of irrigating a crop. The expected benefits identified and used to justify the analysis to both parties, were that the cooling effect of irrigating a large portion of the airside area may result in a reduction in energy use for the airport terminal cooling towers, possible improvements in aviation safety outcomes and aesthetics of the airfield in general through the maintenance of a healthy ground cover throughout the year. From a water utility perspective, the value proposition for SA Water was two-fold. The trial aimed to demonstrate a new use for recycled water from a nearby wastewater treatment plant and provide an opportunity to gather data information on the extent of cooling that can be achieved. This information could be used to demonstrate the benefits of irrigation, particularly for custodians of large open public spaces and not only increase revenue from recycled water use, but also improve liveability in urban areas.

Irrigation trial approach

The site was established on a 4 hectare area 600metres south of the runway, in an area that was far from aircraft activities. Two reel irrigators were installed in a temporary manner, so they could be removed if the trial was prematurely aborted due to an increase in risk to airport operations.

Just over 40 HOBO temperature and humidity sensors were installed around and within the irrigation area to provide a comparison of the climatic conditions associated with the irrigation of the site. Sensors were placed upwind and downwind of the irrigation area to determine the distance required to achieve the greatest cooling threshold for air, and to determine the persistence of cool air once it moves downwind of the irrigation area.

A series of Sentek “drill and drop” soil moisture probes were also installed, both within and outside of the irrigation area. This assisted irrigation scheduling and ensured the soil profile within the irrigation area had a fairly consistent moisture content over the irrigation season. These probes were equipped with a telemetry component with the data being stored and accessed through the “Irrimax” software.

Initially the irrigation area was divided into a number of sectors, with 1 hectare being an “irrigated control” sector, and the other 3 hectares divided into sub- sectors, each meant to be planted out with different grass and ground cover species. Due to timing issues the 3 hectares remained devoid of vegetation for the majority of the first irrigation season. Prior to the second irrigation season the three hectare “non-control” area was divided into three sectors, two of which contained a variety of Tall Fescue (Avanex), and the third containing a winter-active lucerne variety (GTL60). As the lucerne performed better than the tall fescue, the entire 3 hectare area was sown with lucerne in January 2018.

The area was irrigated on average three times per week between the start of December to the end of April for the first year of the trial, and twice per week during the second year of the trial. The irrigation occurred at night, initially during the airport curfew hours of 11pm to 5am, but then extended to the night-time hours of 9pm to

5am. During the first irrigation season around 25 Megalitres (ML) of water was applied to the 4 hectare plot (equating to 6ML/ha) while the second season application volume was around 16ML (4ML/ha). The rate of water application per irrigation event was in the order of 12 to 15 millimetres.

The water used for irrigation was sourced from a nearby stormwater Managed Aquifer Recharge (MAR) scheme that is owned by SA Water. This scheme takes stormwater from an adjacent creek and injections into the Tertiary 2 aquifer (approximately 180 metres below ground) during winter, and extracts the water during summer for supply to a local decentralised network. If the trial is to be expanded in the future, recycled water from the Glenelg Wastewater Treatment Plant would be used as the quality (i.e. nutrient content) and quantity are more suitable for the site.

Financial and economic assessment approach

The monitoring results from the first two years of the trial were used to inform a financial and economic assessment, based on the hypothetical scenario of irrigation and lucerne production occurring across almost 200 hectares of the airside area. Although the airside area is around three times this size, 200 hectares is the land area that is most suitable for irrigation and cropping, without interfering with airport operations.

The overall objective of the assessment was to provide an indication of the order of magnitude of costs and benefits of expanding the irrigation activities. More detailed data gathering, analysis and research will be required to develop a formal business case for the proposed project.

To properly quantify the benefits associated with this type of project, it is important to understand the base case, and the future options, to ensure that the change resulting from the future options can be clearly defined. The base case assumed no irrigation of the airside area and management of the site as required to comply with aviation safety regulations and reduce the risk of bird strike (weed and vegetation management). Until recently less than half of the airside area was actively maintained to limit weed infestation, vegetation growth (height) and bird activity. The remainder was essentially unmanaged with the exception of mowing (to conform to aviation safety regulations) however, more intensive management of the outer areas of the airside has recently been instituted which will further increase the cost of base case land management.

Base case capital and operating costs for current site management, including depreciation of assets, were estimated using current market information for mowing and spraying equipment, chemicals and fuel. Labour costs for site management were estimated using data provided by Adelaide Airport.

The future option considered in the analysis involves installation of an irrigation system to cover approximately 200 Ha of airside area, supply of Class B water from Glenelg Wastewater Treatment Plant, and growth and harvesting of lucerne on the irrigated area. It was assumed that the remaining airside area would be managed in a similar manner as it is currently. Other key assumptions about the lucerne production operation were as follows:

- Existing Adelaide Airport staff can be trained to undertake the lucerne management and harvesting.
- All crop management and harvesting activities that may increase bird activity will occur during flight curfew hours.
- Water is supplied at the appropriate flow rate and pressure (included in the cost of water).
- Irrigation will likely occur from November to March with annual application rate of 6-7 ML/ha

The financial analysis of the future option included both costs and revenue for the crop growing proposal. Costs associated with irrigated lucerne production include labour, capital infrastructure costs for irrigation and crop management, harvesting and operation costs. A relatively high cost per hectare was assumed for the irrigation infrastructure to account for the likelihood of more expensive equipment and installation methods owing to proximity to runways. The cost of maintaining the area not under irrigated lucerne production was included as per the base case.

The net present value (NPV) was determined over 25 years using a discount rate of 5.06% as provided by SA Water. Any financial benefit from depreciation of capital equipment was based on a diminishing value at a rate set by the Australian Tax Office (ATO 2016) at a company tax rate of 30%.

While the financial analysis assessed the direct benefits of the lucerne production and harvesting, the economic analysis focussed on the potential benefits that flow from a reduction in air temperatures due to irrigation and crop growth. Lucerne is a high water use crop, with high evapotranspiration rates so it has a higher potential to contribute to temperature reduction compared to other crops or ground cover. The analysis identified, and where possible quantified, indirect economic impacts that might accrue to customers, operators and businesses using the airport, from the proposed future option.

The quantitative assessment was restricted to those benefits most likely to flow from the expected temperature reduction due to the irrigation and crop growing proposal. Several assumptions needed to be made to enable the economic assessment to occur. These include the vertical extent of the cooling of the air and the persistence of the cooler air over the paved areas downwind of the irrigation area, reaching an air temperature reduction of 4 degrees C on days above 30 degrees C, as well as some operational and capital costs that were unavailable at the time of the assessment.

The following potential benefits were identified by SA Water and Adelaide Airport at the start of the project:

- Reduced energy consumption by cooling towers at the terminal building
- Aircraft fuel savings due to reduced air temperature on and above the runway on take off
- Reduced limitations on payload as a result of high temperatures
- Improved visual amenity
- Thermal comfort for airside workers
- Reduced air temperature for surrounding residents
- Improved pavement longevity due to reduced air temperature

A brainstorming exercise was undertaken to identify additional impacts (both positive and negative) to include in the economic assessment. A list of expected impacts associated with the proposed future option compared to the base case was identified.

Irrigation Trial Outcomes

Two years of temperature data have been obtained from the site. Data from the first year of irrigation showed there was an average 2.4 degree C reduction in air temperature within the irrigation area compared to the non-irrigated area. There was some correlation between the extent of temperature reduction and the maximum daily temperature, with 70% of days over 30 degrees C showing a temperature reduction of over 3 degrees C in the irrigation area. Similar results were obtained during the second year of the trial, with the average temperature reduction being 2.2 degrees C within the irrigation area, again with the largest temperature reductions being on days above 30 degrees C. The following graphs show the number of days per temperature reduction category (categories being every 0.25 degrees C), with the average for the season shown by the vertical line.

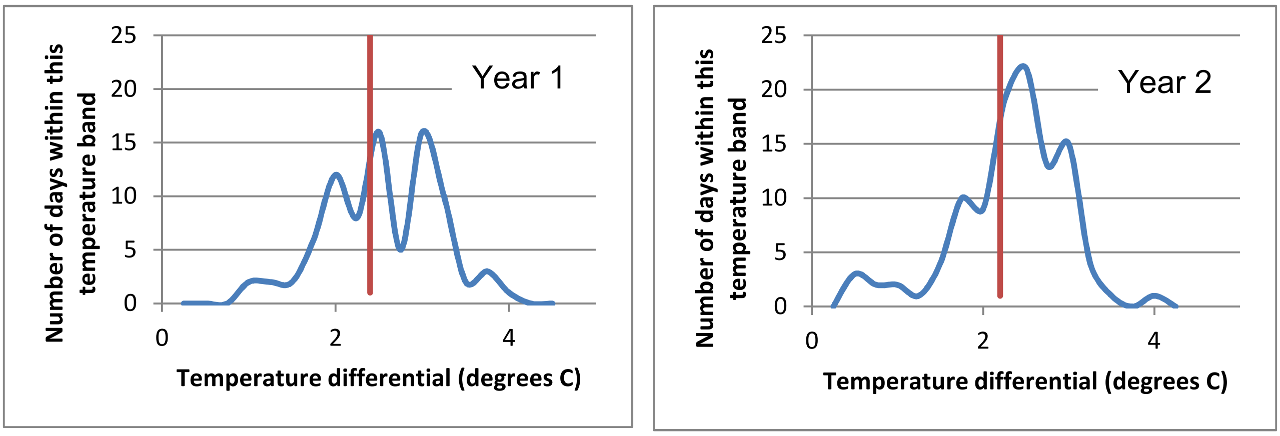

Figure 1. Showing the air temperature differential between the irrigated and non-irrigated land for the first year (left) and second year (right) of the trial. The red vertical line represents the average for that year.

The results for the second year were not as high as expected. As discussed above, the first year had a relative absence of vegetation due to challenges experienced with the initial setup of the trial. The main difference between the two years of operation is the lower volume of water that was used during the second year (16ML in Year 2, 25ML in Year 1). It is clear that this has had an impact on the ability to reduce the air temperature toward the possible optimistic target of between 3 and 4 degrees C. The other point is that this is a relatively small area of irrigation, and there is evidence from sensors just outside the irrigation area that the reduced air temperature does not persist as the air moves over the unirrigated areas. The irrigation rate has increased for Year 3, however expansion of the irrigation area is not likely to occur until Year 4.

Financial and economic analysis results

Financial Analysis

Based on the assumptions outlined in the approach section above, the introduction of lucerne production was shown to provide a financial advantage over the current management practice (base case). The NPV over a 25 year period shows at least a $1 million advantage relative to the NPV of the base case. The financial assessment estimated that the likely outcome of lucerne production is estimated to be a little under $1.8 million benefit to the airport. Whilst there is a significant upfront expenditure due the installation of irrigation infrastructure this cost is expected to be neutral after 9 years compared to the on-going cost associated with current management but could vary between 7 and 12 years, depending on yield outcomes (Figure 2).

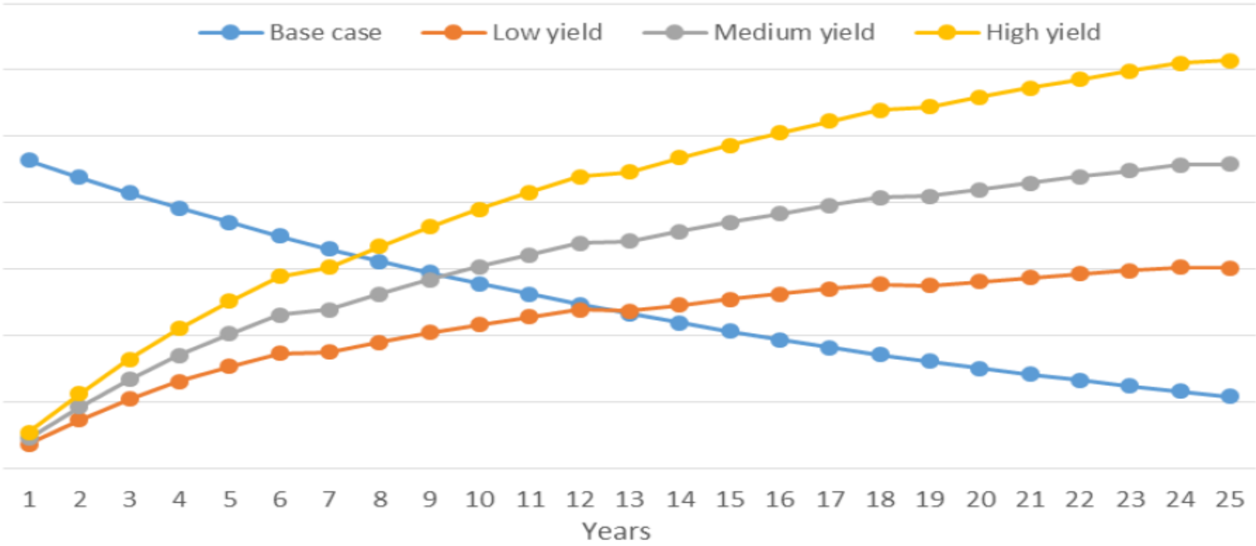

Figure 2: Time series comparison of NPV ($'000) over 25 years between the base case (no change) and the introduction of lucerne production for three yield levels.

Sensitivity analysis considered the following variables:

- Lucerne sale price can vary markedly and is dependent on seasonal conditions and market demand. It was identified that the benefit of lucerne production would be eroded if the sale price for lucerne falls below $250 per tonne.
- The cost of recycled water used in agribusiness in Australia typically ranges between $300 and $500/ML, but can be as high as $2000/ML, depending on its use. The impact of a change in water cost on lucerne production is less pronounced than the price of the lucerne. Additionally, it is assumed water would be supplied under a long-term contract and therefore unlikely to fluctuate significantly over the life of the project. Lucerne production retains a marginal benefit over the current management even with a 50% increase in the water charge
- The high upfront cost of the irrigation infrastructure results in a high sensitivity to the discount rate applied. Despite this, sensitivity analysis on the discount rate applied showed that the introduction of lucerne production remains beneficial compared to the current management practice for all scenarios.

Finally, there may be the potential to share the cost of the irrigation infrastructure with third parties, being other investors that may benefit from either the lucerne production or from the other benefits associated with the cooling aspect. Assuming a significant portion of the irrigation infrastructure cost is shared with third parties based on an annual fixed charge for 25 years, the benefit of lucerne production is significant with all yield scenarios showing a positive NPV over 25 years.

Economic Analysis

Based on the brainstorming exercise outlined in the approach section above, a list of expected impacts associated with the proposed future option compared to the base case have been identified and are presented in the table below, summarised under the three broad categories of economic, environmental, and social impacts.

Table 1: Economic Impacts Analysis of Irrigation at Adelaide Airport

Item	Measure	Likely Impact	Description	Quantified Yes/No
Economic (due to temperature change)	Auxillary Power Unit (APU)	Low	Reduction in fuel consumption as a result of less time running the APU.	**Yes,** dependent on compliance with standard operating procedures (SOPs)
	Engine de-rate	Low	Engine overhaul costs delayed due to reduction in engine revolutions per minute (RPM). Will vary across individual airlines.	**No**, benefits expected, but data specific to each airline and difficult to quantify.
	Reduction in fuel flow at take off	Med	Less fuel used during take-off thrust. This is fairly consistent for most temperature ranges.	**Yes**
	Tyres and Brakes	Low	Reduction in landing distance leading to reduced breaking requirements and more time between replacements.	**No,** cost benefits expected, but data specific to each airline, difficult to quantify.
	Payload and Range	High	Only quantified potential fuel savings. Increase in payload likely to have greater effect but difficult to value.	**Yes**, considering extra range only which is assumed to translate to fuel savings
Environmental	Soil Erosion	Med	Reduced with benefit of minimising dust (aircraft safety)	**No**
	Flooding	Low	Minor increase in risk of flooding due to soil saturation.	**No**
	Wildlife attraction	Med	Expect to reduce the risk of wildlife attraction and activity	**No**
	Air quality	Negligible	Potential improvement in local air quality as a result of planting, impact unlikely to benefit local residents	**No**
	Water quality	Negligible	Reduced sediment but increase in nutrients. Overall neutral effect.	**No**
Social	Airside comfort	Low	Potential temperature reduction means increase airside worker comfort	**No**
	Harvesting at airport	Low	Opportunity to apply to other airports specifically regional airports to maintain financial viability and continue operations	**No**
	Use of recycled water	Low	Use of recycled water from Glenelg Wastewater Treatment Plant (WWTP)	**No,** but part of the financial assessment
	Harvesting/ Site Manageme nt	Low	Increased complexity compared to current site management. Need for specialised contractors assumed with restricted access times and security clearances.	**No,** but part of the financial assessment
	Noise & disruption	Low	Some nuisance for harvesting operation at night time every two months	**No**

Aircraft performance

There are a number of aspects of aircraft performance and maintenance that will potentially be influenced by a drop in maximum air temperature during hot periods. With cooler temperatures there is an increase in air density, hence an improvement in the performance of jet engines. As the maximum revolutions per minute (RPM) of a jet engine is during take-off, a reduction in the amount of thrust, and hence RPM's needed to become airborne can influence the frequency of engine maintenance and overhauls. Engine maintenance is an expensive part of airline operations. The ability to safely reduce the frequency of overhauls means significant savings for airline operators (Tonkin, 2017).

A reduction in thrust during take-off will also have a direct influence on the amount of fuel used for the flight. In some cases, particularly with short flights, take-off will account for 25% of the fuel use for a flight. Whilst this includes both the actual take-off and the climb to cruising altitude, it is clear that a reduction in air temperature, and hence a reduction in RPMs equates to a reduction in fuel use during take-off.

The ability to maintain payload during hot weather may provide a range of additional benefits not only to airlines but also to passengers, exporters and airports where limiting of seat availability, offloading of freight and or baggage can be minimised (Coffel, 2015). Detailed analysis of these factors has not been conducted in the current assessment and require further investigation.

The potential impacts that would result from the four degree temperature reduction scenario (due to the irrigation and production of lucerne) identified in Table 2 were quantified in terms of the resulting benefit. The main quantified benefit related to the ability to maintain payload and fuel loads on hot days, with some reduction in fuel use and minimal savings from the APU (although the APU saving may be significantly higher at airports that do not provide pre-conditioned air and power to the aircraft at the terminal gate).

The relative cost benefits quantified in this study were suggested to be in the order of $1,000,000 each year. The four degree scenario was used as this represents the best case scenario, and although the data to date shows only a 3 degree C reduction in air temperature being achieved on days above 30 degrees, it is anticipated that a larger irrigation area, with a higher water use, will achieve this reduction.

The analysis assessed sensitivity to a variation in discount rate used in the NPV Calculation and also identified that likelihood and magnitude of benefits would be sensitive to:

- Four degrees not being achieved at the irrigation site (reduction in potential benefit).
- The reduction in air temperature at the irrigation site not being fully translated to runway

Cooling towers

SA Water and Adelaide Airport had identified a possible benefit of reduced air temperature would be a reduction in energy consumption for the airport terminal cooling system. A reduction in external temperatures could be expected to reduce the overall load on the cooling system (i.e. may reduce run time of fans and pumps). However, the magnitude of this energy saving is difficult to quantify, would require a number of assumptions and is likely to be offset by other system parameters. Energy consumption for the airport terminal cooling system is made up of three key elements, being cooling tower fans, circulation pumps and chillers. An assessment of the Adelaide Airport cooling system identified that the majority of energy usage and costs are associated with operation of the chillers. The major driver of chiller efficiency is the wet bulb temperature. Any drop in the air temperature due to the effects of evapotranspiration from irrigation would lead to a proportional increase in the humidity of the air. The likely net result would be that the wet bulb temperature would not significantly alter. This would mean that the power requirement to run the chillers would also not change.

Other qualitative benefits

Due to the nature of this trial, being the first of its kind in the world, there were a number of potential benefits that were identified but not quantified. Other potential benefits include

- a potential reduction on wear of aircraft tyres and brakes, (mainly due to the ability to stop faster during landing if the air is denser),
- improved aesthetics of the airport land leading to improved customer experience, and also a reduction in air temperature in other areas of the airport (including the car parks and entrance area) which again contributes to improved customer experience
- reduction in air temperature for residential properties that surround the airport
- reduction in the risk of heat stress for the staff working on the tarmac, including baggage handlers, aircraft engineers, cleaning staff etc.
- potential reduction in fire risk due to the presence of living, green vegetation as opposed to the dead grass that currently exists during the warmer months of the year.

Further work is required to quantify these and other areas of benefits that may stem from this airside management approach.

Sustainability and broadening this approach

One further benefit, which is still under investigation, is the ability to create carbon credits from the growing of crops. A methodology has been developed for carbon farming, which aims to encourage farmers to retain a greater volume of primary-production-related carbon on their farm. This includes influencing changes in stubble management, cultivation practises, and general improvements in soil health and microbial activity within the soil. If the generation of carbon credits could be an outcome of the farming (cropping) activity this could provide investment opportunities for airlines and other airport operators. One plausible scenario may be the co-investment in the irrigation infrastructure by airlines in exchange for carbon credits, which in turn would cool the air thereby further reducing the airline's carbon footprint via fuel savings. Interestingly, most airlines in the world will have a cap on net greenhouse gas emissions after 2020, therefore will be exploring opportunities to reduce their carbon footprint through both efficiencies and also through investment in carbon offsets. Cooling of the airport via crop production would provide great synergies and mutual benefit for the airport, airlines and the water utility.

Other crop types could be considered for cooling at the airport. Lucerne was chosen purely for the simplicity of management in this unique setting, however other crop types could be explored that provided other benefits. Most major cities around the world have an airport, which is usually a large tract of unused land that exists mainly to reduce risks to airport operations. Interestingly, many airports around the world have a "long grass" policy, encouraging the presence of long grass to minimise the risk of bird activity, dust generation and erosion (DeVault *et al.* 2013). In temperate zones, where summer rainfall is minimal, growing of long grass, or any vegetation without irrigation is not possible. There is a potential to use this vacant airside land for production of other crops, such as those for human consumption, particularly in large land-poor cities with high populations. Other crop types could include those grown for energy production via co-digestion, to provide power to the airport and surrounding areas. While the cooling is the main driver for this approach, maximising the secondary benefits is also an important consideration to ensure that the irrigation of airside land is sustainable in the long term, from both an environmental and an economic perspective.

There is also a need to be able to transfer the information gained from this trial to other sites, including other airports in temperature zones, and also other green open spaces such as urban parks, public open spaces and private open spaces (e.g. residential backyards). This is a simple concept which has the ability to address a number of issues in addition to the cooling benefits, via the use of the right economic assessment using a holistic lens.

References

Australian Taxation Office. 2016. *Guide to depreciating assets*. [ONLINE] Available at: https://www.ato.gov.au/Forms/Guide-to-depreciating-assets-2016/. [Accessed 15 January 2018].

Coffel, E., 2015, Climate change and weight-restricted flights, Helix Magazine, [ONLINE] Available at: https://helix.northwestern.edu/blog/2015/01/climate-change-and-weight-restricted-flights

Coffel, E., and Horton, R., 2015 Climate Change and the Impact of Extreme Temperatures on Aviation. Weather, Climate and Society, Volume 7, p. 94 – 102.

CSIRO and Bureau of Meteorology, 2015.*Climate Change in Australia Information for Australia's Natural Resource Management Regions*: Technical Report. Australia: CSIRO and Bureau of Meteorology.

DeVault, T. L, Begier, M. J, Belant, J. L, Blackwell, B. F, Dolbeer, R. A, Martin, J. A, Seamans, T. W, and Washburn, B. E. 2013. Rethinking airport land cover paradigms: agriculture, grass and wildlife hazards. *Human-Wildlife Interactions*, 7 (1), 10-15.

Harlan, S. L., and Ruddell, D. M., (2011), Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation. *Current Opinions in Environmental Sustainability*, Vol 3, p. 126-134.

Washington Post. 2017. *It's so hot in Phoenix that airplanes can't fly*. [ONLINE] Available at: https://www.washingtonpost.com/news/capital-weather-gang/wp/2017/06/20/its-so-hot-in-phoenix-that-airplanes-cant-fly/?utm_term=.a28475c16d8e. [Accessed 15 January 2018].

Tonkin, K, 2017. Adelaide Airport Irrigation Trial – Aviation Aspects. *Aviation Projects*