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Agricultural risk management of a peri-urban water recycling scheme to meet mixed land-use needs

Roger Attwater*, Lyn Anderson, Chris Derry

Western Sydney University, NSW Australia, Australia

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A B S T R A C T

n mean precipitation terms

The use of recycled water as a valued resource is becoming well established worldwide as a means to support agricultural irrigation. This paper describes a case study of agricultural use of recycled water and associated mixed land-use needs in a peri-urban setting of northwest Sydney. The Hawkesbury campus of Western Sydney University has an established water recycling scheme to support both agricultural productivity and landscape amenity, along with increasing linkages to infrastructure protection from bush fire risk. Risk management strategies are described for a range of land use needs across the campus, and discussed in terms of supporting local resilience, activities of the range of communities of practice involved, and ecosystem services from the local peri-urban landscape. Conclusions are drawn in terms of risk management of agricultural water recycling as an integrative process for managing associated land use needs.

1. Introduction

The United Nations has declared the lives of 3.5 billion people in 40 countries as being under threat because of increasing water scarcity, with water supply being the most critical factor in achieving world food security (United Nations, 2014). Given that agriculture uses 70% to 80% of the available water supply internationally, safe water recycling has been identified as a key strategy in meeting global irrigation demands (O'Neill and Dobrowolski, 2011; Wyman, 2013). With ground and surface water reserves already dwindling in many world regions, the need to increase the use of urban effluent as a recyclable irrigation resource has been clearly identified (Asano, 1998; Chen et al., 2013). However, as reliance on recycled water grows there is increasing pressure to use lower quality recycled supplies (Bernstein, 2011). To ensure safe and sustainable use of recycled effluent it is essential that water recycling is strategically managed and monitored, along with the need to apply vision in terms of integrated distribution for a range of peri-urban uses. In many cases this responsibility is best excercised by an informed and experienced agricultural sector, keenly aware of its role as a key extension agency (Plauborg et al., 2010). Managing the water resources and environmental assets of peri-urban landscapes is a dynamic and complex problem worldwide. International peri-urban studies reflect critical challenges associated with planning processes (Allen, 2003), implications for environmental integrity and social justice associated with peri-urban water management (eg Marshall et al., 2009), and the role of local actors in development processes associated with conserving agricultural land (eg Bryant and Chahine, 2011).

In Australia, water security in the principal food producing areas is threatened by extreme climate variability under the action of large-scale atmospheric circulations, including the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) (Ashcroft et al., 2014). In mean precipitation terms, Australia is the driest continent after Antarctica, with one of the World's most unpredictable climates, the coefficient of variation of river flow being 0.70 compared with a World average of 0.43. Australia underwent extreme drought from 2001 to 2003, with significantly decreased rainfall from 2000 to 2010, (sometimes known as the millennium drought) impacting on all uses. This situation highlighted the imperative for research into the position of agricultural management in integrative water recycling (Department of the Environment: Australian Government, 2011; Tan and Rhodes, 2013). Australian agriculture places a very heavy demand on water supply compared to most other countries with 75% of Australia's total available water being used for agricultural irrigation (Hussy and Dovers, 2007; Risbey et al., 2009). With burgeoning competition for existing supplies such as fire control, the maintence of environmental flows, min-

* Corresponding author at: Western Sydney University, Locked Bag 1797 Penrith NSW 2751 Australia.
E-mail addresses: r.attwater@westernsydney.edu.au (R. Attwater), l.anderson@westernsydney.edu.au (L. Anderson), c.derry@westernsydney.edu.au (C. Derry).

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ing, and irrigation of public and recreational grounds, Australia will need to dramatically increase its use of recycled effluent from the present 9% (Kiem, 2013).

To shift political opinion, agriculture must be seen to offer a custodial role in a shift away from its image as a very thirsty and dominant primary industry in many areas (Radcliffe, 2006). In recent years there has been a marked increase in the number of small, peri-urban agricultural and horticultural operations in Australia in response to a demand for high value, labour-intensive products such as salad crops, cauliflower, broccoli, herbs and asparagus, produced close to urban points of sale (Mason and Knowd, 2010; Zasada, 2011). While such schemes are small compared to staple and export crop production schemes, they are nevertheless very important in terms of meeting fresh produce demands of urban areas in an economically sustainable way, and therefore in integrating with local urban and *peri*-urban interests (Verbyla et al., 2013).

The western edge of the Sydney Basin is an area undergoing transformation from a landscape of orchards and small farms to one of encroaching urbanisation. A regional study by Merson et al. (2010) focused on the role of urban and peri-urban agriculture as a buffer between urban expansion and the neighbouring Blue Mountain World Heritage area. Building upon a review of factors influencing the local farming communities, the study investigated the role of agri-industries in relation to resilience, communities of practice, and ecosystem services. Within this region, a peri-urban example of agricultural water recycling is the Hawkesbury Water Recycling Scheme (HWRS) on the Hawkesbury campus of Western Sydney University. This region has supplied most of Sydney with a reliable food supply for over 200 years (Booth et al., 2003). The Hawkesbury campus was initially established as the Hawkesbury Agricultural College in 1891, and in 1988 was incorporated into the University.

This paper describes the role of local agricultural risk management in providing an integrated system for meeting mixed land-use needs relating to a limited yet important supply of recycled urban wastewater. The objective is to add to the existing local and international knowledge base of the role potentially played by the agricultural sector in providing a platform for developing sustainable peri-urban water reuse.

1.1. Risk management framework for agricultural and institutional irrigation

From the establishment of Hawkesbury Agricultural College, agriculture has been an integral part of the Hawkesbury campus. The farmlands of the campus include areas initially cleared as an agricultural commons adjacent to the Macquarie townships of Richmond and Windsor in the early 1800s. The landscape includes flood prone areas of swamp soils, with adjacent areas of duplex soils and perched groundwater higher in the landscape. Recently the farm enterprise has been reinvigorated, with increasing utilisation of recycled water to increase productivity.

The Hawkesbury campus has a long standing tradition of water recycling, with risk management strategies continuing to develop in response to emerging key risks and institutional arrangements. Since the 1960's, reclaimed water from the Richmond Sewage Treatment Plant (STP) has been used to irrigate pastures of the previous University Dairy. An initial agreement for the supply of reclaimed water was initially formalised with Sydney Water Corporation in 1996, with subsequent water use agreements continuing to the present. An important regulatory change in 1997 was the establishment of the New South Wales Protection of the Environment Operations (POEO) Act, which established economic incentives to reduce wastewater discharges to the environment. In the late 1990s, infrastructure to harvest, treat and reuse stormwater on the site was developed in collaboration with Hawkesbury City Council, funded through the Federal Natural Heritage Trust and the NSW Stormwater Trust. Stormwater harvesting was designed to mimic the local hydrology of sodic swamp areas, with the capture of smaller events and environmental flows in pulses following larger rain events. These initiatives established the current structure of theScheme, with its role in transforming urban wastewater and stormwater into valued water resources for agricultural and horticultural production and landscape irrigation (e.g. Booth et al., 2003).

Environmental health perspectives provided the basis for the local assessment of microbial and chemical risks, and associated multiple barrier management strategies (Derry et al., 2003). This was complemented by a focus on risk communication with representatives of the communities of practice involved in active water use and passive use of the facilities (Attwater and Derry, 2005). Risk management of the Scheme took a further step with the establishment of an Environmental Management Plan in 2005, based upon the model of continuous improvement which underpins environmental management systems (Attwater et al., 2006). The publication of the Australian National Guidelines for Water Recycling (NRMMC, 2006)and the associated subsequent stormwater guidelines, enabled a consistent risk framework to be applied to reclaimed water and stormwater (Radcliffe, 2010). The Scheme's current Risk Management Plan reflects the framework outlined in these national guidelines, with the structure including: commitment to water quality management; assessment of sources and uses, water quality and risk assessment; preventative measures and multiple barriers based on critical control points; operational procedures and process control; verification of water quality and performance; management of incidents, awareness and training; and further validation, research and development. The continued operation of the Scheme has supported the development of applied research focusing on the advocacy for practical environmental and risk management strategies. These have included those relating to health risk management (Derry et al., 2006; Derry, 2011) and standard indicator methods (Derry and Attwater, 2014).

The Hawkesbury farm enterprise focuses on a commercial grazing enterprise, with beef cattle and sheep utilising pasture and fodder crops irrigated by recycled water. Recycled water is a critical resource for agricultural productivity, and a valuable buffer for rainfall variability. This is a key component of the case study site as a practical demonstration of risk management and urban agriculture. With the recent establishment of centre pivot irrigators for improved irrigation efficiency, this grazing system based upon water recycling is developing as a local demonstration of best practice peri-urban agriculture. The management of infrastructure and risks associated with the use of recycled water for agricultural productivity also enables broader opportunities for a range of water uses embedded within the campus, or in neighbouring areas adjacent to the campus. Organisations using recycled water resources within the campus include a demonstration area for horticulture, nursery production of native plants, and a community service provider. Along with a focus for productive use for irrigation, supplies of recycled water are provided to top up stormwater storages in the neighbouring horse racing facility, supporting safety and amenity on the site. Storages of recycled water are also important 'static water supplies' for bushfire fighting, contributing to the protection of local infrastructure assets from bushfire. Landscape amenity across the campus is supported by stormwater reuse, with constructed wetlands for stormwater treatment also providing valuable habitat for local birdlife.

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1.2. Risk management for ecological restoration and bushfire mitigation

The Hawkesbury campus also encompasses over 400 ha of priority conservation land that is recognised in the Cumberland Plain Recovery Plan (DECCW, 2010). These native woodlands are important for ongoing peri-urban research and management, highlighting the resilience of remnant Cumberland Plain vegetation after years of major disturbance caused by agriculture. Of significance are the ecological interactions associated with fragmentation and anthropologically induced edges, where agriculture, urban infrastructure and bushland interact (Anderson and Burgin, 2002, 2008). In recent years, collaborative bush regeneration and weed management programs around remnant edges has established a knowledge base for management of ongoing urbanisation in the region. Similarly, collaborative research has enabled understanding the distribution and behaviour of feral animal pests to aid targetting of control strategies. These are examples of adaptive management involving the blending of scientific investigation and management interventions to address environmental risks.

The fragmented nature of native vegetation remnants has contributed to limitations on natural fire regime as an important ecological factor for maintaining biodiversity (eg Baker and Catterall, 2016). In this situation, a suite of activities have been planned and implemented to mitigate risks from bushfire, including controlled hazard reduction burns, a development of fire fighting capacity, and planning around the use of the recycled water resource. A fire protection system has been installed in a bushland research facility, utilising both potable and recycled water and designed to protect from grass fire and ember attack. Along with a trained campus bushfire team, the ability to access and use recycled water is an important part of the developing emergency response to bushfire risks.

2. Discussion

The supply and utilisation of recycled water can be a mitigating factor to the vulnerability of our agricultural and urban water supplies in the face of rainfall variability and climate change (Radcliffe, 2010). The resilience, or capacity of a system to cope with shocks and retain its essential functions, is a management concept increasingly applied to complex problems of landscape function and process (Walker and Salt, 2012). A core component contributing to resilience in this case study is the active management of recycled water, mimicking the broader landscape processes while focusing them on critical uses. Water recycling provides a buffering capacity against short term variability of rainfall, and potentially longer term climate change. Secure water resources for agricultural activities enable improved tactical choices relating to improvement in soil health, production and engagement with markets.

The provision of recycled water also provides buffering strategies for related water resource needs associated with a range of local water uses across the area. Building upon studies which look to the role of local actors or stakeholders, the concept of 'communities of practice' has become increasingly common. This analytical construct links individual and collective action through the central role of learning, knowledge transfer, and participation (Koliba and Gajda, 2009). A focus for engaging communities of practice in this local context is a key component of risk management strategies (Attwater and Derry, 2005). The mosaic of built, agricultural and bushland areas, requires a multi-faceted approach to the range of values held by local and regional communities of practice. The interests and activities of researchers and students are key to the University, and the local peri-urban landscape has become a dynamic platform for teaching, research and engagement. Continued efforts are being made to engage organisations within and neighbouring the campus, and to develop partnerships with agency stakeholders and interest groups for local and regional landscape management.

The overlapping risk management strategies discussed reflect the challenges and opportunities inherent in the local peri-urban context. In recognising that agricultural water management influences tradeoffs or synergies with ecosystem services, Gordon et al. (2010) suggested a strategy of multi-functional agroecosystems. Such ecosystem services are enhanced through management strategies which are informed by local landscape processes and contribute to regulating landscape functions. Water recycling transforms waste into a water resource, and in this situation mimics landscape scale ecological services associated with the local hydrology and hydrogeology. Similarly, the management of ecological remnants contributes directly to biodiversity, and good agricultural husbandry contributes to soil health and associated ecosystem services.

Against the general trend of the continuing fragmentation and development of agricultural lands, the flood prone edges of the local landscape show a clear complementarity of opportunities for water recycling and associated agricultural productivity. Similarly, while fragmentation of bushland remnants in the peri-urban landscape means that regeneration from natural processes such as fire is problematic. However, careful management of edges and hazard reduction burns can potentially mitigate risks to assets while contributing to the a mosaic of functioning land use processes. The case study outlined in this paper reflects how the Hawkesbury campus is developing as a working demonstration of the management of peri-urban land uses and processes. Risk management strategies relating to water recycling, agricultural productivity, bush fire mitigation, and bushland management contribute to integrated peri-urban landscape management.

3. Conclusions

This case study demonstrates how systematic risk management of water recycling for agricultural use can provide not just a valued resource, but an integrative process for managing broader environmental risks. Agricultural water management which incorporates water recycling therefore has potentially an important integrative role in managing the connectivity of land uses in our peri-urban landscapes. The connectivity through the peri-urban water cycle contributes to resilience in the face of variable rainfall, engagement of a range of communities of practice, and the provision of ecosystem services. In this way, agricultural use of recycled water can contribute to the management of mixed land uses and underlying landscape processes.

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