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Review

Achieving Resilience through Water Recycling in Peri-Urban Agriculture

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Abstract: Pressures on urban, peri-urban and rural water and agricultural systems are increasingly complex with multiple interacting stresses and impacts. As a way of addressing these issues there has been increasing consideration as to how to build and manage resilience in these complex social-ecological systems. This paper presents a case study of the role of water recycling for agricultural use within the context of the peri-urban water cycle in Western Sydney, Australia. Building upon a description of the water cycle associated with water reclaimed from urban wastewater and stormwater harvesting; aspects which enhance resilience are identified and discussed. These include water resource security, avoidance of wastewater discharges to receiving waters, enhanced processes of landscape ecology, provision of ecosystem services, environmental risk management, local agricultural products and services, social values, livelihood opportunity, and the industrial ecology of recycled organics.

Keywords: resilience; water recycling; peri-urban agriculture; water cycle management

1. Introduction

Worldwide, complex pressures on urban, peri-urban and rural water and their relationship to agricultural systems are of growing concern. Multiple interacting stresses and impacts associated with climate change and water pollution are common issues for urban and peri-urban agriculture [1], and for coping mechanisms relating to drought mitigation in rainfed agriculture [2]. In addressing the complex biophysical and social dimensions of these issues, there has been a growing dialogue around building and managing resilience as an emergent property of adaptive social-ecological systems. Resilience is the capacity of a social-ecological system to cope with shocks and changing internal and external environments while retaining its essential function [3–5].

Integrated approaches that address both social and environmental dimensions of health and water resource issues include that of Bunch et al. [6], who posed resilience as a key management concept to help reduce vulnerability to natural hazards, maintain the provision of ecological services and promote sustainability. In the case of rainfed agricultural systems, Rockstrom [2] describes how droughts have clear social and ecological dimensions, proposing a range of strategies for developing social resilience (e.g., institutional development, land reform) and ecological resilience (e.g., farming system development and integrated soil and water management). A study of nine cities across Africa and Asia by Padgham et al. [1] focused on climate change withurban areas becoming more vulnerable to impacts including storm surges and flooding, heat stress, drought and water scarcity. A key conclusion was the need for broad ranging risk management encompassing resilience for urban agriculture, optimising the multi-functionality of urban and peri-urban agriculture, and an understanding of environmental services and non-agricultural demands for land. In a recent article, Attwater et al. [7]

described how risk management of agricultural recycled water can support an integrative process for addressing broader risk management needs, assisting in the connectivity of our peri-urban landscapes, providing for multi-functionality and ecosystem services. This paper builds upon knowledge of the local peri-urban water cycle in Western Sydney, to identify attributes which contribute to resilience.

2. A Case Study of Peri-Urban Water Cycle: Western Sydney, Australia

The Sydney Basin and the lower Blue Mountains are areas where farms and market gardens supplying Sydney markets have been significantly reduced due to urban expansion. A study by Merson et al. [8] investigated the role of agri-industries as landscape buffers in relation to communities of practice and ecosystem services in the achievement of resilience. The social, economic and environmental drivers were investigated at a range of scales, and the opportunities identified included an integrated biosystems approach to waste conversion. In a preliminary report as part of this study, Attwater and Merson [9] applied the conceptual dynamics of Gunderson and Hollings [3], identifying the role for systemic inquiry, and the interactions of slow and fast variables in the adaptive cycles were interpreted. A key spatial opportunity for capital accumulation was that of water harvesting, and water recycling as a strategy for re-organisation. Water recycling, risk management and agricultural use has been described by Attwater et al. [7] as a key integrative strategy for connectivity in the peri-urban landscape. The following section describes the general peri-urban water cycle in which the case study of water reuse at the Western Sydney University Hawkesbury campus operates. The Hawkesbury Water Recycling Scheme (HWRS) supports agricultural operations along with co-existing uses on the Hawkesbury campus, adjacent to residential suburbs and remnant Cumberland Plain woodlands.

Rainfall for potable water supply to Sydney is caught in upland catchment areas managed by Sydney Catchment Authority, with storages such as Warragamba Dam, in the Blue Mountains just west of Greater Sydney. Throughout the Greater Sydney region, potable water supply and sewerage treatment is managed by Sydney Water Corporation which operates treatment and distribution pipelines to residential and industrial areas. As a result of this controlled supply, treated urban wastewater represents one of the most stable regional water supplies. Wastewater is piped from households to treatment plants such as the Richmond Reclaimed Water Plant, which supplies the Scheme with 500 mL of recycled water per year. Any surplus discharge to receiving waters (creeks and rivers) is regulated under the load based licensing provisions of the NSW Protection of the Environment Operations Act.

Stormwater runoff from rainfall is generally captured and discharged through stormwater channels separate to sewer infrastructure, as opposed to combined sewer systems. Stormwater treatment trains commonly include transfer in grassed swales/channels with primary gross pollutant traps, and secondary treatment in wet or dry compensating/detention basins before discharge to receiving waters. It is becoming more common to include additional water sensitive urban design features, such as raingardens for run-off from new urban developments. Within the established suburb of Richmond adjacent to the Blue Mountains, stormwater is captured in open grass swales with stormwater transferred to the stormwater harvesting component of the HWRS. In this Scheme runoff from a catchment of approximately 400 hectares is captured in a wet detention basin, and then treated in 4 hectares of constructed wetlands before storage for reuse. The area where these constructed wetlands are established are within a flood prone zone (below an expected 1 in 100 year flood occurrence), with functions mimicking the sodic swamp that would have naturally captured water from this catchment. Historically, small events would have been caught and slowly released by a sodic swamp of low hydraulic conductivity. Larger rainfall events would have flowed over this area and downstream as a pulse of environmental flow into the local Rickabys Creek and ultimately Sydney's major waterway, the Hawkesbury-Nepean River. The capture of stormwater by the Scheme mimics this local landscape process, capturing smaller events, with larger pulses of environmental flows going downstream.

Further treatment, distribution and reuse of the two resource streams of the reclaimed water and stormwater are as follows. The reclaimed water is primarily used for agricultural irrigation, with transfer to dams from where centre pivot irrigators and other agricultural irrigators are used for pasture and fodder crop production. Reclaimed water is also used following further distribution and treatment through filtration and UV disinfection for irrigation of playing fields, and irrigation of horticultural areas. Transfers are also made to a range of organisations who are lessees within the campus for horticultural use, along with neighbouring organisations such as a technical college (TAFE) and racecourse who are supplied by topping up available stormwater dams on an 'off-peak' basis during winter when irrigation demand is low. The reclaimed water is also used as a supply for bushfire protection of a research facility based within Eucalypt woodlands. A perimeter line of irrigators protects the western and southerly boundaries from grassfire driven by westerly winds, and sprinklers around the research infrastructure can be used as a last resort to bushfire to reduce the run of flames through the research site. The stormwater is distributed then further treated through filtration and UV disinfection before being used to maintain campus landscape amenity through an automated pop up sprinkler system.

Monitoring across the Scheme is undertaken as a collaborative research program, building upon investigations such as that reported by Derry and Attwater [10]. Ongoing interests include algal identification, and testing of faecal indicator bacteria to monitor the dynamics and effectiveness of established treatment trains.

3. Resilience and Agricultural Use of Recycled Water

The role of agriculture and the use of recycled water in the context of the peri-urban water cycle outlined above provides a number of examples of social-ecological resilience as summarised in Table 1. These include services associated with the capture and treatment of wastewater and stormwater discharges from urban areas, avoiding the impacts on receiving waters from pollutant rich material and symptomatic issues associated with ecological health and public health downstream.

Table 1. Aspects of resilience contributed by agricultural use of recycled water.

Aspect	Brief Description
Water resource security	Recycled water resource buffering variable rainfall
Environmental discharges	Reduced discharges to receiving waters
Landscape ecology	Mimic cascades of water and energy
Ecosystem services	Riparian corridors/multifunctional agro-ecology
Environmental risk management	Connectivity of risk management needs
Agricultural productivity	Local products marketed through variety of means
Social amenity	Managed agriculture and bushland near suburbs
Livelihoods	Contributing diversity and opportunity
Peri-urban industrial ecology	Reuse of a range waste products

In these examples water resource security is strengthened through the utilisation of traditional wastewater from sewerage and stormwater as a valued water resource, buffering productivity against climate variability and climate change. Wastewater flow is consistent due to predominantly household water use, and stormwater harvesting enables the capture and efficient infiltration and utilisation of rainfall and runoff pulses of which only a proportion would be captured. Future climate change is expected to increase the variability in droughts, rainfall distribution and storm intensity.

In developing a management strategy, agricultural resilience has to be offset against environmental and public health risk associated with discharges of municipal and other wastes into receiving waters, with subsequent algal and toxic cyanobacterial blooms being an increasing problem worldwide. Appropriate treatment trains for sewerage and stormwater treatment, along with associated risk management planning is increasingly important to reduce these issues. The subsequent water and nutrients resulting from treatment can be utilised as quality assured recycled products as inputs to agro-ecological productivity, along with the use of ecological systems and their assimilative capacity as treatment processes (e.g., stormwater treatment through constructed wetlands).

In terms of enhancing processes of landscape ecology, managed riparian and agricultural landscapes contribute to mimicking natural cascades of water, energy and materials through the ecotones and edges across the landscape. These enhance landscape scale processes and transformations, and provide the connectivity/interstices of the fragmented urban landscape and its transition into flood zones and peri-urban riparian corridors.

The provision of ecosystem services include those associated with agricultural productivity, and habitat at a number of scales. With mainstream practices of agriculture increasingly utilising minimum tillage and composted organic fertilisers, the soil organic carbon provides a fundamental building block for the considerable ecosystem services associated with soil health. Similarly, constructed wetlands contribute to habitat 'stepping stones' for bird species, within the transitions through and along peri-urban riparian corridors. These aspects contribute to multi-functional agro-ecologies providing productivity, connectivity and ecosystem services.

Environmental risk management is a very important aspect in the peri-urban landscapes of Western Sydney. Threats to life and assets from bushfire are a significant issue where suburbs are close to remnant vegetation and grasslands. There are also the needs for broad 'biosecurity' risk management associated with feral animal pests, invasive weeds, and diseases such as a range of mosquito borne viruses and domestic stock diseases. Water recycling infrastructure and the management of the edges and connectivity in the peri-urban landscapes address these.

Productive agro-ecosystems supported by the use of recycled water generate local agricultural products and services, which can be marketed locally, regionally or internationally. In the case described above, the major agricultural commodities produced are beef and lamb from irrigated grazing systems. These are marketed through local suppliers along with regional markets for the production of Australian smallgoods and meat products in supermarkets, and also sold through export markets to Asian city destinations. There are an increasing number of marketing options available, including traditional product supply chains or through alternative local marketing reducing 'food miles' and transport costs.

The social values and connection to nature and sources of food are very important, both for local residents living in urban environments just around the corner, or for weekenders from inner city environments or international tourists. Australians are very similar to most people in Western countries in living in highly urban environments, but having a strong cultural history and persona based upon connection with agriculture and natural environments. Here a shared agricultural environment is a source of revitalisation, and a real opportunity for progress towards urban environments which incorporate green spaces and water sensitive design. Diversity of activity helps promote increased richness and opportunity for livelihoods associated with urban, peri-urban, agricultural enterprises and the protection of natural assets. Opportunities for innovation and creativity include those associated with educational and service industries, and those associated with diverse forms of product supply chains.

Through the incorporation of agricultural use of recycled water in the peri-urban water cycle, there are increasing opportunities to integrate other organics recycling as part of broader peri-urban industrial ecology. These opportunities include composted poultry manure sourced from poultry production as a fertiliser input for agricultural productivity, or soil injection of liquid organic consumer waste. This type of organics recycling is essential to avoid increasing problems of organic pollution of our landscapes and cities and subsequent threats to public health and environmental quality.

4. Conclusions

This paper builds upon a case study of water recycling for agricultural use, with a focus on achieving resilience in the context of the local peri-urban water cycle. Aspects which enhance resilience are identified and discussed, including water resource security enhanced through the utilisation of treated wastewater from sewerage and stormwater, buffering against increasing variability in climate. Active management of these water resources avoids wastewater discharges to receiving waters and subsequent toxic algal blooms, with harvesting and treatment strategies seeking to mimic landscape processes enhancing ecosystem services from multi-functional agro-ecologies. The connectivity enabled through this strategy provides opportunities for enhancing the range of environmental risk management needed in peri-urban landscapes, including bushfire mitigation, management of ecological remnants, and broad biosecurity threats. The agro-ecosystems and associated water resources support tactical management for the development of products and services, along with social values associated with reconnecting urban environments to their agricultural and natural environments. Water recycling also complements other opportunities for the reuse of other organics, with similar potential avoidance of threats to public health and natural environmental quality.

Resilience through water recycling in peri-urban agriculture reflects a connectivity with landscape processes and risk management needs [7]. Peri-urban agriculture in a case like this thus provides a pivotal link between the pattern of catchment or watershed management through the urban water cycle, and the proactive re-connectivity back through the peri-urban landscape.

Author Contributions: The authors have worked collaboratively on a range of issues relating to the case study described.

Conflicts of Interest: The authors declare no conflict of interest.

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