Agricultural Water Management 205 (2018) 50–62

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Assessing lifestyle, productive and environmental consequences of tailwater reuse in the Shepparton Irrigation Region, Australia

L. Finger[a,1], T. Thayalakumaran[a,*], S. Longley[a], G. Kaine[b]

[a] Agriculture Victoria Research, Department of Economic Development, Jobs, Transport and Resources, Carlton, 3053, Victoria, Australia
[b] Geoff Kaine Research, Hamilton, 3204, New Zealand

ARTICLE INFO

Keywords:
Surface irrigation runoff
Water quality
Dairy
Irrigation efficiency
Filterable reactive phosphorous

ABSTRACT

Installation of tailwater reuse systems in irrigated farms is encouraged to achieve river water quality outcomes however, assessment of their efficacy in improving irrigation efficiency or intercepting nutrients and chemicals is limited to a few studies. The lifestyle, productive and environmental consequences of tailwater reuse dam on dairy farms was investigated using interviews, field monitoring and risk assessment in the Shepparton Irrigation Region (SIR) of Australia. Thirty one reuse dams were monitored during the 2013/14 and 2014/15 irrigation seasons, with water quantity and quality data collected.

The farmers believe that reuse dams provide greater flexibility in water management and recycling on farm. Between 3 and 28% of water delivered to a reuse dam catchment was captured in the reuse dam. On average 63% of the total water captured in a reuse dam was pumped out for reuse. Only 14% of dam capacity was available to capture unanticipated storm runoff for 90% of the time. Reuse water satisfied environmental guidelines thresholds with respect to EC, pH and NOx-N, but greatly exceeded maximum levels for TN, TP and FRP with median concentrations of 8.1, 3.7, and 1.9 mg/L, respectively. Under current irrigation and resue practices productive risk appears low however, there is a likelihood of reuse water spills to regional drains following 25 mm in 24 h rainfall events. Even in the absence of large rainfall events number of spills were recorded on 46% of farms. Although it appears that the reuse dams in the SIR provide productivity benefits and environmental benefits to some extent, current reuse dam management practices on many farms do not conform to key recommended practices. Thus, the risk to the environment from spills of nutrient enriched water is greater than that envisaged by the regulatory agencies. The impact of water spilled into the drains is unclear and requires further investigation.

1. Introduction

Agricultural runoff contributes to non-point source pollution of waterways by mobilising or increasing loads of nutrients, sediment, salt, pathogens, chemicals and other toxins. In addition to any rainfall initiated runoff, farms using irrigation may routinely generate runoff as a direct consequence of farm irrigation practice. Well designed and managed sprinkler or micro irrigation systems produce little runoff (Burt et al., 2000), but on farms using flowing water surface irrigation such as furrow or border irrigation, adequately irrigating the lower portion of a field inevitably generates some tailwater runoff. This runoff ranges from 10 to 20% of applied water under best practice (Burt et al., 2000; Wood and Finger, 2006) through to 20–50% (Bjorneberg et al., 2002; Horst et al., 2007; Sojka et al., 1998) or for 'wild flood' irrigation 69% of applied water (Tate et al., 2000).

Tailwater runoff collection and reuse systems are designed to collect runoff from the end of the irrigated field and deliver it to a storage (pond or sump), from which the water may be pumped for reuse elsewhere on the property (Schwankl et al., 2007; Southorn, 1997). On farm advantages of these systems include improved irrigation efficiency, increased flexibility in timing and length of irrigations, and the removal of standing water from ends of fields. Disadvantages can include the initial capital cost, ongoing maintenance and operating costs, and loss of productive land for the storage and associated drainage channels (Mosley and Fleming, 2009; Myers et al., 2012; Schwankl et al., 2007). Tailwater collection systems also intercept and contain any nutrients, sediment, salt, pathogens and chemicals carried in runoff within the farm property (Carruth et al., 2014; Carter et al., 1993; Davis et al., 2013; Shock and Welch, 2011; Smukler et al., 2010). Thus from a catchment or regional perspective, tailwater reuse systems are expected

* Corresponding author at: AgriBio, Centre for AgriBioscience, 5 Ring Road, Bundoora, Victoria, 3083, Australia.
E-mail address: thabo.kumaran@ecodev.vic.gov.au (T. Thayalakumaran).
[1] Present address: Student, Melbourne Graduate School of Education, University of Melbourne, Victoria 3010, Australia.

https://doi.org/10.1016/j.agwat.2018.04.028
Received 9 January 2018; Received in revised form 10 April 2018; Accepted 18 April 2018

to raise irrigation efficiency, reduce demands on surface or groundwater supply systems and enhance downstream water quality for environmental or consumptive purposes (Bouldin et al., 2004; Carruth et al., 2014; Mosley and Fleming, 2009). However, if collected water is left in the runoff collection system and not reused, this can increase leaching of nutrients and chemicals to the groundwater system (Kim et al., 2000; Prichard et al., 2005; Smukler et al., 2012; Spalding et al., 1979) or overflow into surface drainage networks.

While debate exists as to whether on-farm water 'conservation' measures such as tailwater reuse improve irrigation efficiency and/or reduce overall water consumption at a river basin level (Clemmens et al., 2008; Huffaker, 2008), there is general consensus that well managed reuse systems should beneficially improve water quality in downstream rivers, lakes and wetlands by decreasing salt, sediment, nutrient and chemical loads. Accordingly, organisations such as the Natural Resources Conservation Service in the United States Department of Agriculture provide financial incentives for reuse system installation in river basins including the Mississippi (Bouldin et al., 2004; Karki et al., 2015) and Colorado (Ward et al., 2008), while government agencies in Australia have provided similar incentives in the Murray-Darling Basin (GBCMA, 2010; Mosley and Fleming, 2010), Great Barrier Reef region (Australian Government and Queensland Government, 2015) and the Gippsland Lakes (Roberts et al., 2012). Despite a long history of promoting reuse systems for water quality improvement, assessment of their efficacy in improving irrigation efficiency or intercepting sediment, nutrients and chemicals is limited to a few studies in the United States of America (Carruth et al., 2014; Karki et al., 2015; Smukler et al., 2012) and two baseline studies in Australia (Mosley and Fleming, 2010; Shannon and McShane, 2013).

This study investigates the social, productive and environmental consequences of current reuse dam management on dairy farms in the Shepparton Irrigation Region, Australia. Specific objectives were to (1) understand the benefits that farmers gained from reuse dams, (2) assess the operational performance of reuse dams, and (3) assess whether if managed inappropriately reuse water and operational practices posed risks to the environment or productive land.

2. Materials and methods

2.1. Study area

The Shepparton Irrigation Region (SIR) is a 5000 km^2 area of the southern Murray-Darling Basin of Australia (Fig. 1). Long term average annual rainfall and Class A pan evaporation in the region are 450–490 mm and 1360–1590 mm respectively, supplemented by an average 1.5 km^3 of irrigation water each year. Irrigation water is delivered under gravity from surface water storages to farms via a 6300 km network of open canals and channels during each irrigation season (15 August through to 15 May). Some irrigators also secure water from other sources such as pumped groundwater, treated wastewater, dairy effluent and collected irrigation tailwater runoff.

The dairy industry in the SIR generates 24 percent of Australia's total milk production from a total area of 2980 km^2 (ABARES, 2015), relying on grazed forages as the main feed source for dairy cattle. These farms depend on border-check irrigation for forage and fodder production between September and May, when evaporation greatly exceeds rainfall. In border-check irrigation, water is released through a gate at the top of the rectangular border then freely advances down a graded slope to the bottom, with lateral spread of water controlled by check banks running parallel to the slope. Under best practice between 10 and 20% of water applied will become runoff (Austin et al., 1996; Mundy et al., 2003; Wood and Finger, 2006). Runoff from irrigated grazed pastures has elevated nitrogen (N), phosphorus (P), salt and sediment levels due to direct washing or mobilisation of applied fertilisers, plants, animal excreta (manure and urine patches) and soil during each irrigation event (Bush and Austin, 2001; Duncan et al., 2008; Mundy et al., 2003; Nash and Barlow, 2008).

Installation of reuse dams on dairy farms is encouraged by natural resource managers to minimise waterlogging, maximise farm water use efficiency and minimise flow and nutrients in the SIR regional drainage systems (Feehan and Plunkett, 2003). Government incentives for the installation of reuse systems in the SIR were provided between July 2001 and June 2010, with installed systems expected to satisfy recommended design and operating principles. Key operating recommendations included using captured water quickly, keeping the reuse dam empty as much as possible, and ensuring that water only spilt to regional drains during winter or after a summer storm of more than 50 mm in 24 h. This would maximise water collection whilst minimising the concentration and build-up of salt and nutrients (DNRE, 2002).

Although reuse dam installation has been encouraged in the SIR since the 1990s, the exact number, distribution and capacity of reuse dams is not known. It is estimated that approximately 3300 reuse dams are installed in the SIR, of which 2700 were installed prior to the incentive scheme. Within the SIR all water supplied to farms is metered and the flows/loads in regional drains are regularly monitored, yet the effectiveness of reuse dams in reducing farm nutrient exports to drains and receiving water bodies has never been explicitly assessed.

2.2. Farm interviews

Convergent interviewing (Dick, 1998) was used to identify key elements of the dairy farm system influencing benefits from reuse dam management, and to identify the relationship between these key elements and producers' decisions and behaviour in relation to irrigation management. Interviews were conducted with twenty farmers from across the SIR between November 2013 and January 2014. The twenty interviewees were selected using convenience sampling from lists of past participants of regional irrigation extension programs. Interviews were conducted with farmers from a range of contexts (Walter, 2006) to minimise the risk that the sample was unrepresentative of certain groups of the population. The farms varied in soils and topography, ranging in size from 0.25 km^2 with a milking herd of 120 cows through to 15 km^2 and a milking herd of 1200 cows. The interviewees varied in their age and educational background.

A semi-structured interview schedule was developed prior to interviewing the selected sample. The interview was designed to obtain information to understand how dairy farmers managed their irrigation water at the whole farm level. Questions about farm characteristics, irrigation systems and irrigation practices provided the information to identify key elements of the farm system that influenced the benefits to be had from reuse dam management. During the interviews, the laddering technique (Grunert and Grunert, 1995) was used to systematically explore the reasoning underlying the decisions and actions of the interviewee. Interview responses were recorded manually by two interviewers, summarised, then analysed using case and cross-case analysis (Patton, 1990). This resulted in identification of benefit segments for reuse dam management on surface irrigated dairy farms in the SIR.

2.3. Field monitoring

Reuse system operation under normal farm practice was monitored on 16 dairy farms for three-week periods between December 2013 and May 2014, and on 15 dairy farms for five-week periods between November 2014 and May 2015. Three sites were monitored concurrently. Sites were purposively selected to cover a range of reuse management segments (see Section 2.1 and 3.1) and the diversity of water sources available to farmers (gravity supplied surface water, groundwater, treated wastewater). Perennial pasture (perennial ryegrass and white clover), lucerne, sorghum, millet or annual pasture were irrigated on the farms, with milking herd sizes ranging from 160