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Potential contributions of surface and ground water to nitrous oxide emissions from irrigated cotton production systems

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ABSTRACT

The potential contribution of surface and ground water to overall nitrous oxide emissions from irrigated production systems has not yet been quantified. In this study we have used the International Panel on Climate Change (IPPC) emission factor five (EF5) to determine the indirect emissions from the irrigation water surface and from the ground water when it is pumped back onto the surface for irrigation. The additional land surface emission from the irrigation water source N was also calculated and termed the "indirect land surface emission". The study primarily used data collected (2000–2010) from the Australian Cotton Research Institute, Narrabri, Australia to calculate indirect and direct farm emissions during the cotton production season from the research station. The average annual direct and indirect N_2O-N emissions are 0.90 kg N_2O-N ha^{-1} yr^{-1} direct; 0.30 kg N_2O-N ha^{-1} yr^{-1} indirect emissions from the land surface; 0.08kg N_2O-N ha^{-1} yr^{-1} from the head ditch; 0.03 kg N_2O-N yr^{-1} from the tail drain. In total 26% of the emissions could be potentially emitted via the indirect pathway at the farm scale using river water for irrigation. If ground water with a concentration of (1.0 NO_3-N mg L^{-1}) was used to irrigate the crop then in total ~1.4% of the emissions would be emitted via the indirect pathway at the farm scale. But further refinement of the indirect emission factor and improved monitoring of temporal and spatial surface and ground water total N concentrations are required for mass balance calculations. Direct measurement of the N_2O-N water surface emissions is required to validate the IPCC calculated values.

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1. Introduction

The emission of nitrous oxide (N_2O-N) from agricultural production systems contributes significantly to global warming and stratospheric ozone depletion (Skiba and Rees, 2014). For this reason there has been many studies investigating the relationship between agricultural fertiliser applications, management and N_2O-N flux from the soil (Dalal et al., 2003). These studies have discovered possible large N_2O-N losses from irrigated agriculture systems (Dalal et al., 2003; Scheer et al., 2013), due to N fertiliser application. In cotton production systems, between 0.5 to 10 kg N_2O-N ha^{-1} have been measured (Macdonald et al., 2015). More specifically, in irrigated systems N losses via run-off (McHugh et al., 2008) and deep drainage (Chaudhuri et al., 2012) can also be large (10–20 kg N ha^{-1}). The N which is exported by the irrigation and deep drainage can be transformed into nitrous oxide and emitted to the atmosphere (Harrison and Matson, 2003; Mosier et al., 1998).

In Australian cotton production systems, at least 80% of the area is irrigated using gravity surface-irrigation systems (Roth et al., 2013). Indirect N_2O-N, as opposed to directly form the soil surface, can be produced along many stages of the irrigation network (Fig. 1) and contribute to the total greenhouse gas footprint. There are no current estimates for the potential contributions of surface and ground water to nitrous oxide emissions from irrigated production systems in Australia.

2. Methods

2.1. Location

The Namoi River catchment, New South Wales, Australia, was used to investigate the potential contributions of surface and ground water to nitrous oxide emissions from irrigated production systems. The catchment is approximately 40,000 km^2, and the Namoi River rises in the Great Dividing Range at elevations over 1000 m, falling to 250 m. The river then flows through sedimentary

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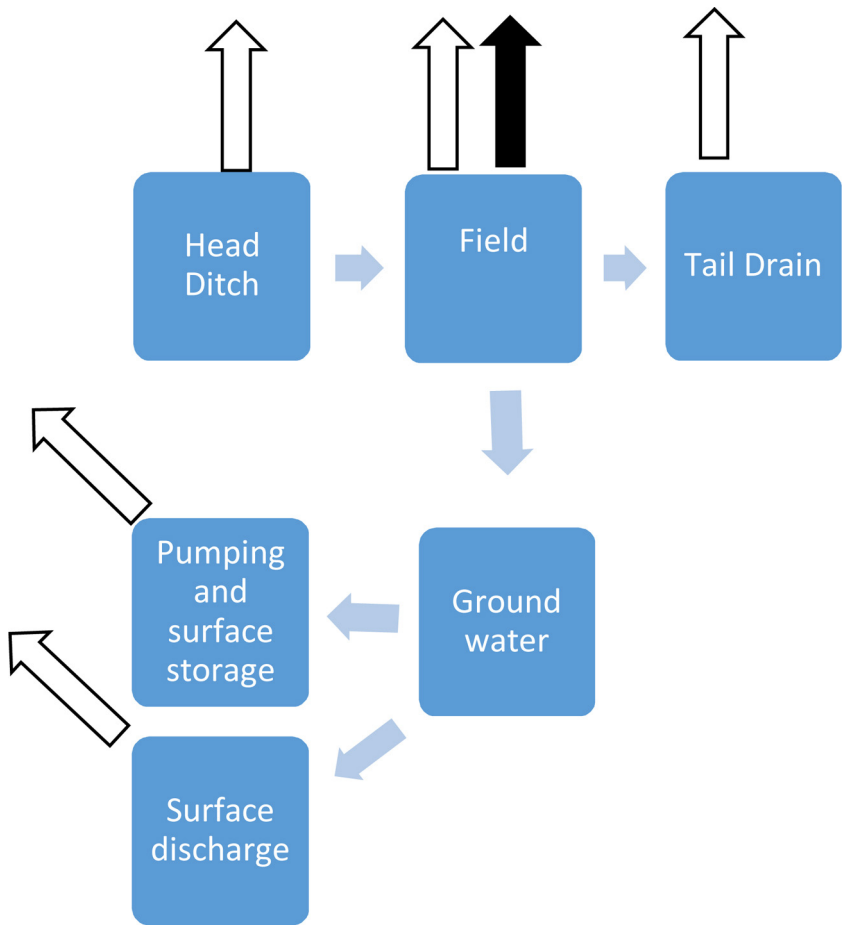

Fig. 1. Indirect (open) and direct (patterned arrow) emissions from irrigated production systems. Grey arrows represent transfers of N with water.

slopes to the open floodplains in the west. The Namoi catchment is the second largest cotton growing region in Australia, with an average of 68,800 ha of irrigated cotton grown annually. The Australian Cotton Research Institute (ACRI; 149°27′E 30°18′S) is located within the Namoi Catchment and the climate is semi-arid with a mild winter and a hot summer (Fig. 2).

2.2. Climate data

The average rainfall is 646 mm and is seasonally distributed (Fig. 2). Summers are hot and irrigation is required to maintain soil moisture and subsequent crop growth. Monthly rainfall data (2000–2010) was sourced from the Australia Bureau of Meteorology.

2.3. Ground water quality data

The average nitrate-nitrogen (NO_3-N) and ammonium-nitrogen (NH_4-N) concentration (Table 1) in the lower Namoi catchment was calculated from data collected by McLean (2003). Samples were collected by McLean (2003) after purging bore and NO_3-N (cadmium reduction) and NH_4-N (Nessler method) determined in the field using a Hach DR3000 Field Spectrometer.

2.4. Field experiment data from the Australian Cotton Research Institute

A series of N and water balance experiments were conducted at the ACRI between 2001 and 2010 (Hulugalle et al., 2012a,b; Weaver et al., 2005, 2013) and the irrigation water quality, fertiliser application (Tables 2 and 3) and deep drainage data from these studies was used to calculate the potential contributions of surface and ground water to N_2O-N emissions from irrigated production systems. Detailed descriptions of the experimental design, farming systems and environmental characteristic can be found in the above studies and will only be briefly described.

All of the field experiments were undertaken at ACRI. The soils at the site are a self-mulching grey vertisol and are classified as fine, thermic, montmorilonitic, Typic Haplusterts (Soil Survey Staff, 1998). A crop rotation experiment has been undertaken at this site since 1999. The data from 2000 to 2001 and 2002 to 2003 (Weaver et al., 2013) is from the cotton phase of the cotton–wheat

Table 1
Groundwater nitrate-nitrogen (NO_3-N) and ammonium-nitrogen (NH_4-N) concentration (mg N L^{-1}) within bores from the Namoi Catchment (McLean, 2003).

Aquifer	Sample number	Nitrate			Ammonium		
		Mean	Maximum	Minimum	Mean	Maximum	Minimum
Narrabri	84	1.74	11.62	0.00	0.32	5.12	0.00
Gunnedah	138	1.08	7.63	0.00	0.39	18.06	0.00
Cubbaroo	45	0.82	2.98	0.00	0.33	2.36	0.01

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