Soil & Tillage Research 145 (2015) 37–46

Contents lists available at ScienceDirect

Soil & Tillage Research

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

Effects of cultivation on soil and soil water under different fertiliser regimes

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ARTICLE INFO

Article history:
Received 7 February 2014
Received in revised form 23 July 2014
Accepted 18 August 2014

Keywords:
Mouldboard ploughing
P stratification
Dairy
Pasture

ABSTRACT

Nutrient exports from agriculture are an important environmental issue in many countries. In some production systems phosphorus (P) and nitrogen (N) accumulate at or near the soil surface and cultivation is one option for addressing the legacies of previous nutrient applications.

This study aimed to compare the effects of cultivation (mouldboard ploughing), pasture type (ryegrass or ryegrass–clover) and P fertiliser application rate (10, 35 or 100 kg P/ha per annum) on P and N in soil and soil water from dairy pastures over a three year period. The results are generally consistent with inversion of organic matter and P rich surface soil (i.e. 0–140 mm). Cultivation lowered surface soil (0–20 mm) P and N concentrations. Surface soil P concentrations also increased with increasing P fertiliser rate but organic matter and P buffering did not. The effects of vegetation were more equivocal. Ploughing lowered most P and N species in surface soil water. The concentrations of P in soil water increased with increasing fertiliser rates as did ammonia concentrations where pastures included clovers.

Analyses of trends with time suggests that, for pasture re-establishment, cultivation reduced the risk of N exports through surface pathways. Moreover, analyses of P export risk measured as the dissolved reactive P concentration in surface soil water (0–20 mm) suggests that where there is no predisposition to erosion, mouldboard ploughing not only reduces the risks of P exports, but that effect is likely to be more enduring where paddocks are in positive P balance. It follows that the use of cultivation as part of pasture renovation activities may reduce catchment-scale P exports, particularly in critical source areas where the risks of erosion and subsurface exports of N are low.

1. Introduction

Phosphorus (P) is an essential input for many farming systems (National Land and Water Resources Audit, 2001). Some of that P is lost in water runoff to aquatic ecosystems where it can contribute to algal blooms and thereby degrade water quality. Not surprisingly, the control of P exports from agriculture has been the focus of water quality improvement activities in many jurisdictions. (Anon, 2003; European Parliament, 2009; Parry, 1998; U.S. Environmental Protection Agency, 2002)

The Gippsland Lakes and the associated wetlands in south eastern Australia are important national assets that are adversely affected by algal blooms (Mulvenna et al., 2012). The major tributaries to the Gippsland Lakes include the Thompson, Tambo, Latrobe, Mitchell, and Macalister rivers which drain predominantly agricultural catchments. A broad range of strategies have been implemented to minimise the export of P and N to the Gippsland Lakes especially in areas where dairy production predominates (Anon, 2003; Christie, 2013). These strategies include on-farm measures such as: (a) minimising tail-water run-off and construction of tail-water re-use systems on irrigated farms; (b) improving dairy shed effluent management; (c) controlling soil erosion through riparian plantings, especially in upland areas; (d) fencing off creeks and irrigation drains to prevent stock access; (e) optimising P fertiliser application rates in line with soil monitoring results; and (f) not applying fertiliser at times of high export risk.

While both particulate and dissolved P are found in runoff from Australian dairy pastures (Burkitt et al., 2010; Fleming and Cox, 1998, 2001; Fleming et al., 2001; Nash and Murdoch, 1997),

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http://dx.doi.org/10.1016/j.still.2014.08.006
0167-1987/

dissolved P is the most important component in well managed systems (i.e. >80%) (Fleming et al., 1997; Nash and Murdoch, 1997; Nash and Halliwell, 1999; Nelson et al., 1996). Modelling of P exports (Nash et al., 2005, 2000) suggests that while recently applied fertilisers (<1 year) contribute P to runoff, it is the legacy of previous fertiliser additions that is the primary cause for concern (Nash and Hannah, 2011). Importantly, P exports from dairy farms in the Gippsland Region are generally inconsistent with the annual 75th percentile targets for total P (TP) and total nitrogen (TN) in rivers and streams, set at 0.045 mg/L and 0.6 mg/L, respectively (Environment Protection Authority, 2003).

In many farming systems deposition of fertiliser, animal wastes, and decaying plant material increases nutrient concentrations in surface soils (Mathers et al., 2007; Sharpley et al., 1993; Sims et al., 1998). Cultivation can mix the nutrient-rich upper layer with less fertile lower layers, and hence decrease the P and N export potential (Ahuja and Lehman, 1983; Costa et al., 2010; Sharpley, 2003). In one Gippsland study laser grading, an extreme form of cultivation characterised by surface soil removal and subsequent redistribution, decreased TP and TN in runoff by 41% and 36%, respectively, decreased surface soil P and N and increased P absorption capacity (Nash et al., 2007). Where more conventional cultivation practices were tested on commercial farms the initial results were similar. After the first year, cultivation (>100 mm) decreased P in soil and soil water, and this was reflected in lower concentrations of P in run-off. However, despite cultivation lowering soil test P and soil water P over the three years of the study, the same was not true for runoff P (Nash and Castlehouse, 2009). The authors attributed those results to grazing effects, drought (and the associated management changes) and variability between sites, bays and years.

In this study we investigate the changes in P and N in mouldboard ploughed and unploughed soils over a three year period with two types of pasture and three different rates of P fertiliser additions. Our original hypothesis was that ploughing would mix surface and subsurface soil, exposing new adsorption sites and increasing P adsorption capacity. Similarly ploughing was expected to mix organic matter at the soil surface with material from lower in the profile decreasing surface soil organic matter concentrations and the associated decomposition products, including various N species. It was expected that in a mixed pasture sward, clover, which has a slightly higher P requirement than ryegrass (i.e. Olsen P > 12 and >15 kg/ha for ryegrass and clover, respectively) would fix atmospheric N, increasing its concentration in soil and soil water. Further, as it is known that when inorganic P is adsorbed to soil the number of sites available for adsorption and their affinity for P decrease (Barrow et al., 1998), it was thought that the effects of cultivation would diminish less rapidly with time at higher P fertiliser application rates. The specific aims of the study were: (a) to compare P and N in cultivated and uncultivated soils and soil water and investigate the effects of pasture type and P fertiliser application rate on those analytes; and (b) to investigate the longevity of the changes that cultivation may induce. Preliminary results were published after the first year of the study (Watkins et al., 2012).

2. Materials and methods

2.1. Site selection and preparation

The experimental site was located on a commercial dairy farm near Poowong, in south-eastern Australia (−38.2782°, 145.7404°, Fig. 1) in an undulating low hills landscape with a slope of 4%. The soil has a fine sandy clay loam topsoil and is classified as a Grey Dermosol (Isbell, 2002) or Udollic Endoaqualfs (United States Department of Agriculture, 1998) with some areas of Dermosolic Hydrosol (i.e. where the soil profile is saturated for months at a time in most years). The area has a mean annual rainfall of 1025 mm. In the five years prior

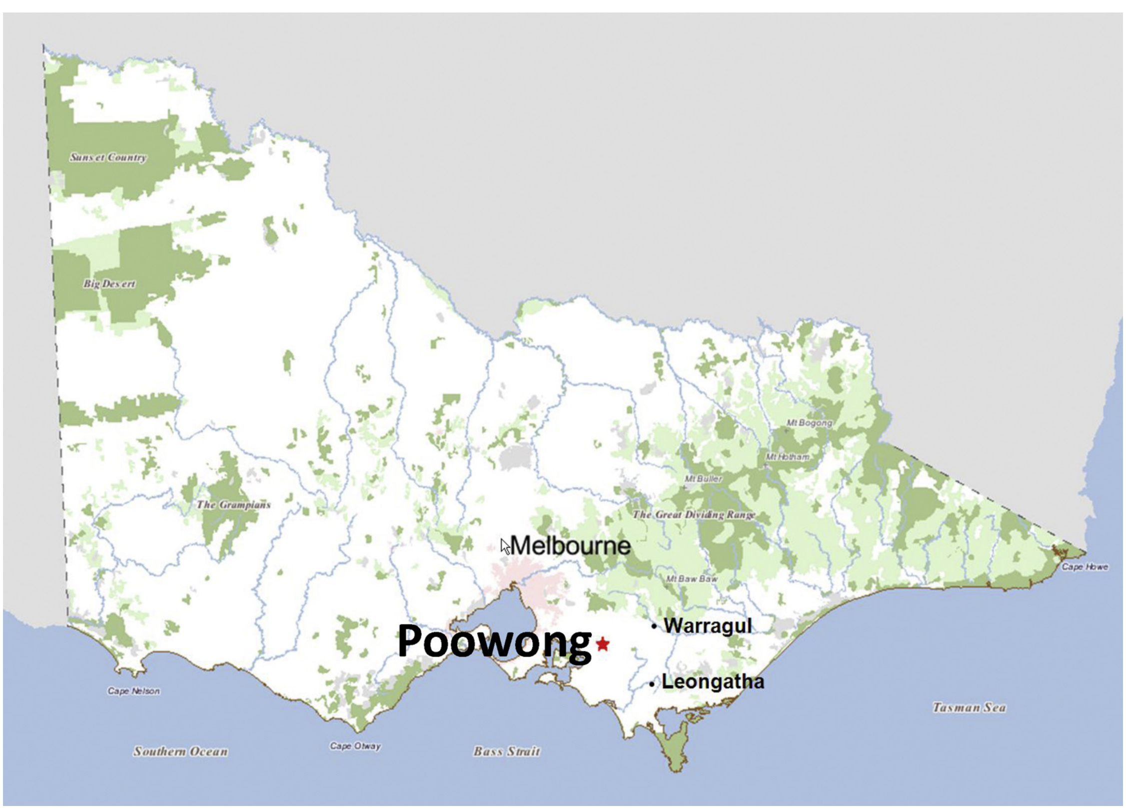

Fig. 1. Location of the experimental site at Poowong, Victoria, Australia.