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Bruce Thorrold, PhD

Bruce Thorrold is the Science Leader for Sustainable Development at Dexcel in Hamilton. This role allows Bruce a wide brief to work with the Dairy Industry, local government and research and extension staff from Dexcel and many other organisations to understand the issues faced by dairy farmers as they attempt to meet business and family goals, while also meeting the wishes and demands of consumers and the community. Current projects that Bruce is involved with include the effects of irrigation restrictions in Canterbury, designing government policy and new farm systems for the Lake Taupo catchment and the evaluation of genotype by nutrition interactions in Holstein-Friesian cows.

Bruce graduated from Lincoln College in 1984 with B.Agr.Sc. (Hons 1), and returned to Lincoln University to do a PhD in Soil science, graduating in 1994. Bruce came to Dexcel after 15 years with MAF and AgResearch where he worked in soil science and catchment management including hill country and lowland studies. This wide range of experience has given Bruce an interest in all facets of agriculture and the environment. This wide interest is reflected in membership of the DairyInsight Dairy and Environment Committee, the Steering Committee on the MAF Policy Pathogen Transmission Route Project and the Research and Science Committee for the Maungatautari Ecological Island Trust.

Bruce maintains a keen interest in the business side of dairying through shareholding in a Westland dairy farm company. Bruce and Jane live with their four children on a hobby farm near Hamilton, where they own more sheep than any other Dexcel staff member.

LIVESTOCK IMPROVEMENT CORPORATION LECTURE

The development of environmental best practices for intensive dairying

R.M. MONAGHAN, J.D. MORTON, R.J. MCDOWELL, J.J. DREWRY AND B.S. THORROLD[1]

AgResearch, Invermay Agricultural Research Centre, PB 50034, Mosgiel

ABSTRACT

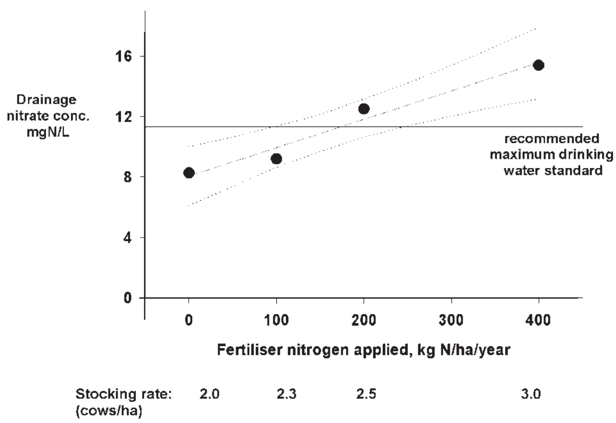
Research since 1995 has focused on soil, fertiliser and animal management factors affecting soil and water quality in intensive dairy systems on imperfectly to poorly drained soils in Southland and Otago. Derived from this on-farm research, best practice for effluent, fertiliser and soil management to ensure that required environmental standards are attained, is outlined.

Keywords: environmental, best management, effluent, fertiliser, soil.

INTRODUCTION

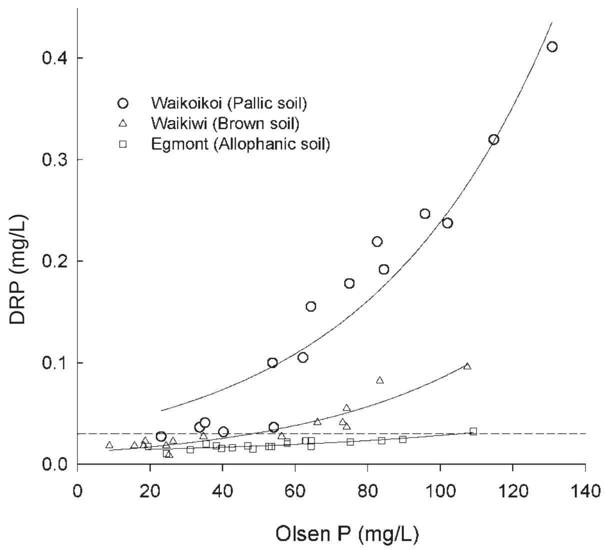
The dairy industry in Otago and Southland has expanded rapidly in the last decade. Cow numbers now total about 320,000 (LIC, 2001), a predicted increase of 50% in land under dairying over the next 8 years. The change in land use from sheep to dairying is typically accompanied by the production of large quantities of nutrient and pathogen-rich effluent, application of higher rates of fertiliser nitrogen (N) and phosphorus (P) and, most importantly, the introduction of dairy cows whose excretal nutrients are more easily leached and whose hooves can more easily compact the soil. Associated with this dairy expansion has been an increase in nutrient, sediment and faecal bacteria observed in lowland streams (Crawford, 2001) and the increasing public concern about the environmental impacts resulting from this. In the Oteramika study in Eastern Southland, the nutrient- and sediment-loss model that at that time incorporated our understanding of the processes involved, gave similar estimates of nitrate N leached as measured, but underestimated sediment and phosphorus (P) losses (Thorrold *et al.*,1997). Since then, the AgResearch Land

FIGURE 1: Nitrate-N concentrations in drainage water under varying N inputs and stocking rates, (mg/L dotted lines represent upper and lower 95% confidence limits).



[1]Dexcel, Box 3221, Hamilton

FIGURE 2: Relationship between soil Olsen P levels and DRP concentration in surface runoff from pallic, brown and allophanic soils.



and Environmental Management Group at Invermay Research Centre has been carrying out on-farm research to better understand the impact of management factors and develop best-management practices to mitigate any detrimental effects of dairy management. This paper summarises the results of this work.

FERTILISER MANAGEMENT

Intensified land use in Southland and Otago has raised local concerns about the resulting impacts on groundwater quality, particularly the increased leakage of nitrate from soil to groundwater through urine patches. To address the concern about the effect of high rates of N fertiliser use on dairy farms causing increased leaching loss of nitrate from urine patches, a four-year trial was carried out in Eastern Southland with cattle stocking rates of 2-3 cow equivalents/ha (Monaghan *et al.*, 2002). The trial results indicated that drainage water concentrations did not exceed the 11.3 mg N/L drinking water standard until annual fertiliser inputs exceeded 150-200 kg N/ha (Figure 1). Based on this work and other studies, best practice fertiliser managements to minimise N losses to groundwater and optimise profitability for Southland and Otago dairy farms were identified. These practices include application of no more than 150 kg N/ha per annum, in individual applications of no more than 50 kg N/ha, and avoiding N application during winter.

Phosphorus can be lost from soil to water via overland and subsurface flow of dissolved soil P, and particulate P from soil, fertiliser and faeces and sediment-attached P. Excessive levels of P in surface waters encourages nuisance weed and algal growths. Potential P losses and concentration in water will increase with available soil P concentration as demonstrated by the relationship between soil Olsen P and DRP (Dissolved Reactive Phosphorus) measured in overland flow from simulated rainfall on small plots (Figure 2; McDowell *et al.*, 2003). For the weakly weathered Otago pallic soil (Waikoikoi) that has few iron and aluminium oxides to retain soil, P, a critical DRP concentration for surface water quality is reached at an Olsen P concentration near the low end of the agronomic target range (20-30 mg/L) for average milksolids/ha production for a supply area. In contrast, for the Taranaki allophanic soil (Egmont), which has a high amount of P-fixing clays, the critical DRP concentration is only exceeded at very high Olsen P levels. The moderately weathered Southland Brown soil (Waikiwi) was intermediate between those of the pallicWaikoikoi and allophanic Egmont soils, exceeding the critical level at soil DRP concentration at Olsen P values greater than 50 mg/L. It should be noted that it is unwise to extrapolate the results in this study to P concentrations in streams as many other soil processes occur between the site of P loss and the receiving water body. Rather, the data is presented here to show potential differences in P loss between soil types.

From this we can conclude that potential phosphorus (P) loss to waterbodies can therefore be minimised, and economic return maximised (Morton *et al.*, 1997), by maintaining soil Olsen P concentrations in the target ranges (20-30 mg/L for allophanic and sedimentary soils, 35-45 for pumice and organic soils) for average milksolids/ha production for a supply area. Soil Olsen P concentrations in excess of 30 on ash and sedimentary soils, and 45 on pumice and organic soils, can only be economically justified if milksolids production/ha is in the top 25% for the supply area (Morton *et al*,. 1997).

It is also important to minimise pugging of soil, especially soon after fertiliser P application or in close vicinity to streams and drains. Losses of P in pasture soils are much greater if the soil has been treaded. In a study using a Waikoikoi silt loam soil in South Otago, total P loss in overland flow was linearly related to the amount of soil treading damage (McDowell *et al*., 2003).

Based on these studies and as recommended in the Fertiliser Code of Practice, best management practices to minimise P losses include :

- Allowing a margin of greater than 20 metres between the fertilised area and open water (applies to all fertiliser)
- Fencing off all waterbodies from stock to prevent P entering the water body from dung or via streambank erosion
- No application of P to saturated soils or before heavy rainfall. Rainfall on a soil that is already wet promotes overland flow and hence P loss
- Fencing off a riparian strip on each side of all swamps, drains, streams and rivers.

Some of these recommendations have more relevance to less-developed recent and pallic sedimentary soils.

EFFLUENT MANAGEMENT

Dairy-cow effluent contains high concentrations of N, P and faecal micro-organisms that can be lost to waterbodies if they are applied to land at high rates where the effluent flows preferentially into tile drains and groundwater. Additionally, if the soil is wet and/or lightly pugged, effluent can move into drains or streams via overland and subsurface flow. A large proportion of soils used for dairying in Southland and Otago are imperfectly to poorly drained and have mole-tile, sub-surface drainage systems which increase the risk of preferential flow. In a trial in West Otago on a Waikoikoi pallic soil (Monaghan *et al.*, 2002), when effluent was spray irrigated in October 2001 so that the maximum depth of effluent applied was less than the soil water deficit at the time of application, no preferential flow was observed from the tile drains (Table 1). Conversely, application of effluent in January and November 2001, when the maximum depth of application exceeded the soil water deficit, resulted in low volumes of preferential flow that nevertheless contributed more than 95% of the annual loads of *E. coli* and ammonium-N, and 94% of the total annual P load in drainage from the plot. The rotating twin-gun travelling irrigator used in this study and also commonly used on dairy farms, also applied twice the amount of effluent to the outside compared with the middle areas of the irrigator run. This non-uniformity in effluent application made a large contribution to the excessive contaminant loads measured.

Results from this on-going project indicate that significantly greater effluent pond storage capacities are especially important for farms that have soils with mole-tile drainage. Ideally, ponds should have sufficient capacity to store effluent until it can be safely applied, i.e., when soil moisture deficits allow. For many parts of Southland and Otago this often equates to at least 60 day storage. Other best practices for effluent application derived from this and other studies include (i) using a rate of application that does not exceed the soil moisture deficit, (ii) applying effluent to sufficient land area so that no more than 150 kg N/ha/yr is applied, (iii) ensuring that the irrigator is adequately maintained to give an even distribution of effluent (iv) irrigating at right angles to the direction of the tile line and (v) running the irrigator at maximum ground speed.

TABLE 1: Depths of effluent applied, soil water deficit at time of application and preferential flow volumes for three irrigations in West Otago during 2001. Nutrients and bacteria concentration in preferential flow also shown.

	Month effluent applied		
	January	October	November
Mean depth of effluent applied (mm)	23	8	9
Maximum depth of effluent applied (mm)	34	13	16
Soil water deficit (mm)	30	16	11
Preferential flow (% of applied)	2	0	3
Concentration in preferential flow (mg/L)			
Total-N	210	-	730
Nitrate-N	<5	-	<5
Ammonium N	53	-	240
Total-P	40	-	250
Dissolved reactive-P	27	-	230
E. coli (cfu/100 ml)	3.0×10^5	-	1.6×10^7

TABLE 2: Nutrient budgets (kg/ha) for effluent and non-effluent blocks on a typical Southland dairy milking platform (172 ha, 2.7 cows/ha, 900 kg MS/ha).

		N	**P**	**K**	**S**
Grazing area	Inputs:				
(non-effluent)	Fertiliser	75	35	36	45
	Atmospheric (clover)	71	0	2	4
	Slow release from soil	0	3	42	0
	Supplements brought in	34	4	32	4
	Outputs:				
	Product (milk etc)	71	13	16	4
	Transfer	33	4	32	4
	Supplements sold	0	0	0	0
	Atmospheric loss	45	0	0	0
	Leaching	20	1	15	44
	Immobilisation/absorption	11	21	0	1
	Change in inorganic pool or "Balance"	0	3	49	-1
Effluent block	Inputs:				
	Fertiliser	25	16	0	45
	Atmospheric (clover)	59	0	2	5
	Effluent	135	19	135	18
	Slow release from soil	0	3	23	0
	Supplements brought in	34	4	32	4
	Outputs:				
	Product (milk etc)	71	13	16	4
	Transfer	40	4	36	4
	Supplements sold	0	0	0	0
	Atmospheric loss	66	0	0	0
	Leaching	34	1	18	57
	Immobilisation/absorption	42	21	0	4
	Change in inorganic pool or "Balance"	0	3	1162	1

SOIL MANAGEMENT

Treading damage to pasture (short-term burial of plant material) and soil (longer term compaction and loss of structure) from cows grazing during wet soil conditions can often occur on poorly drained soils. In a two-year trial in Eastern Southland, Drewry & Paton (2000) observed 15-40% reductions in pasture production at 8% soil macroporosity from normal dairy management compared with nil grazing. Closing spring-grazed pasture for silage to allow rejuvenation by natural soil processes, or only grazing cows on the paddock for 10-12 hours/ day, resulted in a lower reduction in pasture production. There are now monitoring tools available to dairy farmers to allow them to assess the physical state of their own soils. Soil macroporosity in the top 5 cm can be measured in the laboratory from a sampling of 20 cores per paddock. Alternatively, soil structure in the topsoil can be visually assessed and scored from comparing it with a pictorial description of structural condition. For on-the-spot decisions about how long to graze cows in a paddock, penetrometer readings, which measure soil penetration resistance to a cow hoof, will predict the reduction in pasture production from a defined period of grazing.

For soils to be managed in an optimal state for drainage, aeration and root penetration, appropriate artificial drainage systems are required on soils with naturally imperfect or poor drainage. This usually takes the form of mole-tile systems. Shallow sub soiling is also sometimes employed to loosen compacted topsoil layers. If soils are very wet during winter and spring, pastures should not be grazed, with cows instead kept and fed on wintering pads. In moderately wet soil conditions, cows should only be grazed for 3-4 hours before being removed to minimise soil damage.

NUTRIENT BUDGETS

Nutrient budgets are an essential tool in nutrient management to ensure that both farm nutrient surpluses which contribute to the contamination of water bodies and the atmosphere, and nutrient deficits that cause losses in productivity, are minimised. AgResearch, in association with MAF and the fertiliser industry, have developed the OVERSEER™ nutrient budget programme to allow land users to estimate a nutrient balance for their own farm. Using this programme, nutrient budgets for effluent blocks and grazing areas can be constructed to highlight situations of nutrient deficit or excess. A nutrient budget for a typical Southland farm following best-management nutrient practices (4 ha/100 cows for effluent application, fertiliser N<150 kg/ha/yr, annual fertiliser P rate to maintain Olsen P in optimum range, fertiliser K applied to replace soil K reserves) is shown in Table 2 .

For the effluent block, high rates of N and K are applied (Table 2). The surplus N not exported from the farm, is lost from the soil through leaching and gaseous emissions (ammonia, nitrous oxide) or immobilised in the organic matter to give a neutral N balance. Although fertiliser K was not applied, there is still a large surplus in the inorganic pool that will increase available soil K levels in brown soils or be retained in non-exchangeable K pools in recent and pallic soils. The fertiliser P application rate has been reduced to accommodate the P returns in effluent, with the result that the P budget is virtually in balance. Extra fertiliser S to that required (20-30 kg/ha/yr) has been applied in superphosphate which has a fixed P:S ratio, resulting in a large degree of S leaching, mainly from urine patches.

In the non-effluent grazing area, there are lower N inputs with resulting lower losses to the environment. A higher rate of P and K fertiliser is applied to give a surplus in the inorganic pool to replace most of the K slowly released from clay minerals and sustain the pool. With nutrient budgets it is essential to check the balance with trends in soil test levels over time to ensure that they are accurate.

CONCLUSIONS

The results from a research programme translated into best management practices for dairy farmers in Southland, with relevance to other dairying areas has been outlined for effluent, fertiliser and soil management. From this, tools have also been developed, such as nutrient budgeting and soil macroporosity corers, that can be used to sample soil on any one farm. Future research needs will include treatment of drainage water to remove nutrients and faecal pathogens, winter-crop management to reduce soil damage and loss of nutrients, sediment and pathogens and differential management on areas of land that have connectivity to water bodies. Apart from the benefits in environmental protection from application of the best management practices, there are also significant associated economic benefits for the dairy farmer.

REFERENCES

Crawford S. 2001: Water quality and our changing agricultural landscape. Proceedings of the Southland dairy forum. Invercargill 2 April 2001. pp 11-15.

Drewry J.J. & Paton, R.J.2000: Effects of cattle treading and natural amelioration on soil physical properties and pasture under dairy farming in Southland, New Zealand. *New Zealand journal of agricultura l research 43*: 377-386.

McDowell R.W.; Drewry J.J.; Paton R.J.; Carey P.L.; Monaghan R.M.; Condron L.M. 2003: Influence of soil treading on sediment and phosphorus loss in overland flow. *Australian journal of soil research 41(5): In press.*

Monaghan R.M.; Smith, L.C.; de Klein C.A.M.; Drewry J.J.; Paton R.J.; Morton J.D.; McDowell R.W.; Muirhead R.W. 2002: Research to sustain a clean-green dairy industry in Southland and Otago. *In*: Dairy farm soil management. (*Eds* LD Currie and P Loganathan). Occasional report No. 15. Fertilizer and Lime Research Centre, Massey University, Palmerston North. Pp 21-30.

Morton J.D.; Roberts A.H.C.; Thomson N.A. 1997: Increasing profit from phosphate fertiliser. *Proceedings of the Ruakura dairy farmers' conference 49*: 86-91.

Thorrold B.S.; Hamill K.D.; Monaghan R.M.; Rekker J.; Rodda H.J.; Ryder G. 1997: Oteramika catchment study. *Proceedings of the New Zealand Fertiliser Manufacturers' Research Association 24*: 119-128.