Using turnips to reduce soil K loading on the effluent block

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Abstract
Soil potassium (K) accumulation and associated metabolic cow health risks result from increased volumes of land-treated farm dairy effluent (FDE) generated by the intensification of dairy farming in New Zealand. A dairy farm system is described and modelled, in which turnips are supplementary feed to a daily pasture ration during summer. The model shows how a K-rich crop of turnips can be grown and grazed to mine up to 283 kg K/ha from K-rich soils of effluent blocks to reduce soil K accumulation and cow health risks and redistribute K to pasture blocks.
Keywords: potassium, effluent, strip-grazing

Introduction
Intensification of dairy farming in New Zealand has increased the average stocking rate to 2.83 cows/ha (LIC 2009). This is associated with increased N fertiliser use and/or the increased importation of supplementary feed onto the farm. This combination of increased cow numbers and inputs has generated larger volumes of K-rich farm dairy effluent (FDE). Therefore, K enrichment of land and pasture receiving FDE becomes a potential risk because cows in early lactation may suffer from metabolic disorders such as hypocalcaemia and hypomagnesaemia.

The nutrient concentration in FDE varies from farm to farm (181-400 mg N/L, 40-80 mgP/L and 164 -705 mgK/L, Longhurst *et al*. 2000) but is usually K-rich. The Overseer Nutrient Budget model estimates that farms with approximately 3 cows/ha, feeding pasture and additional supplements at 1 000 kg DM/cow/yr, will apply 150 kg K/ha/yr to an effluent block occupying 18% of the farm area. If soil quick test potassium (QTK) status of the block is already above optimum (>10) excessive soil K (90 kg/ha/yr) will accumulate, even in the absence of K fertiliser application. To prevent K accumulation in soil, the annual K loading rate should not exceed the annual K maintenance requirement. This often requires irrigation of FDE to a larger proportion of the farm (30-40%) than is currently required to meet the N loading requirements (10-15 %).

Periodically harvesting maize or multiple cuts of grass silage to remove K (Table 1) may avoid the need for excessively large land-treatment areas (Hedley *et al*. 2004). Turnips potentially produce larger amounts of dry matter with a higher metabolisable energy and K content (Table 1) than conserved pasture. For the same growing period, turnips at a yield of 10 t DM/ha, extract 10% less N and P but 40% more K and S than a crop of maize yielding 18 t DM/ha (Table 1). Turnip crops are often grown as part of the farms re-grassing strategy and when grazed *in situ* they involve no additional capital cost.

This paper describes a model designed to estimate how much K can be transferred from K-enriched effluent block soils to other parts of the farm by duration controlled, strip grazing of turnips.

Method and Assumptions
A simple model that quantifies the net amount of soil K that can be transferred when a summer turnip crop is stripped-grazed as part of the dairy cows' diet was developed using the concepts of Williams *et al*. (1990). The K loss model estimates the daily loss of K in animal product, and the fate of excreta K, by allocating excreta K to unproductive areas and grazing areas based on the proportion of a 24 h period (Table 2) a cow spends in these areas. The parameterisation of the model was based on a case study of management of a 'Barkant' turnip crop grown for late summer grazing on the No. 4 Dairy farm at Massey University.

Table 1 The effect of crop type and yield on the removal of K from the soil.

		Nutrients (kg/ha)			
	Yield (t DM/ha)	N	P	K	S
Pasture Silage/baleage	2 – 6	70 - 210	6 - 18	44 - 132	4 - 12
Maize silage	18	234	41	216	23
Turnip crop	10	210	37	300	33

Average yields multiplied by average nutrient concentrations from Hill laboratories (1998) and Holmes *et al.* (2002).

K ingested by cows

The maximum feeding rate of turnips was set at 4 kg DM /cow/day (Table 2) with the remainder of the diet being grazed pasture (12 kg DM /cow/day). Feeding rates above this (Harris *et al*. 1998) do not achieve increased milksolids production. Ingested K (g K /cow/day) was determined daily according to the cow's diet and the default values for K concentrations (DM basis) were 3.90% for turnips (from a survey of Manawatu farms; Salazar (2006)) and 2.56 % for pasture (pasture analysis from Massey No. 4 Dairy farm, Salazar (2006), Table 3).

K product losses

Product K (g K/cow/day) lost from the farm was the sum of K in milksolids and liveweight gained by the cows. These components were calculated separately based on mean data for milksolids production per day and milk composition in late lactation (Jan-March) and mean cow liveweight gain/day (Tables 2 & 3).

K transfer losses and K returned to paddocks

To calculate K transfers and losses on the farm (g K / cow/day) we assumed that the excreta deposition rate was constant per hour each day and allocated excretal K (total K ingested minus total K product) to lanes, milking shed and collecting yards, and the turnip and pasture paddocks based on estimates of times cows spent in each area (Table 2). To convert the units of g K /cow/day to K removed or deposited per hectare, it was necessary to determine the number of cow-days required to graze a hectare of turnips. Therefore, the total turnip yield (e.g. 8 000 kg DM/ha on the case study farm) was multiplied by a utilisation factor (0.85)

Table 2 Assumptions used in the simple K balance model, based on information from the Massey University No. 4 Dairy farm in the summer 2005/06.

Time in raceway/milking		
t1(h)	First cow	0.3
t2 (h)	Last cow	0.5
Average time (h)		0.8
Time in shed and yards		
t1(h)	First cow	0.4
t2 (h)	Last cow	2.0
Average time (h)		2.4
Yield turnip kg DM/ha/cycle		8000
Turnips allowance		
Time grazing turnips (h)		3.0
Daily turnip intake (kg DM/cow)		4.0
Pasture allowance		
Time on pasture (h)		17.8
Daily pasture intake (kg DM/cow)		12.0
Total daily DM intake (kg DM/cow)		16.0
Number of cows		490
Number of ha		192
Liveweight gained (kg cow)		0.5
Milksolids (kg MS/cow/day)		1

Table 4 Daily transfers of potassium calculated by the simple model (Table 3) and expressed per cow and per one hectare of turnips, grazed in 3.5 days by 490 cows at 4 kg DM turnips/cow/d, averaging 3.90% K and 12 kg DM pasture/day from 11.33 ha pasture averaging 2.56% K.

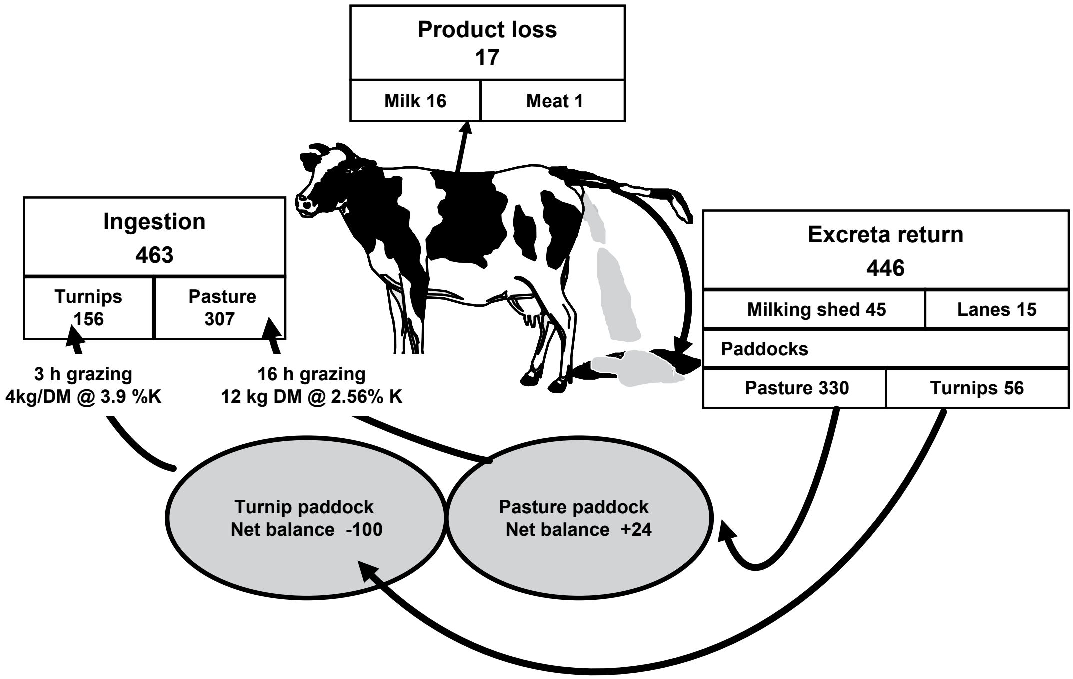
			g K/ cow/d	kg K/ha of turnips eaten
Intake Total			463	787
		Turnip intake	156	265
		Pasture intake	307	522
Product loss Total			17	29
		Milk	16	27
		Meat	1	1
Excreta return Total			446	759
		Laneways	15	25
		Milking shed	45	76
	Paddock	subtotal	386	658
		Turnip	56	95
		Pasture	330	563
Net returns to paddocks				
		Turnip	-100	-170
		Pasture	24	41

Table 3 The default K concentrations for feed and products used in the simple K balance model (summer 2005/06).

	Milk[2]	Meat[2]	Pasture[1]	Turnips[1]	Grass silage[2]
	% fresh wt.		% of DM		
K	0.14	0.15	2.56	3.90	2.20
Milksolids[2]	8.7				

1. Actual measurements on the No.4 Dairy farm, Massey University.
2. Values from Holmes *et al*. (2002)

Figure 1 Daily ingestion and redistribution of potassium when a Friesian dairy cow is on a daily diet of 12 kg DM pasture and 4kg DM turnips strip grazed in 3 h (units g K/cow/day).



and then divided by the daily turnip intake per cow (e.g. an ingestion rate of 4 kg DM/cow/day, 25% of the diet) to give cow-days/ha (e.g. 1 700 cow-days/ha in this case). Given these values, it would take 3.47 days for 490 cows to graze 1 ha. The net K returned to turnips and pasture paddocks was obtained by multiplying the total cow-days/ha by the net daily return/cow of excreta K to turnips and pasture (Table 4).

The area of pasture required whilst grazing 1 ha of turnips was calculated by multiplying the herd size by the per cow pasture intake and the days taken to graze 1 ha of turnips divided by the grazeable pasture cover (difference pre- and post-grazing). If the grazeable pasture cover of the No 4 Dairy farm in this period is assumed to be 1 800 kg DM/ha then 11.33 ha of pasture would be required to accompany the grazing of 1 ha of turnip crop over 3.47 days by 490 cows.

Results and Discussion

The model was used to estimate K losses and the K returns per cow and per hectare of turnips grazed at the Massey No 4 dairy farm (input data shown in Tables 2 and 3). The model outputs are shown in Table 4 and Fig. 1. When the daily cow dry matter intake was 12 kg DM pasture and 4 kg DM turnip, the total daily intake of K was 463 g K/cow. The largest proportion of this K (307 g K/cow/day or 66% of K ingestion) was derived from the pasture. Despite the lower (25%) DM intake from turnips, the K ingested from turnips was 34% of the total K intake. This was because turnips had higher K concentrations in their tissues compared with pasture.

When product (17 g K/cow/day) and excreta dropped in lanes and yards (60 g K/cow/day) were accounted for, excreta returned to paddocks was 386 g K/cow/day and made up 84% of K intake. Cows grazing turnips for only 3 h per day returned only 14.4% (46 g K/cow/day) of this to the turnip paddock. As K ingested from the turnip paddock was 156 g K/cow/day, the turnip paddock K was depleted at a rate of 100 g K/cow/day. If 490 cows take 3.47 days to graze one hectare of turnips (i.e. 1 700 cow-days) then the turnip paddock was depleted by 170 kg K/ha. Depending upon soil order this level of K depletion could be expected to lower the exchangeable K soil test by 2 to 4 Quick test units per year.

Transfer of K from the turnip paddock to pasture is important. Of the 265 kg K/ha ingested from the turnip paddock, 190 kg K is returned in excreta to the pasture paddocks (16.8 kg K/ha over 11.33 ha) leading to a net K accumulation (41 kg K/ha over 11.33 ha) rate under pasture of 3.62 kg K/ha over 3.47 days. To put this K gain in perspective, if the cows were on a pasture only diet of 16 kg DM/day they would be grazed at 112 cows/ha/day and would deplete the pasture at a rate of -7.6 kg K/ha.

The K transfer rate from the turnip paddock to pasture paddocks is sensitive to the proportion of the diet that is turnips, their K concentration and very sensitive to the time required for the cows to graze the turnips and time they spend on the pasture. The most efficient transfer of K is achieved if the turnip grazing time, and time in yards and raceways are minimised and the pasture grazing time is maximised. Optimising the proportion of turnip in the diet and the grazing time increases the K transferred to pasture. For example, if the grazing time required to harvest 4 kg DM of turnips is reduced to 2.5 h then 186 kg K/ha is removed from the turnip paddock and K accumulates at 4.9 kg K/ha on 11.33 ha of pasture paddocks. If, however, the cows remain in the paddock for 3 h but only 3 kg DM of turnips are consumed it will take 4.63 days for 490 cows to graze 1 ha of turnips and only 143 kg K/ha will be removed from the paddock. Over that time the cows will have required 16.4 ha of pasture with a grazeable cover of 1 800 kg DM to complete their diet. The removal of K from pasture land to product, raceways and yards will exceed the return of K to pasture land resulting in a net depletion of -1.6 kg K/ha from pasture paddocks.

Salazar (2006) grew a summer crop of 'Barkant' turnips on a paddock ploughed out of pasture on a Pallic soil previously used for FDE application. Using conventional tillage, pre-plant fertiliser (Cropmaster 15@ 250 kg/ha) and five FDE applications during growth, which supplied another 57 kg N/ha and 105 kg K/ha , the crop produced 8.4 t DM/ha (bulbs plus leaves) in 100 days with an average potassium concentration of 5.8% of DM. Grazing one hectare of these K-rich turnips using the strategy in Table 2 would remove 283 kg K/ha from the effluent paddock and return a net gain of 12.0 kg K/ha to grazed pasture. On a 3 cow/ha farm (as described in the Introduction) this level of K removal will allow K mining on K rich effluent paddocks even if FDE is applied to fertilise the turnip seed bed and irrigate the growing crop.

Conclusions and Recommendations

Elevated soil K status in dairy farm effluent block soils is common, and inefficient use of an expensive nutrient that represents a hypocalcaemic and hypomagnesaemic risk. A simple mass balance K model for a dairy farm system in which turnips are supplementary feed to a daily pasture ration has illustrated how a K-rich crop of turnips can be grown and grazed to mine K-rich soils of effluent blocks. The maximum reduction in K loading in the effluent block soils could be achieved if the area targeted for turnips has silage cut off it in spring-early summer; the final cut producing the conditions for establishment of the turnip seed bed in early summer. If the cow time on the turnip block is grazing only and cow time at milking and in yards and raceways are minimised, then the most efficient transfer of K to other pasture blocks is achieved.

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