"IT'S RAINING EFFLUENT", EFFECT OF HERD HOME SLURRY ON GROWTH OF MAIZE AND SORGHUM IN WAIKATO

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Abstract

There has been unprecedented growth in the dairy industry in New Zealand over the last 15 years, with increases in average dairy size and cows per hectare, making it necessary to look at the way in which effluent on farms is being managed. One potential solution for effluent that has accumulated from areas such as dairy sheds and herd homes is to apply it to crops as a fertiliser.

The problem with this treatment method is that over-application can result in run-off of effluent into waterways. This practise is a relatively new concept and some farmers have experienced difficultly in implementing sustainable land application systems. The purpose of this project was to measure plant growth from two different application rates of herd home slurry, compared to control, on two supplementary feed crops currently used in the Waikato, maize and sorghum. Data on yield, percentage dry matter, leaf count and height was collected at three different stages of plant growth. Additionally, soil and plant chemical analysis was undertaken on the sorghum to create a nitrogen budget.

The results showed that the plants grown from the double application rate were significantly larger and leafier than plants grown from single and control applications, as would be expected. There was no difference between control and single applications.

The nitrogen nutrient budget for the sorghum showed that even though a higher rate of nitrogen was added to the soil, at application, the sorghum plants did not find a point at which they could no longer take up the nitrogen available. All the final nitrogen soil levels were lower than at the start of the season which indicates that the soil has not been affected with the use of the natural fertilizer or have had an excessive amount added that the plants cannot use. Therefore, it may be possible that a higher application rate could be applied to feed crops without having a major effect on the environmental nitrogen levels. Testing for the level of and the side effects of other environmental chemicals e.g. potassium was beyond the scope of this study and would need to be done before considering higher application rates.

Introduction

The intensity of present day dairy farming is much greater than in previous decades with notably larger herd sizes and more cows per acre of land The average number of cows per hectare has increased by 35% since 1981, (2.1p/ha compared to 2.83p/ha).[1] However, due to the recent introduction of Herd Home Shelters, herd sizes can reach up to 3.33 cows per hectare. Therefore, dairy farmers have to manage increasing volumes of effluent. Another issue is that the animals' diet has changed from purely grass based to having feed supplements regularly added to their diet, which has changed the effluent composition and the concentration of certain elements (e.g. nitrogen) excreted in the urine and dung has increased. Previously, effluent would have been treated by pond treatment and then discharged into the waterways. However, there is too much effluent to keep in these ponds, subsequently creating a problem of finding a way to use it in an environmentally sustainable way.

There is now an increased awareness of the need to manage farming practises and above all control what is going into the waterways. The Ministry of Environment in 2001 estimated that the main source of nitrogen loading into New Zealand surface waters was agriculture, with a significantly higher level of 110,000 tonnes in contrast with the other sources that do not reach above 20,000 tonnes.[2] In 2001 agricultural non-point sources (generally surface runoff from paddocks) accounted for 75 percent of the total nitrogen loading to New Zealand surface waters. The principal sources of high nitrogen levels on farmland are urine and dung from livestock, the application of nitrogenous fertiliser and nitrogen fixation by clovers. Elliot et al (2005) also commented that '*land used for dairying makes a disproportionately large contribution to the total load of nitrogen in relation to the area of land (37% of the load versus 6.8% of the land)*'.[3] It might be deduced that this figure would be a lot higher today, given the expansion in dairying and a concomitant increase in nitrogen fertiliser use. Most dairy farmers are applying 25–100 kg of nitrogen as fertiliser per hectare per year, and some up to 200 kg [2] . The environmental impact of the nitrogen leaching into groundwater due to farming practises has resulted in a new evolution in agriculture systems to ensure environment sustainability.

Nitrogen is an element that is essential for plant growth; specifically it is needed as a major component in all proteins; of chlorophyll; and nucleic acids, such as DNA. Although there is plenty of nitrogen in the Earth's atmosphere (N_2) plants need nitrogen compounds available in the soil so that they can grow. These compounds can be supplied from decaying plants and animal material (organic matter), nitrogen fixing bacteria, animal waste or through the application of specific agricultural fertilisers. Some nitrogen already in the soil cannot be accessed by the plants due to the nitrogen not being in the right available form for the plant to use. Organic materials such as manure add some readily available nitrogen. Nevertheless, getting the balance is vital. Too much nitrogen can produce weak stems in grain crops, reduce the quality of the seed and make soil acidic, and create an excess of nitrate in the edible foliage leading to a possible health risk for animals and humans.[4] However, excess nitrogen can also have major detrimental effects on the environment. Nitrogen added by fertilizer and effluent leaches through the soil to ground waters in the form of soluble nitrate.[5] This can create extreme growth in algae and other aquatic plants, water that is unsuitable for drinking and eventually lead to polluted lakes and rivers.[6] Leached nitrates can also change the quantity and type of food available to stream life, deplete the water's dissolved oxygen levels, and can also be poisonous to livestock.

In 1991 the Resource Management Act (RMA) bought together a number of previous Act's to ensure the sustainable management of New Zealand's natural resources. Section 5 of the Act stated three main principles that had to be abided by:

1. Sustaining the potential of natural resources for needs of future generations.
2. Safeguarding the life supporting capacity of air, water, soil and ecosystems
3. Mitigating the adverse effects of human activities

In carrying out the provisions of the RMA, regional councils have established rules and regulations that are to be complied with when effluent is being spread on pasture. Briefly, the regulations state that the effluent that is produced on a dairy farm must not discharge into surface water (streams, lakes, ponds or drains) or contaminate ground water. The application of the effluent to the land surface must not pond and any effluent storage facilities must be at least 20m away from surface water and sealed so that discharge cannot occur. More specifically, during the application, the effluent cannot seep any further than 25mm deep into the ground (per application). Nitrogen loading from effluent that is applied to grazed pasture must not exceed 150kg/ha. However, if applied to cropped land (like maize silage) then a loading of 200kg/ha must not be exceeded. [7]

In recent years, dairy farmers have been encouraged by regional councils to move to land based methods of dairy shed effluent treatment, such as irrigation of effluent back onto pasture, as opposed to the standard oxidation two-pond system that has been used extensively since 1975[2]. The two-pond system is comprised of an anaerobic pond followed by a facultative pond[8] from which, the excess liquid can be safely discharged into the waterways as many of the harmful elements have been removed. However, because of the current increase in herd sizes, the effectiveness of these ponds has decreased as more effluent is produced than can be managed by the limited capacity of the pond. Therefore, regional councils are increasingly favouring the use of land for treatment of effluent. Soil microorganisms are able to filter effluent particles, break them down, and incorporate them into the soil structure. Additionally, soil absorbs the nutrients from the effluent, so that it is available for the plants to use (such as converting nitrogen). Agriculture effluents and manure by-products can improve soil properties such as plant nutrient availability, soil pH, the organic matter content, cation exchange capacity and water holding capacity. All of these factors are essential in growing crops, thus the application of effluent to soil can increase crop and pasture yield.[8]

With the expansion in the diary industry there has been a marked increase in nitrogen fertiliser use to boost grass growth. Farmers are buying nitrogen to put on their land when they already have fertiliser in the form of effluent that they can use they just need to know how to utilize it in the most effective and efficient way. When captured in large quantities, either in the ponds or storage places like herd homes, it can be turned from causing harm to the environment to benefiting the environment. Research done by Bob Longhurst from AgResearch, Ruakura in 2010 has shown that effluent from the manure bunkers in a Herd Home can be stirred to form slurry, which can be sprayed onto crops or pasture and evenly distributes nutrients. However, what is not known is what the uptake of the nutrients from the effluent and growth response of crops is.

Two supplementary feed crops commonly planted on Waikato dairy farms, maize (*Zea mays*) and sorghum (*Sorghum bicolour*). Sorghum is drought tolerant, which is useful in the Waikato as it should withstand hot, dry summers, and makes it a very reliable source of nutrition for the animals. Maize is another supplementary feed crop widely used throughout New Zealand, as it is a crop that generally gives a good return and has nutritional value because it can be turned into silage for the stock.

The purpose of this study was: first, to determine how efficient maize and sorghum feed crops are at absorbing the nutrients from applied slurry, in order to maintain acceptable levels of nitrogen in the soil; second, to determine the optimum application rate (weight and volume) of slurry onto maize and sorghum crops to find out which application rate will give the optimal feed by measuring, crop growth, total green yield, and percentage dry matter.

Methods

The farm used in this project was located in Te Kauwhata, Waikato, New Zealand. It was a dairy farm which has approximately 360 Ayrshire cows and uses two 60m Herd Home Shelters. The herd home has an under floor concrete bunker that holds the manure produced when the cows are located inside the herd home. The manure bunker, which was almost full, was the source for the effluent used.

Two paddocks were chosen, that were wide enough to have nine 12 m strips, no fertilizers recently applied, ploughed, little variation in soil cover, and were both flat without boggy areas.

One paddock was planted in sorghum, and the other in Maize. These paddocks were divided into 9 x 14m (Sorghum) and 12m (Maize) strips, which were sprayed alternatively with zero, low (20t/ha) or high(40t/ha) applications of slurry/effluent. The paddocks were ploughed and planted within a week of the application of slurry. Multiple soil samples (0-15cm deep) were taken from both paddocks, to test for soil available nitrogen, before the application of slurry and again after harvest. The latter samples were taken from the centre of each strip to avoid contamination from possible overlap from spaying slurry.

The Slurry

To make the slurry, pond water was applied to the Herd Home manure bunker (approximately 12% by volume) and a vertical stirrer designed by Richard Stewart of Waeranga, was placed inside the bunker which churned the manure. Samples were taken for nutrient analysis. The slurry was pumped into a 7.5m^3 slurry tanker on the back of a tractor to spray the effluent onto the strips set out in the paddock. The slurry was sprayed in a straight-line strip and plate under the tanker spout created an even fan-shaped spread of the effluent. The spray width was approximately 14m. The slurry was sampled and tested for nitrogen, phosphorous and potassium nutrient levels.

Figure 1 The vertical effluent stirrer.

Figure 2 Application of slurry

To check the slurry was evenly spread, sample bins that were placed in the middle, to the left and to the right of the strip prior to spraying, were then weighed to find the mass of the effluent and therefore how much was applied to the land. These masses were each recorded as well as an average spread mass.

The bulk density of the effluent, the relationship between the mass of the effluent and the volume, was calculated and used as an indicator for how even the spread across the strip was. The mass of 250mL of effluent was weighed and the result recorded. Using the calculation below the bulk density was found and then converted into m^3/t. These calculations were done for each of the high and low rate strips,

(Bulk Density = $^{\text{mass(g)}}/_{\text{volume(ml)}}$).

Plant & Soil Sampling

Sorhgum: The first data collection was done one month after sowing. A count of germinating plants, within a 2.75m (1/1000 per acre) x 0.7m (seed drill spacing) quadrant in the centre-line of each strip, was taken. Second and third data collections were both done three days before the crop was cut for silage. Inside the sorghum strip a 2.75m x 0.7m quadrant was placed along a drill line in the sampling strip. From this area, ten random plants were cut 15cm above the ground, the height and number of leaves was recorded for each plant.

Maize: As maize is only cut once within a season, measurements were taken at three stages of the maize growth five week intervals. The first sample, a germination count, was done to find the number of plants in 1/1000th of an acre. For the second and third samples, plants were cut 15cm above the ground, the height and number of leaves was recorded for each plant. The last sample was taken just before the crop was cut for stacking as pit silage.

Soil samples were also taken (0-15cm depth). These were bagged and picked up for later analysis by NZ labs.

Percentage dry matter and total green yield method

Analysis of plants material was done at Ruakura Research Centre, AgResearch, Hamilton. A tripod and hanging Salter scales were used to measure the total green yield for the 10 plants. 3 plants were randomly taken as a subsample, weighed and were cut to fit into an ovenproof container for the drying ovens. The container was then placed in a drying oven at 65°C, as anything above 80°C would cause nitrogen losses from the plant tissue. After at least 12 hours the plants were removed from the drying ovens and reweighed to find the total dry matter of those three plants and percentage dry matter calculated. The oven-dried plant samples were sent away to NZ Labs for tissue analysis of TKN and NO_3.

Statistical Analysis

Microsoft Office Excel was used to store, investigate and create graphs from the quantitative numerical data collected. The mean was calculated for each trial and the standard deviation (SD) from the mean was calculated to show the spread of the data. The accuracy of the calculated mean was shown by the 95% confidence interval (CI). An ANOVA was used, to see if there were significant differences between the sample means. If $p<0.05$ then the null hypothesis is rejected.

Results:

Effects of different application rates of effluent on growth of feed crops

Sorghum Crop: At both the first cut and the second cut there was no significant difference between the control and single rate of application for height ($p<0.06$) or for number of leaves ($p=0.72$). However, there was significantly higher growth at the double rate of application when compared to the controls ($p<0.0001$) and single application rate ($p<0.0001$). There was also a significantly higher number of leaves produced per plant at the double application rate when compared to both the control (p<0.0001) and the single application rate (p<0.0001). However, the average height of the sorghum plants prior to the first cut was over twice that of the plant height prior to the second cut across all application rates. This was due to the drought in the region from February through to June 2010.

There was a significantly higher green yield at the double application rate when compared to the control and single application rate. However, there was no difference between singe and control rates. At the first cut there was a significantly higher percentage of dry matter in the plants for the double rate of application when compared to the control and the single application rate. However, prior to the second cut there is no significant difference between any of the application rates.

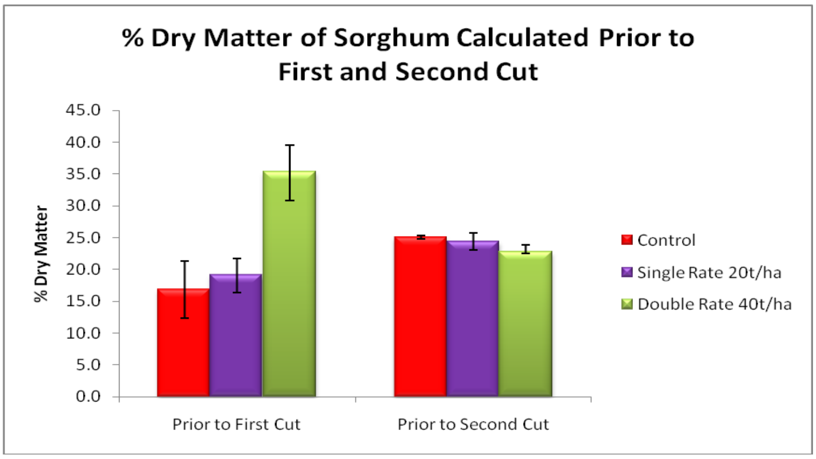

Figure 3 Percentage dry matter prior to the first and second silage cut.

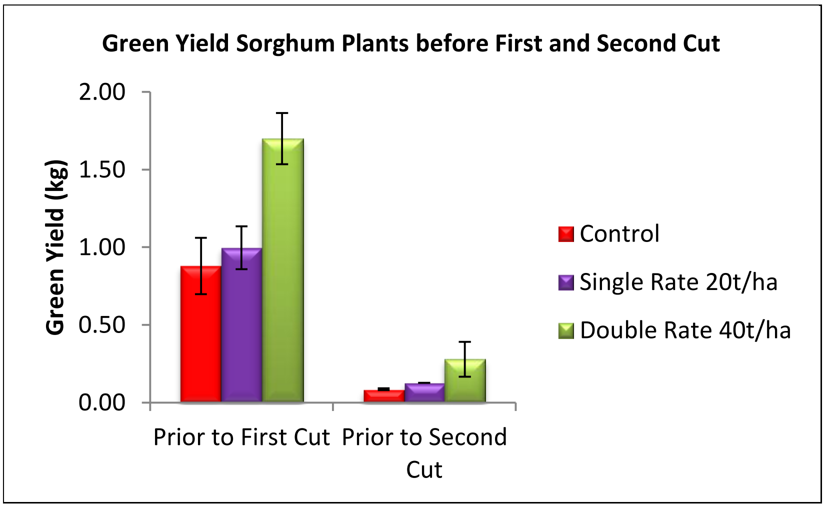

Figure 4 Green Yield Produced by 10 maize plants prior to the first and second cut in comparison within the application rates. Error bars =SD.

Maize Crop: Over the three month period there was significantly higher growth of maize at the double rate when compared to the control (p<0.0001, p<0.0001) and single application rate (p<0.0001, p<0.0001, p<0.0001). There were no significant differences between the control and single application rate over the three months. There was a significant increase in height between January and February however, between February and March there was no significant change in height over all application rates. There was no change in growth between the two months which could be due both to the drought conditions and to maize getting bulkier and growing corn cobs.

Over February and March there was a significantly higher green yield of maize at the double rate when compared to the control ($p < 0.005$, $p < 0.04$ respectively). There were no significant differences recorded in the control and single application rate over the two months. There is no significant difference in percentage dry matter between months and application rates

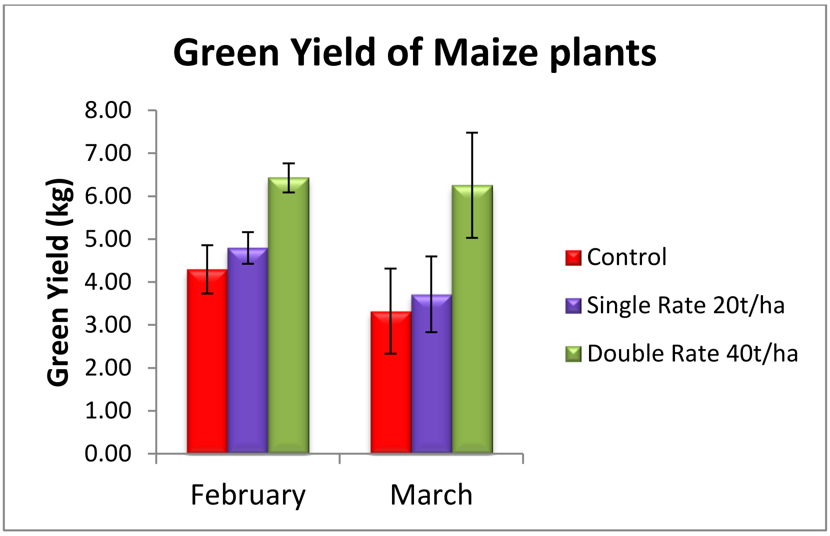

Figure 5: Green Yield Produced by 10 maize plants over the growing period calculated in February and March for comparison within the application rates. Error bars= SD.

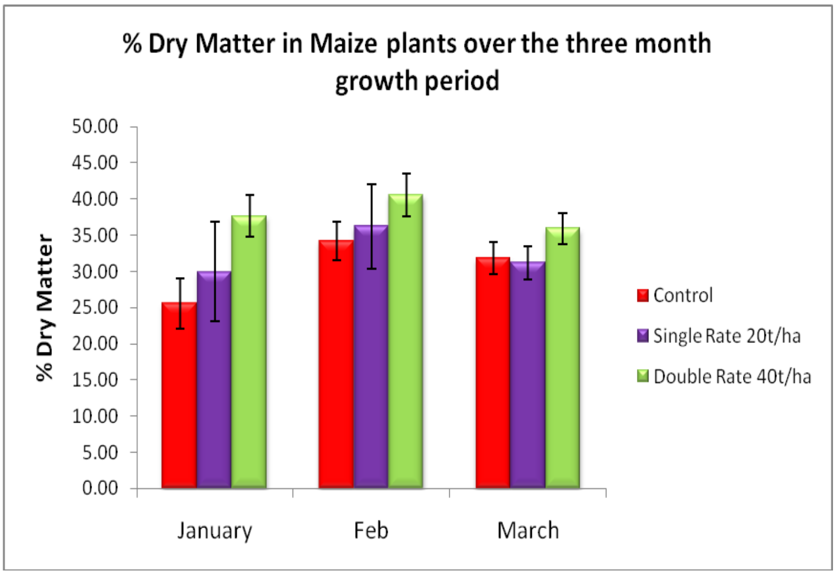

Figure 6: Percentage dry matter prior over the three months of growth of the maize plants. Error bars = SD

<u>The efficiency of a supplement feed crop at absorbing the nutrient from applied slurry in order to maintain acceptable levels of nitrogen in the soil</u>

Irrespective of application rate, the final nitrogen levels in the soil were lower than at the start (table 1), which was unexpected due to a much higher amount of nitrogen being added to different testing strips. This could be due to uptake by the plants, which suggests that the maximum nitrogen demand of the plants had not been met even at the highest application rate, outside of the regulated rules. This is supported by the results showing that crop uptake of nitrogen increased as application rate increased. This also may explain why the final nitrogen levels in the soil are all very similar despite the different application rates. Even though the amount of nitrogen applied was higher than that allowed by Environment Waikato figure 22 shows that a higher amount of effluent could be applied to the sorghum crop without causing run off or an excess amount of nitrogen in the soil.

Sorghum Nitrogen Nutrient Budget:

	Control	Single Rate	Double Rate
N available in soil	272	272	272
N applied (from slurry)	0	118	247
TOTAL N AVAILABLE	272	390	519
Total N Available	272	390	519
Crop Uptake of N	236	239	273
BALANCE	36	151	146
Actual N Available in soil	201	175	200

Table 1: Nitrogen Nutrient Budget for what was present in the land, what was added, what was removed and the total balance. Nitrogen levels in the slurry were measured by chemical analysis at the time of application. Initial and final nitrogen levels in the soil were obtained from the soil tests. The crop uptake of nitrogen was found from the dry matter chemical analysis (n=3).

Discussion

The purpose of this study was to investigate the use of effluent as a natural fertilizer on dairy farms through applying effluent (from herd home bunkers) as fertiliser on two supplementary feed crops currently used in the Waikato area.

When a higher/double rate of effluent was applied there was a significantly higher production and growth than from all other treatments, The higher rate provided more nitrogen in a form that was available for crop growth and therefore more feed for stock was produced.

The sorghum crop was effective in absorbing the nitrogen from the soil and did maintain acceptable levels of nitrogen in the ground after growth. The nitrogen levels were in fact less than what the soil had before any slurry was applied. Each strip started with the same amount of N in the ground (table1). Although slurry was added at a higher concentration in some strips than others, the final balance of how much nitrogen was still in the soil was all relatively the same for each application rate (201, 175, 200 kg). This therefore means that even though a double rate was added, the plants used up the available nitrogen, and that at the end of the growth period the amount of N was the same for the control and the double application rate. This therefore implies that at any application rate whether high, low or none, maintained an acceptable level of nitrogen in the soil after the growth of sorghum plants. Ideally, these analyses would be done for both crops, but budgetary constraints meant that only the nitrogen budget for the sorghum plants was tested. Nevertheless, it was found that the sorghum did take up the amount of nitrogen added to the soil without run off or leaching occurring.

The higher application rate allowed more effluent to be used by applying it to the land as a fertilizer without increasing the nitrogen levels in the soil. This shows that there is the potential for effluent to be applied at a higher rate than previously thought without causing excess nitrogen levels in the soil.

The growth rate, the total yield and the percentage dry matter in the double rate application were all significantly higher than the other two application rates. The results also demonstrated that at the normal rate a farmer uses on his crops was not a good as a fertilizer, but would got rid of the effluent. Therefore, from the point of view of using the effluent as a fertilizer to produce the most feed for the animals, it is more beneficial to use a double rate of effluent than only a single rate or none at all. Overall, the double rate is the most favourable rate to add to crops. It produces the best growth and return for stock as well as utilising the most effluent which is able to be removed from the soil by the sorghum plant to ensure an acceptable level of nitrogen in the soil after growth.

Keeping New Zealand's 'clean and green' image is currently, very important to our society going forward into the future to ensure the continuity of having access to utilities, such as, clean drinking water. Pollution is a major threat to this image and farm effluent is one of the many contributing factors that may affect this, especially in regards to our water quality.

The results of this investigation will provide an alternative way for farmers to deal with their effluent by using it as fertilizer, which coincidently is also beneficial for our environment. They may also result in a decrease in the use of chemical fertilizers and reduce in the amount of run-off we have currently occurring from dairy farms. At the same time, farmers will be able to be more self-sufficient in their farming practices, which will ultimately lead to higher profit margins, whilst being more ecologically sustainable as well.

References

1. Houlbrooke, D.J., Hourne, D.J., Hedley, M.J., Hanly, J.A., Snow, V.O., 2004a. A review of literature on the land treatment of farm-dairy effluent in New Zealand and its impact on water quality. New Zealand J. Agric. Res. 47, 499 – 511.
2. Managing waterways on farms: A guide to sustainable water and riparian management in rural New Zealand. May 2001. Published by Ministry of Environment, Wellington, NZ.
3. Elliot, A.H.; Alexander,R.B.; Schawrz, G.E.; Shanker, Ude; Sukias, J.P.S.; McBride, G.B. 2005. Estimation of nutrient sources and transportport for New Zealand using the hybrid mechanistic-statistical model SPARROW. Journal of Hydrology (NZ) 44(1) 1-27
4. faculty.washington.edu/clh/nmanual/ch2.pdf, Washington state department of ecology, The nitrogen cycle, April 1999
5. H.J. Di, K.C. Cameron., Reducing environmental impacts of agriculture by using a fine particle suspension nitrification inhibitor to decrease nitrate leaching from grazed pastures., March 2005, New Zealand
6. Nitrogen leaching; Environment Waikato Publication; www.ew.govt.nz;
7. Farmer's guide to permitted activities. Environment Waikato, April 2007
8. Sukias, J.P.S., Tanner, C.C., 2005. Ponds for livestock wastes. In: Shilton, A. (Ed.) Pond Treatment Technology, vol. 1. IWA Publishing, London, pp. 408 – 432.
9. Eck, H.V., Steward, B.A., 1995. Manures. In: Rechcigl, J.E. (Ed.), Soil Amendments and Environmental Quality. Lewis Publishers, Boca Raton, pp. 169 – 198.