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# Effect of grazing season length and stocking rate on nitrate leaching

## Key external stakeholders:
Research scientists, dairy industry, policy makers

## Practical implications for stakeholders:
This project examined the effect of stocking rate and grazing season length on nitrate ($NO_3$) leaching to 1 m depth in the soil. Nitrate leaching was measured using ceramic cups.

- As stocking rate and fertiliser N application rate increased there was a trend for nitrate (NO3) leached to 1 m depth in soil to increase.
- Early spring turnout (1st February) tended to have lower quantities of NO3 leached to 1 m depth in soil than later turnout in spring; early autumn housing (21st October) had slightly lower quantities of NO3 leached to 1 m depth in soil than later housing.
- Land use management affects NO3 leaching – including one or two cuts of silage to grazed grassland reduces nitrate leaching to 1 m depth in soil compared to grazing only.
- Bulk density increased as stocking rate increased, and was not affected by grazing season length.
- Increasing stocking rate and grazing season length increases profit per ha.
- Increasing stocking rate and grazing season length increased farm profit.
- The N balance model developed in this project can be used to assess the N use efficiency of grass based milk production systems.

## Main results:
The key results are:

- As stocking rate and fertiliser N application rate increased there was a trend for $NO_3$ leached to increase.
- Increasing stocking rate while maintaining N fertiliser application rate at a given level increases N use efficiency.
- There was a trend for the 1st February turnout date to have lower quantities of $NO_3$ leached than the 21st February or 15th March turnout dates; while the 21st of October had slightly lower (but not significantly) quantities of $NO_3$ leached than the 10th November or 25th November housing dates.
- Increasing stocking rate increased farm profit from €578/ha for 2.0 LU/ha to €914/ha for 2.47 LU/ha and €1097/ha for 2.94 LU/ha. Profit per ha also increased as fertiliser application rate increased.

## Opportunity / Benefit:
This project shows that increasing grazing season length does not increase $NO_3$ leached to 1 m. Increasing stocking rate within a given level of N fertilizer application can increase N use efficiency and farm profitability. Information on herbage production over winter helps farmers understand the requirement for an autumn closing strategy. The N balance model can be used by researchers to assess the N use efficiency of grass based production systems.

## Collaborating Institutions:
Teagasc, University College Dublin



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## 1. Project background:

Along with increasing environmental pressures Irish agriculture is also under increasing economic pressure due to falling incomes, decoupling and increasing costs of production. Producers are increasingly looking towards adopting low cost production systems. Grazed grass is the cheapest feed source for milk production in Ireland. The two main components of grass based milk production systems are grazing season length and stocking rate (SR). Both of these components can affect nitrate ($NO_3$) leaching losses. Nitrate leaching losses can increase with increasing SR due to increased nitrogen (N) fertiliser usage and higher manure production, combined with decreasing N use efficiency at high N fertilizer application rates. Nitrate leaching is greatest in late autumn, winter and early spring when surplus rainfall washes residual N accumulated in the soil during the summer period down through the soil profile, and so extended grazing seasons may have a negative impact on $NO_3$ leaching. Utilisation of nutrients from animal excreta (urine and faeces) during the late autumn period is also low due do low grass growth rates. The Nitrates Action Plan imposes an upper SR limit of 2 LU/ha (170 kg organic N/ha), however, with a derogation SRs of up to 2.94 LU/ha (250 kg organic N/ha) are permitted. Thus, it is important to determine the relationship between $NO_3$ leaching and this range of SRs. The Nitrates Action Plan also limits N fertilizer application.

## 2. Questions addressed by the project:

- Does stocking rate and N fertilizer application level affect $NO_3$ leaching to 1 m on a free draining soil?
- Will increasing grazing season length increase $NO_3$ leaching to 1 m on a free draining soil?
- Can a N balance model be developed to examine N use efficiency in grass based milk production systems?
- What effect do stocking rate and grazing season length have on soil bulk density?

## 3. The experimental studies:

Two main experiments were undertaken. The first examined the effect of SR and N fertilizer application level on $NO_3$ leaching on a free draining soil type and the second examined the effect of grazing season length on $NO_3$ leaching on a free draining soil type. Both experiments had 9 treatments. The treatments in the SR experiment were 2, 2.47 and 2.94 LU/ha with three fertilizer N application rates per SR (165, 205 and 245 kg N/ha at 2 LU/ha; 205, 245 and 285 kg N/ha at 2.47 LU/ha; 245, 285 and 325 kg N/ha at 2.94 LU/ha). The grazing season length experiment was a 3 x 3 factorial design with three spring turnout dates (1$^{st}$ Feb., 21$^{st}$ Feb, 15$^{th}$ Mar.) and three autumn housing dates (25$^{th}$ Oct. 10$^{th}$ Nov., 25$^{th}$ Nov.). A strict set of management rules governing fertilizer and slurry application, grazing management and concentrate feeding were devised for each treatment. There were 5 cows per treatment (18 herds of cows). Each group of cows had its own distinctive area which was divided into 3 blocks – a grazing only block, a grazing and first and second cut silage and a third block which was also grazed and had silage harvested from it. In blocks 1 and 2, 16 ceramic cups were inserted in the paddock to a depth of 1 m, and there were four control paddocks which were not grazed and had no fertilizer N or slurry applied; these also had 16 ceramic cups. Altogether there were 352 ceramic cups per experiment. The ceramic cups were sampled every second week for each experiment between September and April and every month for the remainder of the year. Sampling took place from January 2007 to June 2010. A composite sample of water extracted from the cups in each paddock was analyzed for $NO_3$, TN, $NH_4$ content. Other measurements included pre grazing herbage mass,



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pre and post grazing heights, silage production, milk production, soil bulk density (to give an indication of soil compaction). An economic analysis was undertaken to examine the profitability of each treatment in both experiments using the Moorepark Dairy Systems Model (MDSM) (Shalloo *et al*., 2004). A N Balance Model was developed to determine N use efficiency, N surpluses and N losses from grass based milk production systems.

## 4. Main results:

- Nitrate leaching on all treatments in both experiments was very high at the beginning of the experimental period (average 32.25 mg $NO_3$-N/l), likely due to soil disturbance during ceramic cup installation, and possible previous land use management effects. Thereafter, the largest differences in $NO_3$ leaching occurred between the management systems in place in the experiments, rather than between the treatments. Nitrate leaching was lowest on the control paddocks, and greatest on the grazing only paddocks (average 2008 – 2010 was 5.38 mg $NO_3$-N/l). The differences between the grazing only paddocks (average 2008 – 2010 was 33.47 mg $NO_3$-N/l) and the silage and grazing paddocks (average 2008 – 2010 was 21.79 mg $NO_3$-N/l) were due to the fact that animals were present on the grazing only paddocks for a greater number of days. As paddocks were closed for a number of weeks for first and second cut silage the number of grazing days and hence number of urine depositions were reduced, with the opposite occurring on the grazing only area (increased grazing days and increased urine deposition). The grazing only area was also grazed last in the final rotation and so urine was deposited at a time which is more susceptible to $NO_3$ leaching (grass growth rates are low and high rainfall).
- As SR and fertiliser N application rate increased there was a trend for $NO_3$ leached to increase.
- There was a trend for the 1st February turnout date to have lower quantities of $NO_3$ leached than the 21st February or 15th March turnout dates; while the 21st of October had slightly lower (but not significantly) quantities of $NO_3$ leached than the 10th November or 25th November housing dates.
- Milk production per ha increased as SR increased (782 kg MS/ha at 2 LU/ha; 971 kg MS/ha at 2.47 LU/ha; 1127 kg MS/cow at 2.94 LU/ha). Milk production was similar for all treatments on the grazing season length experiment (approx. 352 kg MS/cow).
- Bulk density was higher in treatment paddocks than in control paddocks. Bulk density increased as SR increases, however, herbage production was not reduced as bulk density increased; therefore this suggests that compaction is not closely correlated with herbage production in a grazing situation. Bulk density was similar across treatments in the grazing season length experiment.
- An economic analysis of the three year average production (2007 – 2009) of each treatment in the two experiments was undertaken using the MDSM (Shalloo *et al*., 2004). Due to the small numbers of animals involved, there was a lot of variation between individual animals. Turning cows out on the 1st February compared to the 15th March increased profit/ha by €311. Delaying autumn housing date from 25th October to 25th November increased profit by €50/ha. Increasing SR increased farm profit from €578/ha for 2.0 LU/ha to €914/ha for 2.47 LU/ha to €1097/ha for 2.94 LU/ha.

## 5. Opportunity/Benefit:

Strategic management of dairy production systems is required to ensure that they are both profitable and reduce $NO_3$ losses to 1 m in the soil. A long grazing season does not result in greater $NO_3$ leaching compared to a short grazing season. Increasing grazing season length increases milk production from grazed grass, the cheapest feed source available for milk production, and therefore can increase farm profitability. There is an effect of increasing stocking rate and fertiliser application on $NO_3$ leaching to 1 m. However, the quantity of $NO_3$ leached to 1 m is not always significantly increased by increasing stocking rate. Increasing stocking rate while maintaining N fertiliser rate at a given level can improve N use efficiency by increasing N output. Mitigation strategies to minimise $NO_3$ leaching to 1 m should be investigated. These include the effects of restricted access time to grazing in periods of wet weather. This management strategy does not have a negative impact on grass DM intake or milk production but will remove animals from the paddock and therefore reduce the amount of N available for leaching from urine patches. Cows that are more efficient at converting grass to milk will also contribute to reducing $NO_3$ leaching. If possible, the silage area should be moved around the farm to help reduce $NO_3$ leaching, but this will only be possible where the silage block is accessible to milking cows. Grass based milk production is profitable, and high stocking rates combined with long grazing seasons have positive effects on farm profit. Modelling of the data can be used to determine the most profitable and the most N efficient treatments.

## 6. Dissemination:

Six monthly progress reports were forwarded to DAFF as required by the Research Stimulus Fund. An overview of the project was given at the Moorepark Open Day in 2007 and 2009. Visitors to Moorepark, both



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national and international, visited the experimental site on a number of occasions in each year of the experiment. Poster and oral presentations were made at the Agricultural Research Forum, BSAS Conference, BGS research Conference and EGF Conference. Three papers have been published from this project, one more is accepted to Journal of Agricultural Science, another is submitted for peer review to Agriculture, Ecosystems and Environment, and two more are in preparation.

**Main publications:**


- Herbin, T., Hennessy, D., Richards, K.G., Piwowarczyk, Murphy, J.J. Holden, N.M. (2011) The effects of dairy cow weight on selected soil physical properties indicative of compaction. *Soil Use and Management* 27: 36-44.
- Ryan, W., Hennessy, D., Murphy, J.J., Boland, T.M., Shalloo, L. (2011) A model of nitrogen efficiency in contrasting grass-based dairy systems. *Journal of Dairy Science* 94: 1032-1044.
- Ryan, W., Hennessy, D., Murphy, J.J., Boland, T.M. (2010) The effects of autumn closing date on sward leaf area index and herbage mass during the winter period. *Grass and Forage Science* 65: 200-211.


**Popular publications:**


Hennessy, D. and Ryan, W. (2009) Winter grass growth. *TResearch*, Vol. 4, No. 3, pp 16-17. http://www.teagasc.ie/publications/2009/14/14_tresearch200908.pdf


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