Effects of stocking rate and grazing season length on nitrate leaching from a vulnerable soil type

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Please tick below the appropriate area on the research continuum where you feel this project fits

BASIC/FUNDAMENTAL APPLIED/PRE COMMERCIAL

Key words: nitrate leaching, dairy cows, stocking rate, grazing season length

1. Rationale for Undertaking the Research
RSF 05 201
Irish agriculture must conform to EU requirements under the EU Nitrates Directive and the Water Framework Directive to reduce the quantity of nitrate (NO3) leaching from farming systems to improve the quality of water. Along with increasing environmental pressures Irish agriculture is also under increasing economic pressure due to volatile product prices and increasing costs of production. Producers are increasingly looking towards adopting low cost production systems. Grazed grass is the cheapest feed source for animal production in Ireland. This project examined the effects of two components of grass based milk production systems (i.e. stocking rate and grazing season length) on NO3 leaching from a free draining soil. It has been reported in the scientific literature that NO3 leaching losses increase with increasing stocking rate and herbage production due to increased fertiliser nitrogen (N) use and higher manure production, combined with decreasing N use efficiency at high application rates. Extending the grazing season offers a low cost production option. However, given that NO3 leaching is greatest during the late autumn to early spring period when surplus rainfall washes residual N accumulated in the soil during the summer period down through the soil profile, there are concerns that extending grazing season length may have a negative impact on the environment, especially in terms of NO3 leaching. Removal of herbage, poaching and reduced utilisation of nutrients due to low grass growth rates in autumn and winter increases the possibility of leaching and runoff of minerals. These may potentially be a source of pollution, ending up in surface and ground water. Work at Johnstown Castle has shown that nitrate leaching from cow urine increases from July to November.

2. Research Approach
This project comprised of two independent studies examining the effect of (1) stocking rate and N fertiliser application, and (2) grazing season length on NO3 leaching to 1 m soil depth on a free draining soil. Sub-project 1 examined the effects of three stocking rates (2, 2.47, 2.94 LU/ha) and three N fertiliser levels per stocking rate on NO3 leaching, and sub-project 2 examined the effects of three spring turnout dates (1st February, 21st February, 15th March) combined with three autumn closing dates (10th October, 25th October, 10th November) on NO3 leaching. There were five cows per treatment in each experiment (9 treatments per experiment). Each treatment had its own independent farmlet. Cows were turned out to grass post calving in sub-project 1 or from their appropriate calving date in sub-project 2 and remained at grass until mid-November in sub-project 1 or until the appropriate housing date in sub-project 2. Nitrate leaching was measured from each treatment using 16 ceramic cups in a grazed only area and 16 ceramic cups in a silage and grazing area. Ceramic cups were installed to a depth of 1 m and sampled from January 2007 to June 2010, every two weeks during the drainage season (September to April) and approximately every month outside this period. Measurements undertaken in the experiment included NO3, nitrite, total oxidised N and ammonia concentrations in soil water samples, NO3 leaching loads to 1 m depth in soil, pre-grazing herbage mass, soil bulk density, soil C:N ratio, milk production and composition, economic analysis.

3. Research Achievements
There are a large number of results from this project. The main results are presented here under.

Sub project 1 – Stocking rate experiment
Soil C:N ratio (9:1) was similar across treatments. Soil bulk density increased as stocking rate increased. Herbage production was not affected by changes in bulk density suggesting that compaction is not closely correlated with herbage production in a grazing situation. Nitrate leaching on all treatments was high at the beginning of the experiment (2007 average 33.9 mg NO3-N/l), likely due to soil disturbance during ceramic cup installation and previous land use management. Nitrate concentration declined during the experiment and in the 2008/09 drainage season averaged 18.5 mg NO3-N/l and 14.2 mg NO3-N/l in the 2009/10 drainage season. Nitrate leaching was lowest on control paddocks (2008 –10 average 5.7 mg NO3-N/l) and greatest on grazing only paddocks (2008 – 10 average 26.7 mg NO3-N/l), with the grazing and silage paddocks (2008 – 10 average 21.0 mg NO3-N/l) lower than the grazing only. During the measurement period August 2007 to April 2010 there was no significant effect of stocking rate or N fertiliser application rate on NO3-N concentrations in the soil water, however as stocking rate and fertiliser N application rate increased there was a trend for NO3 leached to increase. Similarly there was no effect of stocking rate or N fertiliser application rate on ammonia, total oxidised N or total N. The greatest leaching loads were observed in the first full drainage season – September 2007 to April 2008 (average 132 kg N/ha), falling to an average of 124 kg N/ha in drainage season 3 (September 2009 to April 2010). Milk production/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). 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.

Sub project 2 – Grazing season length experiment
Soil C:N ratio was similar across treatments at 9:1. Soil bulk density did not differ between treatments. Nitrate leaching on all treatments was high at the beginning of the experiment (2007 average 35.3 mg NO3-N/l), likely due to soil disturbance during ceramic cup installation and previous land use management. Nitrate concentration declined during the experiment and was on average 28.2 mg NO3-N/l in the 2008/09 drainage season and 14.7 mg NO3-N/l in the 2009/10 drainage season. Nitrate leaching was lowest on control paddocks (2008 – 10 average 5.03 mg NO3-N/l) and greatest on the grazing only paddocks (2008 – 10 average 40.2 mg NO3-N/l), with the grazing and silage paddocks (2008 – 10 average 22.6 mg NO3-N/l) lower than the grazing only. There was a trend for 1st February turnout date to have lower quantities of NO3 leached than the other two turnout dates; and 21st October housing date had slightly lower quantities of NO3 leached than the other two dates. The greatest leaching loads were observed in the first full drainage season – September 2007 to April 2008 (average 170 kg N/ha), falling to an average of 164 kg N/ha in drainage season 3 (September 2009 to April 2010). Milk production was similar for all treatments on the grazing season length experiment (967 kg MS/ha). Turning cows out on 1st February compared to 15th March increased profit/ha by €311. Delaying autumn housing date from 25th October to 25th November increased profit per ha by €50.

Nitrogen Balance Model
A N balance model was developed to evaluate N use efficiency and N surplus, and to predict N losses from contrasting grass based dairy production systems in Ireland. Model development and evaluation showed that the system boundaries imposed affect N use efficiency. Including the whole farm system (i.e. inclusion of replacement animal rearing) reduces N use efficiency. The N balance model was used to assess the treatments in sub projects 1 and 2. Results show that as fertiliser N input increased N surplus/ha increased and N use efficiency decreased; when N balance was expressed on a per cow basis, all stocking rate treatments had similar N use efficiencies, mean of 24.7%; increasing stocking rate at same the fertiliser N application rate increased N use efficiency by an average of 17%. As the number of days spent grazing increased there was an increase in the quantity of N exported from 72 to 202 kg N/ha; the annual farm gate N surplus/ha was similar for all grazing season length treatments which ranged from 194 to 202 kg N/ha; increasing grazing season length by 30 days caused N surplus to reduce and N use efficiency to increase by 2% and 5%, respectively.

The effects of autumn closing date on sward leaf area index and herbage mass during the winter period
Within sub-project 2 the effect of autumn closing date on herbage mass, leaf area index (LAI) and tiller density during winter and early spring was examined. Delaying closing of swards until November significantly reduced herbage mass and LAI in mid-February. On average, 35% of herbage mass present on swards in mid February was grown between 28 November and 30 January. To ensure adequate herbage mass for grazing in early spring swards should be closed before November; swards required for grazing after mid-March can be closed during November.

4. Impact of the Research
The study shows that NO₃ concentrations declined on both experiments over the duration of the experiment. Management of paddocks affected NO₃ concentrations to 1 m. The control treatment had the lowest concentrations, and the grazing only management had the highest, and paddocks that were grazed and had silage harvested from them had lower concentrations than the grazing only. Increasing stocking rate and fertiliser application rate increased the kg leached/ha to 1 m in the soil, though the differences were not significant and were relatively small between the lowest and highest stocking rates. Turning cows out on 1st of February had numerically but not significantly lower kg NO₃ leached/ha to 1 m in the soil than later turnout. The quantity of NO₃ leached/ha to 1 m in the soil was similar for the three autumn housing dates. Increase grass utilisation through increasing stocking rate and grazing season length also increased farm profit. System boundaries included in N balance models affect N use efficiency and N surpluses reported. Implementing an autumn closing strategy on the farm will ensure herbage availability in early spring.

5. Exploitation of the Research
No Intellectual Property/licences/patents were generated from this project. The project has resulted in public good outcomes. It provides data on nitrate leaching from various stocking rates and grazing season lengths. The results show that increasing stocking rate within a fixed N application rate can reduce NO₃ leaching and increase N use efficiency. Similarly increasing the grazing season length does not negatively impact on NO₃ leaching. The inclusion of a silage cut in the management of the land area reduced NO₃ leaching to 1 m. This project provides the dairy industry with information on the effects of stocking rate and grazing season length on N
use efficiency and farm profitability. The data collected in the experiment examining autumn closing date on spring herbage production provides further information for farmers and advisors for making decisions regarding autumn/spring grassland management. The N Balance model developed will be further used in research to examine our milk production systems. The skills develop during this project and the scientific publications resulting from the project will strengthen the potential of the researchers to attract other national and international funding.

6. Summary of Research Outputs

(a) Intellectual Property applications/licences/patents
N/A

(b) Innovations adopted by industry
1. Data from the winter tissue turnover experiment (Ryan et al., 2010) has contributed to dairy farmers understanding of the importance of an autumn closing strategy to ensure grass availability for early spring grazing.
2. The N balance model developed during this project (Ryan et al., 2011) has been used as a research tool at Moorepark to examine aspects of milk production systems. It will be used in the future to assess the N use efficiency of grazing systems.

(c) Number of companies in receipt of information
N/A

(d) Outcomes with economic potential
1. The project highlighted the importance of a long grazing season in terms of increasing milk solids production from grass which is Ireland’s lowest cost feed for milk production.
2. Using the N balance model to assess grass based systems shows that N use efficiency is increased and N surpluses reduced when stocking rate is increased within a given N fertiliser application rate.
3. Increasing stocking rate while maintaining N fertiliser level at the same rate increases N output in product and therefore N use efficiency.

(e) Outcomes with national/policy/social/environmental potential
1. Increasing stocking rate does not necessarily mean an increase in nitrate leaching, or reduced N use efficiency. Increasing stocking rate within a given N fertiliser application rate increases N use efficiency and reduces N surpluses.
2. A long grazing season does not increase nitrate leaching to 1 m compared to a short grazing season.
3. When using an N balance model, the system boundaries imposed can result in different N use efficiencies. It is important that the whole system, including replacement heifer rearing, is assessed to give the true N use efficiency of a system.

(f) Peer-reviewed publications, International Journal/Book chapters.


(g) Scientific abstracts or articles including those presented at conferences


(h) National Report
1. n/a

(i) Popular non-scientific publications
1. n/a

(j) Workshops/seminars/ open days at which results were presented (excluding those in (g))
1. Moorepark Open Day 07
2. Moorepark Open Day 09

7. Permanent Researchers

<table>
<thead>
<tr>
<th>Institution Name</th>
<th>Number of Permanent staff contributing to project</th>
<th>Total Time contribution (months)</th>
<th>Average time contribution per permanent staff member (months)</th>
</tr>
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<tr>
<td>Teagasc Moorepark</td>
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<td>244.60</td>
<td>22.24</td>
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<td>Teagasc Johnstown Castle</td>
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<td>1.74</td>
<td>0.87</td>
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<td>UCD</td>
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<td>8.86</td>
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8. Researchers Funded by RSF

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<th>Average time</th>
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<tr>
<td>Contract Researchers</td>
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<td>PhD postgraduates</td>
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<td>Temporary researcher</td>
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<td>Other (technician)</td>
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<td>Other (Farm Staff)</td>
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<td>Other (summer students/work placement)</td>
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<td>17.04</td>
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<td><strong>Total</strong></td>
<td>10.44</td>
<td>177.88</td>
<td>17.04</td>
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9. Postgraduate Research

Total Number of PhD theses: 1
Mr. Willie Ryan, Teagasc Moorepark and University College.
Thesis title: Nitrogen balances and tissue turnover in grass based dairy production systems

Total Number of Masters theses: 1
Mr. Thomas Herbin, Teagasc Moorepark and University College.
Thesis title: The effects of rotational grazing management on soil physical properties.

10. Project Expenditure

Total expenditure of the project: €740,120.78
Total Award by RSF €740,126.41

Other sources of funding (specify) €145,000

1. Dairy Levy Funding for Dr. Deirdre Hennessy’s contract

Breakdown of Total Expenditure

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<th>Teagasc Johnstown Castle</th>
<th>UCD</th>
<th>Total</th>
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<td>Post graduates</td>
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<td>36,367.23</td>
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<td>178,223.13</td>
<td>157,591.32</td>
<td>740,120.78</td>
</tr>
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</table>

11. Future Strategies

Data pertaining to the NO₃ leaching measurements from the grazing season length experiment and the stocking rate experiment are being compiled for publication in peer reviewed scientific papers. The target is to submit these in 2012. Data published from the project will be further used in the EU Seventh Framework funded project MULTISWARD, contributing information to this project which is aiming to increase the use of grazed grass for ruminant production across Europe. The N balance model developed by William Ryan as part of his PhD will be used at Moorepark to assess the N use efficiency of grass based production systems where appropriate.

12. Industry Collaboration

Direct industry collaboration did not occur in this project. However, this project has provided information which can be used by the dairy industry to optimise production systems. The project highlighted the importance of a long grazing season in terms of milk solids production, N use efficiency and profitability. Data from the winter tissue turnover experiment has contributed to dairy farmers understanding of the importance of an autumn closing strategy to ensure grass availability for early spring grazing. The N balance model developed during this project has been used examine the effects of grazing season length and stocking rate on N use efficiency using the production data from sub-projects 1 and 2. Using the N balance model to assess grass based systems shows that N use efficiency is increased and N surpluses reduced when stocking rate is increased within a give N fertiliser application rate.