THE FERTILIZER ASSOCIATION OF IRELAND

Proceedings of Spring Scientific Meeting 2014

"Harvesting the Production Potential of Soils"

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Horse and Jockey, Thurles, Co Tipperary

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Harvesting the production potential of land – farm case studies

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Land Potential

"The continuance of around 10 million acres of grassland must be associated with a far more intensive production policy if this grassland is to be justified in terms of national economic goals" (Attwood, E.A. 1965).

The past 40 – 50 years have brought tremendous advances in technology and facilities on Irish farms. We have gone from milking cows by hand to rotary and robotic milking systems. Grassland management has advanced from traditional extensive grazing systems to intensively managed systems with farmers commencing the year with a spring rotation planner to budget early season grass, followed by a carefully managed paddock rotation during the summer period, and finished off with the autumn rotation planner to ration autumn grass and set up the grazing programme for the following spring. Grazing is managed by reviewing grass growth every week followed by feeding the data to a computer programme so as to plan the rotation for the following week. Winter feed has gone from hay to silage. We have vacuum tankers for spreading slurry and computer controlled fertiliser spreaders. We have had significant improvements in the varieties of grass and cereals and scientifically proven fertiliser recommendations. Surely there must have been a significant increase in agricultural production as all these changes and technologies were implemented on farms?

Lee and Diamond (1972) reviewed the potential of Irish land and for livestock production. They found that the stock carrying capacity of 3.58 million ha was 8.0 million livestock units (LU) with 48 kg/ha of fertiliser nitrogen (N) and 9.7 million LU with 230 kg/ha N. In addition there was 1.4 million ha of mountain land with a potential for 0.7 million LU. This gave a total livestock carrying potential of 10.4 million LU. They considered that with existing technology at that time, there was a potential to double the existing livestock numbers to give a stocking rate of 2.17 LU/ha with low N inputs and 2.72 LU/ha with high N. The annual N requirements to achieve the low and high stocking rates were 191,000 tonnes and 812,000 tonnes respectively. The fertiliser phosphorus (P) and potassium (K) requirements were 102,600 and 346,500 tonnes, respectively.

The Census of Agriculture 2010 identified that we have 5 million ha of utilisable agricultural area. Predictions based on Food Harvest (FH) 2020 targets indicate that we will have 5.7 million cattle; 1.38 million dairy cows; 0.93 million other cows; 5.02 million sheep and 2.48 million breeding sheep. This equates to a total of 5.4

million LU, assuming that the stock age profile will be the same as reported in the Census of Agriculture 2010. The targets set in FH 2020 are therefore less than half of the stocking rate potential identified in 1972. While milk yields and live weight gains are substantially higher now, this has occurred mainly due to improved animal breeding and husbandry. Therefore, even though output per animal has increased, the overall production potential of the agricultural land base in Ireland remains significantly under-utilised, even within the FH 2020 targets.

Potential vs. Reality

Many of our intensively managed farms are pushing grass and crop yields to the maximum achievable using high levels of inputs. Others are content to operate more extensively and have relied on single farm payments and environmental schemes to provide their income. Under current proposals, incomes from those sources will be reduced on the intensive farms and increased on the very extensive farms. Therefore intensive farmers will have to improve margins from land in order to maintain or improve income.

Removal of milk quotas is viewed as a major benefit by both dairy farmers and indeed other farmers who intend to switch to dairying. This has already (January 2014) resulted in dairy farmers bidding on land in order to increase cow numbers. This is putting land purchase/lease/rental beyond the reach of many drystock/tillage farmers. In order to maintain their land base, the latter are potentially being forced onto more marginal lands.

Achievement of targets under FH 2020 and the Tillage Development Plan 2012 must come from a combination of intensification of what is existing productive land and the re-introduction of what has become disused land into meaningful production again. This can come from better utilisation of land which is presently in intensive use; reclamation of semi-abandoned land and intensification of use of lowly stocked land.

In recent years, I have had several farmer clients who have taken on land that had been extensively farmed and turned it into highly productive land. In some cases that has involved substantial drainage works, while in others it has simply been done by reseeding with grass or tillage crop production, combined with a liming and fertiliser programme.

The objective of this paper is to look in detail at some of these farms as case studies of what can be achieved in terms of enhanced production potential on farms when appropriate land development plans are put into action.

Methodology

Fertiliser usage on three farms in North Tipperary are described in order to demonstrate the benefit of improved land management and fertiliser usage. The first is that of a drystock farmer who rented 23 ha of semi-abandoned land and restored it to full yield potential. This was part of a large farm which was stocked at less than 1 LU/ha. The second is that of a farm that was formerly in tillage, but was left to "run down" due to the fact that the occupier did not have a long term interest in the land and did not maintain soil fertility over time. The third farm is that of a dairy farmer who found in 2007 that his entire farm was Index 4 for P and did not apply any chemical fertiliser P until he resampled again in 2013.

Finally, soil analysis results for a farmer who has rented an additional 75 ha on 5 different blocks of land are also presented and discussed.

Farm 1 - Semi-abandoned farm

The semi-abandoned farm was leased by the current occupier in autumn 2007 for a ten year period. The farm had not been reseeded in living memory and had been used for summer grazing with approximately 40 yearlings on 23.52 ha. Very little fertiliser and no lime had been used in recent years.

Immediate work consisted of scrub removal, cutting of hedgerows, cleaning of existing drains and fencing. Land was soil sampled in February 2008 (Table 1).

Table 1. Soil analysis report (February 2008) for Farm 1.

Field Name	Field Area	Lime Req. (t/ha)	Soil P (mg/kg)	Soil K (mg/kg)
Field 1	4.48	5.00	2.2	124
Field 2	3.31	6.25	3.1	139
Field 3	2.19	6.25	4.1	110
Field 4	3.53	2.5	3.7	101
Field 5	4.21	3.75	1.9	84
Field 6	3.46	6.25	2.8	138
Field 7	2.34	0	2.0	80

The fertiliser programme was designed to raise lime and P levels as fast as possible so as to enable establishment of ryegrass. Spring P application before autumn reseeding was seen as a priority due to the poor recovery of annual P applications (Haynes, 1984; Kinsey and Waters, 2013). Recovery of N and K is substantially higher in the season of application.

Farm management in 2008

Lime was applied in mid-March 2008 to each field in accordance with recommendations. Triple superphosphate (16% P) was applied in early April at a rate of 350 kg/ha (56 kg/ha of P) on the Index 1 soils and at 200 kg/ha (32 kg/ha of P) on the index 2 soils. This was followed a few days later with 250 kg/ha of 18-6-

12 compound (45, 15 and 30 kg/ha of N, P and K, respectively) on the entire farm. There were two further applications of 27% N + S at 125 kg/ha (34 kg/ha of N) which took place in late June and early September. Lands were grazed from early May to the end of September with approximately 70 yearlings. Fields 2, 3 and 4 were reseeded in August.

Farm management from 2009 to 2011

The above programme was repeated with the reseeded fields receiving a total 600 kg/ha of 27% N (162 kg/ha) over 4 applications each year. Fields 2, 5 and 6 were reseeded in spring 2010. They received 33 m^3/ha slurry in 2010 and 2011. A late silage cut was taken in 2010 and two cuts of silage were taken in 2011.

The soils in each field of the entire farm were resampled in autumn 2011 (Table 2).

Table 2. Soil analysis report (October 2011) for farm 1.

Field Name	Field Area	Lime Req. (t/ha)	Soil P (mg/kg)	Soil K (mg/kg)
Field 1	4.48	3.75	6.0	96
Field 2	3.31	0	9.7	108
Field 3	2.19	0	5.9	78
Field 4	3.53	0	3.0	63
Field 5	4.21	0	6.2	55
Field 6	3.46	0	4.4	74
Field 7	2.34	0	2.0	36

P levels have risen substantially and there are now 3 fields in Index 4; all of which received slurry in the preceding two years.

Farm management in 2012 and 2013

Fields were closed for two cuts of silage in both years. Slurry was applied at 22 m^3/ha for the first cut on fields 1, 3 and 4 followed by 80 kg N. They received 11 m^3/ha slurry for the 2nd cut and 70 kg N.

Fields 2, 5 and 6, received 250 kg/ha of muriate of potash (50% K) (125 kg/ha of K) in the preceding autumns followed by 50 kg/ha of muriate of potash (25 kg/ha of K) in March. They received 125 kg N for 1st cut and 100 kg for 2nd cut.

Field 7 was drained in 2013 and reseeded in the autumn. It received 50 kg/ha N, 50 kg/ha P and 120 kg/ha K at reseeding.

Costs incurred in bring the farm to full yield potential

Substantial costs were incurred during the 2008 to 2013 period. These are summarised in Table 3. Consideration must also be given to the fact that grass production was very poor in year 1 and while the reseeded lands performed well in year 2 the remainder of the farm was poor.

Table 3. Costs (€) incurred in bringing study farm 1 to full yield potential.

Expenditure	Total Cost (€)
Reseed entire farm	15,080
Tidy ditches	1,600
Repair boundary fences	1,200
Clean drains	5,040
Lime	2,415
Increase soil P fertility	8,000
Total cost for 23.5 ha	33,335
Cost/ha	1,419
Cost / yr (over 10 years)	3,335
Cost /ha/yr (over 10 years)	142

The farm, which is 2007 produced very little is now at or close to full yield potential and is expected to yield close to 12 t/ha/yr of grass DM. Improvement of soil fertility and reseeding were the key factors for success on this farm.

Farm 2 - "Run down" tillage farm

The second case study farm was typical of a farm that has been rented out annually for several years. As is typical in these cases, due to uncertainty as to who would be farming it in the following year, basic requirements for land maintenance such as soil sampling, was neglected.

Farm management 2010

The "run down" farm was leased in April 2010 by a progressive tillage farmer. It was immediately ploughed, tilled and sowed with spring barley. He used the maximum fertiliser usage permitted under the regulations: 135 kg/ha of N and 25 kg/ha of P. Fertiliser also supplied 90 kg/ha of K. The crop was uneven, had visual symptoms of P deficiency and yielded 5.8 t/ha of grain, which was low compared with the national average yield in that year of 6.7 t/ha.

The farm was soil sampled after harvest and a fertiliser programme was put in place for the following year. Soil sample results are shown in Table 4.

Table 4. Soil analysis report from samples taken in September 2010 from farm 2.

Field Name	Lime Req. (t/ha)	Soil P (mg/kg)	Soil K (mg/kg)
Field 1	6.25	5.4	124
Field 2	2.50	4.4	139
Field 3	5.00	3.2	110
Field 4	5.00	4.5	101
Field 5	2.50	3.5	84
Field 6	2.50	6.2	138
Field 7	7.50	3.8	80

Lime was applied before end of September as per recommendations.

Farm management 2011 and 2012

The fertiliser programme for 2011 and 2012 consisted to 135 kg of N, 35 kg of P and 75 kg of K in all fields with exception of field 6 which received 25 kg of P, as the soil P was in Index 3, compared to the other fields which were all in Index 2. Grain yield in 2011 was 6.2 t/ha (national average yield 6.1 t/ha) and in 2012 was 7.3 t/ha (national average yield 7.0 t/ha). The improved fertiliser programme put in place based on the soil test results in these years contributed to the fields achieving increased grain yields.

The soils were resampled in December 2012. Results are shown in Table 5. The results showed that only one of the seven fields were in Index 2 for P at the end of 2012, compared with six of the seven fields that had been in Index 2 in 2010.

Table 5. Soil analysis report (December 2012) for farm 2.

Field Name	Lime Req. (t/ha)	Soil P (mg/kg)	Soil K (mg/kg)
Field 1	0	8.6	177
Field 2	3.75	7.0	111
Field 3	3.75	4.9	135
Field 4	0	4.5	<30
Field 5	0	11.0	81
Field 6	0	7.7	117
Field 7	0	9.1	120

Farm 3 - Dairy farm

The third farm in this set of case studies was a 46 ha dairy farm. The soils of this farm were sampled by a young dairy farmer in 2007 who was planning a major expansion programme at the time. The results of the soil analysis are shown in Table 6. Soil fertility on the farm was found to be very good overall, with almost no lime required, all fields being in Index 3 or higher for P. Five of the eleven fields were low in K (Index 2), and one field being just marginally in Index 1.

Table 6. Soil analysis report (December 2007) for farm 3.

Field Name	Field Area	Lime Req. (t/ha)	Soil P (mg/kg)	Soil K (mg/kg)
Field 1	6.30	0	7.6	81
Field 2	6.03	1.25	10.5	116
Field 3	2.31	0	6.2	83.4
Field 4	3.82	0	21.9	122
Field 5	2.52	0	10.3	72
Field 6	1.86	1.25	5.6	49
Field 7	5.85	0	10.0	140
Field 8	5.12	0	6.7	75
Field 9	3.79	0	7.8	57
Field 10	3.19	0	7.5	123
Field 11	5.10	0	7.8	127.1

Farm management 2007 and 2012

Soil fertility was very good and under Nitrate regulations no chemical P fertiliser was permitted as any P requirement was deemed to be met by the P content of imported concentrates and the P content of slurry. The fertiliser programme, until 2013, consisted of 80-90% of slurry being applied to grazing ground along with an average of 170 kg/ha of N and 20 kg/ha of K being applied as chemical fertiliser. Stocking rate throughout 2007 to 2010 was close to 170 kg/ha of Org N and averaged 210 kg/ha in 2011 to 2013.

Grass yields were poor in 2012 and the entire farm resampled in 2013. The results are shown in Table 7.

Table 7. Soil analysis report (March 2013) for farm 3.

Field Name	Field Area	Lime Req. (t/ha)	Soil P (mg/kg)	Soil K (mg/kg)
Field 1	6.30	10	4.2	121
Field 2	6.03	0	4.1	63
Field 3	2.31	10	2.7	46
Field 4	3.82	6.25	6.3	70
Field 5	2.52	7.5	3.9	89
Field 6	1.86	10	3.7	66
Field 7	5.85	7.5	7.5	125
Field 8	5.12	2.5	4.6	68
Field 9	3.79	7.5	2.3	45
Field 10	3.19	1.25	6.2	47
Field 11	5.10	0	8.5	<30

The farmer had observed that grass performance was suffering in the 3 to 4 years prior to 2012. The soil test results for lime requirement, P and K are compared in Figure 1.

Lime requirement is shown to have increased in all fields. While only two fields had a small lime requirement in 2007, nine fields needed lime by 2013. The fields that required lime, five of the field required rates of 7.5 t/ha (3 tons/acre) or greater. This indicates that while the initial soil test results needed little lime, the soil sampling interval of six years on this farm was probably too long; therefore allowing what would have been a gradual increase in lime requirement over this period to go unnoticed.

Soil P decreased in every field except field 11, which increased form P Index 3 to 4. Field 10 was the only that maintained soil P Index constant. The other nine fields all decreased in soil P Index, with four fields decreasing by two Index levels (either form 4 to 2 or form 3 to 1). Similar to the lime requirement, the results show that while the farm may have sustained grass output with no P fertiliser for some years, there may have been a benefit to a shorter soil sampling interval in order to have picked up the declining P fertility sooner, and to have been able to apply some fertiliser P in recent years.

Soil K increased by one Index in Field 1 and Field 6, but declined by one Index in four fields, and by two Index levels in another 2 fields. The Index was held constant in three fields.

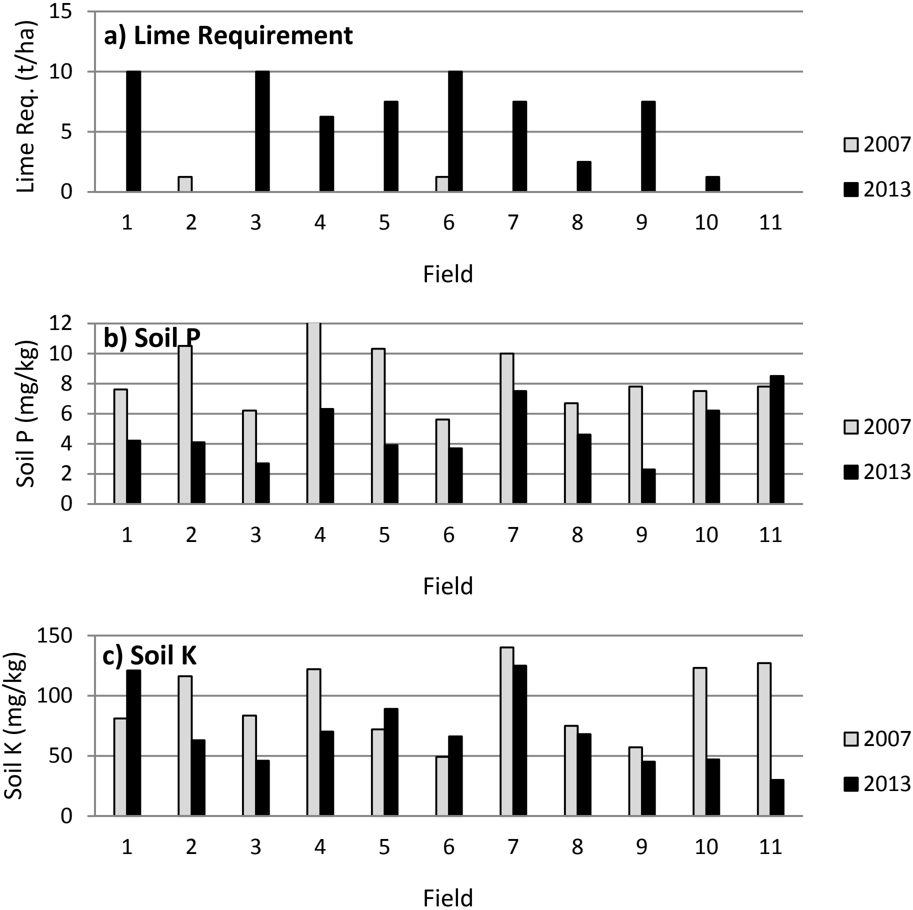

Figure 1. Comparison of lime requirement (a), soil test P (b), and soil test K (c) in 2007 and 2013 on farm 3.

Soil results on newly acquired lands.

Many farmers have lost land in 2013 due to landowners taking back land to try to establish entitlements for themselves. Others have already lost good quality conacre this year to dairy farmers who can afford to pay more than drystock or tillage farmers. The results in Table 8 are for one such farmer who has managed to replace land he had lost. However soil analysis results indicate that he has a lot of work to do to improve soil fertility to required levels to achieve good productivity. While P fertility on this land is generally good, five of the samples (30%) are either low (Index 2) or very low (Index 1) in soil test P. Soil K fertility is much lower by comparison with P, as 10 of the samples (63%) or either low or very low in K. The average lime requirement on the farm is 4.5 t/ha.

Table 8. Soil analysis report (March 2013) on newly acquired lands for a tillage farmer.

Field Name	Lime Req. (t/ha)	Soil P (mg/kg)	Soil K (mg/kg)
Field 1	5.00	5.8	<30
Field 2	0.00	11.9	43
Field 3	0.00	>30	39
Field 4	3.75	5.1	95
Field 5	8.75	2.7	138
Field 6	1.25	9.6	214
Field 7	2.50	7.9	66
Field 8	0.00	14.2	87
Field 9	8.75	6.0	67
Field 10	1.25	4.3	63
Field 11	0.00	7.9	87
Field 12	0.00	>30	42
Field 13	5.00	9.1	<30
Field 14	7.50	3.0	134
Field 15	11.25	3.1	126
Field 16	16.25	3.0	84

Discussion

The cases outlined above were selected from farms, sampled by me in recent years, to demonstrate responses to fertiliser application. The samples may not be representative of all farms but they are typical of what is commonly found on farms of the types described in these case study farms.

The semi abandoned farm is typical of many "outfarms" where the entire holding is understocked. There is scope for such farms to lease out or enter partnerships on part of their holding to other farmers who want to expand. Terms can include improvements to farm infrastructure and soil fertility such as happened in this case. The investment for the incoming farmer can be substantial, so agreement periods of 5 to 10 years are desirable. In the past, participation in REPS kept some landowners from doing so. In recent times fear of issues with single farm payments and unrealistic expectations of what the next CAP reform will do for farmers has retarded such advances.

Soil fertility on the semi-abandoned farm was improved over 4 years to give a satisfactory lime status, substantially improved soil P status from an average of

Index 1 to Index 3 with the application of approximately 20 kg/ha/yr of P surplus to offtake. Soil K dropped from an average of Index 3 to Index 2 with increased offtakes. K fertilisation has been increased since the 2011 results.

The rundown farm is typical of a substantial area of conacre with soil pH dropping and tenants not liming because they may not be on the farm long enough to benefit from the application. The soil P levels were reasonable at Index 2 – better that a lot of “new conacre”. Over the period of three cropping seasons, soil P levels were increased to the target Index of 3. The greatest increase in available P came from the field with the highest lime application. Crop yields increased substantially with the application of lime and recommended nutrients.

The dairy farm demonstrates the need to continue to monitor soil nutrient levels after changing the fertiliser programme. The farmer believes that he lost substantial production in recent years due to the reduction is soil fertility. I recommend as a routine that if you make a substantial change to your normal programme that you resample lands after two years. All intensively managed lands should be sampled every three years and in general do the entire farm each time you sample. This enables the preparation of a properly balanced fertiliser plan for the farm.

The soil results for the newly acquired tillage lands were a significant shock to the farmer and a timely warning to anyone who is presently looking for conacre. The land is from five different holdings with an average distance of 10 km from one to the next. All of the lands except for fields 14, 15 and 16 were in tillage crops prior to being sampled. With the exception of two fields all fields had either a lime requirement or was in Index 1 for either P or K. Yield potential is depressed and disease risk increased until such time as the lime and nutrient issues are resolved.

Conclusion

Soil fertility is one of the basic keys to unlocking the potential of land. Concerns with water quality and fear of cross compliance penalties have moderated fertiliser use. Some farmers have over-reacted resulting is depressed yield potential. The other issues are availability of finance, age structure, management skills etc. There is no point in correcting soil fertility and increasing land potential unless the production is utilised. In the case of underutilised grassland we need to get arrangements in place whereby the potential surplus production is taken off the land and sold. The simplest solutions on some farms will be by either leasing out land or entering partnerships or share farming on part of the holding. The remainder of the farm should then be farmed more intensively so as to produce the same or a greater number of livestock.

There is no justification for having good quality land and stocking it substantially less than its potential. This country has land resources for in excess of FH 2020 targets.

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Delivering farm productivity while sustaining water quality improvements - NAP 2013-2017

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Introduction

Food Harvest 2020, an industry led initiative, published by the Department of Agriculture, Food and the Marine, identifies noteworthy potential to increase financial output from Irish Agriculture. The report, following on from previous road maps such as Agri Vision 2015, sets out ambitious expansion plans across the agricultural sectors seeking to increase the value of primary production by 33%, value added output by 40% and exports by 42%. Sectoral targets in the beef, sheep, pig and poultry sectors are value driven whilst expansion in milk production is volume based.

This report differs from previous road-maps by identifying opportunities strongly linked to sustainability criteria. The ambition for smart, green, growth underlying the report recognises both environmental and market place realities. The Department of Agriculture, Food and the Marine commissioned an Environmental Analysis of the report. In relation to water quality, the analysis has identified potential slight negative impacts that require mitigation. It specifically highlights the importance of knowledge transfer, catchment monitoring and nutrient management planning amongst other proposals as mitigation measures and recommends using the Rural Development Programme (RDP) to target such measures towards protecting and improving water quality. The set of measures in the Nitrates Regulations provide a basic level of protection against possible adverse impacts to waters arising from current agricultural production activities and the potential agricultural expansion under FH 2020.

Requirements of the Nitrates Directive (91/676 EEC)

The EU Nitrates Directive was introduced in 1991. This Directive included specific requirements on each member state regarding the control of nitrates losses to waters arising from agriculture. These specific requirements include:

- water monitoring of all water body types (with regard to nitrate concentration and trophic status);
- identification of waters that are polluted or at risk of pollution, on the basis of criteria defined in Annex I to the Directive;
- designation of nitrate vulnerable zones, which are areas that drain into identified waters and contribute to pollution;

- the establishment of codes of good agricultural practices, implemented on a voluntary basis throughout the Member State territory;
- the establishment of action programmes, which include a set of measures to prevent and reduce water pollution by nitrates and are implemented on an obligatory basis within designated nitrates vulnerable zones or throughout the entire territory;
- the review and possible revision at least every 4 years of the designation of nitrate vulnerable zones and of action programmes; and
- the submission to the Commission every four years of a progress report on the implementation of the Directive.

Implementation of the Nitrates Directive in Ireland

Since the early 1970's, Local authorities and the Environment Protection Agency (EPA) have undertaken extensive monitoring of nitrate levels in waters in Ireland. Water monitoring by the EPA has continued and increased to meet the requirements of the Nitrates Directive. A further action was the publication of 'The Code of Good Agricultural Practice', which was jointly developed by the Department of the Environment and the Department of Agriculture, Food and Forestry in July 1996. (This booklet was widely circulated and set out guidelines aimed at reducing the loss of nutrients from agriculture. The advice in this booklet was used in the subsequent formulation of the Regulations that were signed in 2005).

In July 2000, 14 groundwaters in Counties Carlow, Cork, Kerry, Louth and Waterford were identified as 'affected waters' under the Nitrates Directive. Ireland adopted a whole territory approach in 2003 for the purposes of implementing the Directive (European Communities (Protection of Waters against Pollution from Agricultural Sources) Regulations, 2003).

A judgement of the Court of Justice of the European Union (ECJ), delivered in 2004, held that Ireland was non-compliant with the Nitrates Directive (Commission V Ireland; case C-396/01). Regulations giving statutory effect to certain elements of Ireland's first National Action Programme were enacted in 2005 in the European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2005 (S.I. No. 788 of 2005). These Regulations were subsequently replaced by S.I. No. 378 of 2006. The European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2009 ((S.I. No. 101 of 2009) revised and replaced amending legislation made in 2006 and 2007. The 2009 Regulations provided for strengthened enforcement provisions and for better farmyard management in order to comply with an ECJ judgment in relation to the Dangerous Substances Directive. They also provided the legal basis for the operation of a derogation under the Nitrates Directive granted to Ireland by the European Commission in 2007.

Agricultural Catchments Programme

The effectiveness of the package of measures contained in Ireland's Nitrates Action Programme (NAP) is being evaluated on an ongoing basis by the Agricultural Catchments Programme (ACP) run by Teagasc.

Phase 1 of the Programme was conducted over four years and finished at the end of 2011. This joint advisory/research programme is based on a partnership with over 300 farmers in six intensively farmed catchments. It takes a rigorous scientific approach to monitoring a range of biophysical and socio-economic parameters used to evaluate the impact of the NAP measures and the derogation implemented by farmers under the Nitrates Directive. The outcomes of this research provide broadly positive indications for Irish farming and its impact on water quality.

Average stream and groundwater in all six catchments had nitrate levels well below the human health limits and there were some indications of recent signs of improvement in water quality, likely due to the adoption of better management practices by farmers. Phosphorus loads in catchment streams were low to moderate by international comparison, albeit three catchment streams had, on average, phosphorus levels above the WFD quality standards for good status water.

Similar to the Environmental Analysis of FH 2020, significant scope to improve nutrient management on farms, with consequent benefits for both water quality and farm profitability, was identified. It was also found that soil type and geology are likely to be important in determining the nutrient pathways and risk to water. However, work relating to soil type and geology were not sufficiently advanced for it to support the identification of potential national measures in the forthcoming NAP.

Ireland's first Nitrates Action Programme (NAP1)

Ireland, in common with 10 other member states applied its NAP on a country-wide basis, thus ensuring 100% territorial coverage compared to an EU overall coverage of 46.7%. In addition, the Programme also provides for phosphorus limits for all crops, an approach currently replicated in only 3 other action programmes. The scope of the NAP to date has been comprehensive, both in terms of addressing the major sources of agricultural nutrients and in covering a national farming population of over 139,860 farm holdings.

The principal elements of the NAP include:

- limits to farm stocking rates;
- legal maxima for nitrogen and phosphorus application rates;

- prohibited spreading periods preventing the application of organic and chemical fertilisers during more environmentally vulnerable times of the year;
- minimum storage requirements for livestock manures;
- requirements regarding maintenance of green cover in tillage lands; and
- set-back distances from waters.

In common with other EU member states in which intensive agricultural activity is practised, Ireland availed of a derogation from the 170kg livestock manure nitrogen limit as provided for in the Nitrates Directive. The derogation was originally granted by the Commission in 2007 and renewed in 2010.

In conjunction with the introduction of the Regulations which required large scale investment in livestock manure storage facilities, a grant scheme was put in place which resulted in an overall investment of €2 billion in farmyard facilities. The Directive required that an Agricultural Catchments Programme be established to monitor the effectiveness of the measures in the regulation and this has been supported by a comprehensive research and advisory programme. The on-going benefits of the first action programme have been reduced environmental pressure from agricultural sources due to improving management and more efficient use of fertilisers.

Ireland's second Action Programme (NAP2)

In accordance with the Nitrates Directive and Article 28 of the Good Agricultural Practice Regulations, the Minister for the Environment, Community and Local Government, in consultation with the Minister for Agriculture, Food and the Marine reviewed the NAP for the first time in 2010.

A public consultation was held which resulted in 45 submissions being received and these were reviewed by an expert group. This expert group comprised of senior scientific experts from the Department of Agriculture, Fisheries and Food, Department of Environment, Heritage and Local Government, Teagasc and the EPA.

The expert group recommended changes which were accepted in their entirety by both Ministers and the Commission. These were:

- An extension of the transitional period for the use of phosphorus from pig, poultry manure and spent mushroom compost to facilitate the need to find more spreadlands for these valuable fertilisers.
- Changes to the green cover requirements allowing earlier ploughing of arable land.

- Adjustments to nitrogen and phosphorus maximum application rates for certain tillage crops.
- Introduction of a phosphorus allowance for reseeding grassland.
- Recognition of different levels of phosphorus in various concentrates fed to grazing livestock.
- Introduction of site specific and risk based approach to set back distances around drinking water abstraction points following assessment of conditions.
- Introduction of a buffer from waters when storing silage bales outside farmyards.
- Reduction of maximum soil sampling area to 8 ha.

This resulted in a revised Nitrates Action Programme (NAP2) and the current Good Agricultural Practice Regulations (also known as the 'GAP Regulations' and as the 'Nitrates Regulations').

Ireland's third Action Programme (NAP3)

The second review of the NAP took place in 2013. To further inform the review, the Department of the Environment, Community and Local Government (DECLG) and the Department of Agriculture, Food and the Marine (DAFM) jointly published a consultation paper on 1 May 2013 and invited submissions from interested parties and the public by 12 June 2013. A total of 30 written submissions were received in response to this invitation. These included submissions from local authorities, farmers and farming representative bodies, environmental non-government organisations (eNGOs), scientists, agricultural co-operative societies, trade and professional bodies and Teagasc. Similar to the previous review an expert group was established to assist the Departments in taking forward the review process. The Group worked with the following guiding principles:

- that NAP3 should maintain and support the environmentally progressive outcomes achieved under the two previous NAPs and continue to secure consistency with the EU Nitrates Directive;
- that the NAP3 regime should be designed to operate as efficiently as possible, and particularly in the current challenging economic climate, the developmental objectives for Irish agriculture, as set out in FH 2020, should be encouraged on the basis of sustainable farming practices; and
- that the present review should seek incremental improvements to the existing NAP that will build on the considerable achievements made to date and contribute to the delivery of WFD objectives.

Summary of main changes in the Nitrates Regulations within NAP3

The following sections show details of specific changes in the Regulations that have been incorporated into NAP3. Changes to the Regulations are formulated to be consistent with the guiding principles previously outlined.

Phosphorus

A number of changes are included that impact on phosphorus allowances on both grassland and tillage crops. These include:

- A reduction in the available P allowance on lowly stocked farms through the introduction of an additional grassland stocking rate band for farms less than 85 kg/ha.
- A correction of the available P allowance for other farms based on an adjusted calculation of P removals for grazing and silage.

The combined effects of these changes on the total available P allowances for grassland are shown in Table 1.

Table 1. New annual maximum fertilization rates of phosphorus on grassland.

Grassland stocking rate (kg/ha/year)	Phosphorus Index			
	Index 1	**Index 2**	**Index 3**	**Index 4**
	Available Phosphorus (kg/ha)			
≤ 85	31	21	11	0
86-130	36	26	16	0
131-170	41	31	21	0
	Grassland stocking rate greater than 170 kg/ha/year			
171-210	46	36	26	0
211-250	51	41	31	0
> 250	51	41	31	0

Other changes impacting on phosphorus include:

- The first 300 kg of concentrate fed per 85 kg of livestock manure N (or equivalence in terms of P content if using non-default values for P in concentrate feeds) are discounted when calculating the available P fertiliser allowance, net of available P in slurry and concentrate feeds used.
- The availability of P in organic fertilisers is reduced to 50% when applied to soils with P Index 1 or 2.

- The annual P allowance on maize crops grown on Index 4 soils is increased from 0 to 20 kg/ha where the P fertiliser is incorporated into the seedbed prior to or during sowing.
- 20 kg/ha of P is allowed on cereal crops, on index 4 soils, where the soil pH is 7.0 or above.
- The assumed P concentration in SMC is changed from 2.5 kg/t to 1.5 kg/t.
- The period for which a soil sample remains valid on non-derogation farms is being reduced from six years to five years.

Watercourses and set back distances

The use of the term “watercourse” in Article 17(17) of the current Regulations is to be amended to “waters”. The following amendments regarding uncultivated zones and set back distances from waters are included in NAP3:

- A 2 m uncultivated and unsown zone must be maintained alongside all surface waters identified on the 6” OSI maps (1:10560) of Ireland for tillage crops, excluding establishment of grassland or grass crops.
- The distance from which farmyard manure can be stored near waters is increased from 10 m to 20 m.
- Article 17(13) (reduction of buffer zone from 5 m to 3 m in certain circumstances) is deleted.
- A new set back distance is introduced which requires that supplementary feeding points must be located at least 20m from waters and must not be placed on bare rock.

Prohibited periods for the application of fertilisers

The setback distances from surface water in Article 17(2)(f) are doubled from 5 m to 10 m for the two weeks before the closed period begins and for the two weeks after it concludes in each region.

An assessment of the current levels of storage capacity compared to that likely to be required by the numbers of animals predicted due to potential expansion under FH2020 will be carried out.

Soiled Water

Article 3(2)(c) of the regulations is amended as follows: “*For the purposes of these Regulations, soiled water which is stored together with slurry is deemed to be slurry*”. This is to provide legal certainty to the definition of soiled water.

Newly constructed soiled water tanks constructed on or after 1 January 2015 must have 15 days storage capacity.

Changes specific to tillage crop production

There are changes included regarding the control of grass weeds in specific cereal crops. The requirement to establish green cover following non-selective herbicide use is removed where the herbicide is applied after 15 October on 25% of the land harvested for specific contracted cereals where pre-harvest control is prohibited (i.e. cereal crops grown for malting, seed or human consumption).

There also changes to the permitted nitrogen application rate limits on some tillage crops. The maximum allowed annual nitrogen fertilisation rates on winter barley and spring wheat are increased by 20 kg/ha across all N Indices. The rate of N permitted for top-dressing broccoli in Table 18 is corrected from 20 kg/ha up to 120 kg/ha.

Other amendments to specific articles

The scope of the regulations is being extended so that all movements of livestock manure are subject to the regulation. Article 3 is amended by updating the definition or organic fertiliser to include reference to SMC. Article 13(1)(c) is amended to reflect updated position and reference to the Waste Management Act to be replaced by reference to the European Communities (Transmissible Spongiform Encephalopathies and Animal By Products) Regulations 2008. Regulation 23(1)(g) is to be amended to state that records of livestock manure and other organic fertilisers moved on or off a farm will be in a format as specified by DAFM. Article 23(4) is amended to include Local Authorities as a body who may request information in relation to the movement of organic fertiliser. Article 26(4) is amended to refer to a “summary prosecution”.

Potential to optimise fertiliser N inputs based on soil N supply

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Introduction

Chemical fertiliser use is one of the main factors underpinning the increased agricultural productivity across developed regions leading to food security and economically viable farming businesses. The purpose of fertilisation is the optimisation of plant nutrition and the maintenance of soil fertility for increased grass and crop production. Nitrogen (N) fertiliser is one of the single biggest inputs to grassland and tillage farming systems. When used efficiently, N fertiliser inputs are vital to attain target crop yields and, ultimately, a satisfactory return on investment. Grass growth is the basis for dairy and beef production in temperate regions. The optimum N application rates and N-use efficiency vary widely across the range of soil types and production intensities that exist in Ireland. This is partly due to the widely varying quantities of soil N supplied through biological N mineralisation (N_o).

Better knowledge of soil N supply levels would enable farmers to tailor N fertiliser rates to individual soils in order to achieve target production and profit levels, while minimising the negative environmental impacts associated with N losses to air and water. Inefficient use of N on farms has significant economic implications for farmers as well as for the wider environment (Oenema and Pietrzak, 2002; Buckley and Carney, 2013). The requirement for maximum efficiency in N fertilizer use is being increasingly emphasised in terms of achieving strict environmental targets under Water Framework Directive and Green House Gas Emissions legislation. Achieving and demonstrating increased N efficiency is a key requirement for farmers, if Irish agriculture is to meet production growth targets as set out in Food Harvest 2020 in an environmentally sustainable manner. This paper outlines the importance of the N supply for grass production and the effects of native soil N supply on N fertiliser rates for grassland.

Soil N pools and their availability

The total N concentration in Irish grassland soils has been shown to range from 2,155 to 7,433 kg/ha in the top 10 cm (McDonald *et al*, in review). The majority of this soil N is associated with soil organic matter (SOM) (organic N). Soil organic matter is very heterogeneous and consists of different fractions with differing composition and stability. Apart from relatively small amount of uptake of small organic molecules in the soil, organic N has to be decomposed by microorganisms to mineral N forms (nitrate and ammonium) before it can be taken up by plants (Figure 1.) Within the SOM, soil microbial biomass represents a small but labile N pool which may become available to plants when the microorganisms die. Microorganisms require both carbon (C) and N for energy and growth and generally consume on average 1 part of N to every 8 parts of C (Brady & Weil, 2002). Therefore, the C:N ratio of a material been decomposed influences the quantity of N that is released. Where C is abundant in the soil, inorganic N can be assimilated by microorganisms and converted into organic N constituents in the cell and tissues of the microorganisms in a process known as immobilisation. Immobilisation reduces N availability in the soil. The ratio of the organic compounds in the soil controls the assimilation or release of N. If a lower C:N ratio exists (<25:1) in the soil, the microbial biomass may be turned over (e.g. cell death, predation and excretion of waste products) causing the organic N assimilated by the microbial biomass to become available once more. This process is known as N mineralisation (N_o) and increases N availability in the soil for uptake by plant roots.

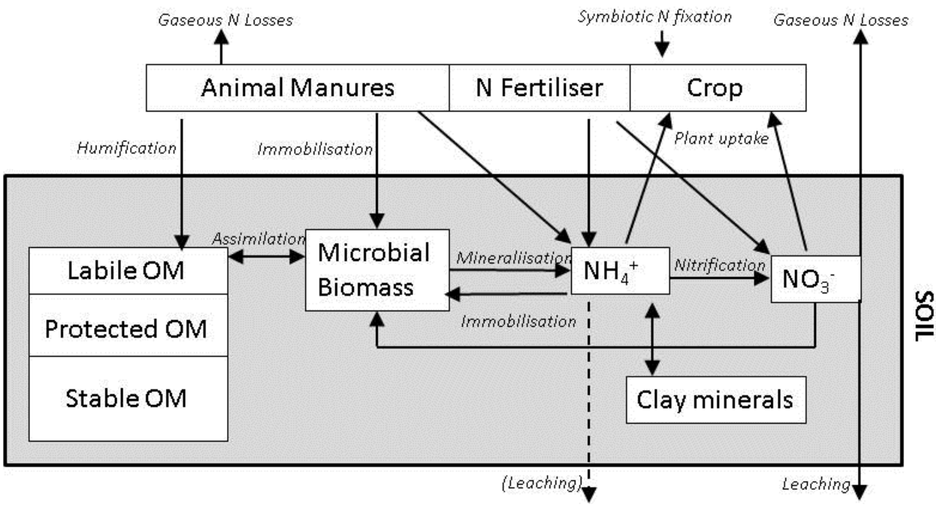

Figure 1. Nitrogen pools and fluxes in the soil.

Mineralisation and immobilisation can occur simultaneously in the soil. However, net mineralisation increases soil N availability for plant uptake. The mineral N pool, which is directly plant available, comprises of ammonium (NH_4^+) and/or nitrate (NO_3^-). In the absence of N fertilisers there is usually less than 1% mineral N in the soil solution which represents a small fraction of total N (Stockdale *et al*, 2002). After plant roots have extracted mineral N, this N pool is replenished through microbial decomposition of plant and animal residues, animal excreta and humidified soil organic matter, or directly through the application of fertilisers (Whitehead, 1995). The soil's role in providing plant available N to the grass through N_o of SOM is well known as been an important resource for agricultural productivity. Recently, McDonald *et al,* (2011) evaluated the potential N_o across 35 Irish grassland soils found that N_o rates ranged from 92 to 403 kg/ha of N in the top 10 cm depth. However, accurately predicting the quantities of N to be mineralised and taken up by the plant can be difficult, as many soil, climatic and land management factors affect the N_o processes (Griffin, 2008).

Soil nitrogen recovery by grassland

Nitrogen is an essential constituent of plant proteins, nucleic acids and chlorophyll (Whitehead, 1995). The N content of herbage varies according to the growth stage of the plant and the soil N availability. The average dry matter (DM) N content of grass is approximately 3.51% of DM (range 0.86% to 6.27%) (Rogers and Murphy, 2000). Intensive grassland production has a high demand for N as large quantities of protein-rich leaf are produced (Ryan *et al,* 1984). While the rate at which grass grows is determined by many factors (e.g. water, sunlight, temperature, nutrient availability), the level of N available for plant uptake has a major effect on yield.

There are three main components to N supply for grassland, namely the native soil N supply (through N_o processes), inorganic fertiliser and manure N inputs and fixed atmospheric N associated with legume species (mainly white clover). The mineralisation/immobilisation turnover of N plays an important role in supplying N to grassland, even in well fertilised soils. Mineral N released from the pool of organically bound N in the root zone usually accounts for half the N found in grassland receiving adequate dressings of N in mineral fertilisers, the other half originating directly from the fertiliser. The residual fertiliser N is mainly incorporated into the soil pool of organic N.

An indicative measurement of the native soil N supply can be made by quantifying the amount of N harvested in the grass if no N fertiliser is applied. McDonald *et al,* (in review) evaluated the relative N_o rate in 28 grassland soils by measuring the N uptake over 5 week growth intervals under controlled environmental conditions. Large differences were found between these soils in terms of their grass production potential from soil N reserves as shown in Figure 2.

Grass dry matter (DM) yield over a five week growth period ranged from 845 to 3,133 kg/ha and was tracked closely by N uptake which ranged from 23 to 114 kg/ha. Under these controlled conditions the influence of climate on N losses was standardised, therefore isolating the soil type related effects on N supply.

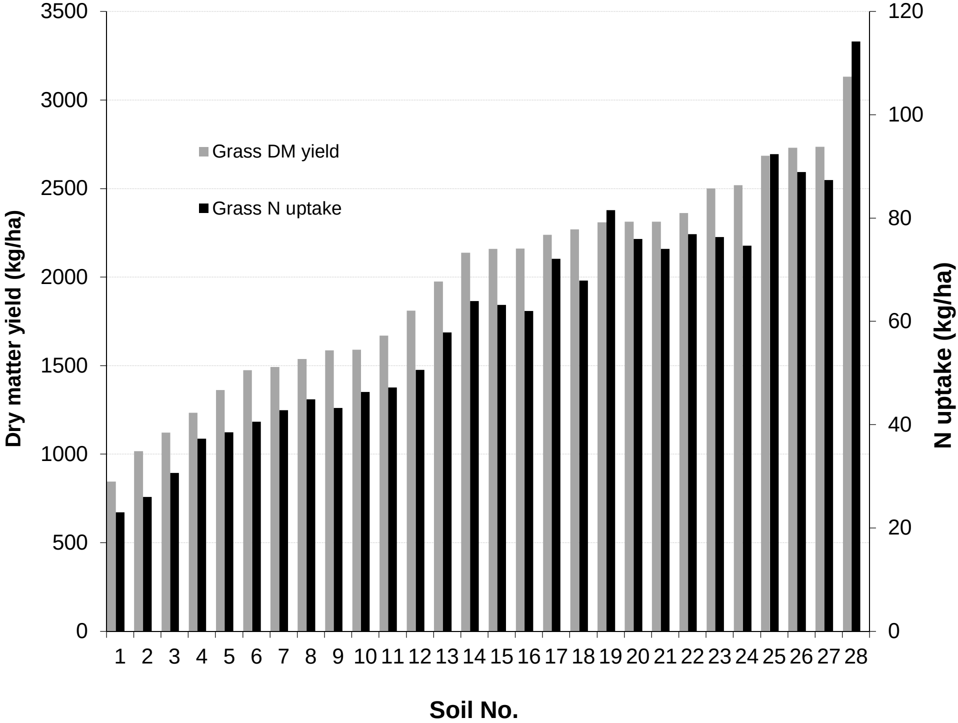

Figure 2. Mean grass dry matter yield and nitrogen uptake for 28 Irish grassland soils over a five week grass growth interval under optimised growth conditions.

Ryan (1976) reported a 4-year mean grass N uptake with zero N input from 135 to 273 kg/ha across 10 major soil types. In a similar studies the cumulative annual N uptake by grass ranged from 74 to 212 kg/ha per year across 15 Irish grassland sites (Humphreys, 2007). A study on 16 grassland sites in the UK measured cumulative annual N uptake ranging from 40 to 150 kg/ha per year (Hopkins *et al*, 1990). Murphy *et al*, (2013) reported that approximately 49% of the annual N uptake obtained at two contrasting Irish grassland sites, receiving high rates of N fertiliser (300 kg/ha per year) came from mineralisation of soil organic N. Recently, grassland studies at Johnstown Castle and Moorepark (McDonald *et al*, 2013) reported grass N uptake with zero N input from 195 kg/ha (grass DM yield 8.53 t/ha) on a moderately drained clay loam to 236 kg/ha (grass DM yield 9.39 t/ha) on a well-drained loam soil (Figure 3). Collating the data from across these studies shows that there is large variability in the soils potential to supply N for plant uptake.

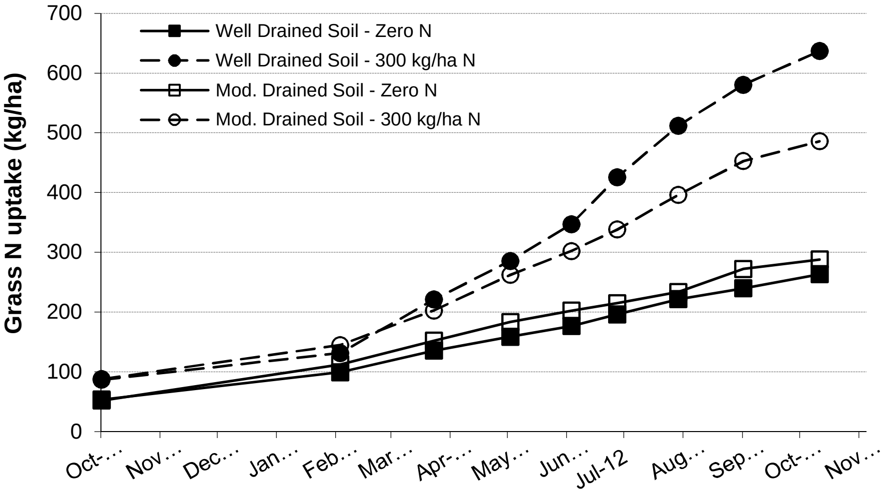

Figure 3. Grass nitrogen uptake with zero fertiliser N applied and with 300 kg ha^{-1} N applied on a well-drained loam soil at Moorepark, in Cork and a moderately drained clay loam soil at Johnstown Castle in Wexford.

Soil testing for N availability

Soil testing for N availability has long been an aspiration, but there is uncertainty about the practical application of predictive soil N tests. This is due to the large temporal and spatial variability in soil N pools imposed by interaction of weather, management and plant growth, and the opposing N transformations of mineralisation, immobilisation and denitrification as well as movement of mineral N deeper into the soil profile through leaching processes.

Various soil N testing methods have been developed, all which have had mixed levels of success in the field (Keeney, 1982; Griffin, 2008; Ros *et al*, 2011b). The majority of soil N tests fall into two main categories; biological or chemical. Biological N techniques include short and long term soil incubations that measure relative production of mineral N produced by the N_o process over a defined period (Sharifi *et al*, 2007). Incubated conditions create a soil environment that promotes biological activity, resulting in estimation of the N_o of labile organic N pools (Dahnke and Vasey, 1973). Long-term incubation (>30 weeks) with periodic measurement of soil mineral N pools in combination with curve-fitting, can be used to reflect the total quantity of soil organic N that has the potential to be mineralised. In comparison, short term incubations (aerobic and anaerobic) measure the rate at which organic N mineralises over a specified time period under controlled conditions, sometimes termed as net N mineralisation rate (Ros *et al*, 2011a). Although useful for research purposes, these biological tests are time-consuming and impractical for routine use, especially where a rapid turnaround time is required (e.g. soil sampling in spring for making early season N fertiliser decisions).

These fundamental requirements of a soil N test have contributed to the development of numerous chemical soil N tests in an effort to find suitable alternatives to the biological N tests (Griffin, 2008; Ros *et al*, 2011b). Worldwide, the most prominent chemical index of N availability is soil mineral N levels. However, under humid and high rainfall climates, such as in Ireland, these tests are of limited value as these soil mineral N pools are too dynamic and transient for making even short term predictions (Keeney, 1982). More recently the focus has been placed on identifying and quantifying the labile fractions of N in SOM that will be potentially become available for plant uptake through N_o.

The Illinois soil nitrogen test (ISNT, Kahn *et al*, 2001), which estimates the quantity of the amino sugar-N fraction of SOM, has been used to categorise soils under maize crops that were responsive or non-responsive to N fertiliser applications. To date the majority of studies using the ISNT to estimate soil N supply have mainly been on arable soils in North America.

Following an evaluation of a range of chemical N tests to predict N_o in Irish grassland soils, McDonald *et al*, (2011) found the more practical and rapid ISNT to have a strong relationship with a standard biological 7-day anaerobic incubation test across 35 Irish mineral soils (R^2=0.82). In a follow up pot study the ISNT was positively correlated to grass DM yield and N uptake on these soils over 5 week growth intervals (Figure 4).

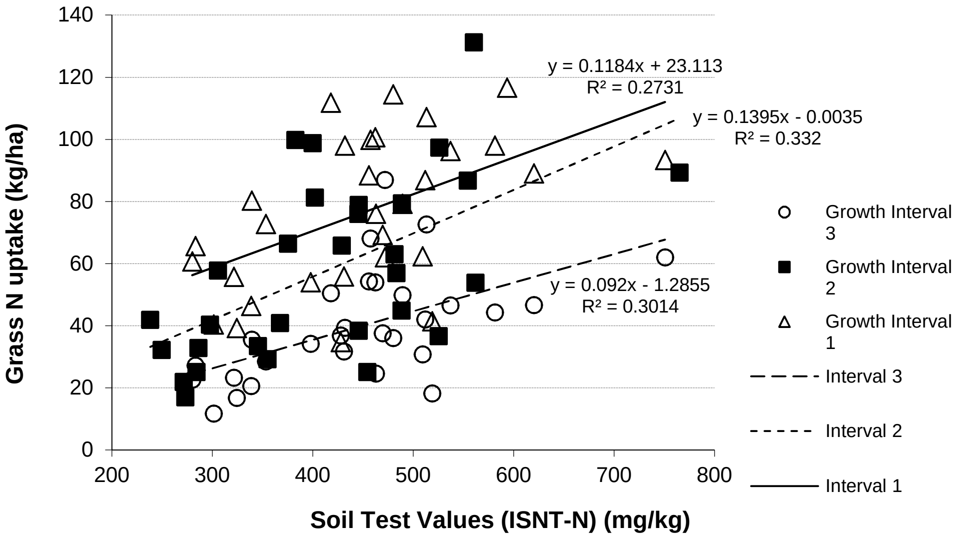

Figure 4. The relationships between Illinois soil nitrogen test values and grass nitrogen uptake over 3 growth intervals (5 weeks each) across 28 grassland soils.

Although the ISNT was a good predictor of soil N_o, it cannot detect nitrate-N concentrations within the root zone which will also significantly contribute to plant N response (Klapwyk & Ketterings, 2006). Therefore combining residual N and N_o, as measured by nitrate-N and ISNT-N respectively, significantly improved the prediction of grass N uptake (R^2=0.78) and DM yield (R^2=0.56) in this study.

Nitrogen fertiliser requirements for grassland

Across Irish dairy farms Griffith *et al*, 2013 reported large variation in grass DM production from 6.7 to 16.2 t/ha of DM. This equates to a mean N uptake requirement from 235 to 568 kg/ha across these farms, assuming average N content in the grass of 3.51%. However, the N concentration within herbage can vary (range 0.86% to 6.27%) according to the growth stage of the plant and the soil N availability in Ireland (Rogers and Murphy, 2000). The N requirement at high grass yields (>10 t/ha of DM) is therefore well above soil N supply levels, which means that high rates of N fertiliser must be supplied to make up the deficit in order to achieve these yields. Irish grassland has been shown to be responsive to high rates of N fertiliser (linear response up to 450 kg/ha of N per year) especially under a frequent cutting regime of 4-5 weeks (O'Riordan 1997; Forristal P.J. (*pers comm*). Under a grazed grass system, grass may not respond to N fertiliser application rates as high as this, as a large proportion of the N input to the soil may be supplied through re-deposition by the grazing animals in urine and dung. At stocking rates of 2 cows/ha, approximately 170 kg/ha of N may be re-deposited of which a proportion is available for grass uptake. Approximately 1.1 million ha of grass silage is grown in Ireland each year. Fertiliser use survey results show that the average N fertiliser application rate for silage is 101 kg/ha (Lalor *et al,* 2010). About 83% of the silage area is cut once mainly between May and June and a further 16% is cut twice. Only approximately 1% is cut more than twice. With slurry often recycled back to silage ground it is likely that the average N application is close to 125 kg/ha advised by Teagasc for one cut silage.

In order to determine fertiliser requirements, two factors need to be known: 1) crop N requirements (based on grass demand by grazing livestock or target silage yield); and 2) the soil's ability to supply N. Although there has been extensive research, scientists have been unable to date to reliably differentiate between Irish soils in within agronomic advice based on the soils ability to supply N. This is mainly due to the limitation that soil organic N and the microbes that mineralise N are poorly understood. Soil N supplied for plant growth is often ignored in intensive agricultural systems (Griffin, 2008) and the emphasis and dependency is placed on N inputs alone to meet the grass N requirements over a long growing season where N is continuously removed during either grazing or cutting (Whitehead, 1995).

Within the Republic of Ireland, the input of fertiliser N to meet demand is adjusted to account for stocking rate (determined as either kg/ha of organic N deposited, or as LU/ha) in grazed grassland situations. N inputs are also limited within Ireland's Good Agricultural Practice (GAP) Regulations. Currently, N management in Ireland is based on a 'one soil fits all' philosophy for grassland which may not be the optimal approach due to the diverse range in net N mineralisation across soil types. Therefore, estimating the potential mineralisable N in soil over a growing season would be useful to improve fertiliser N advice and management. At present there is no method validated for accurately determining this soil N supply, but the research previously described that is being conducted in this area by Teagasc is aimed towards achieving this objective.

Nitrogen use on Irish dairy farms

Nitrogen use in Ireland declined from 443 kt in 1999 to its lowest level of less than 300 kt in 2012 (DAFM). The mean N fertiliser input on grassland was estimated to be 86 kg/ha in 2008. Across the grass based production systems, N use is highest on dairy farms (mean 134 kg/ha in 2008) with cattle and sheep farms applying much lower quantities of N fertiliser (mean of 43 and 40 kg/ha, respectively in 2008) (Lalor *et al,* 2010). In recent years the environmental performance and efficiency of different farming systems is under increased scrutiny as policy makers, consumers and NGO's seek indicators of improvements in sustainability (Brouwer, 1998; Halberg *et al*, 2005). Farm-gate nutrient balances and nutrient use efficiencies can act as such indicators (Oborn *et al,* 2003). Such nutrient accounting systems have been proposed as a means of assessing N management efficiency at farm level while also providing an indicator of environmental pressure.

In a recent national study of N use on Irish dairy farms Buckley *et al*, (2013) reported that chemical fertiliser was the dominant N import, accounting for 85% of total N imports (155 kg/ha) while milk was the primary N export through the farm gate from these specialist dairying systems, accounting for 75% (29 kg/ha) of total N exports. Average farm-gate N surplus was considerably lower and N use efficiency is considerably higher than results found in earlier smaller scale studies of intensive dairy farms across the Republic of Ireland. Results also suggest that there is significant potential for decreasing N surplus further on many farms while maintaining or increasing stocking rates and/or milk production per hectare.

A positive trend for improved N management on Irish dairy farms has emerged since the introduction of GAP Regulations in 2006, however, other factors including advisory contact and increased N fertiliser price, may also be contributing to this improvement. There is significant potential for decreasing N surplus further on many Irish dairy farms while maintaining or increasing stocking rates and/or milk production per hectare.

Managing nitrogen inputs on grassland farms

Efficient management of N on farms requires that N is supplied to the soil at a time and manner that ensures that as much N as possible is taken up by the growing grass sward. If the fertiliser N applied is not recovered by the grass over a relatively short period then it is more likely to be leached below the rooting zone where it is no longer available to the grass for uptake. As N fertiliser costs continue to increase, poor management leading to N loss will inevitably lead to a poorer return of investment. However, there is scope to improve N fertiliser efficiency and for cutting costs on most farms and planning ahead can make a big difference.

Timing N fertiliser applications

On grassland farms, the N management is important for maintaining a constant supply of good quality grass for grazing livestock. It is important to plan ahead to have optimum grass covers at each stage of the grazing season. A good start is important so plans for the first N application should be in place in advance of stock turn out. In the early spring grass growth is very dependent on soil temperature, and an adequate supply of N. Grass growth will commence once the soil temperature reaches about 5^{o}C, and a low rate (20-25 units) N application will help stimulate growth at this point. However care should be taken where a blanket application is being applied across a farm, as the utilisation of N applied may be poorer in fields with cold wet soils. It may be better to hold off applications on these fields until ground conditions improve.

The second application of N fertiliser should take place during March, between 4 to 6 weeks after the first application. At this stage, most if not all grazing livestock will be at grass so the N fertiliser application rate should be matched to the higher stocking rate. The third N fertiliser application should coincide with closing up for first cut silage in April.

An important part of any nutrient planning exercise is to stay within the total farm fertiliser allowance and to adhere to the fertiliser and slurry spreading dates required within the GAP Regulations.

Nitrogen application advice for dairy farms has been developed based on grass growth requirements and average net soil N mineralisation (Humphreys, 2009). Typical advice for dairy farms is shown in Table 1. Total annual rates as well as recommended rates throughout the season are included.

Table 1: Recommended rates of nitrogen fertilizer for grassland during the year where approximately half of the farm is cut for first-cut silage and the amount of second-cut is kept to a minimum (0 – 30% of the grassland area). Rates of nitrogen fertilizer are presented in kg/ha (units per acre in brackets) (Humphreys, 2009).

Stocking Rate (kg/ha organic N)	Jan/Feb	Mar	April	May	June	July	Aug	Sep	Total (kg/ha)	Total (u/ac)
155-170		28 (23)	43 (35)	34 (28)	34 (28)		25 (20)		164	(133)
170-180	28 (23)	28 (23)	43 (35)	34 (28)	34 (28)		25 (20)		192	(156)
180-190	28 (23)	37 (30)	49 (40)	34 (28)	34 (28)		34 (28)		216	(175)
190-200	28 (23)	49 (40)	49 (40)	34 (28)	34 (28)	34 (28)		25 (20)	253	(205)
200-210	28 (23)	49 (40)	51 (43)	49 (40)	34 (28)	34 (28)		25 (20)	270	(219)
211-250	28 (23)	43 (35)	43 (35)	34 (28)	34 (28)	30 (24)		25 (20)	247	(200)

Utilising slurry-N

In the past, slurry was applied after first cut silage in May and the remainder late in the year following the last grazing rotation on many farms. The contribution of N in slurry applied in summer is normally very low as low grass cover and high temperatures can lead to high N losses through volatilization. Many farmers are now applying slurry earlier in the year as the best response to N has been shown from slurry applied in spring (mid-Jan to April) when cool, damp, misty conditions prevail and grass is actively growing. The solid material in spring applied slurry has time to move into the soil and decompose, slowly releasing N and P over the remainder of the growing season. Where possible use watery slurry to replace N fertiliser applications in spring if ground conditions allow. An application of 2,500 gals/acre of slurry will supply approximately 15 units of N, 13 units of P and 75-95 units of K. Slurry is a cheap source of P and K, and should be used in fields with low soil P and K levels first. Dairy soiled water is also a good substitute for N fertiliser, and has been shown to have a nitrogen fertiliser replacement value of up to 80% when compared to CAN. An application of 2,500 gals/acre of soiled water will supply approximately 10 units N, 2 units of P and 13 units of K.

There are three opportunities when slurry application should be targeted in spring:

- Apply to around half the farm in late January – bearing in mind that this ground should be grazed for the following six weeks. Pick paddocks for slurry that have low covers and that will be grazed later in the first rotation. Use the spring rotation planner to pick paddocks. This approach works well where a contractor is brought in to apply a lot of slurry in one go.
- For paddocks grazed early in spring – apply slurry after the first grazing. Follow the cows with the slurry tanker. This works well on paddocks grazed in January and February. Bear in mind the date that you plan to finish the first rotation and stop spreading slurry six weeks in advance of this date.

- Apply slurry for first cut silage in late March or early April allowing six weeks before the intended date of silage harvest. Slurry tanks should be more-or-less empty at this stage. Where slurry is applied – cut back on fertiliser N accordingly.

A six week period is generally advised as a gap between slurry application and the next grazing or silage cut. Where band spreaders, trailing shoes or injectors are used, this period may be reduced as the herbage contamination is substantially reduced with these application methods compared with conventional splash plate.

Selecting N fertiliser type

Nitrogen fertilisers such as CAN (calcium ammonium nitrate) supply N both as nitrate and ammonium which are directly available for plant uptake. In contrast, all of the N contained in urea will be made available in an ammonium form. When urea is applied, it must first undergo hydrolysis which results in ammonium in the urea being made available for uptake. Ammonium is held quiet well in the soil and is less prone to being lost in drainage water compared to nitrate, which is loosely held and may leach freely with draining water. However, free ammonium in the soil that is not taken up by the grass roots will likely be converted to nitrate relatively quickly.

Urea works best under moist soil conditions which facilitates movement into the soil and breakdown to ammonium, which is more easily taken up than nitrate under colder soil conditions. Under these soil conditions the nitrate in CAN is more likely to be leached thus reducing its efficiency. Therefore urea has been traditionally used in spring for first two N fertiliser applications before switching to CAN. Urea application in warmer and drier conditions is generally avoided due the increased risk of ammonia volatilisation to the air. However, recent studies comparing CANwith urea show that annual grassland yields were broadly similar for both N types (Antille *et al,* 2012) with a small yield penalty using urea during the dry summer periods. This work indicates that urea can be a more cost effective N source (per kg N) than CAN depending on prices.

Conclusions

Managing the soil N supply with N fertiliser and manure inputs is a critical factor for productive and profitable grass based farming systems. Nitrogen is one of the largest input costs on intensive grassland farms, but has the potential to dramatically increase the supply of grass which is the most cost effective feed source on the farm. With evidence of large diversity in nitrogen mineralisation potential across our soil types, increased knowledge of soil specific N supply is needed. Tools such as soil based N tests are currently not available for use on farms, however, new research in this area looks promising. In the absence of such information, farmers should follow the current N advice which is tailored to the grass demand required at different stocking rates and to expected silage yield. Other tools such as the nutrient calculator wheel are also available to help calculate N requirements in a more user friendly manner.

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