Crops
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Programme

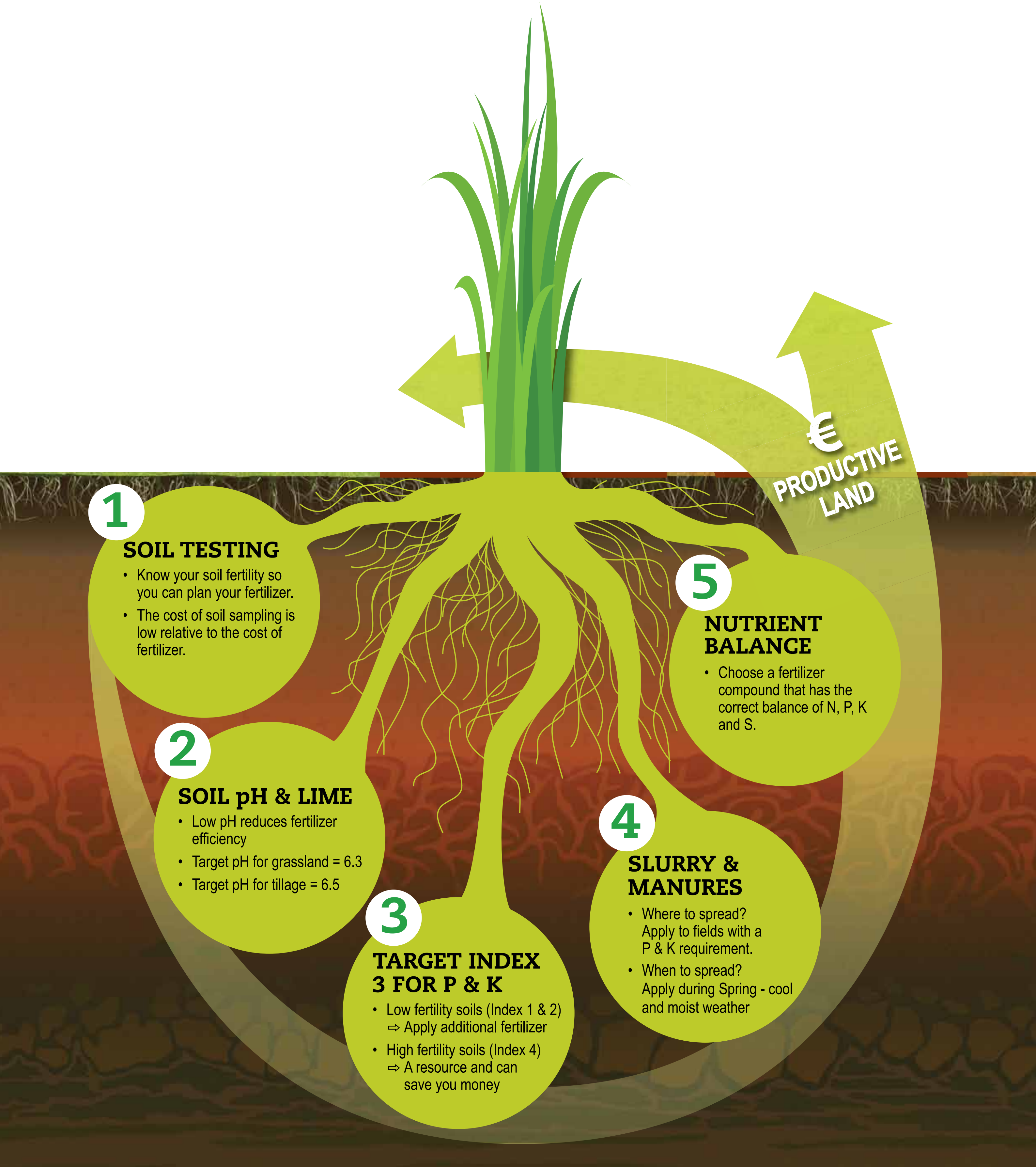
Soil Fertility Conference 2015

‘Fertiliser for growth in grassland farming systems’

Teagasc
Agriculture and Food Development Authority

SOIL FERTILITY

THE KEY TO GROWING YOUR PROFIT



Soil Fertility Conference 2015
'Fertiliser for growth in grassland farming systems'

Agriculture and Food Development Authority

Maximising farm productivity and profitability through efficient use of fertilisers in grassland farming systems

Launch of NMP Online
Farm Nutrient Management Planning System

Clonmel Park Hotel, Clonmel, Co Tipperary
Friday 16th October 2015
10.00 am to 4.00pm

Edited by David Wall, Mark Plunkett and Pat Murphy
Teagasc, CELUP, Johnstown Castle, Co Wexford

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CLAAS
JAGUAR

Soil Fertility Conference 2015
Fertiliser for growth in grassland farming system

Introduction

Teagasc welcomes you today to this event as part of the national soil fertility campaign. The theme of this event is maximising farm productivity and profitability through efficient use of fertilisers in grassland farming systems.

Grass-based dairy and dry-stock systems hold certain advantages over confined and high concentrate feeding systems in terms of lower cost structure; increased farmer control over feed supply, high quality of the milk and meat produced and increased levels of environmental sustainability. As many Irish dairy farms strive to increase their milk output per ha post milk quota, it is critical that Irish dairy maintains its 'green' image in order to compete in a fiercely competitive world dairy market. Good productive soils are the foundation of any successful farming system and key for growing sufficient high quality grass to feed the herd. Post quota, Irish dairy farmers are in a position to maximise the potential milk output from their farms and to achieve high grass growth rates over an extended season is needed. This places an increasing demand on soil nutrient supply. The ability of soils to supply nutrients at a time and in appropriate quantities for grass growth is a key determining factor of how productive a field or farm can be. Therefore, the management of soil fertility levels should be a primary objective of every dairy farm.

Soil fertility Management

Now is the time for farmers to make decisions regarding fertiliser and manure management strategies for their farms. High fertiliser prices and strict limits under the Nitrates Action Plan have led to decreasing trends in national soil fertility. A recent review of soils tested at Teagasc indicates that the majority of soils in Ireland are below the target levels for pH (i.e.6.3) or P and K (i.e. Index 3) and will be very responsive to application of lime P & K. On many farms sub-optimal soil fertility this will lead to a drop in output and income if allowed to continue. It is important to complete a farm fertiliser plan to guide fertiliser / manure decisions in 2016 and to avoid further decline in soil fertility levels.

During this Soil Fertility Conference Teagasc is highlighting 5 steps for effective soil fertility management:

1) Have soil analysis results for the whole farm.
2) Apply lime as required to increase soil pH up to target pH for the crop.
3) Aim to have soil test P and K in the target Index 3 in all fields.
4) Use organic fertilisers as efficiently as possible.
5) Make sure the fertilisers used are properly balanced.

The main focus of this event is to highlight and discuss issues related to good soil fertility management for maximising the productivity of our soils. For those farmers aiming to improve soil fertility on their farms, following these 5 steps provides a solid basis for success.

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9.00: Coffee on arrival

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10.00:	**Opening & Welcome** Paddy Browne Teagasc	
Session I.	**National Soil Fertility – Setting the scene** **Chair:** Liam Woulfe, Managing Director of Grassland AGRO	
10.10:	National Soil Fertility Trends Mark Plunkett, Teagasc	6
10.30:	NMP-Online- An integrated tool for adaptive nutrient management planning Pat Murphy Teagasc	8
10.50-11.30:	NMP Online & FAI Technical Bulletin Series launch	
Session II.	**New Developments in Soil Fertility Research** **Chair:** Harold Kingston, Chairman of IFA Environment and Rural Affairs Committee	
11.30:	Lime - the foundation for soil fertility David Wall, Teagasc	10
11.50:	Nutrient requirements for Grass Silage John Bailey, Agri Food and Biosciences Institute (AFBI), Northern Ireland	12
12.10:	Taking a fresh look at urea performance in grassland Patrick Forrestal, Teagasc	14

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12.30 – 13.30: Lunch

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Session III.	**Soil Fertility Research into Practice** **Chair:** Sean Molloy, Director of Strategy Glanbia Ingredients Ireland	
13.40:	The slurry hydrometer – Do farmers view it as a useful decision support tool for nutrient management? Cathal Buckley, Teagasc	16
13.50:	Fertilising grass-clover swards for pasture-based milk production systems Brian McCarthy, Teagasc	18
14.00:	Pig manure –a valuable fertiliser for grassland Gerard McCutcheon, Teagasc	20
14.10:	The Global Fertiliser Supply Chain and future market outlook Eoin Lowry, Irish Farmers Journal	22
14.40:	Fertiliser use on commercial dairy farms James Humphreys (Teagasc)	26
15.00:	Ag Catchments Programme: On-farm Nutrient management planning Noeleen McDonald, Teagasc	28
15:20:	Heavy Soils Programme: Building soil fertility on wet farms Ger Courtney, Teagasc	30
15.40:	Q&A	
16.00:	Conference Close	

National Soil Fertility Status and Trends

Mark Plunkett, P. Murphy and D.P. Wall

Teagasc, CELUP Johnstown Castle, Co Wexford.

Summary

- Nationally, 90% of grassland soils have sub-optimal soil fertility (good overall soil fertility for grassland = pH >6.2, P & K Index 3)
- Soil test results indicate that up to 70% of dairy and dry-stock soils have a large requirement for lime.
- Over half of soils tested have very low to low P (54%) and K (50%) status (P index 1 or 2) in 2014.
- Soil test results showed a very rapid decline in soil P and K levels between 2008 and 2011 however, these trends appears to have stabilised in the last 2 years.

Introduction

Soil test results indicate that soil fertility levels are declining as a result of the reduction in fertiliser usage in recent years. This is occurring across all farming enterprises. Currently, data from soil samples analysed by Teagasc, indicate that only 1 in 10 grassland soils have the optimum balance of phosphorus (P), potassium (K) and pH status (i.e. Index 3 for P & K, and pH > 6.2, Figure 1) to maximise grass production annually.

Soil pH and Lime

Currently approximately two thirds of soils nationally have sub-optimal pH status. Results from Teagasc show the majority of soils have had lower than desired soil pH status for a number of years indicating the requirement for lime applications on most farms (Figure 2). These soil test results indicate a large requirement for lime on dairy and drystock farms (65% and 69% soil tested have pH <6.2). Lime has a major role in regulating nutrient cycling in soils. For example, grassland soil maintained at the optimum pH can release up to 80 kg/ha/year of N from the soil. Low soil pH can negatively affect the efficiency and availability of freshly applied P and K as either fertilisers or organic manures.

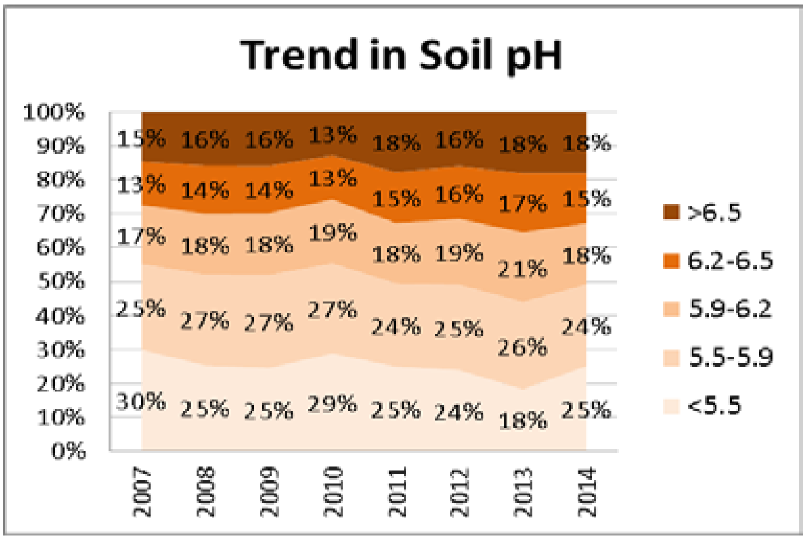

Figure 1. *Percentage of all grassland soils tested falling within defined soil pH ranges between 2007 and 2014.*

Phosphorus (P)

Since 2007 the proportion of soils tested, across dairy and dry-stock enterprises, with low soil P fertility (i.e. P index 1 or 2) have increased to approximately 55 % in 2014 (Figure 2). A sharper decline in soil P fertility occurred between 2008 and 2012, most likely triggered by the lowest national P fertiliser sales recorded in 2008 and 2009 for the previous two decades. This overall trend reflects the soil P fertility status on dairy and dry-stock farms, and indicates a serious loss in potential productivity. Since 2012 this declining trend in soil P has stabilised. Currently approximately 1 in 4 of the soils tested have target soil P fertility status (i.e. P Index 3) with and a further ~20% of soils tested having above optimum P levels,

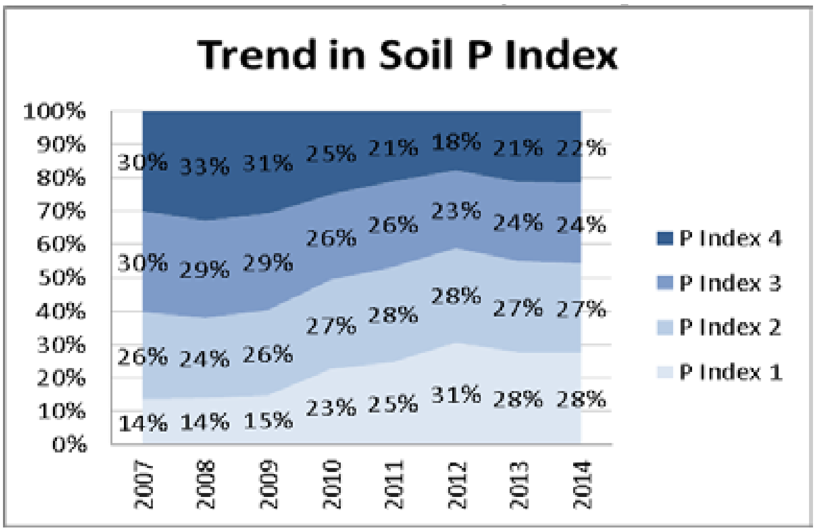

Figure 2. *Percentage of all soils tested falling within each soil P index (1-4) between 2007 and 2014*

Potassium (K)

This analysis shows that the trend in soil K status, across dairy and dry-stock enterprises, broadly mirrors that for P. Despite no legislative limits on K fertilisers, K usage dropped in line with P fertiliser applications especially in 2008 and 2009. Consequently soil test results indicate a sharp increase in soils with low K status between 2008–2011 (i.e. samples with K index 1 or 2) however, this trend has stabilised in recent years. In 2014 approximately half of the soil samples tested by Teagasc had very low to low soil K status (i.e. K Index 1 or 2)

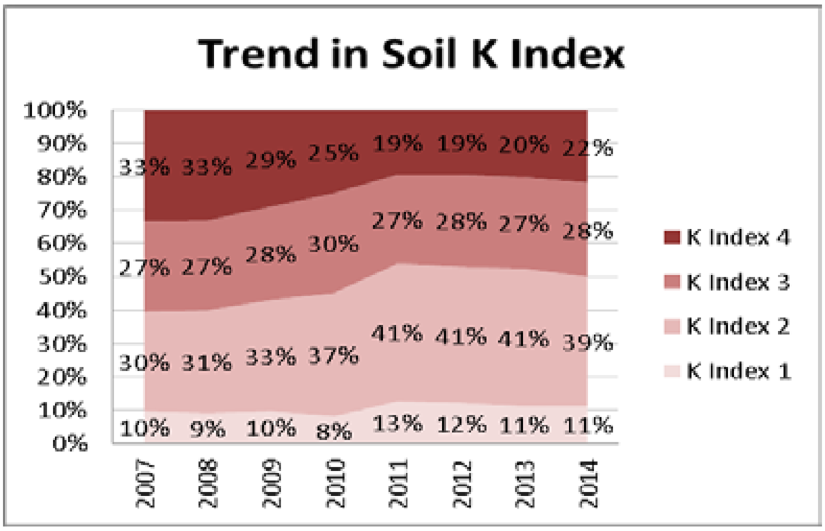

Figure 3. *Percentage of all grassland soils tested falling within each soil K index (1-4) between 2007 and 2014*

NMP-Online- An integrated tool for adaptive nutrient management planning

Pat Murphy[1], S.T.J. Lalor[3], S. Mechan[2], M. Plunkett[1] & D.P. Wall[1]
[1]Teagasc, CELUP, Johnstown Castle, Co Wexford, [2]Teagasc, Agricultural Catchments Programme, Johnstown Castle, Co Wexford, [3]*Grassland AGRO, Dock Road, Limerick*

Summary

- The combined effect of the implementation of the Water Framework / Nitrates Directives and the increase in fertiliser prices has made effective nutrient management difficult at farm level
- Regulatory based NMP tools have proven to be ineffective in communicating with farmers
- Farmers indicated a clear preference for map based outputs
- NMP online has been developed to meet the regulatory requirements while at the same time delivering map based outputs to clearly set out action plans for farmers
- NMP Online will be available to all agricultural professionals for use on Derogation and GLAS nutrient management plans.

Introduction

Nutrient management planning has become a key skill for farmers, one which is essential in the achievement of a balance between achieving high levels of output and protection of the environment. In the past the task was relatively straightforward based on following recommendations from a soil sample results. However, environmental regulation and the increase in price of fertiliser have been game changers. A new approach is needed which delivers effective nutrient management planning meeting both regulatory requirements while facilitating farmers in implementing those plans at farm and field levels. NMP Online has been developed to meet this need

The Problems

The introduction of the Water Framework and Nitrates Directives were a game changer for nutrient management on Irish farms. They set strict limits on the amounts of nutrients that could be used and on the timing of their application. From a farmers perspective the regulation shifted the focus from a field by field approach to nutrient management recommendations proofed against overall farm limits, based on farm gate inflows and outflows of nutrients. This created the need for complex computational systems and outputs.

The falling trend in soil fertility represented a significant threat to expansion of the Agri-food industry. Teagasc implemented a soil fertility campaign in 2012 to tackle the issue and to support improved nutrient management at farm level. The drop in fertility was largely blamed on a combination of regulation and fertiliser price increases. An examination of case studies where soil fertility had fallen estimated that the third factor in the equation related to farmers capabilities in relation to nutrient management and in their willingness to fully utilise the level of allowable nutrient. The same study identified that only a small proportion of farmers with nutrient management plans for statutory purposed used them for agronomic purposes. The clear implication was that the nutrient management plans that were being prepared for farmers, involving considerable expense for farmers, were not fit for purpose, in that they were not effective in communicating to the farmers for which they were prepared.

Development of NMP Online

In an exercise co-ordinated by staff from the Agricultural Catchments Programme, farmers and their advisers were asked in focus groups to indicate how nutrient management plans could be made more usable. Their answer was clear, indicating that a map based output was required to enable farmers to understand and follow nutrient management plans. Figure 1 sets out an example of the type of mapping solution suggested by the group, in this instance to indicate soil P levels.

Teagasc has undertaken the development of NMP Online to meet a number of key criteria including:

- Ease of use
- Integration of nutrient advice from the Teagasc Green Book
- Integration with DAFM data for land parcels and animal numbers
- Capability to import soil analysis results
- Flexible plan formats to include Agri-environmental schemes and Derogation
- A statutory record of nutrient usage
- Farm facilities computation and mapping
- Map Based outputs for farmers

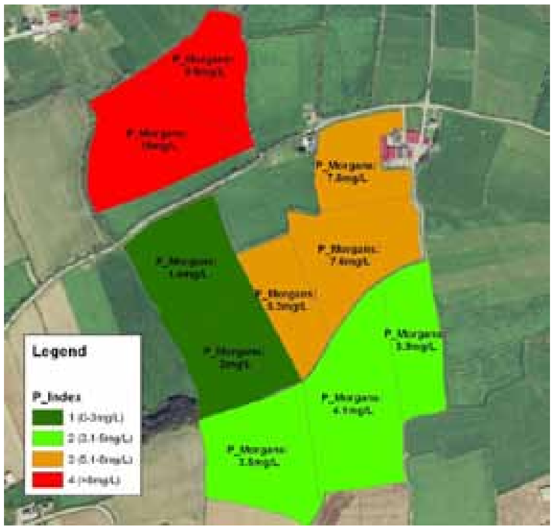

Figure 1. Farm map with colour coded soil test P results according to P index

NMP Online is being launched at the Soil Fertility conference in October 2015. It will begin operation in November following the provision of training to users. Teagasc will provide comprehensive training for users and on going back-up in relation to training and support in soil fertility and nutrient management. The ultimate objective of the NMP Online is to deliver production and environmental outcomes through better soil fertility management across all farms based on improved utilisation of organic manures, increased lime utilisation and effective use of the chemical fertiliser input.

Conclusions

The current poor fertility status of soils in Ireland poses a significant threat to the achievement of growth targets for the industry. The challenge facing the industry is to improve soil fertility while at the same time achieving environmental objectives. This can only be achieved by improving nutrient management planning at farm level, which in turn can only be achieved if farmers have a good understanding of the principles of soil fertility management and a clear understandable plan for its implementation. NMP Online is a first step to achieving this.

Lime - the foundation for soil fertility

David P. Wall[1], T. Sheil[2], S.T.J. Lalor[3] & M.Plunkett[1]
[1]*Teagasc, Johnstown Castle, Co Wexford*
[2]*Alltech Crop Science, Dunboyne, Co Meath*
[3]*Grassland AGRO, Dock Road, Limerick*

Summary

- Aim to maintain a soil pH 6.3 to 6.5 on mineral soils
- Always apply lime as recommended on the soil test report

Liming acidic soils to correct soil pH will result in the following;

- Increased grass and crop production annually
- Increase the release of soil N by up to 80kgN/ha/year
- Increase the availability of soil P and K and micronutrients
- Increase the response to freshly applied N, P & K as either manures or fertiliser

Introduction

As the majority of agricultural soils in Ireland are naturally acidic (low soil pH) it is critical that lime is applied to restore more neutral pH conditions which are more favourable for nutrient release and grass and crop production. Soil pH is a measure of acidity or alkalinity of a soil. When soil pH is low (more acid pH <6.0), grass yields may be reduced or reseeds may fail due to high levels of aluminium (Al) and manganese (Mn) interfering with root growth and nutrient uptake. On mineral soil types a target soil pH of 6.3 is recommended for grassland. Peat soils have lower quantities of Al and Mn present and therefore the target soil pH required is lower at pH 5.5. In recent years there has been a declining trend in soil pH on Irish farms and currently approximately 60% of soils have sub-optimal soil pH levels (i.e. soil pH less than 6.3). With the majority of agricultural soils nationally at low soil pH status the under application of lime is likely costing farmers dearly in terms of grass yield and quality.

Increasing soil nutrient availability

Lime is a soil conditioner and corrects soil acidity by neutralising the acids present and allowing the micro-organisms and earthworms to thrive and break down plant residues, animal manures and organic matter. This helps to release stored soil nutrients such as nitrogen (N), phosphorus (P), potassium (K), sulphur (S) and micro-nutrients for plant uptake. In addition, ryegrass and clover swards will persist for longer after reseeding where soil pH has been maintained close to the target levels through regular lime applications. For example, grassland soils receiving regular lime applications have been shown to release up to 80kg/ha additional N compared to un-limed acid soils.

Recent research from Johnstown Castle clearly shows the importance of lime in relation to the availability of soil P reserves and improved efficiency of freshly applied chemical P fertiliser. Figure 1 shows the benefits of lime for unlocking soil P and is the first step to consider when setting out to building-up soil P levels. Figure 2 shows the grass yield response to lime and P fertiliser in grassland. The application of 5t/ha ground limestone produced similar grass yields compared to the application of 40 kg/ha P fertiliser alone. However, the addition of lime + P fertiliser in combination produced the largest grass yield response (1.5

t/ha more grass than the control). These results show how effective lime is for increasing the availability of both stored soil P (from previous fertiliser and manure applications) and freshly applied fertiliser P.

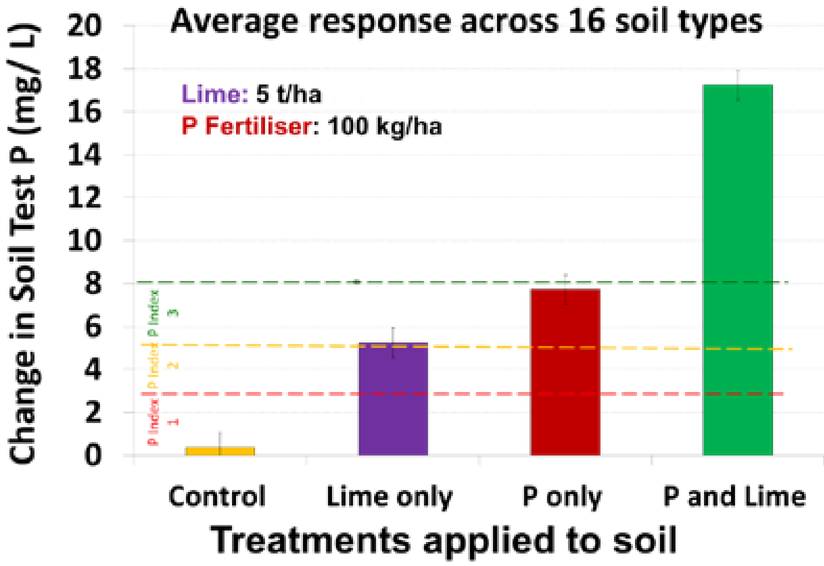

Figure 1. Average change in soil test P (Morgan's) across 16 soils (av. pH 5.5) treated with Lime (5 t/ha of lime), P fertiliser (100 kg/ha of P), and P + Lime and incubated over 12 months in controlled conditions

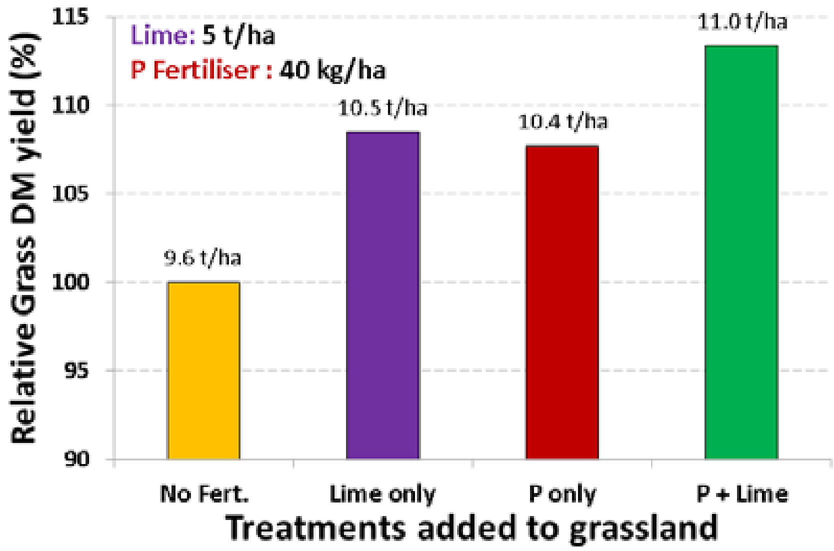

Figure 2. Relative grass DM yield response in grassland treated with Lime (5 t/ha of lime), P fertiliser (40 kg/ha of P), and P + Lime over a full growing season

Management tips to increase lime efficiency

Apply lime based on the soil test report to achieve the target soil pH of 6.3 for grassland. Split lime applications when required rates exceed 7.5 t/ha and reduce lime rates on high molybdenum (Mo) levels so that soil pH does not exceed 6.2. This will help reduce the Mo uptake into grass which can induce copper deficiency in ruminant animals. Ground limestone is the most cost effective source of lime and can be applied throughout the year when the opportunity arises. Maintaining soil pH at the target level will increase the release of nutrients from the soil and up to 80 kg/ha additional N release has been shown over the growing season. Lime is the foundation of soil fertility and is a primary step to take when correcting soil fertility.

Nutrient management for sustainable grass silage production

John Bailey
Agri-Food and Biosciences Institute (AFBI), Newforge Lane, Belfast BT9 5PX.

Summary

- Grass silage is a valuable feed, but poor nutrient management is hampering its production and also jeopardising animal health and environmental quality
- Better distribution of manure phosphorus (P) and potassium (K) across grassland platforms based on regular soil testing, is needed to improve grass production, reduce animal health problems and improve environmental quality
- Sulphur (S) containing fertilisers should be applied routinely to ALL silage swards in SPRING to prevent yield losses worth up to €100/ha/cut
- Optimising nitrogen (N) inputs is essential to maximise forage production and quality (14% protein) and minimise N losses to the environment

Introduction

Grass silage is a valuable farm resource worth up to €150/t DM as a ruminant feed. Well managed grassland can produce in excess of 16 t DM/ha annually. However, on many farms, less than half this level of production is being achieved largely because of poor nutrient management, which not only curtails grass production, but also jeopardizes animal health and performance and poses a threat to the environment.

Improve manure P and K distribution

Uneven distribution of P and K across grassland platforms is a major problem, particularly intensive dairy farms, and has arisen because of applying manures to fields closest to farmyards, and a general lack of soil testing. This results in some fields having very high soil P and K levels (Figure 1). Excessive levels of soil P increase the risk of P entering rivers and lakes, and excessive levels of soil K can result in luxury K uptake and heightened risk of grass tetany and milk fever in cattle. In contrast, fields and land parcels at greater distances from farmyards often have sub-optimal soil P and K levels (Figure 1), and can be low-yielding owing to P or K deficiencies. Regular soil testing should be carried out (pH, P and K), and manures (and fertilisers) applied to meet, but NOT exceed, crop requirements.

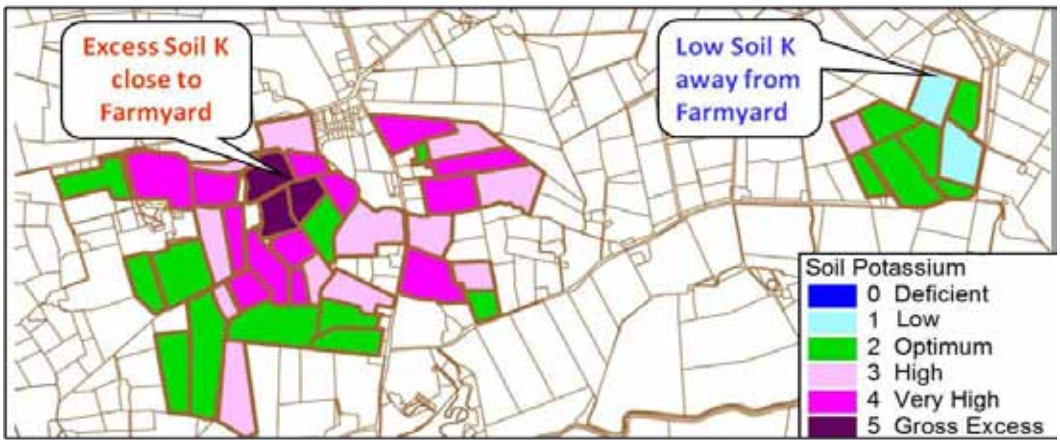

Figure 1 Soil K distribution across a typical intensive dairy farm in Northern Ireland

Prevent S deficiency

Because of declining inputs of S from the atmosphere and in fertilisers, soil S reserves are insufficient to support grass production on large areas of Irish grassland but particularly during the EARLY part of the growing season. Out of 67 dairy farms in Northern Ireland (NI) surveyed recently, 49 had swards testing as S deficient at 1st cut in April/May (Figure 2). While sands, shallow soils and sandy loams with low organic matter levels are generally most prone to S deficiency, S deficient swards (Figure 3) are now occurring on all soil types, including heavier textured clays and clay loams.

Figure 2. 49 farms with S-deficient swards in spring

Figure 3. S-deficient swards

It is recommended that 25 kg SO_3/ha should be applied routinely as fertiliser to ALL silage swards in spring. This moderate dressing of S, which costs about an extra €6/ha, should not be detrimental to livestock and has the potential to prevent yield losses worth up to €100/ha. Sulphur-containing fertilisers should also be applied routinely for 2nd and 3rd cut silage crops on land that has received little or no slurry or where soils are shallow or sandy in texture.

Optimise N inputs

Optimising N inputs as fertiliser and manure is essential to maximise forage yield, maintain adequate protein contents (14% DM), and reduce N losses to the environment. On land receiving regular slurry applications, too much N may be applied for 1st cut, and too little for 2nd and 3rd cut crops. Based on recent research in NI, it is recommended that 115 kg N/ha is sufficient for 1st cut crops, followed by 125 kg N/ha and 100 kg N/ha for 2nd and 3rd cut crops, while making allowance for the N applied in manures. Care should be taken, to ensure that the N limit for the entire grassland area (Nitrates Action Programme) is not exceeded.

Conclusions

Sustainable grass silage production will not be achieved until regular soil testing becomes the established practice on grassland farms, to show where manure may be applied to meet crop P and K requirements, and where it should be withheld to reduce the risk of environmental and animal health problems. Sulphur deficiency, once mainly a problem for 2nd and 3rd cut silage crops, is now manifesting at 1st cut, and is best addressed by routinely applying S-containing fertilisers to ALL grassland in early spring, even where manures have been applied. Finally, research has indicated that 1st cut silage may be over-supplied with N on land with a history of manure application, whereas 2nd and 3rd cut crops can respond to higher rates of N than typically applied.

Taking a fresh look at urea

Patrick.J. Forrestal[1], M. Harty[1], G.J. Lanigan[1], D.P. Wall[1], D. Krol[1], J. Murphy[1], D. Hennessy[2], R. Carolan[3], K. McGeough[3], C.J. Watson[3], K.G. Richards[1]
[1]Teagasc, Johnstown Castle, Co Wexford, [2]Teagasc Moorepark, Co Cork,
[3]Agri-Food and Biosciences Institute (AFBI), Newforge Lane, Belfast BT9 5PX.

Summary

- Urea [46% nitrogen (N)] is more widely available than calcium ammonium nitrate (CAN) internationally
- Urea rapidly converts to ammonium-N and then to nitrate-N. Both ammonium-N and nitrate-N are crop available
- Urea is susceptible to ammonia (NH3) loss during its conversion to ammonium-N
- As the N rate increases the percentage of NH3 loss from urea increases
- Spring: Dry-matter yield with urea was slightly better than CAN at low application rates, but this advantage declined with increasing N rate
- Summer: Dry-matter yield with urea was comparable to CAN, particularly at low rates but the gap in performance widened at high rates
- Urea stabilised with N-(n-butyl) thiophosphoric triamide (source KaN) reduced NH3 losses from urea by 78.5%
- CAN had the highest and most climatically sensitive emissions of the greenhouse gas nitrous oxide (N2O)

Introduction

Nitrogen addition is a key input for optimising crop production, including grass production. Calcium ammonium nitrate (CAN) and urea are the main straight fertiliser N addition options used in Ireland. Bear in mind that if other aspects of soil fertility and pH are not optimum and swards are not vigorous, no N source will provide its full benefit. In Ireland CAN dominates the straight N market. In New Zealand, which has similar grass based production systems, urea dominates the straight N market. Globally, fertiliser N consumption is dominated by urea.

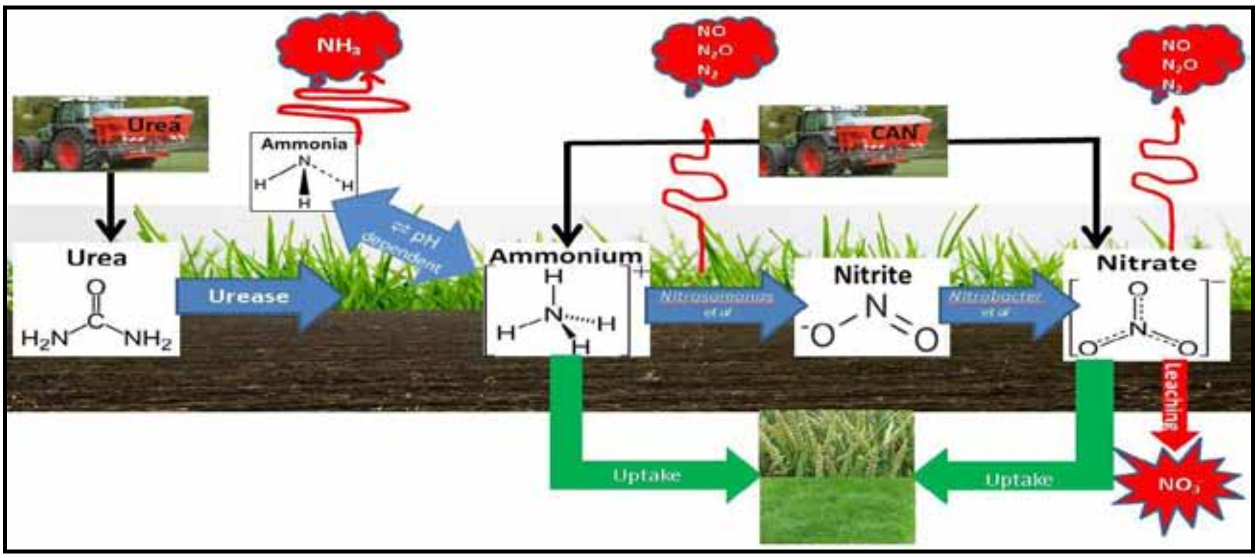

Figure 1 Urea, ammonium-N and nitrate-N uptake and loss pathways (simplified)

Recent field work

Teagasc and the Agri-Food and Biosciences Institute evaluated the performance of urea, CAN and stabilised urea during 2013 and 2014 with 30 separate side by side applications in spring and summer. Stabilisers are compounds which can be incorporated with the fertiliser granule to alter the rate of the transformation in Figure 1. They potentially reduce N losses and improve crop performance. This work was undertaken as part of Department of Agriculture, Food and the Marine Stimulus funded projects focused on understanding losses of NH_3 and the greenhouse gas N_2O (Figure 1) and crucially developing viable solutions to underpin sustainable intensification.

Yield performance

Combining the recent work with data from field trials conducted between 1976 and 1981 (Murphy, 1983) shows that urea performance relative to CAN is stronger in spring than in summer (Figure 1). There is a trend for urea performance relative to CAN to decline with increasing N rate which is related to NH_3 loss.

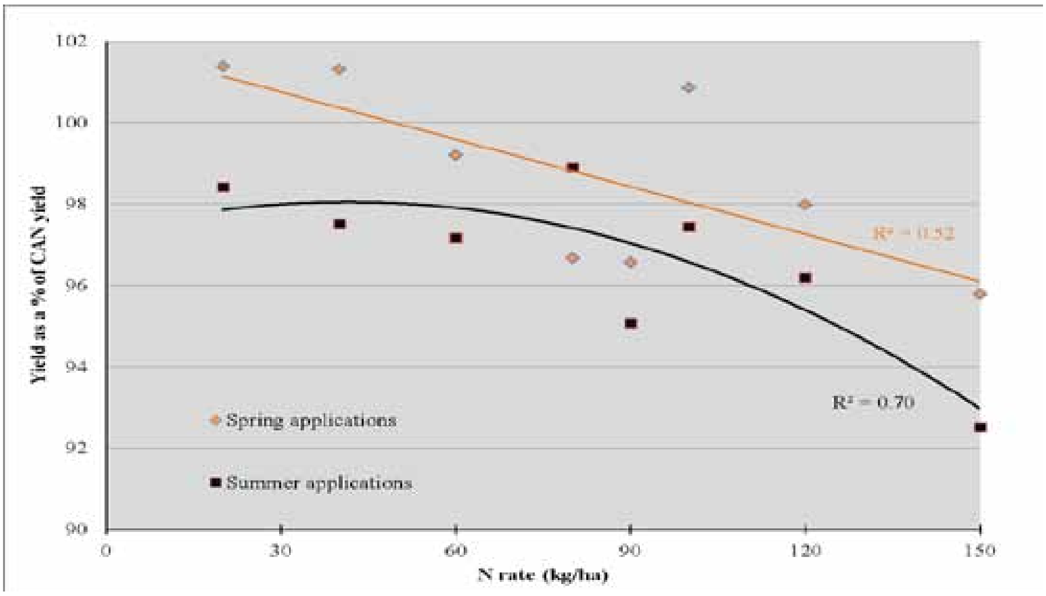

Figure 2 Grass dry matter yield for spring and summer applied urea as a percentage of CAN yield

Ammonia loss

Trial data from 2014 showed than the percentage NH_3 loss from urea increased with increasing N rate. Additionally, ammonia loss from urea occurs rapidly, usually reaching maximum rates in the second day after application over a range of weather conditions. Urea stabilised with N-(n-butyl) thiophosphoric triamide (source KaN) reduced ammonia losses from urea by 78.5%.

Greenhouse gas nitrous oxide

Urea and particularly stabilised urea reduced N2O emissions compared with CAN which had the highest and most climatically sensitive emissions profile.

Conclusion

Urea is a viable N source for Irish agriculture, one which is more abundantly available on world markets than CAN. Urea introduces uncertainties in terms of ammonia loss and more work is needed in this area. However urea stabilised with the urease inhibitor **N-(n-butyl) thiophosphoric triamide** effectively controls this loss, resulting in dry-matter yield which is comparable to CAN, but with lower greenhouse gas emissions.

Is the slurry hydrometer a useful decision support tool? A case study across the Agricultural Catchments Programme

Cathal Buckley
Agricultural Catchments Programme, Teagasc, Athenry, County Galway.

Summary

- This case study involves the introduction of the slurry hydrometer tool across a sample of farmers participating in the Teagasc Agricultural Catchments Programme.
- A high proportion of farmers indicated that the slurry hydrometer was easy to use, useful in decision making, complementary to existing practices and was likely to aid productivity and profits.
- A high proportion of farmers also indicated that they would continue using the slurry hydrometer and would recommend its use to other farmers.
- Results from the case study indicated that between 24-32% of the time, results from the slurry hydrometer tool were in line with farmer expectations in terms of nutrient content of slurry. However, only 44% of farmers indicated changing the slurry application rates post hydrometer use even though nutrient content results varied from expected values 68-76% of the time.

Introduction

This case study assesses the ease of use and usefulness of the slurry hydrometer as a decision support tool across a cohort of farms participating in the Teagasc Agricultural Catchments Programme. Chemical fertilisers and livestock manures are both sources of nutrients (nitrogen (N) & phosphorus (P)) in agricultural production and are substitute products. The N and P content of chemical fertiliser are well defined at manufacturing level and are priced on this basis; this is not the case for organic manures. Research has shown that the nutrient content of cattle slurry can be highly variable. This can result in over or under application of nutrients at field level with agronomic and environmental consequences. Slurry dry matter content is a good predictor of nutrient content. The hydrometer tool provides a reliable method of obtaining instant estimates of nutrient concentrations based on DM content after slurry agitation and prior to spreading. Use of the hydrometer can potentially improve the precision of slurry allocation. This improved accuracy in managing the applied nutrients has the potential to improve economic returns for the farmer, increase nutrient use efficiency and reduce the risk of nutrient loss to water thus delivery financial and environmental benefits. To date, the use of the slurry hydrometer has not been widely promoted among farmers in Ireland.

Methodology

The target group in this study included a sample of farmers participating in the Teagasc Agricultural Catchments Programme (ACP). The ACP is an integrated research and advisory based programme which was set up to evaluate the effectiveness of measures introduced under the EU Nitrates Directive across the Republic of Ireland. The ACP works with circa 300 predominantly family farms, spread across six catchments. In this context, this case study supplied a group of farmers (25) across the 6 catchments in the ACP with slurry hydrometers and supporting materials around how to use as well as interpretation of results. These farmers were selected based on quantities of organic manures used on farm and willingness to partake in the study. Each was approached by their ACP agricultural advisors and asked to trial the hydrometer in the first half of 2015. Farmers were subsequently contacted at the end of this period and were interviewed including a series of open and closed ended questions around the use of the hydrometer.

Results

In all 84% of farmers in the case study agreed or strongly agreed with the statement "*The slurry hydrometer is easy to use*" and a total of 96% of farmers who trialled the hydrometer agreed or strongly agreed with the statement "*Results from the slurry hydrometer are easy to understand*". Having trialled and assessed the hydrometer, farmers evaluated it positively as 88% plan to "*use the slurry hydrometer for nutrient management decisions making again in the next 12 months*" and 92% of farmers in the case study "*would recommend the use of a slurry hydrometer to other farmers*".

Farmers are only likely to persist with the technology if it's an improvement on existing practices and a total of 84% of farmers in the case study either agreed or strongly agreed with the statement "*Use of a slurry hydrometer is better than what it replaces*". Results also indicate that 60% of case study farmers agreed or strongly agree with the statement "*Use of a slurry hydrometer fitted well with my existing farm practices*". Finally, farmers are likely to persist with the technology if it improves outcomes on the farm and a total of 76% of farmers agreed or strongly agreed with the statement "*Use of a slurry hydrometer will help increase my profits*" and 72% agreed or strongly agreed with the statement "*Use of a slurry hydrometer will increase productivity on my farm*".

Results from the case study indicated that between 24-32% of the time results from the slurry hydrometer tool were in line with expected values in terms of the nutrient content of slurry. Hence, farmers would be expected to adjust application rates on the basis of this result as in 68-76% of cases results differed from expected values. This was not ubiquitously observed as 44% of farmers indicated changing they slurry application rates post hydrometer use. This indicates an immediate response to the information provided by the hydrometer technology in some instances, and that it may take extended use and/or advisor interaction for others to change application rates on the back of hydrometer results. However, a number of farmers commented on the how the use of the hydrometer had increased their awareness of the nutrient value of organic manures and gave a very good indication of right levels of organic manures to be applied. Others commented that it had improved resource use and led to savings on chemical fertilisers by using lighter application rates leading to more efficient use of resources. Some farmers stated that the tool validated what they were doing in terms of organic manure application and recommended the tool for further use among the farming community.

Conclusions

Farmers in the case study trial generally found the slurry hydrometer easy to use and useful in decision making. Use of the hydrometer tended to complement existing practices and was seen as a potential aid to productivity and profitability. Results provided by the hydrometer in the majority of cases tended to differ from farmer expectations in terms of the nutrient content of their slurry. The majority of farmers amended application on the back of this results but a significant cohort did not. Additional research is required to explore this behaviour.

Fertilising grass-clover swards for pasture-based milk production systems

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Summary

- In grazed plots, grass-clover swards increased grass dry matter (DM) production by 2.9 t DM/ha compared with grass only, regardless of N fertiliser application rate
- In farmlet studies, grass-clover swards increased grass DM production by 0 to 2.5 t DM/ha
- Grass-clover swards increased milk solids production by 33 to 55 kg/cow
- Grass-clover swards, in combination with varying levels of inorganic nitrogen (N) fertilisers, offer the potential to increase both animal and grass DM production

Introduction

Grass-based production systems rely on highly productive perennial ryegrass (*Lolium perenne* L.) swards to achieve long grazing seasons in order to meet animal feed requirements. Forage legumes offer the opportunity to increase the performance of grass-based production systems and consequently there is renewed interest in forage legumes, such as white clover, (*Trifolium repens* L., henceforth clover). Traditionally, in mixed perennial ryegrass clover swards, inorganic nitrogen (N) fertiliser inputs are reduced, due to the ability of clover to replace inorganic N with symbiotic N fixation. However, there may be opportunities to combine high inputs of inorganic N with clover swards to increase the productivity of grass-based production systems in terms of both milk and grass dry matter (DM) production.

The interaction between N fertiliser application and grass-only and grass-clover swards

A plot experiment established in May 2009 investigated the effect of N fertiliser application rate on grass DM production and sward clover content. The treatments consisted of two sward types (grass-only and grass-clover) and five fertiliser application rates (0, 60, 120, 196 and 240 kg N/ha per year) and measurements were taken from 2010 to 2013. Regardless of N fertiliser application rate, grass DM production increased by 2.9 t DM/ha when clover was included in the sward (Table 1). As fertiliser N application rate increased, average annual sward clover content decreased from 33.3% when 0 kg N/ha was spread to 19.6% when 240 kg N/ha was spread. The average amount of N fixed by the grass-clover swards was 161 kg DM/ha however, as the N fertiliser application rate increased, N fixation decreased.

Table 1 Average annual grass production (t DM/ha) and average sward clover content (%) from grass-only and grass-clover swards receiving 0, 60, 120, 196 and 240 kg N/ha per year between 2010 and 2013

	N application rate				
Grass production (t DM/ha per year)	0	60	120	196	240
Grass-only	9.1	9.2	11.0	11.3	12.6
Grass-clover	13.3	13.1	13.1	13.8	14.4
Sward clover content (%)	33.3	30.6	27.0	21.7	19.6
N fixation (kg N/ha per year)[1]	220	205	148	122	112

[1]Average of 2011 – 2013.

Farmlet experiments investigating the impact of clover on spring milk production systems

Two recent experiments have been undertaken in Ireland investigating the use of clover in intensive grazing systems. The first experiment was established at Teagasc, Moorepark, Fermoy, Co. Cork, in January 2013. It is a systems experiment with three treatments, a grass-only sward receiving 250 kg N/ha (Gr250), a grass-clover sward receiving 250 kg N/ha (Cl250) and a grass-clover sward receiving 150 kg N/ha (Cl150). Treatments were stocked at 2.74 cows/ha and rotationally grazed in 2013 and 2014. The second experiment was established at Teagasc Agricultural College, Clonakilty, Co. Corkin January 2014. The experiment is also a systems experiment, with four treatments, a tetraploid only sward (TO), a diploid only sward (DO), a tetraploid with clover sward (TC) and a diploid with clover sward (DC). Treatments were stocked at 2.75 cows/ha and rotationally grazed in 2014. All four treatments received 250 kg of inorganic N fertiliser per ha. Grass DM production results from both experiments are presented in Table 2. Sward clover content ranged between 24% and 40% on the clover treatments in both experiments. Including clover into perennial ryegrass swards increased grass DM production in the Clonakilty experiment by 2.5 ton DM/ha in 2014, regardless of grass ploidy. Although there was no difference in grass DM production between the three treatments in the Moorepark experiment over two years. It is interesting to note that, at Moorepark, the Cl150 treatment had the same herbage DM production as the Gr250 and Cl250 treatments despite receiving 100 kg N/ha less than Gr250 and Cl250. Milk and milk solids production per cow were greater on the grass-clover swards compared with the grass-only swards in both experiments (+ 306 and + 647 kg of milk and + 33 and + 55 kg of milk solids on the Moorepark and Clonakilty experiments, respectively).

Table 2 Grass production results from both the Moorepark (2013 and 2014) and Clonakilty (2014) experiments

	Treatment[1]			
Moorepark Experiment	Cl150	Cl250	Gr250	-
Clover content (%)	26.6	22.5	-	
Grass production (t DM/ha)	14.4	14.3	14.2	
Clonakilty Experiment	TO	DO	TC	DC
Clover content (%)	-	-	39.1	40.3
Grass production (t DM/ha)	14.9	14.8	17.5	17.2

[1]Cl150 = grass white clover 150 kg N/ha, Cl250 = grass white clover 250 kg N/ha, Gr250 = grass only 250 kg N/ha, TO = tetraploid only; DO = diploid only; TC = tetraploid + clover; DC = diploid + clover

Conclusions

In conclusion, incorporating clover into grass-based milk production systems in conjunction with high levels of inorganic N offers an opportunity to increase animal performance and in some circumstances increase grass DM production in high stocking rate grass-based milk production systems. Clover may also offer the opportunity to strategically reduce inorganic N input to high stocking rate grass-based systems. The experiments from which results are presented here are in their infancy and must be undertaken for 5 to 6 years to allow a comprehensive analysis of the impact and role of clover in grazing systems.

Pig Manure -A valuable Fertiliser

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Summary

- Pig manure is a valuable organic fertiliser source when used to offset chemical fertiliser inputs
- The nutrient content of pig manure is dependent of its dry matter content, where good quality manure contains >5% solids.
- The slurry hydrometer is an effective tool to measure the nutrient content manures and to calculate its value
- On average 1000 gallons/ha of pig manure has the nutrient content equivalent to one 50kg bag of 19-7-20 (N-P-K)
- An up to date fertiliser plan is required when importing pig manure to maximise its benefits.
- As fertiliser prices increase, the value of manures also increases and manure transport over longer distances becomes economical.

Introduction

It is well known that farmers can make substantial savings in fertiliser costs by using pig manure to grow their grass and tillage crops. Pig slurry is an organic fertiliser and its value is based on the nutrients that it can supply for crop growth. Most of the pig manure available in this country is in the liquid form (slurry).The nutrient content is closely related to the solids or dry matter content. The solids content is variable depending mainly on the amount of water added either in the feeding and watering of the pigs or from extraneous sources such as washing of houses, leaks, spills or from roofs, open tanks or dirty yards. Good manure management on the pig unit will ensure minimal dilution with water. This will result in reduced storage and transport costs for the pig producer and a product with higher solids and nutrient content for the customer farmers. Pig manure that contains 4.3% solids is of reasonable quality. Good quality pig manure will contain more than 5% solids.

Nutrient value of pig manure

The value of pig manure as a fertiliser depends on how much chemical fertiliser is replaced as well as the cost of the chemical nutrients replaced. The fertiliser value of pig manure at 4.3% solids is €5.85 per m^3 when there is a requirement for N, P and K. This translates into €26.59 per 1000 gallons. One thousand gallons is equivalent to a bag of 19:7:20. A lorry tanker conveying $25m^3$ or 5500 gallons will contain nutrients to the value €145 based on 4.3% solids. 1000 gallons/ha of pig manure is equivalent to a 50kg bag of 19-7-20 (N-P-K)

Table 1. Total Nutrient content and value of pig slurry (4.3% solids):

	Nitrogen	Phosphorus	Potassium
Nutrient content kg / m^3	4.2	0.8	2.2
Nutrient availability %	50	100	100
*Fertiliser cost per kg €	1.04	2.32	0.83
Value €	2.16	1.86	1.83

*Note: 1 m^3 equals 220 gallons. *Based upon Chemical Fertiliser prices in September 2015*

Environmental constraints on manure imports

The EU Good Agricultural Practice for Protection of Waters Regulations (often referred to as the "nitrate" regulations) have been reviewed and updated giving some benefits to farmers using pig slurry. The new Statutory Instrument (SI 31 of 2014) came into effect on 31st of January 2014. A number of changes introduced in these regulations are discussed briefly below:

- The P requirement for crop growth depends on whether the stocking rate of the grassland is less than 85, between 86 to 130 or between 131 to 170 kg organic N /ha.
- No "organic fertiliser" may be imported if the Stocking rate is above 170 kg/ha.
- If hay or silage is sold off the farm allowance can now be factored in for extra P to grow these forage crops.
- The first 300kg of concentrate fed to each grazing livestock unit (ie 85kg organic N) is now discounted in calculating the P from concentrates fed to grazing livestock.
- The availability of P is considered to be only 50% if used on soils with a P index of 1 or 2 as per the Morgan's extractable P test.

Save money using pig slurry

If you use chemical P on your farm it will greatly reduce the level of pig slurry you may use on your farm. It is important that you are aware of the volume of pig slurry you may use in compliance with the "nitrate" regulations to ensure maximum savings in fertiliser costs. The best practice is to get a fertiliser plan drawn up by your agricultural adviser /consultant and then let the pig farm manager/ owner know how much you will need as early in the year as possible. The pig farm may then make arrangements to ensure a supply of the required volume. Exporters are responsible for submitting DAFM records by 31 December each year.

Measuring Manure Dry Matter

The solids or dry matter content of a sample of pig slurry can be determined using a slurry hydrometer. This is inexpensive and relatively easy to use. However it is very important to obtain a representative sample of manure when testing for solids. Pig manure solids tend to settle in the bottom of the storage tank. The manure from different parts of the unit will have different solids contents.

Transport Costs

Transport and spreading costs should be included when assessing any savings made if an organic fertiliser. Research at Moorepark modelled the loading, transport and spreading costs of slurry in different situations using a standard slurry tanker for short distances or using a truck to transport the slurry over longer distances. The costs were shown to vary greatly based on the distance travelled and the tanker size used to transport the slurry. An example of the factors involved will be shown in this paper.

Conclusion

Farmers can save substantial money if they use locally available organic fertilisers to replace chemical fertilisers. Pig manure is a valuable organic fertiliser source and when used effectively it can be a relatively cheap nutrient source for grass and crop production.

The global fertiliser supply chain and the factors affecting price

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Summary

- Fertiliser production does not cover consumption within the EU and it imports 20% of its fertiliser needs.
- The EU is a CAN market, the world is a Urea market
- Mid-term projections predict EU consumption to be basically constant
- Arable crops drive fertiliser demand, accounting for 68% of the fertiliser consumed in the EU. This compares to grassland, which accounts for 24%.
- The CAP and the impact of the EU's climate change and energy policies will be the main internal drivers of fertiliser consumption in the EU over the next 10 years.
- Natural gas used in fertiliser production represents 60-80% of the cost of the process.
- The fertiliser industry is the EU's largest industrial use of gas, accounting for almost 4% of total EU consumption.
- The weak euro is the single largest factor driving current prices.

Introduction

As one of the largest farm input costs, the market for fertilisers is a global one with the price of raw materials as well as finished product primarily driven by world demand. The global fertiliser industry is complex, driven by geo-political, macro-economic factors, trade barriers and is also impacted by several distinct commodity sectors, including not just agri-commodities but also energy and mining. The European fertiliser market is one of the most globally integrated, with imported products servicing some 20% of its nitrogen needs and between 61-70% of its phosphate and potash requirements.

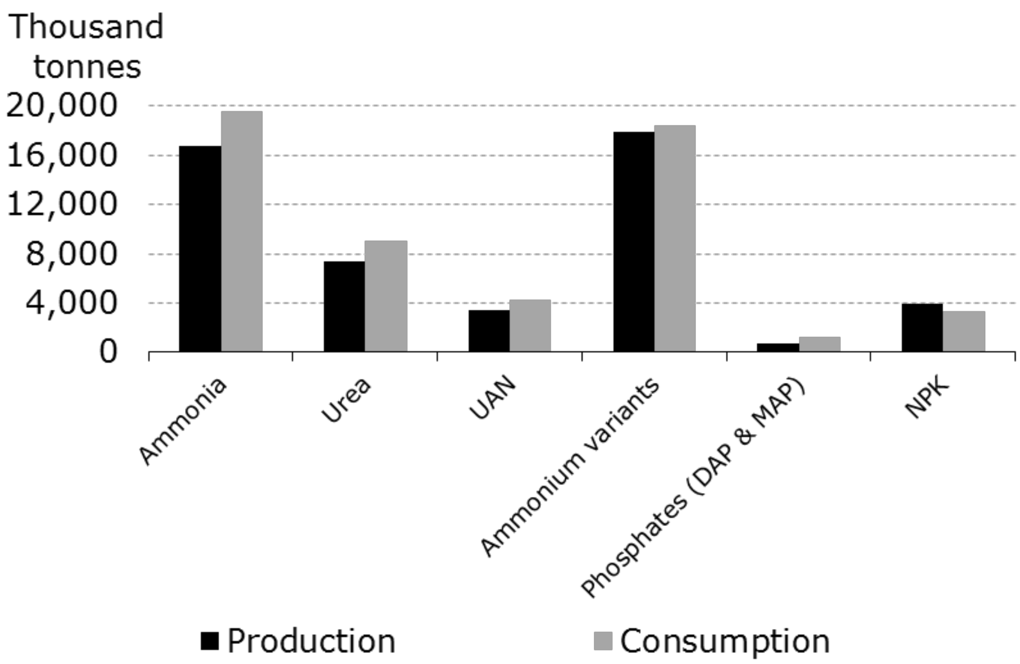

Figure 1. The production versus consumption of different types of fertiliser within the EU.

Global supply and demand - context

About 240m T of fertiliser are produced in the world every year. Of this, 61% is N, 25% is P, and 14% is K. Europe produces 17.4m tonnes of fertiliser (7% of global production), of which 73% is N, 10% is P and 17% is K. The world consumes 180m tonnes of fertiliser every year. Europe consumes 9% of the world's fertiliser at 16.5m T. Overall the EU consumes 10% of global nitrogen, 7% of global phosphate, and 10% of global potash. The EU exports almost 3m T of fertiliser every year despite it being a net importer. It imports 7m T in total of which half is nitrogen. The EU imports about 20% of its N requirements, 61% of its P requirements, 70% of its K requirements.

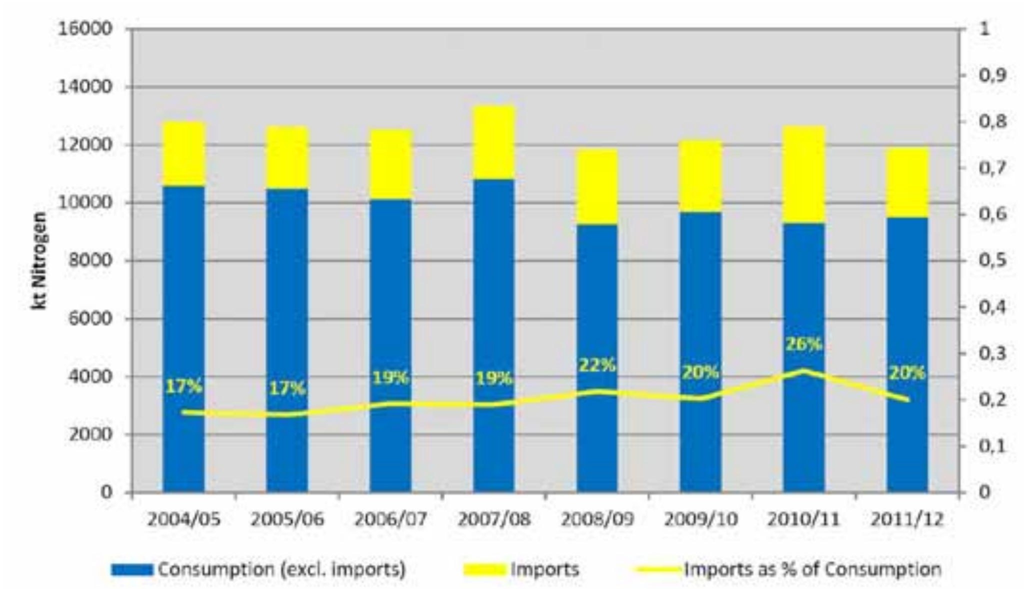

Figure 2. Nitrogen consumption (tonnes) including imports as a % of consumption

Nitrogen Fertiliser Sources

CAN is the main form of nitrogen used in Ireland and makes up 50% of the 1.3m T market. The majority is produced in Western Europe (Norway, France, Germany, Spain). Nitrogen consumption in the EU is mainly in the form of nitrates (AN/CAN).

Urea accounts for 19% of the EU market. The majority (95%) of Urea into Ireland is produced in Egypt.

Table 1: % market share of Urea, AN/CAN in the world and EU 27.

Nitrogen Mkt	World (100mt)	EU- 27 (10mT)
Urea	56%	19%
AN/CAN	8%	47%

Phosphorus

Phosphorus production is limited to regions where phosphate mines are plentiful. DAP is the main form of phosphorus used in Ireland. The main sources of P used in Ireland are Morocco and Russia

Table 2 World's largest Phosphate Rock producing countries and their % share of world production.

Phosphate Rock Producer	% share of world P production
China	40%
US	16%
Morocco	13%
Russia	6%
Other	25%

Potash

About 55m T of potash is sold around the world with 17m T supplied by Russia and Belarus. Canadian potash does not travel to the EU.

Table 3. World's largest potash producing countries by volume and their % share of world production

Potash Producer	000 tonnes	% share of world K production
Canada	16,550	30%
Russia	10,000	18%
Belarus	6,950	13%
China	6,000	11%
Israel/Spain/UK	5,150	9%
Germany	4,950	9%
World	55,100	

Factors affecting fertiliser price

Supply/demand balance

There has been a paradigm shift in how fertilisers are priced. The market has moved away from a cost plus model to a demand driven model. In general, when demand is low, there tends to be a "supply-driven" fertiliser market in which the established price floor indirectly determines fertiliser prices. This price floor is set by the producing region with the highest natural gas prices. When fertiliser demand is high, there is typically a "demand-driven" market with fertiliser prices above floor prices for highest cost regions- as we have now.

Weaker euro

The Euro has weakened 15% over the past 12 months against the dollar. As most fertiliser is traded in dollars, a weaker Euro has a major impact on price here.

Gas cost

Europe must import gas making it an uncompetitive place to produce nitrogen. The natural gas used in fertiliser production in Europe represents between 60-80% of the cost of the process. The fertiliser industry is the EU's largest industrial user of gas, accounting for almost 4% of total EU consumption.

Grain Prices

Grain is the largest user of fertiliser in the EU, with wheat and grains using 51% despite it taking up only 31% of the land. Grassland uses 17% of all fertiliser similar to it using 18% of the land. Oilseeds which take up 7% of the land consume 10% of all fertiliser used in the EU.

EU Policy

The new CAP and the impact of the EU's climate change and energy policies will be the main internal drivers of fertiliser consumption over the next 10 years.

Fertiliser use on the commercial dairy farms

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Introduction

Since 2003 we have studied nutrient management practices on commercial dairy farms in the southwest of Ireland. Average annual stocking density on these farms was 2.47 LU per ha and changed very little during this period; ranging between 2.36 and 2.58 LU per ha from year to year. Dairy cows as a proportion of total livestock on farms increased from 62% in 2003 to 73% in 2014. This change had little impact on surplus N (the difference between N imported and N exported from farms), which averaged 250 kg per ha and on N use efficiency (NUE: The proportion of N imported that was exported in products), which averaged 20% and ranged between 18 and 23% from year to year.

In contrast, there was a decline in surplus P from 11.2 kg per ha in 2003 to 3.3 kg per ha in 2011 and this subsequently increased to 8.1 kg per ha in 2014. Mean surplus P between 2003 and 2014 was 7.5 kg per ha and mean P use efficiency (PUE) was 69%, ranging between 63% and 78%. On average between 2009 and 2012 farmers imported approximately two-thirds of the P they were allowed under the Nitrates Directive regulations, with 15% of farmers importing less than half of their annual allowance. On the other hand, approximately 75% of the variation in fertiliser use on farms from year to year can be explained by price; increasing cost of fertiliser caused less of it to be used on farms.

Across all farms 89% of fields were sub-optimal for either soil pH, soil P or soil K. Mean soil pH was 5.95 with 75% of samples with a pH of less than 6.3 and 54% of samples less than 6.0. 39% of samples were deficient in soil P and 39% of samples were deficient in soil K with no relationship between soil P and soil K levels in soils; in other words the soils that were low in P were not the same ones that were low in K. This creates difficulty in the efficient recycling of slurry back to paddocks and for the selection of compound fertilisers for use on farms.

There was variation in soil fertility between and within farms. In the case of soil K, for example, only 2 out of 48 farms had all paddocks in Index 3 or greater (Figure 1). Twelve of the farms had paddocks with soil K in indices 1, 2, 3 and 4 and most of the remainder had soils in indices 2, 3 and 4. Likewise for soil P (Figure 2) and soil pH (Figure 3).The high paddock to paddock within farm variation in soil fertility indicates that farmers were either unaware or were not making efficient use of their soil results. Within a farm there were typically agronomically sub-optimal soil fertility levels status in some paddocks and excessive levels in others. There was considerable potential to improve soil fertility management practices on these farms with clear agronomic benefits.

Improving soil fertility on intensive dairy farms

The solution to sub-optimal soil fertility is well known. The first step is to take soil samples and then study the results to identify deficiencies in particular paddocks. The next step is to (i) apply lime to soils with low soil pH; (ii) recycle slurry to paddocks with low soil K and soil P status and (iii) targeting fertiliser K and P to paddocks in index 1 and 2. There is a clear economic incentive to improve soil fertility and grow more grass on dairy farms. The cost of a tonne of grazed grass dry matter is approximately €80, which is less than half of the cost of grass or maize silage and less than one third of the cost of concentrate. It is a false economy to cut costs by cutting fertiliser use. Another disincentive is increased regulation partly because many farmers are fearful of exceeding the limits but more importantly the regulations are so complicated that drawing up a fertiliser plan is beyond the capacity of the vast majority of farmers. There is a discontinuity between drawing up the plan by advisor and the implementation of the plan by the farmer. It is evident from the results presented that slurry and fertiliser are often not being applied where they are needed.

The rising cost of fertiliser has been more instrumental in lowering fertiliser use on farms than the regulations, which have not contributed to improved efficiency on farms partly because the decision making process has been taken out of the farmer's hands. More efficient fertiliser use is fundamental to profitable grass-based dairy production, which is the key to increasing milk output in line with Food Harvest 2020. Making more efficient use of fertilisers on farms will require a simplification of the current excessively complicated regulatory regime and a farmer-friendly decision support system for fertiliser management that puts the decision making process back in the farmer's hands.

Figure 1. Soil K concentrations in paddocks plotted against the average soil K on each farm

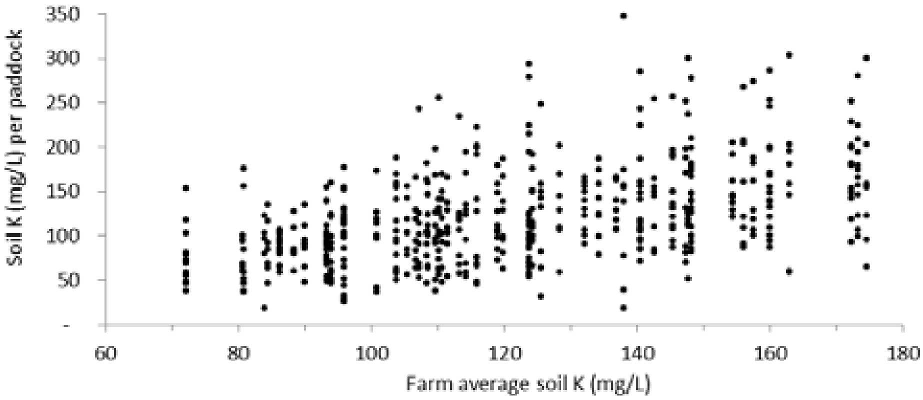


Figure 2. Soil P concentrations in paddocks plotted against the average soil P on each farm

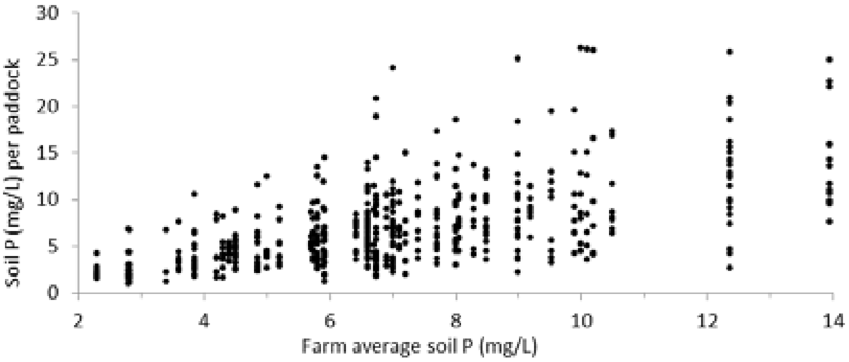
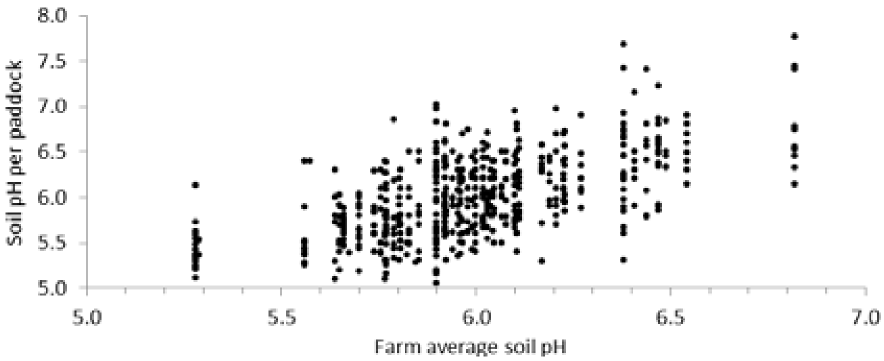


Figure 3. Soil pH in paddocks plotted against the average soil pH on each farm



The Agricultural Catchments Programme - Improved Nutrient Management on Intensive Dairy Farms

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Summary

- The Agricultural Catchments Programme (ACP) is tasked with evaluating the effectiveness of on farm nutrient management under the Good Agricultural Practice (GAP) measures, to maintain and achieve high water quality status.
- Initial baseline soil samples from grassland fields in the ACP found that 10% were of good overall soil fertility status (pH, P, K); in line with recent national Teagasc reports. This improved to 13% following re-sampling of these fields.
- Good overall soil fertility improved by 3% in the intensive dairy catchment of Timoleague with an 8% reduction in the proportion of soils with excessive P levels.
- Intensive dairy farms in the ACP have demonstrated that soil fertility levels can be improved on the farm, and that both environmental and productivity goals can be delivered through better nutrient management.

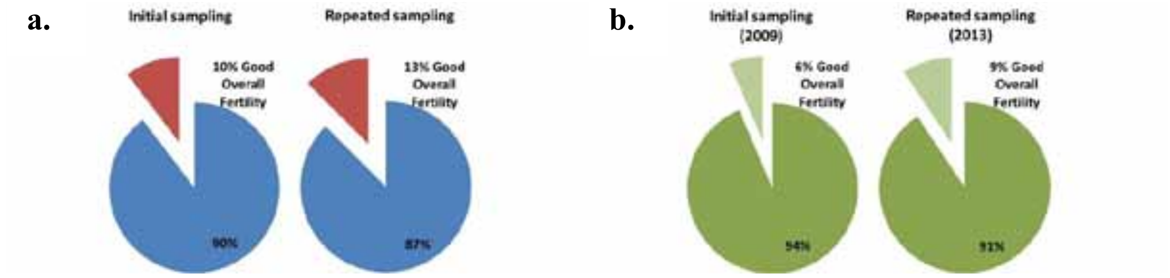
Introduction

The ACP is a national advisory/research programme, supported by funding from the Department of Agriculture Food and Marine (DAFM), to evaluate the GAP measures. The ACP aims to support profitable, productive farming while protecting or improving water quality, with nutrient management playing an essential role in helping to achieve these “win-win” targets. The six catchments in the programme cover the main farming systems across a range of soils and landscapes with differing nutrient loss risks. Four out of the six catchments are classified as predominantly grassland, while the other two are mostly arable. However, a number of grassland farming systems, mainly dairy, have replaced some arable areas in these catchments. The south-west Cork catchment of Timoleague represents an area of intensive dairy farming with an overall stocking rate of 1.94 LU ha^{-1} (165 kg organic N ha^{-1}) with some farms (34% of catchment area) stocked under derogation limits (170-250 kg organic N ha^{-1}). At the outset of the programme, in each catchment, soils were sampled using sample areas of 2 ha or less for their current nutrient status (phosphorus [P] and potassium [K] and pH), and after 3-4 years, sampling of these same fields was repeated. Initial soil results were given to each catchment farmer by their Teagasc catchment advisor for further recommendations.

Catchment Soil Fertility Trends

Initial soil fertility results from grassland fields across the catchments mirror those reported nationally by Teagasc, with only 10% of soils (234 samples) reported to have overall good fertility status (pH > 6.2 and index 3 or 4 for P and K). Following repeated sampling the proportion of soils in this category had increased by 3% (274 samples) (Figure 1a). The soils sampled in 2009 in Timoleague had 6% (22 samples) good overall fertility and improved to 9% (38 samples) following resampling and analyses in 2013 (Figure 1b). The improvement in soil fertility in this catchment can be attributed to effective nutrient management that resulted in a reduction in deficient P soils (index 2; 25 to 22%) and soils with excessive P concentrations (index 4), which are most at risk of loss to water (32 to 24%), as the soils in this catchment converged to the optimum P target of index 3 (27 to 36%).

Figure 1 (a) trend in ACP grassland soils and **(b)** in Timoleague catchment grassland soils with results of good overall soil fertility, pH >6.2 and index ≥3 for P and K.



Improvement of Soil Fertility on an Intensive Catchment Dairy Farm

This example farm is a spring calving dairy herd, with some tillage, a whole farm stocking rate of 1.9 LU ha^{-1} and a grazing stocking rate of 2.5 LU ha^{-1} In 2009 and 2013, 74% of the farm that is within the catchment was soil sampled. The soil results show that the proportion of the sampled area on this farm has improved in P, K and pH, as soils previously deficient and excessive have converged to index 3 for P and K, with 42% of the sampled area at optimum for pH (Table 1). The farm-gate P balance (inputs-outputs) was 3.9 kg ha^{-1}. However, considering the allowance of P required for build-up of index 1 and 2 soils to index 3, the optimal P balance was -1.45 kg ha^{-1}. Through applying good nutrient management on this farm, by avoiding applications to already sufficient index 4 soils and targeting manures onto lower index fields for P and K, overall soil fertility has improved and the risk of P loss from the soil and impact on water quality has reduced. At the same time, overall milk production and profitability remained comparable to the 10% of national dairy farms.

Table 1 Area proportional change of soil P, K & pH on a catchment farm from 2010 to 2013.

	% Farm in P index			% Farm in K index			% Farm in pH threshold		
P & K Index /pH thresholds	2009	2013	*% Diff	2009	2013	*% Diff	2009	2013	*% Diff
1 /<5.5	17	7	-10	5	1	-3	6	1	-5
2/5.5-5.9	21	20	-1	61	45	-15	27	14	-13
3/5.9-6.19	24	51	+27	16	41	+25	30	43	+13
4/>6.2	38	22	-16	18	13	-5	37	42	+5

*Difference in percentage area in 2009 minus percentage area of the same index in 2013

Conclusions

When the ACP was established, the grassland soils reflected recent national Teagasc figures in soil fertility. Since then, repeated sampling and analysis has allowed the farmer, advisor and researcher to assess the trend of soil fertility at field, farm and catchment scale and link it to the performance of farm nutrient practices. The proportion of soils with optimum soil fertility levels is still alarmingly low for both national and catchment farms. However, there is evidence that soil fertility trends are moving in the right direction, illustrating that effective nutrient management on farms can benefit both production and the environment.

Soil Fertility on Heavy Soils Farms

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Teagasc, Heavy Soils Programme

Summary

- The nature of nutrient behaviour on heavy soils makes it imperative that soil pH is corrected before embarking on high applications of organic/chemical fertilisers.
- A farm fertiliser plan is required that sets out target lime applications for each year.
- Ideally spread lime when ground conditions are good over the late summer period.
- A "little and often" approach works best where high rainfall can lead to excessive losses through drainage and high lime applications can impact on soil trafficability
- The nutrient 'lock up' on soils with high clay content is significant especially at low soil pH. Unlocking this potential source of 'free' nutrients by judicious use of lime is an economically and sustainably sound use of stored nutrient resources
- Fertiliser planning and effective nutrient management is critical on farms in order to navigate through this difficult period of low dairy enterprise profitability.

Introduction

There has been a notable decline in soil fertility nationally and the impact is even more serious on farms with heavy soils in high rainfall areas. On heavy soils there is the potential to increase annual grass production by 30% where soil pH, and soil P & K fertility status is built up to optimum levels. Seven dairy farms on 'heavy 'soil types have been participating in a monitoring and development programme for the past number of years and contributing key data on farm performance. Data collected from these farms over the period 2011-2014 shows that on the heavy farms grass growth varied from 6.8 tonnes DM/ha in 2012 to 11 tonnes DM/ha in 2014.

Baseline soil fertility levels on the heavy soils farms

The Teagasc Heavy Soils Programme has been monitoring farm practices and outcomes specific to dairy farms on 'heavy' soils e.g. predominately clay mineral soils located in high rainfall areas in the South West of Ireland. A baseline soil analysis of basic soil fertility across 5 of these farms is presented in table 2.

Table 1. Soil pH, and soil test phosphorus (P) and potassium (K) levels over the baseline period (2010 to 2013) for five heavy soils farms in the south west of Ireland.

Farm Location	pH		Phosphorus (mg/l)		Potassium (mg/l)	
	2010	2013	2010	2013	2010	2013
Castleisland	5.8	5.4	6	5.2	174	90
Doonbeg	5.4	5.8	4.1	3.2	85	80
Athea	5.8	5.8	3	3.5	101	95
Kiskeam	5.4	5.9	3.8	1.9	106	43.2
Listowel	5.3	5.7	10.9	7	118	112
Average	**5.54**	**5.73**	**5.56**	**4.16**	**116.8**	**84.0**

Farmer participants embarked on a programme of soil fertility improvement when recruited into the programme. The constrained use of compound fertiliser (because of farm level P limits under the EU Nitrates Directive) had a knock on effect on K usage (although K fertilisers are not restricted). Reduced P and K fertiliser inputs, coupled high potential for K losses in these high rainfall environments has led to declining soil K fertility on these farms. Low soil pH on these farms is due in part to low usage of lime in these areas, with higher N usage often masking the impact of low soil pH on grass growth. Farm fertiliser plans developed in 2013 showed that on an average farm size of 68 ha, stocked at approximately 1.8 LU/ha, there was a total lime requirement of 278 tonnes.

The difficult weather (and fodder) years of 2012 and 2013, where the emphasis was placed on survival and recovery, meant that the focus on lifting soil pH by way of lime applications in these years. Changes to the regulations that came into force in 2014 have allowed a higher chemical P limit on farms with low P Index status. For example the Heavy soil farms in Castleisland, Doonbeg and Athea saw their farm chemical P limit increase by 35% from an average of 785 kg P to 1066 kg P. However, initially the impact of the additional P fertiliser was not seen in either additional grass growth or increasing soil P readings. The reason for the poor response to the additional P applications on heavy clay soils was closely linked to the low pH on these farms and the scientific rationale is outlined in a separate paper by my colleague David Wall, Johnstown Castle. A comprehensive soil testing programme took place across all the Heavy soils farms in January 2015 and the summary outcome is presented in table 2. Average soil pH at 5.7 was unchanged from the 2013 soil analysis results.

Table 2. Soil pH, and soil test phosphorus (P) and potassium (K) levels in 2015 compared to 2013 for five heavy soils farms (n=5) in the south west of Ireland.

Sampling period	Soil pH	Phosphorus (mg/l)	P Index	Potassium (mg/l)	K Index
2013	5.73	4.16	3	84	2
2015	5.71	6.40	3	117	3

Lime requirement on these farms

Because these farms are located in high rainfall areas lime loss is estimated to be >500 kg/ha/year or a loss through drainage alone of 1 tonne/acre over a five year time frame. In addition lime required to counteract acidity from chemical N use and calcium off-take in milk/meat means a maintenance requirement of 2 tonnes/acre every five years is required on these farms. In effect, any lime applied in 2011-2014 was only keeping pace with the maintenance requirement and was not having an impact on lifting soil pH levels across these farms. In late 2014 and 2015 a more focused approach to lime application was put in place on these farms.

On heavy soils individual applications were limited to 2-2.5 tonnes/acre, and based on soil analysis additional lime required to achieve target pH will be applied after a further two years. The farms are on target to grow an average of 11 tonnes grass DM/ha in 2015 (see table 3) and as soil fertility increases an additional 1.5 t DM/ha may be achievable.

Table 3. Average grass growth to date in 2015 across 5 farms involved in the Heavy Soils Programme

Grass Measurement Start date	Grass Grown YTD* (t DM/ha)	Quarter1	Quarter2	Quarter3*	Quarter 4*
10/02/2015	**9.0**	**0.6**	**6.8**	**1.5**	**0**

*Year to date (YTD) up to 15th September 2015

Conclusions

Increased grass production on heavy soils requires a clear management focus on increasing soil fertility in a planned manner. In particular, a renewed campaign of lime application is required on all heavy soils programme farms. Stocking rates and concentrate feed usage must be matched to the grass growth and grass utilisation capacity of the farm. Based on 12.5 t DM/ha grass growth with all winter feed requirement conserved within the farm (including reserve) a potential whole farm grassland stocking rate of 2 LU/ha is achievable on these farms.

Notes

5 STEPS TO BETTER SOIL FERTILITY

1 SOIL TESTING

- Provides you with vital information about your soils
- A foundation for your fertilizer plan
- A small farm expense costing in the region of €1.25/ha/yr and is valid for 5 years
- A standard soil test will give the soils fertility status as follows; pH, lime requirement, phosphorus (P) and potassium (K).

2 SOIL PH & LIME

- Lime improves the availability of Nitrogen, Phosphorus, Potassium, Sulphur, Calcium and Magnesium
- Lime at least every 5 years
- Ground limestone can be spread at any time
- Apply lime as per soil test report. Avoid over-liming as it can result in trace element imbalances.

3 TARGET INDEX 3 FOR P & K

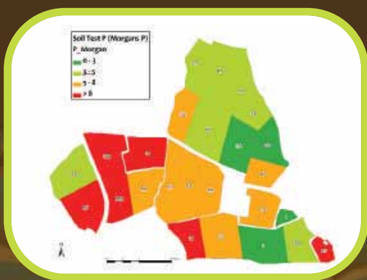
- Index 3 is the optimum level for crop growth
- Only by soil testing will you know your P & K levels
- Index 4 soils (high fertility) are a resource - use them to save money on fertilizer
- Index 1 and 2 soils (low fertility) need additional nutrients
- Monitor your soil fertility by looking at previous analysis.

4 SLURRY & MANURES

- Plan when and where slurry/manure will be best utilised
- Aim to apply slurry in spring during moist cool conditions
- Apply slurry and manures on land that requires P & K
- Take account of nutrients contained in slurry if applying chemical fertilizer to the same area
- Always observe buffer zones from watercourses and wells.

5 NUTRIENT BALANCE

- Develop a fertilizer plan for your farm
- Get the best value from fertilisers and organic manure
- Enhance crop yield and animal performance
- Reduce environmental risks due to field losses of excess nutrients
- Potential cost savings when all nutrient inputs are accounted for.



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