THE FERTILIZER ASSOCIATION OF IRELAND

Proceedings of Spring Scientific Meeting 2016

“Fertilising for Yield and Profit”

2nd February 2016

Horse and Jockey, Thurles, Co Tipperary

Soil Fertility Trends - Latest Update
Mark Plunkett

Managing Sulphur to Optimise Grass Production
John Bailey

Fertilising for Profit on Grassland Farms
Christy Watson

Soil and Fertiliser for Tillage Yield Improvement
Andy Doyle

www.fertilizer-assoc.ie
Publication No. 51
## Fertilizer Association of Ireland Presidents

<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
<th>Name</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr T Walsh</td>
<td>1968</td>
<td>Mr LT Stafford</td>
<td>1992</td>
</tr>
<tr>
<td>Mr WJC Milne</td>
<td>1969</td>
<td>Mr R Walsh</td>
<td>1993</td>
</tr>
<tr>
<td>Mr G Foley</td>
<td>1970</td>
<td>Mr J Gavin</td>
<td>1994</td>
</tr>
<tr>
<td>Dr JN Greene</td>
<td>1971</td>
<td>Mr J Murphy</td>
<td>1995</td>
</tr>
<tr>
<td>Mr EJ Sheehy</td>
<td>1972</td>
<td>Mr L Larkin</td>
<td>1996</td>
</tr>
<tr>
<td>Mr JC Brogan</td>
<td>1973</td>
<td>Dr N Culleton</td>
<td>1997</td>
</tr>
<tr>
<td>Mr T James</td>
<td>1974</td>
<td>Dr P Barry</td>
<td>1998</td>
</tr>
<tr>
<td>Prof DM McAleese</td>
<td>1975</td>
<td>Mr B Barnes</td>
<td>1999</td>
</tr>
<tr>
<td>Mr S McCann</td>
<td>1976</td>
<td>Mr C Watson</td>
<td>2000</td>
</tr>
<tr>
<td>Mr M Roche</td>
<td>1977</td>
<td>Mr M Cunningham</td>
<td>2001</td>
</tr>
<tr>
<td>Mr G Cussen</td>
<td>1978</td>
<td>Mr P Drennan</td>
<td>2002</td>
</tr>
<tr>
<td>Mr WE Murphy</td>
<td>1979</td>
<td>Mr J Carroll</td>
<td>2003</td>
</tr>
<tr>
<td>Mr P McEnroe</td>
<td>1980</td>
<td>Dr T Storey</td>
<td>2004</td>
</tr>
<tr>
<td>Mr T Fingleton</td>
<td>1981</td>
<td>Dr B Coulter</td>
<td>2005</td>
</tr>
<tr>
<td>Mr J Leonard</td>
<td>1982</td>
<td>Dr B Coulter</td>
<td>2006</td>
</tr>
<tr>
<td>Mr P Duffy</td>
<td>1983</td>
<td>Mr J McGrath</td>
<td>2007</td>
</tr>
<tr>
<td>Dr M Ryan</td>
<td>1984</td>
<td>Mr T Carroll</td>
<td>2008</td>
</tr>
<tr>
<td>Mr P Keane</td>
<td>1985</td>
<td>Dr JJ Fleming</td>
<td>2009</td>
</tr>
<tr>
<td>Dr JF Collins</td>
<td>1986</td>
<td>Mr K Murphy</td>
<td>2010</td>
</tr>
<tr>
<td>Mr M Stanley</td>
<td>1987</td>
<td>Mr K Murphy</td>
<td>2011</td>
</tr>
<tr>
<td>Mr W O'Brien</td>
<td>1988</td>
<td>Dr STJ Lalor</td>
<td>2012</td>
</tr>
<tr>
<td>Mr T King</td>
<td>1989</td>
<td>Dr STJ Lalor</td>
<td>2013</td>
</tr>
<tr>
<td>Mr G Leonard</td>
<td>1990</td>
<td>Mr P Casey</td>
<td>2014</td>
</tr>
<tr>
<td>Dr TF Gately</td>
<td>1991</td>
<td>Mr P Casey</td>
<td>2015</td>
</tr>
</tbody>
</table>
FERTILISER ASSOCIATION OF IRELAND

Proceedings of Spring Scientific Meeting 2016
2nd February 2016
Horse and Jockey, Thurles, Co. Tipperary

Publication No. 51

Contents

Soil Fertility Trends - Latest Update .................................................................3
   Mark Plunkett and David Wall
   Teagasc, Johnstown Castle, Co. Wexford

Managing Sulphur to Optimise Grass Production ......................................13
   John Bailey
   Agri-Food and Biosciences Institute, Newforge Lane, Belfast BT9 5PX

Fertilising for Profit on Grassland Farms ....................................................27
   Christy Watson and Fiona Doolan
   Teagasc, Friary Rd., Naas, Co. Kildare

Soil and Fertiliser for Tillage Yield Improvement ......................................39
   Andy Doyle
   Irish Farmers Journal
Soil Fertility Trends - Latest Update

Mark Plunkett and David Wall
Teagasc, Johnstown Castle, Co. Wexford.

Over the last 10 years Teagasc have analysed an average of 38,694 soil samples annually for its farmer clients. The annual pattern of soil sample submission for laboratory analysis tends to be very cyclical with the peak soil sampling taking place over the winter months (main sampling period from September to April). Nationally, it is estimated that between 100,000 and 120,000 soil samples are taken annually on Irish farms as a basis for fertiliser planning and nutrient legislation and agri-environmental scheme requirements. Historically, agri-environmental schemes as Rural Environment Protection Scheme (REPS) and Agri-Environment Options Scheme (AEOS) had a positive impact on soil sample numbers. For example in 2007/08 coinciding with the start of REPS 4, soil sample numbers exceeded 50,000. Over the last 3 to 5 years, factors including a renewed focus to improve soil fertility at farm level and changes to nutrient legislation have encouraged more farmers to soil sample their farmland. More recently with the introduction of the Green Low-carbon Agri-environmental Scheme (GLAS) in 2015/16 soil samples are expected increase further over the coming years. It is expected that 50,000 farmers will participate in the scheme and the scheme requires the completion of a mandatory farm fertiliser plan by all participants.

Table1. Soil sample numbers analysed through Teagasc from 2006 to 2015

<table>
<thead>
<tr>
<th>Year</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>50,189</td>
</tr>
<tr>
<td>2007</td>
<td>51,981</td>
</tr>
<tr>
<td>2008</td>
<td>50,500</td>
</tr>
<tr>
<td>2009</td>
<td>33,923</td>
</tr>
<tr>
<td>2010</td>
<td>36,172</td>
</tr>
<tr>
<td>2011</td>
<td>21,900</td>
</tr>
<tr>
<td>2012</td>
<td>36,294</td>
</tr>
<tr>
<td>2013</td>
<td>37,893</td>
</tr>
<tr>
<td>2014</td>
<td>36,336</td>
</tr>
<tr>
<td>2015</td>
<td>31,743</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>38,694</strong></td>
</tr>
</tbody>
</table>

The objective of this paper is to review soil fertility trends for soil pH and the major nutrients (Phosphorus (P) & Potassium (K)). Given the geographic spread (all counties) and large numbers of soil sample data included, the Teagasc soil
nutrient data has provided valuable insights into soil fertility trends at a national level. This information has helped to highlight the areas and farm enterprises where action on nutrient management is most required by the agricultural industry including farmers, advisors, fertiliser companies and policy makers.

**Introduction**

Overall soil test results for 2015 (Figure 1) indicate that 11% of soil samples have the optimum mix of soil pH, P & K which is the same as the previous 2 years. A closer look at this data indicates that soil P and K levels have declined compared to the previous 2 years which is of major concern. Soil pH has shown a small improvement with an increase in the percentage of soils achieving pH >6.2.

![Good Overall Fertility: Soil pH > 6.2; Soil P and K Index 3 or 4](image)

**Figure 1. Percentage of all soils with optimum soil pH, P and K fertility in 2015.**

**Soil pH on Grassland Soils**

Currently 64% of grassland soils have below the optimum soil pH of 6.3 (target pH threshold for efficient grassland production). In 2015 the soil data indicates a slight reduction in the percentage of soils with less than a soil pH 5.9. The percentage of soils analysed in the pH range just below the target (i.e. pH 5.9 to 6.2) remained stable and soils with pH above 6.2 increased by 3%. Since 2010 there has been a trend of decreasing proportions of soil samples with soil pH below 5.9. This is positive but the pH results continue to indicate that there is a large requirement for lime applications on most grassland farms.
When soil samples are categorised by grassland enterprise, i.e. dairy and drystock enterprises, there has been little change over time. For example on dairy farms, soil pH levels in 2015 are similar to 2014, with 63 and 64% of samples, respectively, below the target soil pH 6.2. On drystock farms there was a slight improvement in soil pH levels in 2015 with 67% of samples with sub-optimal soil pH compared to 69% in 2014.

Figure 2. Percentage of all grassland soils tested falling within defined soil pH ranges between 2007 and 2015.

**Soil pH on Tillage Soils**

On tillage farms the percentage of soils below the target pH 6.5 has decreased by 6% in 2015. Currently approximately 45% of tillage soils have soil pH >6.5. Again these results indicate that a large percentage (55%) of tillage soils have a lime requirement.

Maintaining the correct soil pH is the cornerstone for maintaining the productivity of our soils. Maintaining mineral soils in the optimum range of soil pH of 6.3 to 6.5 will increase the availability of all the major nutrients N, P and K both stored in the soil and freshly applied. Recent research from Johnstown Castle indicates the benefits of liming and soil P availability. Liming is the first step to take when aiming to improve soil fertility levels.
Soil Phosphorus (P) on Grassland Soils

Over the last decade, the percentage of soils at Index 1 and 2 has increased from 40% in 2007 to 61% in 2015 (Figure 4). Between 2009 and 2012, there was a sharp increase from 40% to 59% in the number of soils that are sub-optimal for P (i.e. Index 1 and 2 combined). This is likely to be connected to the reduced fertiliser P usage (see Figure 5) in the previous 3 years from 2007 to 2009. Between 2012 and 2014, there was indication of a potential recovery in soil P test levels on grassland farms. This was supported by a recovery in fertiliser P usage between 2010 to 2015 from approximately 20,000 tonnes to 36,000 tonnes.

The most recent soil test results (2015) show a return to levels 2012 levels of P deficient soils at 61% (i.e. Index 1 and 2 combined). This indicates that there is insufficient P fertiliser applications annually on Irish grassland farms and that P off-takes are exceeding P inputs resulting in a further decline in soil P levels. While fertiliser usage has recovered somewhat, the intensification of grassland farming systems, especially on dairy farms, over the past number of years has resulted in higher P off-takes that are likely to have eroded any potential gains in soil fertility levels on these farms.

Currently only 22% of soils have optimum soil fertility Index 3 and there has being a gradual decline since 2007 (30% Index 3). This represents approximately a 1%
decrease per year over the last 10 years. There has been a rapid decline in Index 4 soils which is positive in terms of resource use efficiency and environmental sustainability of grassland farms. Soil at P Index 4 presents an opportunity to redirect nutrient allocations to low P soils that require them or to reduce overall P fertiliser costs. Between 2007 and 2015 there has been a 43% reduction (30% in 2007 to 17% in 2015) in the number of soils with P Index 4 status.

These trends in grassland soil P fertility trends between 2007 and 2015 clearly show that the production potential of our grassland soils is being slowly eroded. The declining soil P fertility trends are quite serious, and if allowed to continue pose a serious threat to the expansion of our national livestock sector (dairy and meat output) and to achieving both volume and value targets as set out in Food Harvest 2020 and the more recent Food Wise 2025 strategies. Furthermore large additional costs for soil P build-up will be incurred by farmers in order to regain the production potential of their land in the future.

Figure 4. Percentage of grassland soils tested falling within each soil P Index (1-4) between 2007 and 2015.

**Fertiliser Usage 1984 to 2015**

The usage N, P and K fertilisers between 1989 and 2015 in Ireland is shown in Figure 5. While there has been an overall decline in all, P and K fertiliser usage has declined significantly over the last 2 decades decreasing by 54 and 48% respectively in the last decade compared to the previous decade.
Soil P on Tillage Soils

Phosphorus fertility trends for tillage soils are similar to those described for grassland soils (Figure 6). Across tillage soils there has been a more gradual decline in soil P levels since 2007 with currently 59% of tillage soils with sub-optimal P levels (Index 1 and 2 combined). Over this time there have been a large proportion of tillage soils (currently 36%) at Index 2. There has been a relatively small reduction in the proportion at Index 3 from 26% in 2007 to 21% in 2015 representing a 0.5 percentage point decline per year. The largest changes are in the P Index 1 and 4 category soils where the proportion of very high P soils have declined by 9% and the very low P soils have increased by 10%; a rate of change in both these categories of approximately 1% per year.
Soil K on Grassland Soils

Soil K fertility trends somewhat mirror those of soil P. However the proportions of Index 1, 2, 3 and 4 soils were vastly different at the start of the 10 year period and the changes in soil K are slower compared to that for soil P. This may be due for a number of reasons. Firstly, soils contain approximately 5 times more K than P. Secondly, soil K availability is not as sensitive to soil pH as that of soil P. Even though fertiliser K usage is not regulated under nutrient legislation, the trends show fertiliser K usage has closely tracked fertiliser P usage over the last 2 decades (Figure 5).

Since 2007 the percentage of soils Index 1 and 2 increased from 40% to 54% up until 2011. Between 2011 and 2015 soil K levels have somewhat stabilised with approximately 54% of soils with sub-optimal K levels (Index 1 and 2). The same is true for soils at Index 3 and 4 where there was a rapid decline between 2007 to 2011 (60% to 46%) followed by stabilisation between 2011 and 2014 (46% of soils). This stabilisation in soil K levels may be due to the better management and targeted use of organic manures (cattle slurry and farmyard manure) on grassland farms.
Soil K and Tillage Soils

Between 2007 and 2011, the percentage of tillage soils with low K levels (i.e. Index 1 and 2) has increased from 50% to 57%. This is related to the reduction in K usage in fertiliser applications during that period from 84,000 to 71,000 tonnes. Between 2011 and 2015 the proportion of soils with sub-optimal soil K levels (Index 1 & 2) has decreased from 57% to 47% (slight increase in 2015 on 2014). Soils with K Index 3 levels have increased from 24% in 2007 to 30% in 2015. There was a rapid decline in the proportion of soil with K Index 4 between 2007 to 2011 from 26% to 17%, respectively. Since 2011, soils with K Index 4 have increased from 17% to 23%. Overall, the last 5 years soil K on tillage farms have shown a marked improvement and positive trend in terms of the percentage of soils at index 2 and 3. Firstly, there is a very low percentage of soils at Index 1, on average 13% between 2007 and 2015. Secondly, soils at K Index 2 are decreasing (43 to 34%) and thirdly soils at K index 3 are increasing (26 to 30%). In 2008, the Teagasc K advice for cereals was changed to take account of higher yielding cereal crops. Fertiliser practice has change at farm level where fertiliser compounds now have altered P to K ratios to improve the supply of K requirements to crops.
Conclusions

- The percentage of soils with good overall soil fertility still remains very low (Grassland 10% and Tillage 15%).
- 64% of grassland soils are below the target pH 6.3.
- 55% of tillage soils are below the target pH 6.5.
- Soil P levels continue to decline on grassland and tillage farms with 61 and 59% respectively Index 1 and 2.
- Soil K levels on grassland farms have stabilised over the last 4 years with 54% of soil samples at Index 1 and 2.
- Soil K levels on tillage farms are gradually improving with 47% of soil at Index 1 and 2.
- Soil fertility levels have declined more rapidly on grassland farms than on tillage farms over the last 10 years.
Managing Sulphur to Optimise Grass Production

John Bailey
Agri-Food and Biosciences Institute, Newforge Lane, Belfast BT9 5PX

Introduction

- Sulphur (S) is an essential nutrient for grass growth and nutritional quality but is often ignored by grassland managers.
- Under-supplying S can result in sizeable reductions in grass yield before visible symptoms emerge, and hence farmers may be unaware that the problem exists.
- This paper explores the role of S in grassland agriculture, its effects on grass yield and animal performance and its behaviour in soil.
- It also examines the results of both past and present research to highlight changes that have occurred as regards the likelihood and timing of S deficiency problems on grassland soils.
- Finally, it provides advice and recommendations to minimise the risk of S deficiency in grassland.

Role and importance of sulphur in plant nutrition

Sulphur is one of at least 16 elements essential for plant growth. It is a major constituent of the amino acids, cysteine and methionine, which are building blocks of proteins (Zhao et al., 1999). It is also essential for the formation of enzymes, vitamins and chlorophyll, and for nodule formation and N fixation in legumes. Legumes, e.g. clover, generally have greater S requirements than grasses, and consequently can rapidly disappear out of swards when S supplies become limited.

Sulphur is mainly taken up by plant roots from soil solution as the divalent sulphate ($SO_4^{2-}$) ion, but leaves can also absorb atmospheric $SO_2$ via their stomata (Scherer, 2001). Once taken up by roots, $SO_4^{2-}$ is actively transported across the plasma membrane into the xylem, where it travels to shoots via the transpiration stream (Hawkesford and De Kok, 2006; Nguyen and Goh, 1994).

When grassland becomes S deficient, herbage yield and quality suffer. Sulphur-deficient plants are characteristically small and spindly with younger leaves becoming chlorosed and turning pale green to yellow (Figure 1). Under S-deficiency conditions, the enzyme nitrate reductase is depressed, causing nitrate to accumulate in plant tissue, with negative feed-back effects on nitrate uptake from soil and hence increased risk of nitrate loss by leaching or by gaseous emission as nitrous oxide. Research at IGER has shown that supplying S to silage crops can reduce N leaching by up to 70% on sandy soils (Brown et al., 2000).
Effects of sulphur on herbage yield and quality and animal performance

Grassland receiving high rates of N application may respond positively to applications of S-containing fertilisers. Yield increases of 35% on sandy soils and 11% on clay soils have been reported for swards cut 3 times per year and fertilised with 400 kg N/ha (Brown et al., 2000). Largest yield responses have previously been observed from mid-season onwards, i.e. at 2nd and later cuts (Scott et al., 1983; Stevens and Watson, 1986; Murphy and Boggan, 1988; Brown et al., 2000).

When swards are well supplied with S, more than 80% of N in shoot tissue will be present as protein, whereas under S-deficiency conditions, the proportion may be less than 50% (*with the remainder in soluble organic forms e.g. amides*), thereby necessitating the purchase of expensive protein-containing feeds to supplement ruminant diets. Concentrations of reducing sugars in plant shoots also decline under S-deficiency conditions thus impairing the digestibility and feeding value of ensiled herbage (Bolton et al., 1976).

Excessive use of S-containing fertilisers on grassland, however, can be detrimental to animal health. High concentrations of sulphur in ruminant diets can inhibit the absorption and utilisation of copper leading to copper deficiency in both cattle and sheep (Grace et al., 1998; Suttle, 1975). Such problems with copper utilization are particularly likely in areas where soil molybdenum concentrations are also high, e.g. on the 'teart' pastures of Somerset. Excess S can also depress selenium uptake by herbage and impair animal health (Goodrich et al., 1986; Murphy and Quirke, 1997). However, neither copper nor selenium deficiencies are likely to be triggered by S fertilisation unless S-enriched fertilisers, e.g. ammonium sulphate, are used and crop S requirements are appreciably exceeded. But, regardless of the likelihood of copper or selenium deficiencies, S should nonetheless be applied to optimise pasture growth, since grazing animals can be supplied with trace elements by alternative means, e.g. via injection or oral supplementation (Murphy et al., 2002).
Sulphur availability and behaviour in grassland soils

Sulphur becomes available to plants through mineralization of organic matter, weathering of S-containing minerals, atmospheric SO₂ deposition, applications of mineral fertiliser and organic manure and direct deposits of livestock excreta by grazing animals (Eriksen, 2009). In the last few decades, however, S availability to crops has declined across the island of Ireland partly as a consequence of declining atmospheric deposition, but primarily because of increased usage of fertilisers containing little or no S (Stevens and Adams, 1983; Stevens, 1985; Murphy and Boggan, 1988). Increases in crop yields have also led to greater removal of S from soils and contributed to the decline in soil S reserves (Murphy and Boggan, 1988). At the same time, because sulphate is very mobile in soil, it has been leached out in land drainage water with anything up to 50 kg S/ha/year lost from intensively managed grassland (Nguyen and Goh, 1994; Bailey et al., 2001).

![Figure 2](image_url)

**Figure 2.** (a) Annual S balance (inputs minus outputs), and (b) Cumulative S balances for NI agriculture, between 1940 and 1990 (Bailey et al., 2001)

In Northern Ireland (NI) post-1940, owing to widespread use of S-enriched fertilisers such as ammonium sulphate (24% S) and single super phosphate (12% S) between 1940 and 1960, S inputs exceeded S outputs (including leaching losses),
and average S balances for agricultural land were positive, averaging about 10 kg S/ha/yr (Figure 2a). This resulted in an accumulation of some 200 kg S/ha in soil over this 20 year period (Figure 2b) (Bailey et al., 2001). Thereafter, from 1960 onwards, with increased use of high analysis NPK fertilisers, fertiliser S inputs to farmland declined dramatically and average S balances became negative as more S was lost by leaching and crop offtake than was added in fertilisers and manure. As a result, the cumulative S balance for NI declined, and by about 1980, the S accumulated in soils post-1940 had been lost (Figure 2b). Since then, net losses of S from soils have ranged from 5 to 20 kg S/ha/yr presumably through a depletion of older historical pre-1940 soil S reserves (Bailey et al., 2001).

Similar changes in S balances were observed for Danish agricultural soils over the same period. In the 1960’s, S balances for Danish soils ranged from +8 to +38 kg S/ha/yr, but by the late 1980’s and early 1990’s with the halving both of atmospheric and fertiliser inputs, S balances became negative, and ranged from -11 to -16 kg S/ha/yr (Eriksen, 1997). Although S balances for Irish agriculture have not been computed for this period, they probably followed a similar trend to those for Northern Ireland and Danish agriculture, i.e. with positive balances causing a build-up of soil S reserves pre-1970, and negative balances causing a depletion of S reserves, thereafter.

Field trials in NI to assess the responsiveness of grassland swards to S were carried out in the early 1980’s (Stevens and Watson, 1986), i.e. before the older pre-1940 reserves of S had been noticeably depleted (Figure 2b). The S responses occurred primarily, although not exclusively, on sandy loams with low organic matter contents and largest responses were observed at 2nd and 3rd cuts. In the past 10 years, however, S deficiency appears to have become a problem on heavier textured soils as well, and particularly in the early part of the growing season. This is an important development which has significant ramifications for grassland S management.

Recent evidence of sulphur deficiency in grassland soils in NI

Out of 67 dairy farms (and some 330 grass silage fields) in NI surveyed each year between 2004 and 2006, 49 farms had silage swards testing as deficient in S at 1st cut in April/May (Figure 3a), i.e. based on interpretations of herbage tissue analyses made using the Diagnosis and Recommendation Integrated System for ryegrass (DRIS ryegrass); a highly reliable method for diagnosing S deficiency in grassland swards (Bailey et al., 1997b). As shown in Figure 3a, the deficiencies occurred on soils derived from all 6 major soil parent materials. Sandy loams have previously been shown to be susceptible to S deficiency mid-season (Stevens and Watson, 1986), and accordingly in the absence of fertiliser S inputs, 39% of swards on moderate textured soils (i.e. sandy loams, sandy silt loams and sandy clay loams) were S deficient at 2nd cut. Surprisingly though an even greater percentage
(58%) of swards were S deficient at 1st cut (Figure 3b). Equally surprising was the fact that 33% of swards on heavier textured clays and clay loams were likewise S deficient at 1st cut, but thereafter, the deficiency problems declined dramatically leaving only 8% of swards S deficient at 2nd cut (Figure 3b).

Figure 3. (a) map of NI showing main soil parent materials and locations of farms where silage fields were S deficient at 1st cut, and (b), percentages of fields on moderate or heavy textured soils that were S deficient at 1st and 2nd cuts

In contrast to the earlier field trials (1980s), when S responses at 2nd or 3rd cuts on moderate textured soils were rarely preceded by significant responses at 1st cut, in the present survey, swards found to be S deficient at 2nd cut were likewise S deficient at 1st cut is shown in Table 1. In other words, for moderate textured soils susceptible to S deficiency at 2nd cut, the problem appears to be as great, if not more acute, earlier in the season, unlike in the 1980s when it seemed to be largely a problem from early summer onwards (Stevens and Watson, 1986; Murphy and Boggan, 1988).

For heavy textured soils, which previously displayed little evidence of S deficiency, not only did S deficiencies occur very early in the season (Figure 3b), but they had largely disappeared by 2nd cut without any corrective intervention (i.e. application of fertiliser S). As shown in Table 1, swards on heavy texture soils which were S deficient at 1st cut (sometimes very acutely, i.e. with DRIS S indices < -10 indicating that more than 20% of DM yield had been lost), were S replete by 2nd cut, with herbage S concentrations considerably elevated. By implication, therefore, the soils in question must be releasing significant amounts of mineral S in late spring or early summer to meet the needs of 2nd (and 3rd) cut silage crops.

Data from the survey were further examined to see if fields exhibiting S deficiencies in any one year were similarly affected in preceding or subsequent years. The examination revealed that S deficiencies at 1st and 2nd cuts will recur
year after year in the same fields unless corrective action is taken (*fertiliser S applied*). Furthermore, correcting S deficiency in one year (*with fertiliser S*) will not prevent it from recurring in subsequent years unless the corrective action is repeated each year. In other words, S applications designed to meet current crop requirements do not carry-over into subsequent growing seasons (Webb et al., 2015). However, there was evidence that within a growing season, applying fertiliser S for 1st or 2nd cut crops on light textured soils obviated the need for S applications later in the season.

Table 1. Soil parent materials for heavy and moderate textured soils, and herbage DRIS S indices, S concentrations and N/S ratios for 1st and 2nd cut silage crops on fields that had received no S fertiliser prior to either cuts and little organic manure-S

<table>
<thead>
<tr>
<th>Soil Parent Material</th>
<th>Herbage</th>
<th>Cut 1</th>
<th>Cut 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DRIS S Index</td>
<td>S (%)</td>
<td>N/S</td>
</tr>
<tr>
<td><strong>Moderate texture soils (sandy loams, sandy silt loams and sandy clay loams)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CALP soils†</td>
<td>-8</td>
<td>0.145</td>
<td>14.6</td>
</tr>
<tr>
<td>CALP soils†</td>
<td>-6</td>
<td>0.159</td>
<td>17.4</td>
</tr>
<tr>
<td>CALP soils†</td>
<td>-6</td>
<td>0.170</td>
<td>16.9</td>
</tr>
<tr>
<td>Gravel</td>
<td>1</td>
<td>0.153</td>
<td>13.2</td>
</tr>
<tr>
<td>Gravel</td>
<td>4</td>
<td>0.173</td>
<td>12.4</td>
</tr>
<tr>
<td>Gravel</td>
<td>1</td>
<td>0.154</td>
<td>13.7</td>
</tr>
<tr>
<td>Mica Schist</td>
<td>-2</td>
<td>0.204</td>
<td>15.2</td>
</tr>
<tr>
<td>Mica Schist</td>
<td>3</td>
<td>0.222</td>
<td>13.6</td>
</tr>
<tr>
<td><strong>Heavy texture soils (clay loams, silty clay loams and clays)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old red sandstone</td>
<td>-11</td>
<td>0.123</td>
<td>17.2</td>
</tr>
<tr>
<td>Old red sandstone</td>
<td>-3</td>
<td>0.159</td>
<td>13.1</td>
</tr>
<tr>
<td>Old red sandstone</td>
<td>-12</td>
<td>0.146</td>
<td>17.5</td>
</tr>
<tr>
<td>Organic Alluvium</td>
<td>-3</td>
<td>0.216</td>
<td>15.1</td>
</tr>
<tr>
<td>Old red sandstone</td>
<td>-5</td>
<td>0.142</td>
<td>13.2</td>
</tr>
<tr>
<td>Old red sandstone</td>
<td>1</td>
<td>0.146</td>
<td>13.6</td>
</tr>
<tr>
<td>Old red sandstone</td>
<td>-5</td>
<td>0.135</td>
<td>14.3</td>
</tr>
<tr>
<td>Lough Neagh Clay</td>
<td>1</td>
<td>0.162</td>
<td>12.3</td>
</tr>
<tr>
<td>Basalt</td>
<td>4</td>
<td>0.199</td>
<td>12.4</td>
</tr>
<tr>
<td>Basalt</td>
<td>2</td>
<td>0.176</td>
<td>12.0</td>
</tr>
</tbody>
</table>

Herbage DRIS S indices ≥ 5 indicate S sufficiency and those < 5 indicate S deficiency - the smaller or more negative the Index the greater the deficiency; † a mixed group of soils developed from limestone, shale and sandstone.
A hypothesis explaining why S deficiency occurs at 1st cut on heavy texture soils but is largely self-correcting thereafter

It is known that the vast majority (> 95%) of S in soil is organically bonded, and that several hundred kilograms of organic S are present in the upper horizons of most soils (Eriksen, 2009). Consequently, surplus S stored in NI soils both pre- and post-1940 (Figure 2a), would have been composed almost entirely of organic S compounds, i.e. carbon-bonded-S and ester bonded-SO$_4$, the latter being more readily available to plants and microbes via biochemical mineralization (Eriksen, 2009). Furthermore, since clay particles are known to protect organic-S from microbial mineralization, (Eriksen, 2009), it is likely that the surplus S inputs had accumulated in the heavier textured clay and clay loam soils, which cover more than 60% of the agricultural landscape. Given that historical pre-1940 reserves of soil S were still largely intact in the early 1980s, it is not surprising that responses to S then occurred primarily on sandy loams (Stevens and Watson, 1986), which unlike clays and clay loams, have comparatively low S storage capacities. Since then, however, historical reserves of soil S, and particularly less well protected pools of ester bonded-SO$_4$ (Webb et al., 2015; Eriksen, 2009), have been steadily depleted. Consequently during the spring flush of microbial mineralization, the concentrations of inorganic and ester-bonded-SO$_4$ may not be sufficient to meet microbial demand, and hence much of the S released via mineralization of carbon-bonded-S may be re-immobilized into new microbial tissue and rendered unavailable to plants (Eriksen, 2009). This may explain why S deficiency in grassland is now a significant problem in spring time on heavy and also moderate textured soils. Subsequently, as the season progresses and as soil wetting, drying and microbial turnover intensify, more resistant carbon bonded-S in heavier textured soils is probably being mineralised and made available to plants (Eriksen, 2009), and this may explain why S deficiencies in heavy textured soils, at least, appear to ‘self-correct’ by 2nd cut, (Table 1). However, further research is needed to validate this hypothesis.

Comparative efficacies of fertiliser and manure-S

Previous research suggests that although animal manures contain considerable amounts of S, it is largely unavailable for crop uptake in either short or longer terms (Eriksen, 1997; Nguyen and Goh, 1994). The results of the present survey uphold this conclusion. As shown in Figure 5, 54% of swards receiving no slurry or fertiliser S at 1st cut were S-deficient. While applying slurry-S alone reduced the incidence of S deficiency to 38%, this was still an unacceptably high level of incidence. In contrast, applying both slurry and fertiliser S (and indeed fertiliser S alone) reduced the incidence of S deficiency to almost zero.
Figure 5. Percentages of silage fields that were S replete or S deficient at 1st cut in the absence of fertiliser and manure S (No S), with manure-S only (Slurry-S) and with both manure and fertiliser-S (Fert + Slurry-S)

Diagnosing sulphur deficiency

Sulphate in soil can be extracted with dilute calcium phosphate solution, and the resultant concentrations of SO₄ split into soil S Index ranges. As indicated in Figure 6a, the lower the soil S Index the greater the risk of S deficiencies in swards. However, because SO₄ is mobile in soil (Eriksen et al., 1998), a high soil S Index in winter (when soil samples are collected) is no guarantee that sufficient SO₄-S will be available to meet crop requirements in the subsequent growing season, since it may be leached out in the intervening period. That being said, a low concentration of soil SO₄ (S Index 0 or 1) does indicate that swards are likely to respond positively to fertiliser S, and as shown in Figure 6b, soils of low S Index are more likely to be of moderate texture.

Tissue analysis is currently the most reliable method of diagnosing S deficiency in grassland provided shoot chemical data are interpreted using the Diagnosis and Recommendation Integrated System for ryegrass (DRIS ryegrass). In the past, results of grass tissue analyses have proved difficult to interpret, simply because the minimum or ‘critical’ concentration of a specific nutrient in shoot tissue for optimum growth, changes with tiller age and as the concentrations of other nutrients increase or decline. Some improvement in diagnostic sensitivity has been achieved by using single nutrient ratio pairs, rather than nutrient concentrations, as the reference criteria, since these tend to be relatively stable with crop age (Walworth and Sumner, 1986). For example the use of a critical N/K ratio of 1.3, to distinguish between swards suffering from K deficiency and those adequately supplied with K, has proven quite successful (Dampney, 1992). For other major nutrients such as S though, the improvement in diagnostic sensitivity from using a
critical N/S ratio of 14, has only been sufficient for correct diagnoses to be made about 50% of the time (Stevens and Watson, 1986). DRIS ryegrass, however, goes a step further than the previous approaches, in that it employs four nutrient ratio pairs per diagnosis (Bailey et al., 1997a). For example, the sufficiency status of S in plant tissue is diagnosed on the basis of its abundance relative to the abundances of N, P, Ca and Mg, thus taking into account the need for mineral balance in plants. Compared to the critical N/S approach which only provides correct diagnoses about 50% of the time, DRIS diagnoses are almost 100% reliable (Bailey et al., 1997b).

Webb et al., (2015) in their recent review of crop S requirements and fertiliser recommendations, concluded that for grass swards in England and Wales which are cut more than once, the amount of S currently being applied in fertiliser and organic manure is significantly less than the RB209 recommendation of 16 kg S/ha/cut. Other work on the island of Ireland has indicated that between 25 and 50 kg S/ha should be applied in spring to maximise grass production on S deficient soils throughout the entire growing season (Murphy and O’Donnell, 1989), or 10 kg S/ha/cut (Stevens and Watson, 1986). The results from the recent farm survey in NI suggest that an application of 14 kg S/ha at 1st cut should prevent swards becoming S deficient on either moderate or heavy textured soils, but that higher applications could give rise to excessive levels of S in shoot tissue with implications for animal health (Figure 6a). However, while a late spring application
of 14 kg S/ha will also eliminate S deficiency in 2nd cut crops, on many sites it could result in S being significantly over-supplied (DRIS S indices > 15) (Figure 6b) - possibly because of a carryover of S from 1st cut dressings or because the soils in question have capacity to mineralize appreciable amounts of S in late spring as already hypothesised. Indeed, on some sites an application of just 4 kg S/ha for 2nd cut could grossly exceed sward S requirements, whereas on others sites it appears correct (Figure 6b). Routine application of S to 2nd cut silage crops is therefore not advised. In contrast, applying 14 kg S/ha to all 1st cut silage crops should eliminate S deficiency with little risk of S over-supply even on moderate texture soils, and may obviate the need for S inputs later in the season.

![Figure 6. Herbage DRIS S indices at (a) 1st and (b) 2nd cuts versus rates of fertiliser S application to both moderate and heavy textured soils](image)

**Conclusions**

- Sulphur-containing fertilisers should be applied to swards to optimise grass production and protein quality but care should be taken not to grossly over-supply S and trigger copper or selenium deficiencies in livestock.

- Until recently, S deficiencies in grassland occurred mainly on sandy textured soils during summer, whereas today, significant deficiencies are also occurring on heavy textured soils in early spring.

- While animal manures contain considerable amounts of S, it cannot be relied on to supply the S needs of silage crops.

- As a risk aversion strategy, S should be applied routinely to all grass silage swards in early spring, at a rate of 14-16 kg S/ha, since this rate of application should eliminate all risk of S deficiency and in many cases obviate the need for further S applications later in the season.
References


Fertilising for Profit on Grassland Farms

Christy Watson and Fiona Doolan

Introduction

Good grassland management including appropriate fertiliser and lime use has the potential to increase overall farm profitability. Expenditure on fertiliser and lime should not be seen solely as a cost to the farm business, but also as an investment in the business that can ultimately reduce the cost of each unit of production from the farm.

The National Farm Survey (NFS) has been conducted by Teagasc on an annual basis since 1972. A random, nationally representative sample is selected annually in conjunction with the Central Statistics Office (CSO). The sample represents 78,641 farms nationally. Each farm is assigned a weighting factor so that the results of the survey are representative of the national population of farms. Farms are assigned to six farm systems on the basis of farm gross output, as calculated on a standard output basis.

The distribution of farms by system and area farmed is shown in Table 1, along with the average Family Farm Income (FFI) generated in 2014. Over 91% of farmers are operating a predominantly grassland based system, with less than 9% of farmers classified as being mainly tillage farmers.

Table 1. Farm numbers, land area farmed and family farm income (FFI) on National Farm Survey farms in 2014 (NFS, 2014).

<table>
<thead>
<tr>
<th>System</th>
<th>No Farms</th>
<th>Land Owned (ha)</th>
<th>Land Rented (ha)</th>
<th>Total area farmed (ha)</th>
<th>FFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy</td>
<td>15,654</td>
<td>45.0</td>
<td>12.8</td>
<td>57.8</td>
<td>€67,598</td>
</tr>
<tr>
<td>Cattle Rearing</td>
<td>15,707</td>
<td>33.4</td>
<td>7.1</td>
<td>40.5</td>
<td>€10,369</td>
</tr>
<tr>
<td>Cattle Other</td>
<td>25,674</td>
<td>36.6</td>
<td>5.9</td>
<td>42.5</td>
<td>€13,321</td>
</tr>
<tr>
<td>Sheep</td>
<td>12,195</td>
<td>47.1</td>
<td>10.6</td>
<td>57.7</td>
<td>€15,065</td>
</tr>
<tr>
<td>Tillage</td>
<td>6,651</td>
<td>53.3</td>
<td>14.1</td>
<td>67.4</td>
<td>€28,995</td>
</tr>
<tr>
<td>Mixed Livestock</td>
<td>2,760</td>
<td>50.7</td>
<td>14.8</td>
<td>65.5</td>
<td>€56,183</td>
</tr>
</tbody>
</table>

Dairy farms continue to earn significantly higher incomes on average compared to livestock farmers. Within any system there is huge variation in the income earned from farm production excluding direct payments. The 2014 Teagasc Profit Monitor analysis of beef farms shows the difference in gross margin between the top third of farms operating suckler to weanling/store systems and the average in that system was €358/ha. For non-breeding beef farms, the gap was even greater at €503/ha. Sheep and Dairy farms also show similar trends between the top and the average
performers. This variation clearly shows the potential income benefit of good technical and financial management on farms.

Table 2. Proportion of land rented relative to total areas farmed and stocking rate distribution across different farm enterprises in 2014 (NFS, 2014)

<table>
<thead>
<tr>
<th>Av Total Area Farmed (ha)</th>
<th>Rented Land %</th>
<th>% of farms with different stocking rates (LU/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;1</td>
</tr>
<tr>
<td>Dairy</td>
<td>55.0</td>
<td>22.3%</td>
</tr>
<tr>
<td>Cattle Rearing</td>
<td>38.5</td>
<td>17.9%</td>
</tr>
<tr>
<td>Cattle Other</td>
<td>40.0</td>
<td>14.1%</td>
</tr>
<tr>
<td>Sheep</td>
<td>54.2</td>
<td>18.9%</td>
</tr>
<tr>
<td>Mixed Livestock</td>
<td>63.0</td>
<td>22.6%</td>
</tr>
</tbody>
</table>

Table 2 shows some key land use findings from The Teagasc National Farm Survey for 2014 (NFS 2014). One of the most striking Figures is the amount of rented land farmed by the non-dairy sector. Suckler farmers on average rent almost 18% of the area they farm and yet one in three operate at a stocking rate of less than one livestock unit per hectare (LU/ha), with over three quarters stocked under 1.5 LU/ha. Sheep farmers similarly rent a high proportion of the area farmed, and also farm at very low stocking rates. This very low stocking rate adds considerable land charges to the system, and one wonders what positive contribution all this rented land is making to farm income. One can speculate that the effect is negative on an already low farm income, therefore the issue and value of rented land in the drystock sector has to be challenged. Rented land costs represent just over 9% of overhead costs on Dairy farms, 10% on Cattle rearing farms, 7.5% on Other cattle farms, almost 6% on Sheep farms and 12% on Mixed livestock farms. When one considers that these Figures for rented land represent the average amount rented within any farming system, there are people renting no land and by default some farmers renting a very considerable area at huge cost to the business.

Despite the abundance of land available to support the livestock enterprises as shown in Table 2, the average spend on purchased forage is similar across all systems at between 4 and 5% of direct costs. In a late spring one can see that it is not always the heavier stocked farms that are out-sourcing bales of silage and other fodder, indeed the heavier stocked farms growing more grass often provide this feed from their own resources.

It is likely that the decline in soil fertility that has occurred on Irish farms over the last 10 years is a significant contributory cause of the reduction in the carrying capacity of grassland farms. This has also resulted in an increase in the dependence on purchased concentrates. The renting of additional low fertility land is a poor economic proposition due to the soil fertility limitations. The case for investing in
soil fertility and increasing the productivity of owned land as opposed to renting land is irrefutable.

**Key Soil Fertility Targets**

*Lime*

On all farms irrespective of enterprise type the target must be to correct soil acidity (soil pH >6.2). Up to 70% of livestock farms have a large requirement for lime. It is quite common when recommending the application of lime to a client to be asked “Who spreads lime in this area”. Indeed with many campaigns to encourage the raising of the P and K soil indices, farmers and advisers have overlooked the impact of soil acidity on grassland productivity. Particularly in a large part of Kildare, the fear of excess Molybdenum locking up soil copper has persuaded farmers against liming acid soils. Farmers should be encouraged to lime acid soils up to pH 6.2 as the benefits of lime as a soil conditioner are unquestionable.

In May of each year, a number of discussion group meetings in Kildare are devoted exclusively to grass silage yields and to getting members to measure grass silage yields in the days prior to cutting. On one particular farm there was great variation in yields between the fields on the farm. The field with the lowest silage yield of only 2.3 t/ha of dry matter (DM) had a pH of only 5.29. All fields had received similar applications of nitrogen (N), phosphorus (P) and potassium (K). The main difference between fields was pH. Fields on the farm with similar P and K readings but pH readings in excess of 6 had substantially higher yields. This farmer applied lime to the deficient fields and these fields are now regularly yielding in excess of 5.5 t/ha of DM. This exercise proved to be a real eye-opener for farmers as to the potential return on investment in this case from applying lime.

Because of the large nutrient requirements of silage, the negative impact of acidic soils on yield is very significant. Any on farm plan, to correct declining soil fertility must start with lime as it is the key to releasing many soil stored nutrients to the grass plant such as N, P, K, sulphur (S) and micro-nutrients. Why apply expensive fertiliser to an acid soil when so little of the applied fertiliser is available to the grass plant? On very low stocked farms, the application of lime on acid soils and subsequent release of nutrients could transform productivity on these pastures. Major benefits to applying lime to acidic soils are usually readily evident.

*Silage*

For all grassland farmers the target yield of first cut silage has to be 5 t/ha of DM. Yield has the biggest impact on the cost of ensiled grass, the higher the yield the lower the cost per tonne of DM. The P and K requirements for first and second cut silage are shown in Table 3.
Table 3. Silage P & K requirements to replace removals in harvested herbage (P and K Index 3)

<table>
<thead>
<tr>
<th>P and K requirements</th>
<th>First Cut (5 t/ha DM)</th>
<th>Second Cut (3 t/ha DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg/ha (units/acre)</td>
<td>20 - 120 (16 – 100)</td>
<td>12 - 75 (10 – 60)</td>
</tr>
</tbody>
</table>

The silage fields should be targeted for slurry applications, as these fields have the highest nutrient requirements and greatest potential for utilising the nutrients contained in slurries. Typical undiluted cattle slurry contains 5 units of P and 30 units of K per 1000 gallons. The ratio of P to K in slurry is ideally suited to meeting the requirements of silage fields. When looking at soil test results as they return from the laboratory, it is possible to pick out the fields that have regularly been harvested for silage as they will often have the lowest readings for K.

Farmers often greatly underestimate the K requirement of silage and overestimate the nutrient content of slurries. Many slurry tanks receive extraneous water from adjoining yards or from faulty gutters or leaking water troughs. This additional water leaves the slurry easy to agitate but lowers the concentration of P and K. Over the last 5 years in Kildare, yield measurements are being taken from a selection of silage fields prior to harvesting by discussion group members. This gathers more accurate information from each field, and allows comparison of yield variation relative to the soil test results and applied nutrients on a field by field basis. Measuring the pit of silage is of very little benefit as you only obtain a composite yield across all fields. The true merit of this exercise is in having the group of farmers in the field looking at the crop and measuring yields and having soil fertility data and the records of applied nutrients to hand. Comparing the variation in yield between fields on the same farm and teasing out the causes of variation in yields is a great learning experience for both advisor and farmers. If you really want to see the impact on grass growth of inadequate soil fertility or crop nutrition just carry out this exercise.

The main issues that arise out of silage yield measurement in the field have included the following:

- How poor silage yields are on farms.
- Absence of understanding of what constitutes an acceptable yield.
- Gradual acceptance of poor silage yields: "last year bit lighter than the previous year which was slightly lower than previous year etc. etc." Silage yields have been gradually shrinking over time.
- To get a real understanding of the magnitude of the problem you need to put numbers on the problem. There is nothing like presenting the results in front of a farmer showing the yield is half the minimum accepted yield!
The first farm that conducted this exercise had a low pH in one of the silage fields, all fields were treated the same but one field had just a yield of 2 t/ha of DM. The following year after applying lime the yield doubled, meaning a second cut was not required. This was a valuable lesson for the farmer and the group on the impact of poor soil fertility on grass yields.

- The huge impact of low soil K Index has on silage yields.
- The fertiliser programme for silage is generally fixed across all fields, but giving widely varied responses. The variation in soil fertility and pH between fields is not being catered for and might explain the variety of response to fertiliser observed on farms.

All farms, irrespective of stocking rate or farm enterprise, need good silage yields produced over a 6-8 week growing period. Getting an acceptable yield but requiring up to 10 or more weeks to achieve it means that the quality of silage is poor, increasing meal costs and/or having animals in poor condition. The applied N for first cut silage has been reducing on some farms leading to delaying the harvest date to get an acceptable yield. Advisers regularly come across farms where as little as 70 kg/ha of N has been applied with aspirations of cutting within 8 weeks. Inevitably the crop is slow to bulk up and cutting date is postponed leading to production of silage with low digestibility, leading to poorer animal performance or increased concentrate use.

**Outcomes of Practice Change**

Changing practice on farm that will improve soil fertility management and return on investment in fertiliser inputs must result in an improvement in the bottom line for farmers. The following two case studies of drystock farms in Co. Kildare demonstrate how optimising land area, stocking rate and soil fertility have proven worthwhile for improving farm profitability.

**Case Study A**

The first of two case studies is a 60 ha drystock farm with small tillage enterprise. There are 40 single-suckling cows. Heifers finished and bulls are sold as stores. There are also 200 ewes, lambing in mid-March. This farm is pretty typical of many farms in that over the last 10-15 years, soil fertility has declined to a critical level, leading to a reduction in farm output and productivity. Stocking rate was pretty constant over the last five years at 2 LU/ha, but this did not truly reflect the emerging problem.

The soil P and K Indices were poor (74% of the farm is in Index 1&2 for P and 79% of the farm is in Index 2 for K). The soils were also acidic, with only 12% of the farm tested optimal for pH. The result of this soil fertility problem was a constant shortage of grass even in seasons when grass growth was good. This of
course impacted negatively on the livestock enterprises. Litter size in the sheep flock was low resulting in low lamb sales; store cattle were sold at light weights and heifers required high levels of meals to achieve a finish. Suckler cows also had reduced body condition scores at critical times. So essentially output was compromised due to poor soil fertility resulting in a significantly reduced farm income.

The farm was exiting the REPS scheme in 2011 and this prompted a review of the whole farm system as the income from the REPS scheme had to be replaced. The problems as mentioned earlier were identified and a plan put in place to address the critical issue of lack of grass supply. The farmer took on board the advice to address the grassland management issues of poor soil fertility and large field sizes that were preventing any chance of operating a rotational grazing system.

In 2013, the farmer attended a discussion group meeting on a farm where similar problems existed and were being addressed with very encouraging results. The farmer was really impressed with the progress being made in terms of abundant grass supply and livestock thriving as a result of good nutrition. This was a turning point in the farmers approach on his own farm. Later in 2013, a paddock system was designed for the farm and an application for grant aid was made. Paddocks were installed at a cost of €4,000 on 35 ha of an out-farm in 2014 where the stock spend the majority of the grazing season.

A twin-track approach was taken to address the problems present. Firstly, a programme to address the soil fertility issue began in 2011 when lime was applied to the most deficient fields. The expenditure on fertiliser increased by 68% from 2010 to 2014. The impact of improved soil nutrition was really evident when the paddock system was put in place in 2014. Some of the key benefits to the beef system of the investment in Fertiliser/Lime and paddock grazing are outlined in Table 4.

Cattle performance has improved already despite the new paddock system being really only fully operational for a complete season in 2015. Compared with 2014: store bulls have been sold 22 days earlier weighing 25 kg heavier; and heifers have gained an extra 17 kg live weight. The combined increase in sale value for cattle in only one year is €2,600. All other livestock on the farm have shown similar increases in productivity.

Has this increase in output put extra money in the farmers pocket? Annual fertiliser expenditure has increased by 68% over the five years 2010-2015. The Teagasc Profit Monitor shows the farm Gross Output increased from €54,313 in 2010 to €72,398 in 2014, resulting in an increase in gross margin of 30% over that same period. The investment in additional fertiliser/lime to address soil fertility along with paddock fencing is paying off very quickly in additional farm income.
Table 4. Trends in Key Performance Indicators (KPIs) for store bulls and heifers on Farm Case Study A corresponding with improved soil fertility and grassland management over the same period.

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>Change in 2015 vs. 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Store Bulls Spec</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days On Farm</td>
<td>477</td>
<td>457</td>
<td>435</td>
<td>- 22</td>
</tr>
<tr>
<td>Sale weight (kg/hd)</td>
<td>440</td>
<td>451</td>
<td>476</td>
<td>+ 25</td>
</tr>
<tr>
<td>Change in sale value</td>
<td>+ €1,400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Heifers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days On Farm</td>
<td>636</td>
<td>634</td>
<td>634</td>
<td>No change</td>
</tr>
<tr>
<td>Carcass Wt. (kg/hd)</td>
<td>N/A</td>
<td>312</td>
<td>329</td>
<td>+ 17</td>
</tr>
<tr>
<td>Change in sale value</td>
<td>+ €1,200</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All livestock now have very satisfactory condition scores, which will result in additional output benefits over time. This farm is on a journey not yet complete. The financial benefits of improving farm performance will continue to increase over the coming years. The farm is now poised to increase stocking rate and the genetic potential of the breeding stock is now being targeted.

Table 5. Farm Nutrient Balance for Case Study Farm A. (Total N offtake is estimated from recommended N rates for grass and crops).

<table>
<thead>
<tr>
<th></th>
<th>Crop (kg)</th>
<th>P (kg)</th>
<th>K (Kg)</th>
<th>N (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Live weight (kg)</td>
<td>29,879</td>
<td>299</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>Grain (tonnes)</td>
<td>86</td>
<td>292</td>
<td>404</td>
<td></td>
</tr>
<tr>
<td>Total off-takes (kg)</td>
<td>591</td>
<td>628</td>
<td>7,369 (recommended)</td>
<td></td>
</tr>
<tr>
<td><strong>Inputs (kg)</strong></td>
<td>1,300</td>
<td>3,080</td>
<td>5,160</td>
<td></td>
</tr>
<tr>
<td><strong>Balance (kg)</strong></td>
<td>709</td>
<td>2,452</td>
<td>2,209</td>
<td></td>
</tr>
<tr>
<td><strong>Percentage off-take supplied</strong></td>
<td>220%</td>
<td>490%</td>
<td>70%</td>
<td></td>
</tr>
</tbody>
</table>

An estimate of the nutrient (N, P and K) balance for the farm is shown in Table 5. Surplus inputs of P and K are being applied to increase soil Indices. However the picture for N is not so good, with only 70% of the recommended N being applied. Nitrogen is the fuel for grass growth. This is a similar pattern we observe as advisers on farms where N is overlooked in many cases within the whole P and K debate. This is often true of lime as well. There is very little point in increasing soil P and K Indices and then not driving output with appropriate levels of N. Inadequate N use has been a feature of the fertiliser programme on this farm for the last five years. The targets outlined below for this farm will not be met without increasing N application rates to grow more grass.

33
Huge gains in productivity can be achieved on this and many other farms when good soil and grassland management is combined with well-bred livestock. The target for this farm is to increase the kgs of beef produced per livestock unit from the present Figure of 339 kg/LU to 363 kg/LU (+ 7%) and increase lambs weaned per ewe to the ram from 1.1 to 1.5 (+ 36%).

Case Study B

The second case study a suckler-to-weanling farm with 40 single-suckling cows. The farm comprises heavy soils merging into peaty soils at bottom of farm. Much of the farm suffers from impeded drainage. Previous generations drained portions of the farm which are still working well, as indicated by the unimproved peat land that predominates across the boundary fence. It is essentially a difficult farm to operate during times of heavy rainfall.

Similar to the first farm, poor grass supply was restricting farm stocking rate, output and income. This farmer was also exiting the REPS scheme and needed to replace the annual REPS payment through more commercial farming activity. The farm would have been traditionally lowly stocked with additional lands rented.

Soil fertility was above average on this farm with 55% of the farm testing optimal for P and K, with all fields satisfactory for lime. Approximately one quarter of the farm was Index 2 for P with the rest of the farm equally divided between Index 3 and 4. Soil K levels were good in general, with only 18% of the farm with very low levels in Index 1, but with 16% in target Index 3 and 66% in Index 4.

The farmer joined a BTAP group in 2012. In advance of one of the meetings held on his farm, he had been persuaded to install some paddocks. Initially, he only divided one large field with temporary divisions using reels of electrified fencing. After observing the increase in grass supply and resultant improvement in livestock output, the farmer became a firm advocate of paddock grazing. In particular, the concepts of ensuring paddocks are grazed out fully within 2-3 days and not leaving livestock in after three days were fully adopted within the grazing management practices. The aim now is to graze out paddocks within two days by ensuring paddock size is appropriate to the numbers of grazing livestock. This farmer now describes himself as being almost obsessive about paddocks and grazing management. The progress to date has been spectacular, bearing in mind that farming practice has only changed over the last three years. Surplus paddocks are conserved as hay, with this surplus fodder sold over the winter period.

The change in some of the key performance indicators on the farm as a result of the change in grazing practice is shown in Table 6. In 2013, almost 12 ha of rented land was dropped without any negative impact on farm output or increase in fertiliser use. The usage of purchased concentrate feed also reduced. Gross output has increased by 34% in the period from 2012 to 2014. More importantly, gross
margin has increased by almost 55%. Gross margin can be described as the return on farming activity, it is critical that we demonstrate in financial terms the improvement in farm profitability from focusing on improved grassland management.

Table 6. Key Performance Indicators (KPIs) for Farm Case Study B.

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>Change in 2015 vs. 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Farmed (ha)</td>
<td>49.44</td>
<td>37.48</td>
<td>37.33</td>
<td>-12.11 (-24%)</td>
</tr>
<tr>
<td>Stocking Rate (LU/ha)</td>
<td>1.38</td>
<td>1.54</td>
<td>1.76</td>
<td>+0.38 (+28%)</td>
</tr>
<tr>
<td>Fertiliser Cost (€/ha)</td>
<td>€115</td>
<td>€118</td>
<td>€127</td>
<td>+€12 (+10%)</td>
</tr>
<tr>
<td>Purchased Concentrate (€/ha)</td>
<td>€65</td>
<td>€50</td>
<td>€54</td>
<td>-€11 (-17%)</td>
</tr>
<tr>
<td>Gross Output (€/ha)</td>
<td>€773</td>
<td>€782</td>
<td>€1,036</td>
<td>+€263 (+34%)</td>
</tr>
<tr>
<td>Gross Margin (€/ha)</td>
<td>€411</td>
<td>€414</td>
<td>€637</td>
<td>+€226 (+55%)</td>
</tr>
</tbody>
</table>

The farm nutrient balance (Table 7) is negative as applied N, P and K are all below off-take levels. The danger here is that soil fertility levels will be depleted by not replacing off-takes and the progress made with regard to grass growth and stocking will be jeopardised. The dramatic on-farm improvements made over the last three years could well be unsustainable in the long run, so soil fertility levels need to be re-established immediately by soil testing the whole farm. On this farm in some years pig slurry is imported and contributes to reducing the negative balance. To put the farm on a firm footing, an updated soil nutrient plan is to be prepared this spring in advance of any fertiliser purchases. It is hoped that after experiencing the positive effects on output and income that this farmer has seen from good grassland management, that he will be receptive to the other equally important part of the story that the soil will also respond to good nutrition just like the livestock on the farm.

Table 7. Farm Nutrient Balance for Case Study Farm B. (Total N offtake is estimated from recommended N rates for grass and crops).

<table>
<thead>
<tr>
<th>Off-takes</th>
<th>Crop (kg)</th>
<th>P (kg)</th>
<th>K (Kg)</th>
<th>N (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live weight (kg)</td>
<td>18,077</td>
<td>180</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>Hay sales (kg DM)</td>
<td>6,000</td>
<td>24</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Total off-takes (kg)</td>
<td>204</td>
<td>285</td>
<td>3,468</td>
<td>(recommended)</td>
</tr>
<tr>
<td>Inputs (kg)</td>
<td>125</td>
<td>250</td>
<td>2,430</td>
<td></td>
</tr>
<tr>
<td>Balance (kg)</td>
<td>-79</td>
<td>-35</td>
<td>-1,038</td>
<td></td>
</tr>
<tr>
<td>Percentage off-take supplied</td>
<td>61%</td>
<td>88%</td>
<td>70%</td>
<td></td>
</tr>
</tbody>
</table>
In the livestock sector where incomes are quite low it is important to demonstrate the potential of better farm management to improve farm incomes. This example clearly outlines the type of progress that can be made on many lowly stocked farms by replacing non-essential rented land with essentially good grassland management. This farm is now going to be soil tested as samples are now over 5 years old. The increase in grass grown has essentially come from improved management, it is surely having a draw down effect on soil fertility levels. Further progress can be made on this farm with regard to output and profitability, however the soil fertility must not be compromised. Over the last three years livestock condition scores have improved dramatically, leading to an improvement in cow fertility and calf growth rate from improved milk supply.

Fertilising for Profit: Key Tools

1. Soil Samples:
   Having information on soil fertility levels is absolutely essential if one is to embark on any discussion on fertiliser or lime, or indeed for an examination of overall farm output, efficiency and profitability.

2. Nutrient Management Plan:
   The plan identifies the exact steps needed to be taken to correct soil fertility, the soil fertility status of all fields is clearly mapped. Priorities are established as to where sometimes scarce resources are to be deployed to improve farm efficiency and profitability.

3. Measurement:
   As much on farm measurement of output as can be obtained, so that output and efficiency changes can be measured as a result of the investment in soil fertiliser and lime. (Silage yield measurement; grass growth rates; housing and turnout dates; animal growth rates; suckler cow fertility and Ewe weaning rate).

4. Profitability:
   Profit Monitor completed for the farm to demonstrate not only any output benefits from improved soil fertility, but also the financial benefits accruing to the farmer for the investment made. The case for investing in fertiliser and lime needs to be made on the basis of a potential improvement in farm income. We must always ask the question: why should the farmer invest in fertiliser and lime to improve soil fertility?

   ✔ So as to lead to cost reduction (e.g. less rented land, increased output thereby reducing unit cost of production) and ultimately increasing farm income.
5. Best Practice:
Applying the right amounts of N, P, K, and lime is critical. But, they must be applied correctly to maximise the benefit. Over the years, cases of very poor spread patterns are easy to find, particularly in silage fields. Discussion group meetings in Kildare in 2015 used one meeting to address the issues around testing and calibration of fertiliser spreaders. This proved to be a very interesting and worthwhile exercise, as it identified that approximately 30% of fertiliser spreaders tested had a very poor spread pattern. These were recalibrated at the meeting and re-tested to show the improved spread pattern. Most of the problems were as a result of poor machine maintenance such as worn veins, discs, spouts, and incorrect settings. Keeping application equipment well calibrated and maintained is as essential as any other aspect of the fertiliser management programme in order to maximise the return on investment. This highlights the importance of having the complete story when it comes to soil fertility/grassland management.
Soil and Fertiliser for Tillage Yield Improvement

Andy Doyle
Irish Farmers Journal

Soils are the production base for mankind. Without the food they produce globally there would be little to sustain the burgeoning population that the world will have to support going forward. In this regard, soils in good condition will be more productive than those that are not.

Food production is essential for population growth. It has been in the past and it will be in the future. The growth in global population has been significantly linked with our ability to produce food and especially grains. Without all of the technological breakthroughs that have helped crop productivity, famine would have been the main limitation to global population growth.

The increased specialisation in the tillage sector in particular has led to the continuous cultivation of much of the world’s arable land and this has resulted in different problems in different regions, many of which have begun to pose a limit on productivity. Those, coupled with legislative constraints in Europe, have limited the field productivity increases which had existed since the 1960s. Lack of soil maintenance is likely to be a significant factor in this productivity constraint.

The three-legged stool

It has long been said that a healthy soil is like a three-legged stool (Figure 1). When all three legs are in place it provides a solid foundation on which to produce big healthy crops. When any one is missing or damaged, yield potential is reduced and the cost of delivering that potential can be very much increased.

Figure 1. The 'three-legged stool' of soil productivity.
A healthy soil needs all three legs functioning. This has long been established in both the scientific and traditional practice of farming but the drive to intensification moulded farmers' attitudes towards simplicity and specialisation. This lead to increased scale, continuous tillage and often decreased productivity. This has become increasingly apparent over the past 15 years because when the English and Europeans were talking about a yield plateau, our average winter wheat yields were going backwards and spring barley was just about holding still. Only an exceptional year bucked this trend in our national average yields (Figure 2).

(a) Winter Wheat

![Graph showing winter wheat yields over time.](image)

(b) Spring Barley

![Graph showing spring barley yields over time.](image)

Figure 2. Comparison of potential and actual grain yields of (a) winter wheat and (b) spring barley in Ireland from 1984 to present.
An additional problem was the ever increasing cost base that went behind this period of flat yield performance and the two together acted to usurp margins and profit in the sector.

An even greater problem can be seen when actual field performance is mapped against the stated genetic improvement in varieties that is said to have taken place over the same period. The year 1984 is a good base year to take because it was a bit like 2015: yields were extremely good in virtually every field leaving record yield levels. The yield increases that one would have expected since 1984 based on the increasing genetic potential of varieties is shown in Figure 2. The gap between potential yield and the actual achievement is clear and indicates that something is missing in our production systems that is holding back progress with yields.

The continuing deterioration of our soils is a serious limitation to productivity. These genetic productivity levels are quite real and were commonly delivered in the favourable growing year of 2015. Our soils must be made to work harder but to do this we must mind them better. Total dependence on artificial fertiliser has limitations in the delivery of maximum yield potential. So soil health must be revisited at many different levels.

For many years, soil was largely forgotten about – it merely provided the area needed to cash cheques and conacre land suffered worse. The net effect was a continuous drawing down of soil reserves and a depletion of soil organic matter levels. And it is likely that soil fertility trend statistics available largely exclude conacre so it is possible that we have very little handle on our poorest fertility land.

Fertility is important but perhaps even more important for barley than it is for wheat or oats. But what is fertility? Is it the total quantity of elements in the soil or the availability of these nutrients to crop roots? One must presume that it is very much the latter. But there are factors that may be equally or even more important than P and K levels in soil. These are explored later in the context of soil chemistry.

Larger scale with bigger machines has meant more weight, which becomes an even bigger problem when our soils are wet. This puts enormous pressure on the second leg of the stool – soil physics. We tend to be concerned about soil physics in terms of compaction but we need to return to its primary requirement: soil structure.

True compaction is still possible but machinery and tyre manufacturers have gone to great lengths to minimise this possibility. Larger diameter and wider wheels fitted with soft wall tyres act to minimise footprint impact on our soils. Many growers are increasingly aware of the importance of soil protection and some fit even bigger tyres to help protect their soils. But when soil is wet at critical times of the year, such as harvest, you must travel to save your crop and your livelihood.
Physical soil damage is an inevitable consequence of farming in our climate. However, healthier soils can cope better with damage and can recover quicker from it.

Our soils suffer daily stresses in the absence of machines? Rainfall continuously degrades soil where raindrops can hit bare ground. Rain continuously breaks down a soil’s natural crumb structure and this is worst where soil has no vegetation cover. So structure is continuously degraded to sand, silt and clay and the finer particles can move with the water to percolate down into the soil pores to clog them up and constrict further water and air movement.

As well as restricting water flow, reduced pore space also restricts air movement which is essential for both plant and other biological activity. Heat is also a factor and lack of air and water movement can act to keep soils colder for longer during critical growth times. The soil biological complex is critical to undoing the natural degradation which soils are subject to and organic matter is an important soil stabilizer.

Machine size and weight is another big challenge for tillage soils today. As previously stated, the problem of compaction is continuously addressed through the wheels and tyres fitted to equipment and the reduction of the pressure per square centimetre of soil. However, there is an increasing awareness that weight on axles cannot really be hidden by bigger tyres or tracks. Of course they help and they also have a bigger grip surface which should help prevent or reduce wheel slip. But weight is still weight!

Figure 3. Different compression patterns observed in soils arising from different axle and tyre specifications.
Many soils people now look at the compression forces generated by wheels and axle configurations. This has become increasingly important because compression is now being measured down to depths of over one metre. This basically means that the weight on the surface is tightening the soil beneath to these depths by squeezing out the air and reducing pore space. Reduced porosity means less air for plants and biology and reduced water percolation. And when this happens things keep getting worse.

An example of the way this is measured is shown in Figure 3. All the diagrams are the same scale but the compression bubbles are quite different. The one on the right shows considerably less compression to less depth. This uses smaller wheels but four tyres on each side carry the load. The diagram on the left is produced under rubber tracks and the one in the centre is under a pair of bigger 1050/50 R 32s. This bigger tyre may well reduce compaction but it has deep compression activity. And this problem only gets worse when soils are higher in moisture.

![Figure 4.](image.png)

**Figure 4. Field measurements of the impact of tyre specifications on the compression patterns in the soil.**
Some real physical measurements of this effect are shown in Figure 4. The steel bands show the compression forces in the different zones. The narrower tyre had a narrower compression footprint while a wider tyre to its left had a much wider compression footprint that reached to almost the same depth.

When you have a problem that extends to over a metre deep, soil biology is your only friend. This must involve a huge range of organisms, many of which we know little or nothing about, but the earthworm is king. Their activity through the soil opens the door for very many other species to thrive. Many of these organisms also help with other important biological processes such as mineralisation, take-all control, organic matter breakdown etc.

The level of biological activity in our soils is closely linked with the level of organic matter. Growers have spent at least the past three decades taking crops off our tillage land but few have taken the time and effort to put something back. Unless organic matter is returned to the soil on a regular basis, our biological system will underperform.

Described as nature’s ploughmen, earthworms take organic material from the surface and bring it down the profile to be a contributor to mineralisation in the future. But they also consume much of the fine silt and clay produced from degraded soil, which is washed down into the soil pores and take it back up to the surface. This helps maintain soil porosity and water percolation. The mixture of soil and organic matter can subsequently be used to produce humus which also helps many important soil functions.

**Healthy soil**

A healthy soil is, therefore, a much more sustainable entity where all three legs are interlinked to help supply all of the requirements for plant growth. An active biological system helps to restructure soil. Well structured soils can more easily support root and plant growth. They allow enhanced water and air percolation which enables a healthier plant root system to support higher crop yields. Healthy soils contain more organic matter and humus to help supply more of the crop’s needs at critical times and often have lower need for applied fertilisers. Healthy soils drain better but still hold more moisture for times of need.

A healthy soil is also likely to be more resilient against compression damage because of its naturally spongier texture. This does not mean that it cannot be damaged but it should mean that it will recover quicker, primarily as a result of the active biological system it contains.

A balanced biological system is also likely to improve the availability of the nutrients in the soil but that does not lessen the need to have soil in a good state of fertility. Soil fertility is not about the actual amount of nutrient present in the soil –
it is much more about the amount that is available for plant growth and when it is available. Two soil characteristics are very important for this process – soil acidity or alkalinity as measured by pH and humus content.

**Nutrient availability**

Lime is the most basic and yet the most critical element of fertility. If soil pH is not close to optimum then the availability of major nutrients is decreased. The anti-acidity elements in lime reduce the ions which drive acidity and thus prevent them from binding with the important plant nutrients. This helps their availability for plant growth. Lime also helps the activity of the whole biological system by optimising soil pH.

The activity of lime is demonstrated from some recent Teagasc work. Samples of soil from 16 of the major soil series were gathered and each one was split into four treatments in a controlled environment experiment. One sample received no nutrition, another was just treated with lime, a third was treated with just phosphate and the fourth received both lime and phosphate. All were subsequently tested for pH and soil test P levels. The samples that received lime only all showed an increase in P availability in subsequent tests and the biggest improvement was found in samples that received both lime and phosphate.

A similar outcome is likely with soil humus. Humus is a very efficient carrier and delivery system for plant nutrients, making them very available to plant roots. So when humus is generated in the soil, more of the soil nutrient pool will be readily available to plant roots to support growth.

Back in the 1980s and 1990s a common question from growers was “Why were soil test values falling over time when surplus P and K is being applied relative to the estimated requirements”? This is quite likely to have been associated with the fall off in organic matter and humus levels as tillage soils became more worn. The soil test estimates the availability of P and K rather than the actual amount present in the soil. Therefore, optimising crop nutrition is as much about maximising the availability of nutrients in soil and fertilisers as it is about just simply adding nutrients based on 'total nutrient requirements'.

As a basic principle, it is always better to have essential nutrients available in adequate quantities from the beginning of plant growth rather than hoping that they become available during the season. Barley is perhaps more sensitive in this regard and the benefits of fertiliser placement and trace element seed dressings are well proven. The same principle of prior availability is also important for other crops but there may not always be a yield benefit when the growing season is favourable.
Requirements and off-takes

There are issues of concern with regard to P and K (and other nutrients also). The majority of crops have straw removed and this has been going on for decades with no alternative source of organic material applied. But what is the off-take of P and K from crops of straw in Ireland? Two concerns persist:

- The off-take values we use for P and K in straw are of UK origin but are they correct? A crop’s requirement for P and K for growth is partly supplied from fertiliser and partly from the soil. As crops mature, an amount of P and K is normally translocated back into the soil for future use, but is this process fully completed in Irish conditions? With our greener straw conditions at harvest, coupled with the use of glyphosate, the full return of P and K may not be completed resulting in increased off-take.

- Plant breeding efforts over the past two decades have targeted harvest Index resulting in more grain from the same biomass. So have the old off-take Figures for P and K in grain and straw changed? With more grain and less straw, is this affecting the balance of off-take by the different crops fractions? Some researchers in the UK believe that crop production is now being limited by inadequate fertiliser application.

It may be that the off-take values we use are correct but we need to know this for certain. However, despite uncertainty regarding off-take levels per tonne of yield, it is also important to remember that years such as 2015 with very high yields will take more nutrients out of fields, which is worth considering when coming back with fertiliser programmes in subsequent years.

Soil testing

Soil testing is another area worthy of debate and possibly a lot more science. Many new variants are being brought to the market by commercial interests and we need to know if these have anything additional to offer or not? Our current system developed at Johnstown Castle some decades ago was right for that time but our tillage land base is now very different ground and may benefit from different analysis systems.

There is no questioning the need for good soil analysis but does the chemical fraction alone offer a reasonable assessment of the health and potential of soil in today’s agriculture? Some would suggest that soil testing must also involve some biological assessments, as well as measurements of its physical and organic matter condition. Without these can we possibly give a test reading that offers a good assessment of the potential of a piece of ground? Perhaps we can but is it time to re-evaluate our testing system.
The soil test itself is another and separate issue. What does a test represent and who is governing where and when soil tests should be taken. The traditional recommendation to take a sample from a field in a “W” or “M” format may be an outdated methodology for some or many continuous tillage fields.

There is increasing evidence, based on relatively limited experience, that larger fields which have been uniformly managed for a number of decades are now showing quite variable fertility levels. It would be both interesting and useful to understand the cause of this variability. On the assumption that this is not a result of inaccurate spreading in recent years this variability in nutrient availability may be more related to soil texture.

Variability in texture within a field may be more common than might be expected and this can have two consequences. Lighter parts of a field may well have lower organic matter and humus levels and this is likely to decrease the availability of nutrients as well as their quantity. Also, lighter areas with higher sand content may be more prone to loss of nutrients as there is less clay to hold them.

Understanding the causes of fertility variability is important because they can mean a reduction in potential productivity in some areas and/or a waste of applied nutrient in others. Soil samples taken across fields have hidden situations where soil P levels have varied from 3 mg/l to over 50 mg/l in the same field which had uniform husbandry for decades. The same variability has been found with regard to pH and lime requirement.

Farmers need to use soil testing to help the productivity of every square meter of ground and minimise the risk of over application and losses in parts of fields where nutrient levels are already high. Such treatment of fields is now increasingly possible through the help of precision farming technologies and variable rate application. The challenge is to understand the causes of this variability and how to assess it. Is this a matter for grid sampling or soil conductivity testing or is there some better way to unravel this challenge? Growers need research to advise on the most appropriate ways to tackle this problem where it occurs.

**Nutrition for crop protection**

Another aspect of soil fertility / health that deserves more serious consideration is the potential impact that it can have for crop protection. Growers are very aware of the continuously increasing requirement for chemical use in crop production and that comes with a cost. While fungicides, herbicides and many other inputs leave a return in their own right, when the total production cost is not rewarded with margin then we must look towards a different model.

There is a growing belief that a more balanced supply of a big range of nutrients is likely to produce a plant that is more resistant or tolerant to a range of problems. We often hear mention of the importance of zinc or manganese in this regard but a
healthy soil may be supplying many other substances that help plants fight initial infection, or to cope better in the presence of disease. Having a fertile soil which can supply nutrients on a gradual basis, especially during the early part of the growing season, may well have a knock-on effect in terms of how a programme might be redesigned.

Indeed, this may not even be a nutrient issue. Biological activity in the soil is itself a series of complex chemical process and who knows what these chemicals will do, either in a positive or negative context. It is possible that some of these compounds may have a growth promotion effect or even a useful fungicidal effect.

Given our ever increasing dependence on fungicides for disease control and our vulnerability in the face of the continuous evolution of resistance, this is an area that must be explored further.

**Soil potential sets yield potential**

All of the comments made in this paper are made in the belief that it is the quality of our soils – the end product of good chemical, physical and biological properties – that sets the yield potential of the crops we try to grow. Thirty years ago we were able to raise more eyebrows with the level of yield reports from individual fields. Thirty years later we are trying to reproduce the yield levels of thirty years ago, despite the significant genetic improvement that has taken place in the interim. The harvest of 2015 rocked our perspective of yield potential and it is time to shift the expectation of what our tillage soils are capable of, especially owned and leased land.

There is a limit to what improvement can be done in this regard on rented land, especially conacre. If the land owner is not equally committed to improving soil as the grower is, then a grower has no long term future in this land. There are many growers in Ireland who could be better off with less ground if that land could produce the genetic potential of the varieties we plant. If we do not look after the three legs of our soil stool we will not have a future because costs will continue to consume output and support payments are being diluted over time.

**In conclusion**

Our soils are our greatest asset. We cannot grow an acre of crop without an acre and we cannot grow a profitable acre without a good acre. If we want to have a viable future in tillage we must maximise the yield and returns from the acres we grow. Having a healthy soil is not an option in this regard – it is essential. Healthy soil will generate higher yield potential, withstand mechanical damage better, recover more quickly from mechanical compression and possibly result in lower production costs in the process.
If we are to survive we must return to our position of having the highest yield levels in the world – this is the only way we can survive in a high cost low price environment. Healthy soil is not optional – it is an essential part of farm husbandry into the future. “If you look after your soil it will look after you.” Think soil – think potential.