Teagasc submission made in response to the Consultation Paper on

The Third Review of Ireland's Nitrates Action Programme

with associated proposals for amendments

Prepared by:
Teagasc Working Group on the Water Framework Directive:
Shortle G. (chair), Alexander S., Boyle G., Boland A., Browne P., Burgess E., Carroll C., Daly K., Dillon P., Fenton O., Foley M., Hackett R., Hennessy M., Horan B., Humphreys J., Hyde T., Kelly T., Kennedy N, Leach S., McCutcheon G., McDonald N., Micha E., Mellander P.E., Mullane D., Murphy P., NiFhlatharta N., O'Dwyer T., O'hUallachain D., O'Mara F., O'Riordan E., Plunkett M., Richards, K., Ryan M., Shalloo L., Smiddy B., Vero S., Wall D.P.

Editors:
Shortle, G., Wall, D.P., Murphy, P.

Teagasc
Agriculture and Food Development Authority
Oak Park, Carlow
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Teagasc

Agriculture and Food Development Authority

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Executive Summary

Purpose of the Review

This submission is made in response to the invitation from the Minister for Housing, Planning, Community and Local Government, Simon Coveney, T.D., for submissions, observations and comments on the third review of Ireland's Nitrates Action Programme (NAP). This consultation is run jointly by the Department of the Housing, Planning, Community and Local Government (DHPCLG) and the Department of Agriculture, Food and the Marine (DAFM).

The submission has been prepared by Teagasc's Working Group on the Water Framework Directive (WFD); members of which are drawn from both the Knowledge Transfer and Research Directorates of the organisation. It was prepared following consultation with colleagues across Teagasc using their collective knowledge and experience of current agri-environmental science and practice and the implementation of the Good Agricultural Practice (GAP) Regulations.

Derogation

The derogation under the Nitrates Directive in respect of eligible grassland farms that allows farmers to operate at up to 250 kg of organic nitrogen (N) per hectare was considered as an integral part of the review. Evidence of the derogation's current effective operation, additional to that which was included in the Teagasc submission on the last review, is presented in Part 1 of this submission. While the proposed amendments are generally applicable to both derogation and non-derogation farms, some proposals are more specific to farmers availing of the derogation.

Developments in farm practice since the last review

Over the four years since the last review the implementation of the NAP, including the derogation, has resulted in changes in practices on Irish farms which have reduced the risk of nutrient loss to water from agriculture.

Based on a review of current practice and published research this submission presents the following outcomes:

- Since the adoption of the first NAP in 2006 soil phosphorus (P) levels in Ireland have steadily declined. Soils tested with excessive soil P (index 4) have decreased by 43% between 2007 and 2015.The percentage of soils at P Index 1 and 2 has increased from 40% in 2006 to 62% in 2016. Currently only 11 % of soil samples analysed by Teagasc have optimum soil fertility in relation to the pH, P and K. This poor soil nutrient status presents a significant barrier to achieving environmental and economic sustainability on Irish farms and suggests that there will need to be increased use of P fertiliser on the suboptimal Index 1 and 2 soils.

- Analysis of National Farm Survey data for 150 dairy farms over seven years from 2006 has shown declines in farm-gate N and P surpluses and increases in N and P use efficiencies. Similar results were reported in a survey of 21 dairy farms in the south-east of Ireland.
- Through soil analysis and the careful implementation of nutrient management plans, farmers participating in the Agricultural Catchments Programme (ACP) in the West Cork Timoleague catchment were able to reduce fertiliser phosphorus (P) inputs against a background of relatively high soil P levels. This approach enabled the farmers to reduce risk to water while maintaining milk output and high farm profits.
- An ACP study over successive years has shown that current closed period for slurry application has utility and that there was little evidence of increased losses due to slurry spreading during the 4 weeks after the closed period. It was also found that heavy rainfall events throughout the year can drive incidental P losses. This highlights the importance of supporting farmers in decision making regarding slurry spreading decisions.
- A study of lake sediment from the ACP Co. Monaghan catchment shows that while agriculture intensified between 2000 and 2010, P in the lake declined. Agri-environmental schemes, the local group water scheme and the GAP measures were indicated to have influenced changes in farm practice leading to the lake's recovery.
- An EPA study of the Munster Blackwater catchment concluded that recent improvements in farming practices have reduced nitrogen (N) and P loadings to the river with concurrent improvement in estuarine P concentrations, chlorophyll and dissolved oxygen saturation. Changes in management practices on Teagasc's Curtin's farm in Moorepark and the Johnstown Castle dairy farm have led to reduced N and P concentrations in groundwater with a downward trajectory in N concentrations.
- On the five farms in the Teagasc Heavy Farms Programme where high resolution monitoring data is available water quality in open drains, in-field drains and groundwater are below maximum admissible N and P concentrations as a result of favourable denitrification and soil chemistry conditions. All the farms have Nutrient Management Plans implemented with the full GAP chemical P allowance being applied.

Productivity change on Irish Dairy Farms 2005-2016

The environmental and economic sustainability of the Irish grass-based livestock sector is dependent on increased productivity and improved efficiency of conversion of grazed pasture to animal products. In recent years, particularly since the introduction of the GAP measures, substantial progress has been made in improving efficiency and productivity on Irish farms. Grass production and utilisation has trended upwards too, albeit with substantial inter-annual variation due to weather – in 2008 estimated grass utilised on Irish farms was 6.7t DM/ha while in 2015 it stood at 7.8t/ha. During the same period the grazing season has increased too – the average grazing season length for the 2008 – 2011 period was 236 days while for the 2012 – 2015 period it was 240 days. The successful adoption of the Economic Breeding Index (EBI) has resulted in a rapid increase in the overall rate of genetic progress with significant impacts on the performance of the national herd. Milk solids (fat and protein) per cow have increased by almost 15% in the decade to 2016. Similarly other traits have improved, for example, calving interval has reduced by approximately 16 days from a peak of 406 days in the late 1990's to approximately 390 days for females born in 2012. It is anticipated that this rapid improvement within the national herd over the next 10 years which will greatly contribute to the sustainable intensification of the dairy sector in Ireland.

Thus the implementation of a suite of practice change components, in combination, results in a steady trend of productivity and efficiency improvement. Irish research and knowledge transfer efforts have focused on these components over decades and this will continue. Projections based on modelling and expert opinion predict substantial gains will be made particularly in grassland productivity and genetic improvement. Importantly most of the gains will be based on improved efficiency of production rather than significant increases in intensity.

Food Wise 2025 - Implications for the NAP

The effect of Food Wise 2025 (FW2025) on the dairy sector has been examined based on the Strategic Environmental Assessment (SEA) for FW2025 and scenario modelling. Expansion in the agriculture sector must comply with a range of environmental legislation such as the Nitrates Directive and thus there are constraints to this expansion. Overall, the FW 2025 scenario projects a relatively stable cattle population and an increase in milk production. Increased milk production has and will be achieved through a slight increase in cow numbers, increased milk production per cow and based upon accelerated genetic improvement of the national herd. Compared to the 1990 baseline year, in 2015 milk production and milk fat/protein yield has increased by 24 and 39%, respectively while cow numbers have reduced by 5.5%. The increase in dairy cow numbers is largely expected to be offset by reductions in the non-dairy bovine herd. The result of changes in the national herd composition will result in a small (+2.9%) increase in national bovine manure N excretion between 2005-07 and 2030. In 2030, national bovine N excretion is projected to be 2.4% lower than in 1998. FoodWise 2025 is also expected to result in changes to our national inorganic fertiliser use.

Proposed amendments

In this submission, Teagasc makes 8 proposals for amendments to the GAP regulations with a view to achieving:

- More effective protection of water quality, and/or
- More efficient production without increased risk of nutrient loss to water.

1. *Rationalisation of calculations of maximum fertiliser N and P allowance –*
The inclusion of home – produced manures, that are recycled within the farm, into the calculation of maximum permitted chemical fertiliser allowance, unnecessarily complicates the calculations and can seriously compromise the future soil fertility (soil P) and productivity of the farm. The variation in maximum chemical fertiliser N and P allowances between regions with different storage capacity requirements is not in agreement with nutrient advice or with farm nutrient balance.
Proposed Solution - Removal of stored organic P from the calculation of farm P balance and for calculating maximum chemical phosphorus allowed onto a holding.

2. *Adoption of appropriate phosphorus build-up rates for farmed soil* - the P allowances for soil P build-up where STP is suboptimal (i.e. P Index 1 & 2) in the current GAP regulations are too low to facilitate restoration to P Index 3 within a reasonable time. This greatly hinders farmers' ability to attain optimal soil P status thus reducing overall environmental and economic sustainability.
Proposed solution – increase the maximum build-up allowance in addition to crop requirement to 50kg/ha for soils at P Index 1 and to 30kg/ha for soils at P index 2.

3. *Basing nutrient management plans on previous year's data -*
The current system based on the use of the actual year's records has a number of difficulties associated with it which cause problems for farmers and planners:
    - To be effective, nutrient management plans (NMP's) need to be done before the end of the closed period to allow the purchase of fertiliser in advance to meet crop requirements.
    - In planning, farmers are risk averse and often leave a large safety margin below limits for chemical N and P to allow for potential changes in stock numbers etc. This contributes to the undersupply of nutrients, particularly P, and the unsustainable decline in soil P levels.
    - Most farmers wait until their final annual N and P figures are available in the end of January before having their NMP prepared. This leads to most NMP's, being created after the end of the closed period limiting their effectiveness as management tools since many of the nutrient management decisions for the year are already made by then.

    Proposed Solution – there are three components in this proposal:
    i. Allow farmers to use the most recent complete year's stocking rate figures (N and P statement) to determine their maximum N and P fertiliser allowance rather than be compelled to use current year figures. This would

allow for more certainty and facilitate more effective and timely planning. The import and export of organic manures for the planning year would also be based on the previous year's stocking rate figures.

ii. The dates for the calculation of stocking rate would shift from the calendar year to an October 1st to September 30th basis giving a more accurate reflection of actual nutrient loading and allow for early nutrient planning based on certainty of stocking rate on which allowances are based.

iii. The start of the fertiliser accounts year would also move to October 1. As chemical N and P cannot be applied in the October to December period this has no regulatory disadvantage. However it allow NMPs and fertiliser records to be completed from early November facilitating good and timely decision making on nutrient management while also reducing the problem where records of forward purchases have to reconciled in closing stocks though these stocks will not be on the farm.

4. *Substituting organic nutrient sources for chemical fertilisers* - many moderately stocked grassland farms could use imported organic fertilisers (e.g. pig slurry) to meet some of their nutrient requirements and replace chemical fertilisers if allowed to exceed the 170 kg ha organic N limit.
Proposed solution – allow the import of organic N sources onto moderately stocked grassland farms thus replacing imported chemical fertiliser and providing additional land to utilise specific organic fertilisers where needed.

5. *Allowing the carry-over from one year to the next of "organic fertilisers" on farms that import them* - currently when imported manures are not applied in the year of import it is assumed that the manure was used in its year of import. This inhibits farmers from importing and storing manures in a timely manner for the forthcoming growing season.
Proposed solution – allow the carryover of manure stocks from year to year and facilitate this by modifying the Record 3 form as a means of recording this.

6. *Changes in fertiliser N recommendations for potato crops* - more specific N advice is required to meet the N requirements of new potato groups and varieties to satisfy specific market requirements.
Proposed solution – adjust the N allowances to match the maximum recommended rates in the 2016 Teagasc 'Green Book'.

7. *Changes in fertiliser recommendations for vegetable crops - the* current fertiliser allowances in the GAP regulations are based on recommendations drawn up in the 1960's and are now substantially and are largely unchanged since then. They are neither agronomically nor environmentally sustainable.
Proposed solution – align the allowances in the GAP regulations with those in the recently revised 2016 Teagasc 'Green Book'.

8. *Autumn phosphorus application for winter barley* – due *to 'closed period' prohibition of P applications insufficient P supply at sowing is likely to restricting early growth of winter barley, particularly where soil P index is low (i.e. P Index 1 and 2), ultimately leading to yield reductions.*

Proposed Solution - an application of 20 kg/ha of fertiliser P to be permitted when incorporated at sowing for winter barley at soil P index 1 and 2, where such application takes place before October 31st.

Introduction

This submission made in response to the consultation process run jointly by the Department of Housing, Planning, Community and Local Government (DHPCLG) and the Department of Agriculture, Food and the Marine (DAFM) inviting views and comments on proposals for the review of Ireland's NAP. It has been prepared by Teagasc's Working Group on the Water Framework Directive (WFD); members of which are drawn from both the Knowledge Transfer and Research Directorates of the organisation. It was prepared following consultation with colleagues across Teagasc using their collective knowledge and experience of current agri-environmental science and practice and the implementation of the Good Agricultural Practice for the protection of water quality (GAP) regulations within the NAP.

Teagasc has and continues to pursue a comprehensive research and advisory programme in order to address knowledge gaps on the interaction between agriculture and the aquatic environment as identified in reviews of national and international research. This research is conducted by Teagasc in collaboration with a range of Irish and international research institutes and universities, and with financial support from the Department of Agriculture, Food and the Marine Food (DAFM), the Research Stimulus Fund (administered by DAFM), INTERREG, Science Foundation Ireland (SFI) and STRIVE (administered by the Environmental Protection Agency). The Agricultural Catchments Programme (ACP), which has as its principal objective the evaluation of the GAP measures, has been funded by the DAFM since 2008 and is currently in the second year of its third four-year phase. Its outputs constitute a significant part of this submission and this submission cites publications from the ACP as well as the ACP Phase 1 Report (Shortle and Jordan, 2013) and Phase 2 Report (Shortle and Jordan, 2017).

This submission builds on previous Teagasc submissions made during the reviews of the GAP regulations in 2010 (Schulte et al., 2010) and 2013 (Shortle et al., 2013).

In **Part 1** of this submission reviews developments in farm practices that have potential to positively impact water quality published since the last NAP.

In **Part 2** technological and management changes impacting on farm productivity and environmental sustainability are reviewed.

Part 3 deals with the implications of FW2025 for farming and water quality.

In **Part 4** Teagasc proposes amendments to the GAP regulations, including the derogation, based on the outcomes of its environmental research programme and supported by reviews of the current international scientific literature. The objectives of these proposed amendments are:

- To achieve more effective protection of the rural aquatic environment.
- To improve efficiency of agricultural production.
- To rationalise and simplify the operation of the GAP regulations

Teagasc has adhered to three guiding principles in the preparation of these proposed amendments:

1. All proposed amendments are based on solid scientific research from published sources;
2. All proposed amendments have been subjected to an explicit environmental impact assessment, with emphasis on the impact on water quality, and with cognisance to potential impacts on biodiversity and greenhouse gas emissions.
3. All proposed amendments have been cross-evaluated against each other to ensure consistency and synergy between all proposed amendments.

Part 1. Farm practice change and water quality

Farm practice change and water quality

In this part of the submission summaries of the more significant research outputs of most relevance to changes in farm practice and their effects on water quality published since the last review in 2013 are presented. Relevant research outputs published prior to this are included in the Teagasc submission on the first and second reviews (Schulte et al., 2010, Shortle et al., 2013). References for the original publications are provided in the attached bibliography.

1.1 Increases in nutrient use efficiency

Since the introduction of 1st NAP in 2006, there have been declines in farm-gate N and P surpluses and increases in N and P use efficiencies as was shown in a study carried out by Buckley et al. (2016a and 2016b) as part of the ACP, across 150 specialist dairy farms continuously participating in the National Farm Survey (NFS) between 2006 and 2012. The study showed that this efficiency increase is driven by efficient use of inorganic N and P fertilisers and organic nutrient sources on these farms.

Nitrogen balance declined by 25.1 kg/ha from 180.4 to 155.3 kg/ha over the study period, this was attributable to reduced chemical N fertiliser imports of 23.1 kg /ha. Nitrogen use efficiency (NUE) improved by 2.1% over the 2006 -12 period from 20.8 to 22.9%. P balance declined by 50% from 11.9 to 6.0 kg /ha between 2006 and 2012. Decline can be attributed to reduced chemical P fertiliser inputs of 6.5 kg /ha. Phosphorus use efficiency (PUE) improved by 18% over the study period from 60 to 78% Milk solids output increased from 405 to 450 kg/ha (at a stocking rate of 1.86 to 1.84 LU) across these 150 specialist dairy farms. Mihailescu et al. (2014, 2015a, 2015b) also reported notable shifts in farm practice aligned with utilizing organic manures according to their nutrient value (e.g. spring applications) citing the change to the “positive impact of GAP regulations”.

1.2 Farm practice change in the Timoleague catchment (ACP)

Murphy et al. (2015) reported indications of a decline in P source pressure while maintaining production output in response to GAP measures for P in the Agricultural Catchments Programme Timoleague dairy catchment (7.6km^2) between 2010 and 2013. Average inorganic P use declined by 5.2 kg/ha/yr, lower average farm-gate P balances (i.e. applied P over removed P) of 2.4 kg ha/yr, higher average PUE of 89% relative to earlier studies by Treacy (2008) reporting a P surplus of 5.6 kg/ha and PUE of 68% for 21 commercial dairy farms (2003–2006) and Mounsey et al. (1998) reporting a P surplus of 19.5

kg/ha and a PUE of 37%for 12 commercial dairy farms (in 1997). The proportion of soils with excessive P concentrations (i.e. Index 4) decreased from 32 to 24% and there was evidence of a decrease in P in the transfer pathways from the soil surface to the catchment outlet. The catchment dairy farmers produce yields of 1,125kg milk solids/ha which are comparable to the top 10% performing national dairy farmers (2.47 LU/ha) producing yields of 1,045kg milk solids/ha.

1.3 Closed Period

Using high resolution stream chemistry data it has been shown by Shore et al. (2016) that the current closed period for slurry application has utility and during the 4 weeks after the closed period there was no detection of incidental transfer signals (i.e. losses from recent applications) of nutrients. This was, likely, due to farmers either choosing not to spread at a risky time or to spread in a less risky place with lower run-off potential. Evidence of storm events in late autumn and during wet summers (e.g. 2012) that drove incidental transfers suggests that incidental losses can occur throughout the year. This reiterates the importance of good decision making regarding slurry applications and the benefits of supporting farmers in these decisions.

1.4 Lake Sediment P records

Using sediment records from the lake of Lough Sreenty (ACP Co. Monaghan catchment), in an area vulnerable to P run-off from surrounding poorly drained drumlin soils, O' Dwyer et al. (2013) reports that while agriculture intensified in the catchment, with the organic P loading on soils increasing from 8 to 17 kg/ha between 2000 and 2010, there was evidence of a decline in P enrichment. Phosphorus mitigation measures from the rural environmental protection schemes, group water scheme initiatives and the implementation of the GAP measures were indicated as the key tools for the signs in lakes recovery (O' Dwyer et al. 2013).

1.5 Nutrient decline in the Blackwater catchment

A study investigated changes in estuary nutrient concentrations in the Blackwater catchment concluded that recent improvements in farming practices, specifically a decrease in fertiliser application rates, have reduced nutrient loadings to the Blackwater River (Ni Longphuirt et al., 2015). The Blackwater estuary which drains a large (3307km^2), intensively farmed agricultural catchment with a high proportion of dairy farms has a reduction in nitrogen loadings (17%) and phosphorus (20%) in the 2005 to 2015 period. Long-term river monitoring data reflect these reductions while concurrent monitoring data from the Blackwater estuary shows improvements in P concentrations, chlorophyll and dissolved oxygen saturation show.

1.6 Measured sustainable intensification on Teagasc research farms

Teagasc has finished two large studies (Baily et al., 2011; Huebsch et al. 2013) investigating the source, transformation and fate of nutrients lost (including time lag concepts in the analysis) and the effect of management change over time on water quality in intensive dairy scenarios with contrasting soil types (free draining and mixed drainage). For example in the Baily et al. (2011) study water samples using a 10 year dataset from 24 shallow groundwater wells and the dual isotopic composition of nitrate was used to clarify nitrate sources, to assess spatial and temporal variability in nitrate concentrations and to determine if and where denitrification was occurring. Vertical travel time was estimated to correlate nitrate concentrations with management practices. Organically derived nitrogen was the predominant source contributing to groundwater nitrate concentrations. Denitrification was identified as prevalent within specific regions of the study site. The distinct low temporal variability in the isotopic data suggests constancy among nitrate sources and pro-cesses over time across the study site. Vertical travel times of up to 3 years were estimated on site indicating the influence of recent management practices on nitrate concentrations. Very slow horizontal migration of groundwater (decades) indicates a legacy of older management practices. Stable isotope techniques, together with an understanding of time lag, provide an extra mechanism to test the efficacy of monitoring and mitigation programmes. An update study by Clagnan et al. (2016) using similar isotopic techniques shows that a 10 km subsurface drainage system on the same site transports remediated water (from poorly drained areas with high denitrification capacity) to the open ditch network aiding sustainability with respect to water quality. Movement of dairy soiled water irrigation systems to soils with higher attenuation capacity improved nitrate losses to groundwater. The objective of the Huebsch et al. (2013) study using another 10 year+ groundwater dataset was to relate changes in detailed agronomic N-loading, local weather conditions, hydrogeological and geological site characteristics with ground-water N occurrence on an intensive dairy farm with free draining soils and a vulnerable limestone aquifer. In addition, the concept of vertical time lag from source to receptor is considered. Statistical analysis used regression with automatic variable selection. Four scenarios were proposed to describe the relationships between paddock and groundwater wells using topographic and hydrogeological assumptions. Monitored nitrate concentrations in the studied limestone aquifer showed a general decrease in the observed time period (2002–2011). Statistical results showed that a combination of improved agronomic practices (movement of soiled water irrigation systems to thicker zones on site) and site specific characteristics such as thicknesses of the soil and unsaturated zone together with hydrogeological connections of wells and local weather conditions such as rainfall, sunshine and soil moisture deficit were important explanatory variables for nitrate concentrations. Statistical results suggested that the following agronomic changes improved groundwater quality over the 11-year period: reductions in inorganic fertiliser usage, improvements in timing of slurry application, the movement of a dairy soiled water irrigator to less karstified areas of the farm and the usage of minimum cultivation reseeding on the farm. In many cases the explanatory variables of farm management practices tended to become more important after a 1- or 2-year time lag. Results indicated that the present approach can be used to elucidate the effect of farm management changes to groundwater quality and therefore the assessment of present and future legislation implementations.

1.7 The Heavy Soils Programme

Seven intensive dairy farms farming on ‘heavy’ soil types are participating in a Teagasc monitoring and development programme and contributing key data on farm performance and environmental sustainability in heavy soil areas. The farms are deemed ‘heavy’ (i.e. predominately clay mineral soils with drainage installed on either surface or groundwater gleys) located in high rainfall areas predominantly in the south west of Ireland. Both agronomic and environmental performance is being monitored on these farms which are situated in relatively high rainfall areas. On site met stations and flow meters collect data at a 15 minute resolution.

All the farms have been soil surveyed to elucidate soil type at paddock scale and have embarked on a programme of soil fertility assessment and improvement. Lime applications have brought soil pH levels to the optimum of 6.3 in 2016 but there has been a notable decline in soil P and K levels. Increased cow numbers and grass growth during this period had led to increased P and K offtakes as milk production has increased. The full chemical P allowance is being applied on all farms as specified in their NMP’s under GAP regulations (average of 25 kg/ha/farm of chemical P allowed), however, given the current levels of P offtakes and requirement for P build-up these grassland focused farms have large farm gate and structural P deficits.

The heavy soils on these farms tend to have high attenuation capacity with respect to N and high P fixation characteristics which present a major challenge to increasing soil fertility, however, these conditions minimise the risk of N & P transfer in drainage water and overland flow to the extensive drainage network. Water quality is being intensively monitored (pipe flow, groundwater and open ditch grab samples) on each farm both in the newly installed land drainage network (i.e. piped drains), and in the existing open ditch drainage network. In addition isotopic signatures of the sampling areas were obtained by Clagnan et al. (2016) showing that across five farms the attenuation capacity in terms of N is high but some instances of conversion to ammonium was evident. In terms of dissolved reactive phosphorus some breaches existed in high organic areas but overall loads of nutrient losses were low.

1.8 Soil Phosphorus (from Plunkett and Wall 2016)

Currently only 11 % of soil samples by Teagasc have the optimum mix of soil pH, P & K. Changes in fertiliser use nationally must comply with the Good Agricultural Practice regulations under the Nitrates Directive. Any additional use of inorganic P fertiliser requires a farmer to demonstrate a requirement for P on their farm based on soil testing. Any increases in P use must take other non-fertiliser P imports e.g. feed and/or imported manures.

Over the last decade, the percentage of soils at Index 1 and 2 has increased from 40% in 2006 to 62% in 2016 (Fig. 3.5). 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 (Fig. 6) 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 (2016) show a return to declining soil P levels on farms nationally (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 been a gradual decline since 2006 (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 2006 and 2016 there has been a 50% reduction (30% in 2006 to 15% in 2016) in the number of soils with P Index 4 status. These trends in grassland soil P fertility between 2006 and 2016 clearly show that the production potential of our grassland soils is being slowly eroded. The declining soil P 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 (FH 2020) and the more recent FW2025 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.

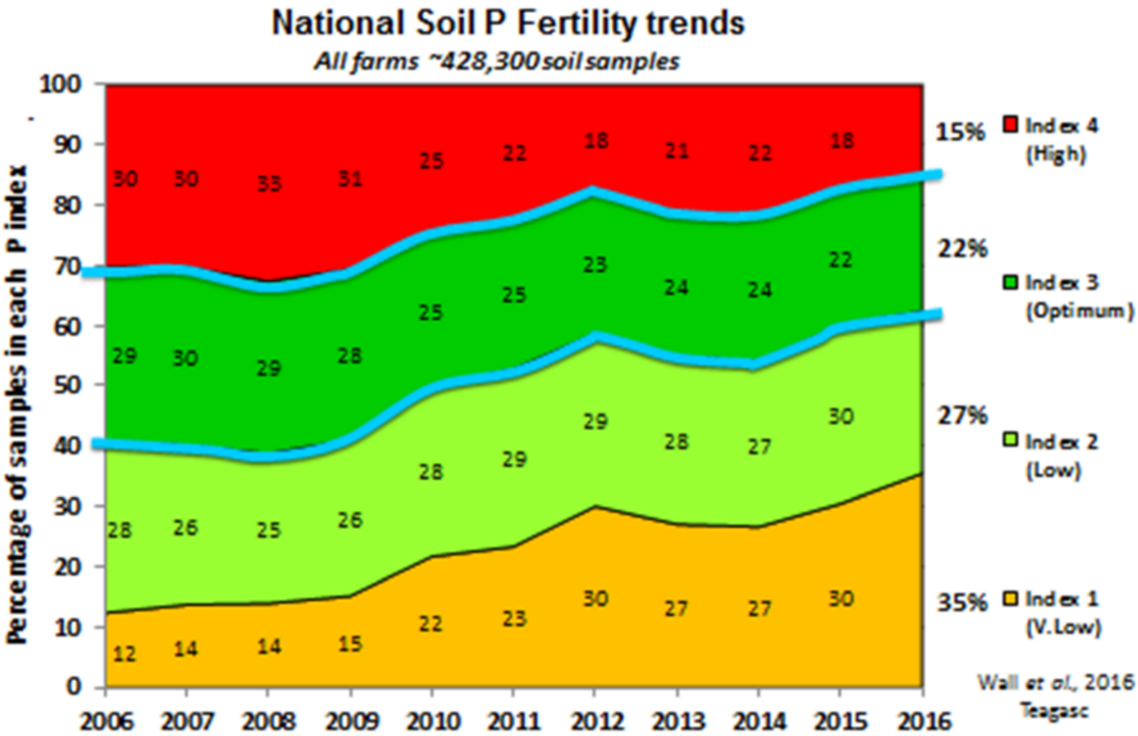
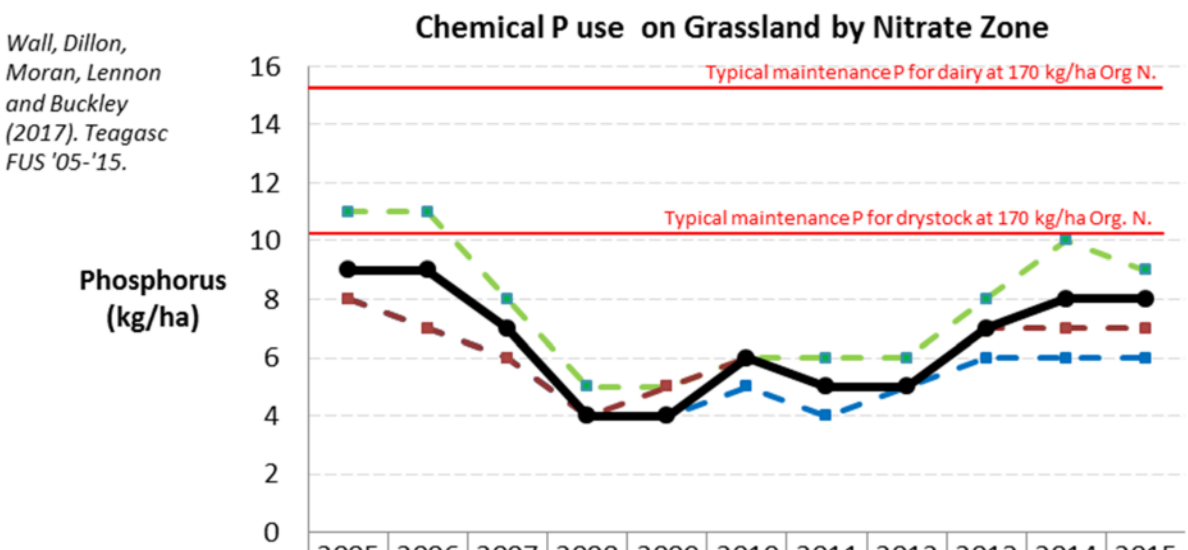


Figure 3.5. Percentage of grassland soils tested falling within each soil P Index (1-4) between 2006 and 2016.

The recent fertiliser use survey (Teagasc 2017) investigated fertiliser use on Irish farms over the period 2005 and 2015. Figure 3.6 shows the fertiliser P use by Nitrates Zone over this period and shows overall the average fertiliser P use was relatively low. The fertiliser P use declined sharply from 2006 to 2008 and remained very low (5-6 kg/ha) from 2008 to 2012. Since 2012 there has been some recovery in fertiliser P use in Zone A (sufficient to maintain ~2 LU /ha of drystock), while the fertiliser P use in Zone B and C has remained low up to 2015 (sufficient to maintain a stocking rate of <130 kg/ha Org. N (~1.5 LU/ha) of drystock and ~ 100 kg/ha Org N (1.2 LU/ha) of dairy. These data provide information related to why national soil P fertility has declined (Fig. 5) so dramatically during this period. The current average levels of fertiliser use across all Zones (8 kg/ha P in 2015) would supply ~70% of the maintenance P requirement for a dry stock farm or ~53% of the maintenance P requirement for a dairy farm stocked at 2 LU equivalents/ha (170 kg/ha Org N)..



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Zone A	11	11	8	5	5	6	6	6	8	10	9
Zone B	8	7	6	4	4	5	4	5	6	6	6
Zone C	8	7	6	4	5	6	5	5	7	7	7
All Zones	9	9	7	4	4	6	5	5	7	8	8

Figure 3.6. Phosphorus usage in fertilisers in Ireland by Nitrate Zone between 2005 and 2015 (Source: Teagasc Fertiliser Use Survey 2017).

Part 2. Productivity change on Irish Dairy Farms 2005-2016

Productivity change on Irish Dairy Farms 2005-2016

The sustainability of the Irish grass-based livestock sector is dependent on increased productivity and improved efficiency of conversion of grazed pasture to animal products. Consequently, the selection of improved animal genotypes coupled with enhanced grazing management has the potential to yield further significant improvements in production efficiency. National statistics reveal clear evidence of increasing productive efficiency within Irish dairy farm systems in recent years through a combination of improved farm management practice allied to accelerated genetic improvement within the national herd. Figure 2.1 below illustrates the consistent improvements in both milk fat and protein composition and yield which have been realised on Irish dairy farms during the period from 2005 to 2016 (CSO, 2016).

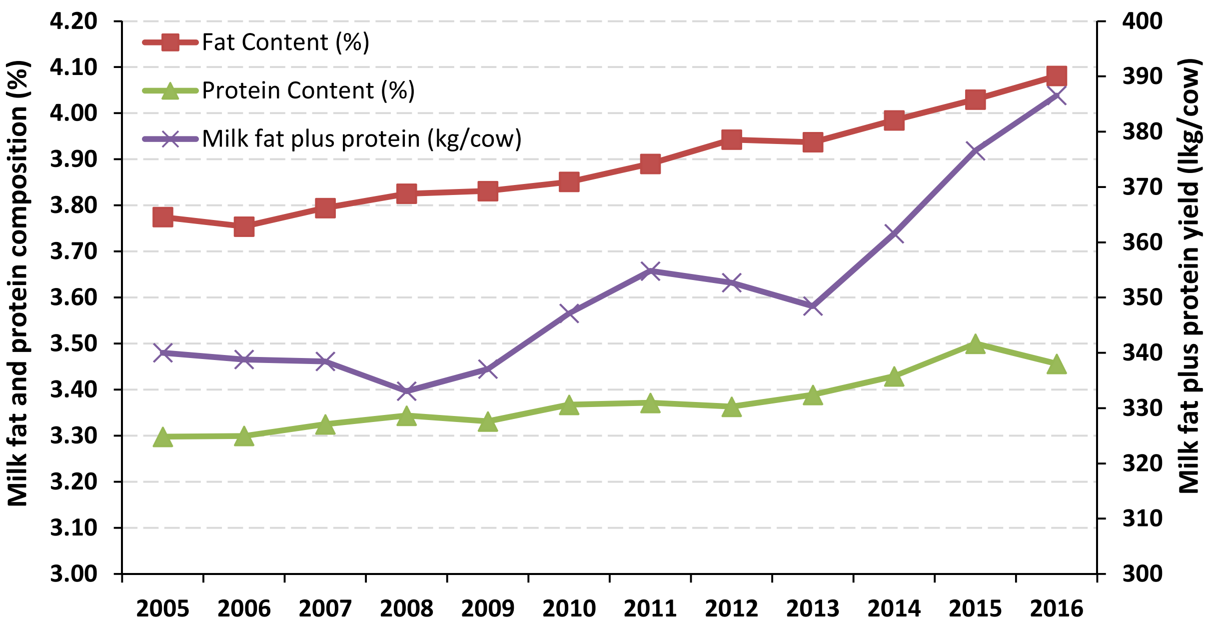


Figure 2.1. Trends in milk production and composition on Irish dairy farms (2005 to 2016, inclusive)

Previous research has reported, the average dairy farm nationally utilises 7.1 tonnes (t) of grass DM/ha (Creighton et al., 2011). While more efficient farms are growing and utilising in excess of 12 to 14 t of grass DM/ha over a 280 day grazing season with stocking rates of over 3 cows per hectare (Shalloo et al., 2011). A wide range of factors affect grass growth and utilisation at farm level which are outside of a farmer's control including soil type, region, altitude and meteorological conditions (Brereton, 1995). However, Shalloo et al., (2011) highlighted grassland management, grass varieties, soil fertility and national reseeding levels to be major limiting factors to overall grass production in Ireland. The removal of the constraints of milk quotas has prompted the Irish dairy industry to reappraise the systems of milk production that are operated at farm level. Hanrahan et al. (2017) evaluated the sources of improved technical efficiency within dairy farms based on a temporal analysis of Teagasc National Farm Survey (NFS) (Teagasc, various years) statistics during the period from 2008 to 2015 using a dataset containing on average 257 specialised dairy farms each year and 2,056 surveys in total. The outputs from the survey provide a range of physical and financial performance indicators for each farm such as farm details, stock details, product yields, sales, purchases, costs and margins. Table 2.1 provides the average values for a number of key physical variables over the eight year period 2008 to 2015. Over the eight years average cow numbers increased from 57 to 70, with a lesser increase in average dairy farm size resulting in a slight lift in stocking rates. The amount and proportion of purchased feed and chemical fertiliser N being used on farms remained relatively static (990 kg, 18% and 169 kg N, respectively. Indeed, the results of the analysis indicate that while milk fat plus protein productivity increased by 29% during the study period, the increased productivity is primarily explained by increased pasture utilisation per hectare increased from 6.7 to 7.8 t DM/ha. The findings of the study using a relatively large nationally representative dataset across an eight year period, show significant improvements in biological efficiency within Irish dairy production systems. Based on increased productivity with relatively consistent supplementary feed and chemical N fertiliser inputs, the results of the analysis are indicative of the improving productive efficiency and sustainable intensification of Irish dairy production systems in recent years.

Table 2.1. The temporal trends in dairy farm productivity during the period 2008 to 2015 (Hanrahan et al., 2017)

Year	2008	2009	2010	2011	2012	2013	2014	2015
Farm area (ha)	45.4	43	44.4	51	51.5	51.2	51.6	52.8
Herd size (No. cows)	57	56	56	66	67	68	69	70
Stocking rate (LU/ha)	1.71	1.95	1.67	1.74	1.72	1.76	1.78	1.93
Grazing season (days)	234	234	236	240	237	236	244	242
Concentrate (kg/cow)	1,115	872	975	870	1,037	1,166	960	926
Nitrogen (kg N/ha)	147	160	161	167	163	183	180	169
Est. Grass utilised (t DM/ha)	6.7	7.3	6.7	7.1	6.8	6.8	7.2	7.8
Proportion feed imported (%)	0.19	0.17	0.18	0.16	0.19	0.22	0.18	0.17
Milk fat plus protein (kg/ha)	602	640	594	641	622	651	675	776

In a separate analysis, Ramsbottom et al. (2015) used the Irish national dairy farm database (eProfit Monitor, Teagasc) which contains farm physical and financial data for approximately 4,000 individual dairy farmer users to evaluate temporal trends in farm productivity during the years 2008 to 2015, inclusive (Table 2.2). Dairy farmer users of eProfit Monitor are on average larger scale, more intensive and more profitable than the average dairy farmer nationally who are better represented annually through NFS. In this study, farm physical and financial performance data were extracted for 315 spring calving dairy farms with >20 cows who were among the earliest continuous users of the program having completed eProfit Monitor financial analysis during all of the years 2008 to 2015, inclusive. The results of this analysis are consistent with the findings of Hanrahan et al. (2017) and are indicative of increased intensity of production based on increased grazed grass utilisation and resulting in increased productivity with Irish dairy farms.

Table 2.2. Measured biological characteristics in a matched sample of seasonal spring-calving, pasture-based dairy farms for the years 2008 to 2015 inclusive (Ramsbottom et al., 2015).

Year	2008	2009	2010	2011	2012	2013	2014	2015
Total farm (ha)	61.6	61.7	63.7	65.6	66.4	67.8	69.0	71.3
Herd size (No. cows)	81.7	86.5	91.3	95.6	97.0	101.9	104.7	115.3
Stocking rate (LU/ha)	2.10	2.16	2.16	2.18	2.22	2.26	2.26	2.31
Est. Grass utilised (t DM/ha)	8.3	8.2	8.4	8.9	8.4	8.2	9.1	9.9
Milk yield (litres/cow)	5,181	4,908	5,308	5,173	5,167	5,269	5,169	5,579
Fat content (%)	3.94	3.96	3.97	4.04	4.11	4.12	4.18	4.24
Protein content (%)	3.45	3.41	3.44	3.46	3.46	3.48	3.54	3.63
Milk fat plus protein (kg/ha)	828	805	875	871	894	932	929	1,045

Improving nutrient efficiency is essential if Irish farmers are to meet both the expansion targets of the agri-food sector while continuing to reduce the environmental footprint in line with our environmental commitments within the European Union. As already mentioned in section 1.1, in a study by Buckley et al. (2016a, 2016b) across 150 specialist Irish dairy farms over a 7 year period (2006 and 2012) the average farm-gate N balance declined by 25 kg/ha and P balance 6.5 kg/ha over the study period and was primarily attributed to reduced chemical N and P fertiliser inputs. While concurrently, milk fat plus protein output increased from 405 to 450 kg/ha over the period resulting in a 2.1 and 18.4% improvement in N and P use efficiency, respectively (Table 2.3).

Table 2.3. Trends in Nitrogen (N) and Phosphorus (P) use efficiency 2006 – 2012 (Buckley et al., 2016a & b)

Year	2006	2007	2008	2009	2010	2011	2012
Stocking rate (livestock units/ha)	1.86	1.84	1.86	1.86	1.82	1.83	1.84
Fat plus protein output (kg/cow)	330	336	322	307	361	365	353
Fat plus protein output (kg/ha)	405	416	405	392	453	464	450
Total N imports (kg N/ha)	221.3	203.0	194.1	198.8	205.9	196.7	197.4
Total N exports (kg N/ha)	40.9	41.1	40.0	37.7	42.2	43.1	42.1
N balance (kg N/ha)	180.4	161.9	154.1	161.1	163.7	153.6	155.3
N use efficiency (%)	20.8	22.4	22.7	20.8	21.8	23.7	22.9
Total P imports (kg P/ha)	21.7	16.3	16.2	14.0	14.8	13.8	15.1
Total P exports (kg P/ha)	9.8	9.6	9.2	8.7	9.1	9.2	9.1
P balance (kg P/ha)	11.9	6.7	6.9	5.3	5.7	4.6	6.0
P use efficiency (%)	59.6	73.5	77.8	80.0	80.2	88.4	78.0

Genetic Improvement of the National Herd

Genetic improvement of the national dairy herd is a key component of the smart and green objectives for agriculture as stated in FW2025 (DAFM, 2016). Among the main productivity improvements at farm level in recent years, the successful adoption of the Economic Breeding Index (EBI) and related genetic progress of the national dairy herd has been an area of significant progress with benefits for both the productivity and sustainability of grass-based dairy production in Ireland (Figure 2.2). Over the last decade, rapid genetic progress with the national dairy and beef herds has facilitated significant productivity improvements at farm level. The science of genomic selection have already enabled more accurate selection with a reduced generation interval compared with conventional selection systems based on daughter performance (Berry et al., 2014). By increasing the accuracy and intensity of selection and shortening the generation interval, the rate of genetic progress for desirable traits has increased rapidly and has already influenced the performance of commercial farms. Coleman et al. (2010) observed that animals of greater genetic merit for the Irish total merit index, the economic breeding index (EBI; Berry et al., 2007), were more productive and feed efficient than lower EBI contemporaries.

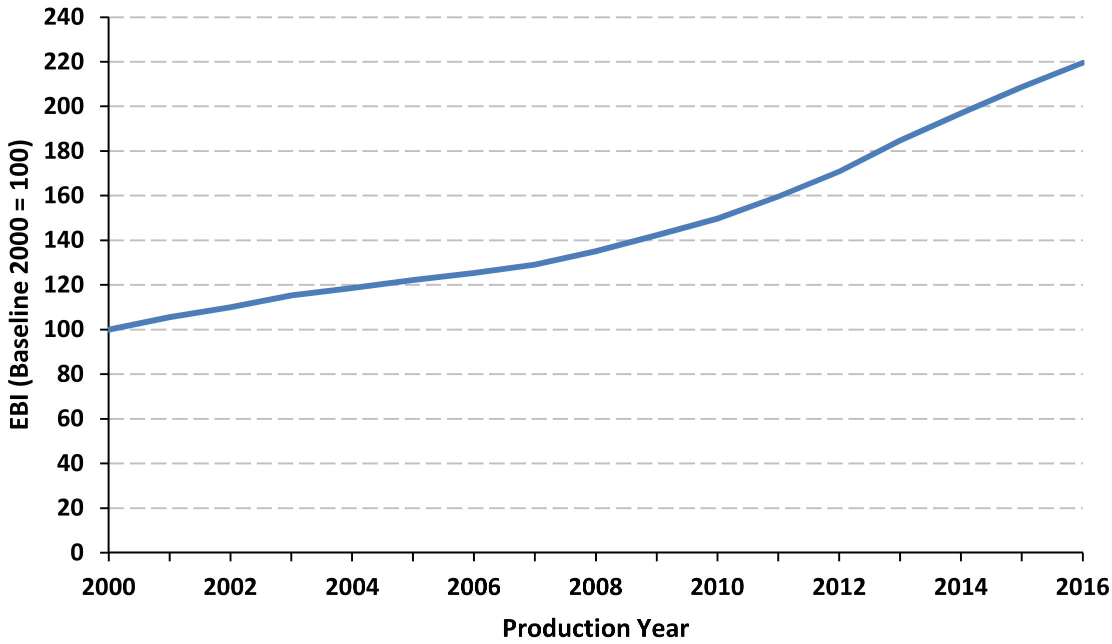


Figure 2.2. Trends in genetic progress within the Irish national dairy herd since the introduction of the Economic Breeding Index (EBI; ICBF, 2016).

While the overall rate of genetic progress has increased in recent years due to the onset of genomic selection techniques, there is also concurrent evidence of significant phenotype progress within the national herd. Looking firstly at protein yield (kg), which is one of the most important traits within the EBI (ICBF, 2016; Figure 2.3), we can see from milk recording data on almost 650,000 cows per annum, that protein yield has increased by about 37 kg per cow over the past 20 years in milk recorded herds (from 160 kg/lactation in 1996 to 197 kg/lactation in 2015) with an equivalent improvement in fat kg over the same period. Looking at similar statistics for animal fertility and survival within the EBI, the results indicate that over the same period, calving interval has reduced by approximately 16 days from a peak of 406 days in the late 1990's to approximately 390 days for females born in 2012 and milking in 2015. With advances in genomic technologies, even greater improvements in EBI and animal productivity and survival can be anticipated within the national herd over the next 10 years which will greatly contribute to the sustainable intensification of the dairy sector in Ireland.

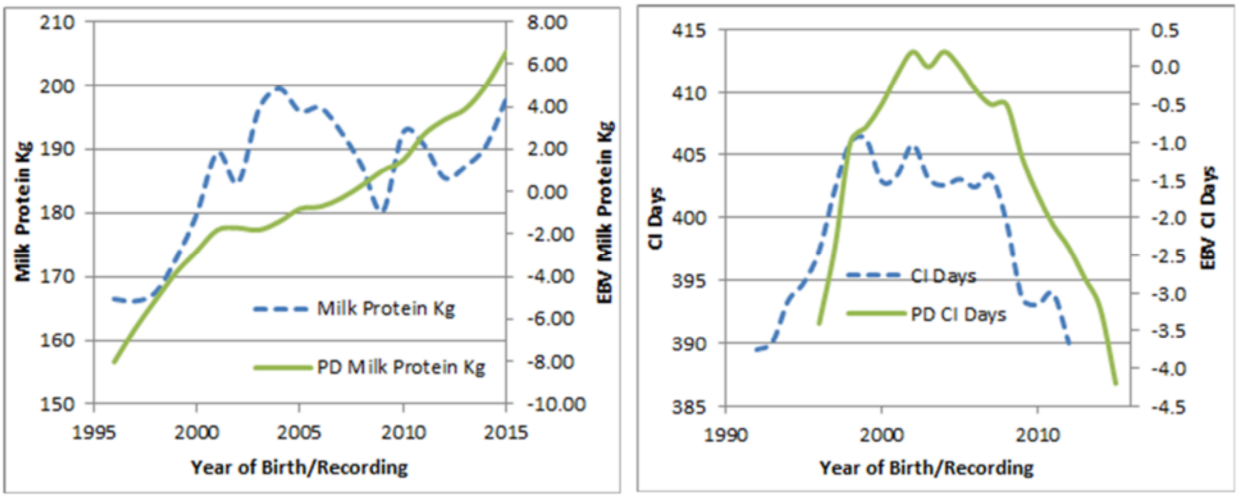


Figure 2.3. Genetic and phenotypic trends for milk protein and female fertility in the national dairy herd (ICBF, 2016).

Looking at similar trends for the national beef herd indicates that over the past 10 years, there have been steady improvements in both carcass weight and carcass conformation (ICBF, 2016; Figure 2.4). For example, looking at carcass weight improvements in steers slaughtered from 16 to 30 months, national statistics reveal that average carcass weight has increased by about 20 kg from 360 kg in 2005 to 380 kg in 2015, while the percentage of carcasses grading at the highest level of carcass conformation (EU score) has increased from 15 to 25% during the same period. Whilst the gains in these terminal traits and significant and positive, recent work undertaken by ICBF and Teagasc also indicates that the genetic improvement of fertility traits within the national suckler herd has the potential to realise comparable improvements in reproductive performance to that achieved within the national dairy herd with consequential benefit for the overall environmental sustainability of beef production systems.

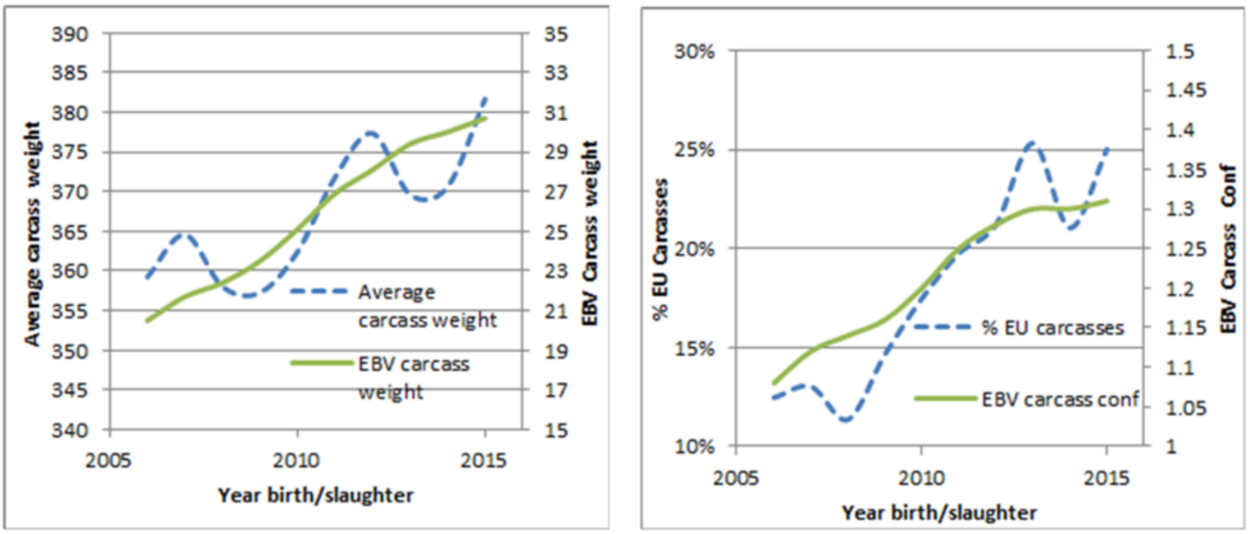


Figure 2.4. Genetic and phenotypic trends in carcass weight and proportion of carcasses achieving high (EU) confirmation score in the National Suckler Beef Herd (ICBF, 2016)

Farm productivity 2015 – 2025: Teagasc Roadmaps Series

Teagasc in consultation with a wide variety of industry experts have compiled a series of roadmaps outlining expected productivity improvements at farm level within each of the main agricultural enterprises over the next decade (Teagasc, 2016a, 2016b). It is anticipated that further technological improvements in farm management practices coupled with genetic gain within animal and plant populations will contribute to the sustainable intensification of agricultural production in Ireland over the next decade. The enterprise specific productivity improvements are outlined hereunder.

Dairy

Future prospects for the Irish dairy industry remain positive with milk production expected to grow significantly over the next decade. In that regard, our grass-based milk production system remains our key comparative advantage over our international competitors. In future, dairy farms will become increasingly specialised with national milk solids production (kg fat plus protein) increased by over 100% compared to the 2007-2009 period. Average milk delivered per farm will increase with further improvements in milk composition arising from increased grassland productivity combined with an increase in the genetic potential of the national dairy herd (Table 2.4).

Table 2.4. Expected trends in milk production performance of dairy herds: Teagasc Dairy Roadmap

Parameter	Current Average[1]	2025
Herd Economic Breeding Index (€)[2]	55	180
Stocking rate (Livestock Units/ha)	1.96	2.15
Herbage utilised (t DM/ha)	7.4	10.0
Concentrate supplementation (kg DM/cow)	900	670
Fertiliser Nitrogen applied (kg N/ha)	176	230
Nitrogen efficiency (%)	25.2	26.4
Inter-calving Interval (days)[2]	394	385
Six week calving rate (%)[2]	57	75
Replacement rate (%)[2]	23	20
Milk fat plus protein delivered (kg/cow)	370	450
Milk fat plus protein delivered (kg/ha)	730	960
Milk fat composition (%)	3.97	4.25
Milk protein composition (%)	3.42	3.56

[1]Three-year average for years 2013, 2014 and 2015 – National Farm Survey except for [2] which is from the Irish Cattle Breeding Federation (ICBF, 2016)

Beef

Ireland exports over 90% of its beef and is the fifth largest net exporter in the world. While EU demand is expected to outgrow domestic supply, the outlook for the sector is heavily dependant on external factors. At farm level, the implementation of the 2013 Common Agricultural Policy (CAP) reform will continue to negatively affect beef farms as EU payments reduce over time while ongoing International trade agreements and the UK exit from the EU continue to represent a threat to the Irish beef industry. The number of suckler beef cows is likely to decline between now and 2025 while there is likely to also be a small reduction in the number of farms with beef cattle as more farms engage in rearing and finishing calves from the dairy herd. Table 2.5 sets out the current physical and financial performance being achieved on suckling farms and gives the targets for each of these to be reached by 2025. The environmental footprint of the beef enterprise is expected to reduce due to a lower number of suckler cows and an increased proportion of beef being bred from the dairy herd. In addition, increases in the efficiency of production (weight for age at slaughter, age at first calving, calving rate, etc.) will contibute to improved sustainability within the sector.

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Table 2.5. Expected trends in production performance of beef herds: Teagasc Beef Roadmap

Parameter	Current Average[1]	2025
Herbage utilised (t DM/ha)	5.6	6.2
Concentrate supplementation (kg DM/LU)	393	390
Fertiliser Nitrogen applied (kg N/ha)	85	95
GHG emissions (kg CO_2e/kg carcass)	25.7	23.5
Inter-calving Interval (days)[2]	407	397
February/March calving (%)	34	55
Twelve week calving rate (%)[2]	70	85
Replacement rate (%)[2]	21	21
Calf yield (No./cow/yr)	0.81	0.85
Steer carcass weight (kg)	353	355
Steer age at finish (months)	28	27
Heifer carcass weight (kg)	307	320
Heifer age at finish (months)	26	25
Carcass output (kg/ha)	230	273

[1]Three-year average for years 2013, 2014 and 2015 – National Farm Survey except for [2] which is from the Irish Cattle Breeding Federation (ICBF, 2016)

Teagasc Extension Activities in Support of Foodwise 2025

Ireland through its national food development strategy, FW2025 (DAFM, 2015; FW2025) has targeted an increase in the value of annual agri-food exports by 85 per cent to €19 billion and increasing value added by 70 per cent to in excess of €13 billion in the period to 2025. In persuance of acieving sectoral targets through sustainable farming practices at farm level, Teagasc advisory service initiatives focus on four particular programme areas, namely 1) Business and Technology, 2) Environmental and Good Farm Practice, 3) Rural Development and 4) Adult training and Life Long Learning. These programmes deliver on diverse farm level outcomes such as profitability, sustainability, biodiversity, diversification, innovation and technology adoption. Recent research has reported on the biological and economic benefits for farmers arising from participation in extension initiatives which support the sustainable expansion in food production as set out in FW2025. Both Heanue and O'Donoghue (2014), Cawley et al. (2015) and O'Neill *et al*. (1999) have all found that extension had a positive effect on farm level productivity while Läpple et al. (2013) and Bogue (2014) also found a positive econmic effect of participation in discussion groups for both dairy and beef farmers. These studies also observed additional benefits due to enhanced management practices learned from the discussion groups, and reported that discussion group members were more likely to adopt emerging technologies and practices.

The Teagasc Advisory Service will continue to support innovation by all farmers, and will actively promote technologies which allow farmers to improve the sustainability of their farm businesses. Our advisers are in contact with some 80,000 farmers and rural dwellers each year, of whom approximately 45,000 are clients of a Teagasc Adviser (Teagasc, 2017, p. 6). Teagasc is committed to continuing to use discussion groups as one of our primary means of fostering technology uptake and will work to increase the participation levels of Teagasc clients in our discussion group network (which currently stands at 14,000 farmers (Teagasc, 2017, p. 7)). Furthermore, Teagasc will continue to play a role in educating the next generation of farmers in sustainable agricultural practices through our college and part-time education courses. Finally, Teagasc will continue to direct maximum advisory effort towards the implementation of sustainable farming systems (Teagasc, 2017, p. 20); this will include:

- The roll-out of four-year, multiple enterprise (dairy, beef and sheep) Grass10 campaign to increase grass utilisation on livestock farms;
- The promotion the increased uptake of genomic technologies and better animal breeding;
- The implementation of Phase III of the Agricultural Catchments Programme, ensuring that the lessons learned from Phases I and II are extended to a wider agricultural audience;

- The Increased usage of both Teagasc NMP Online and Teagasc Bord Bia Carbon Navigator, specifically the use of both tools to focus farmers on sustainable farming choices;
- Support for the implementation of the Sustainable Use Directive (SUD)

Part 3. FW2025 - Implications for the NAP

FW2025 - Implications for the NAP

Background to FW2025

In the FW2025 report Ireland has a declared its aspiration to increase the size of its agri-food sector over the coming decade (DAFM, 2015). It is important to assess the implications that this growth could have, particularly in the context of sustainability.

> A guiding principle to meet these sustainability goals will be that environmental protection and economic competiveness will be considered as equal and complementary, one will not be achieved at the expense of the other. The three pillars of sustainability - social, economic and environmental - are equally important and carry commensurate weight ensuring that as the sector continues to develop and grow this development will be undertaken in the context of addressing environmental challenges.
>
> *FW2025 Strategy p.24*

FW2025 is cognisant of the need to balance multiple goals. The Strategic Environmental Assessment (SEA) for FW2025 introduces the concept of a Sustainable Growth (SG) scenario for the agri-food sector (Farrelly & Co, 2015). To support this, a FW2025 Environmental Sub-Committee was established. As this subgroup was being convened, DAFM invited Teagasc to further develop the concept of the SG scenario. This would allow future implications of the scenario for some key objectives in terms of environmental and economic sustainability to be assessed. This scenario was originally provided to DAFM in November 2015 (Donnellan and Hanrahan, 2015). Subsequently, this scenario was presented to the FW2025 Environmental Sub Committee in April 2016.

To date this sustainable growth scenario has been used as the basis for:

- The development of a MACC for ammonia emission abatement in Irish agriculture (Lanigan et al. 2015)
- Ireland's EU negotiations with respect to ammonia reduction targets (Donnellan and Hanrahan 2015)
- The EPA's agriculture Greenhouse Gas (GHG) emission inventory projections produced in 2016 (EPA, 2016)
- The development of a MACC for agricultural GHG emission abatement in Irish agriculture (Lanigan et al., Unpublished)

For much of the last 20 years there has been little growth in the volume of production at primary level in Irish agriculture. Observed growth in the value of primary output (sales of milk, cattle, sheep etc) has been strongly driven by the inflation in commodity prices in the 2010 -2014 period. This contrasts with the output growth in the food and drinks sector which reflects a combination of both product innovation and price inflation.

Taking emissions of GHGs and ammonia as examples, the environmental impact of primary agriculture has been on a downward trajectory since the late 1990s. However, economic growth ambitions for the sector and potentially ambitious emissions reduction targets may mean that pressures to improve the sustainability of the sector will intensify. The elimination of the milk quota system in 2015 represents a major policy change for the agriculture sector in Ireland, allowing for the expansion of the most profitable mainstream agricultural enterprise.

Concern for the environmental impact of developments in the agricultural sector imply that fewer aggregate emission are better than more emissions, without prescribing how this would impact on the level of production. While the successful deployment of emissions abatement measures might partially decouple the relationship between changes in output volume and emissions, these measures are in their infancy and the extent of the uptake at the farm level over the next decade will be limited. Environmental objectives could be satisfied through the restriction of agricultural activity, but this would conflict with other national policy objectives such as the maintenance of jobs in the agri-food sector.

So how can Irish agriculture expect to grow output and income within the potential confines of environmental constraint as we look towards 2030? The growth ambition of the FW2025 strategy may also be in conflict with environmental policy objectives of reducing ammonia and GHG emissions in Ireland.

If the main objectives of agri-food strategies such as the FW2025 (FH2020) and FW2025 are to be achieved, there must be an assessment of how the Irish agri-food sector can derive the most value added or income/profit per unit of emissions. If environmental policy introduces any constraints to the growth in the volume of Irish agricultural output it will be in the interest of the Irish agri-food industry and wider Irish society that the output and output growth achieved in the future generates the maximum possible value-added for the sector. There is no reason to believe that the current configuration of Irish agricultural activities and associated outputs is that which either currently or in the future maximizes the value added contribution of the agri-food sector.

> Making the right choice now will make sure Ireland is well positioned to deliver sustainable growth far into the future
>
> *Food Wise Report p.4*

> Ireland does however face significant challenges in meeting some national and international environmental targets for air quality, biodiversity and water quality. Agriculture has a key role to play in contributing to meeting these targets. Meeting Greenhouse Gas (GHG) and ammonia emission reduction targets will be particularly challenging, but arresting biodiversity losses and continuing the improvement of water quality while increasing production will be equally demanding.
>
> *FW2025 Strategy p.23*

A sustainable Growth Scenario

Under the SEA directive (EC, 2001) there is a requirement that an environmental report is prepared in which the likely significant effects on the environment and reasonable alternatives to the proposed plan or programme are identified. The draft SEA for the FW2025 Strategy (Farrelly & Co., 2015) outlines a SG scenario as an alternative to two other scenarios, the FW2025 Base Case and Base Case + scenarios mentioned in the report.

The SG scenario outlined by Farrelly & Co. (2015) does not contain detailed information on the agricultural activity or economic aggregates associated with its achievement. Below present projections of agricultural activity levels and associated agricultural output, input and income levels consistent with an SG scenario. The SG scenario developed attempts to square the circle of achieving higher economic growth in the Irish agriculture sector, while also facilitating the sustainable development of the sector from an environmental perspective. By its nature the SG scenario is a compromise between the singular pursuit of economic growth ambitions for the agriculture sector and the singular pursuit of environmental sustainability objectives.

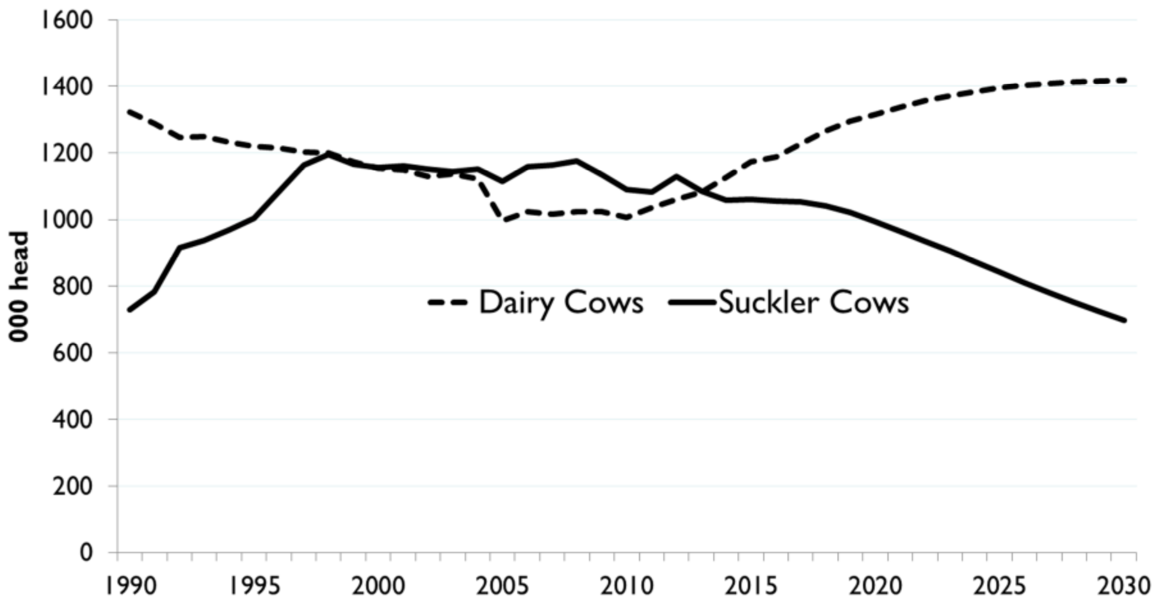

Figure 3.1. Actual dairy and suckler cow numbers (000s head) from 1990 to 2015 and projected cow numbers from 2016 to 2030 based on the sustainable growth scenario.

Bovines: The projected output levels under the scenario reflect an increase in activity in the dairy sector following the removal of the milk quota system. Modelled outputs under the FW 2025 SG scenario also indicate a stable level of beef production (in tonnes of carcass produced) over the medium term. However, the number of suckler cows is projected to contract over the medium term. Overall, the scenario projects a relatively stable cattle population and an increase in milk production. The overall cow population is projected to decrease by 4% by 2030 relative to the 2012-14 reference period (Fig. 3.1). Over the period to 2030 projected growth in the dairy cow herd is matched by the projected decline in the suckler herd.

Decoupling dairy cow numbers and milk production

The number of dairy cows in Ireland has been gradually decreasing since 1990 and has now began to increase in response to the abolition of milk quotas and is currently 5.5% lower than in 1990 (Fig. 3.2). Conversely milk production and milk fat and protein remained relatively constant between 1990 and 2009 while dairy cow numbers had declined by 21%. Between 2009 and 2015 there has been a rapid increase in national dairy production with milk and fat/protein increasing by 24% and 39%, respectively while cow numbers were 5.5% lower. Thus there is a decoupling between dairy cow numbers and milk production which is driven by a range of factors such as genetic improvement within the national herd using the Economic Breeding Index (EBI).

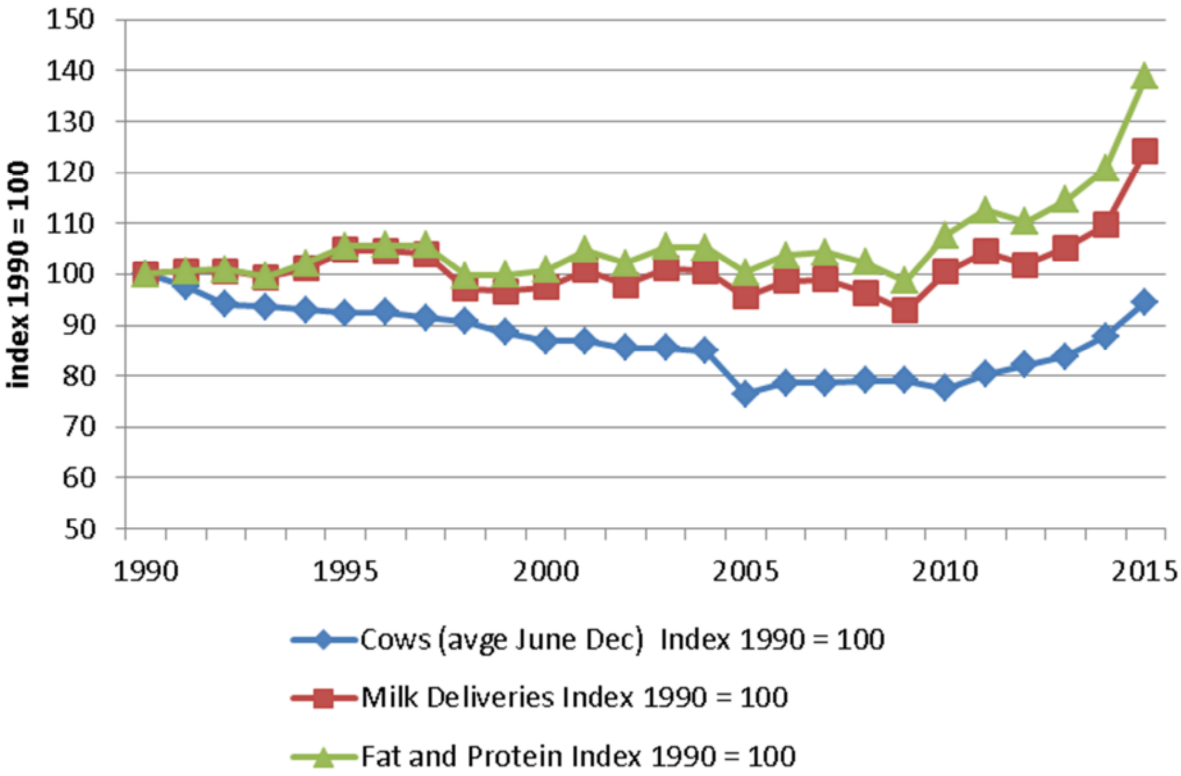

Figure 3.2. Average dairy cow numbers, milk deliveries and milk fat and protein from 1990 to 2015 indexed relative to 1990 (Source CSO, 2016).

Projected impact of FW 2025 on national organic N loadings, N fertiliser and soil phosphorus

Based on the animal numbers presented in figure 3.1 for the FW2025 SG scenario, the national manure N excreted was calculated and presented in figure. 3.3. There is a modest increase in manure N excretion predicted to occur nationally but remaining below the all-time high in 1998. These are the national projections and there is potential for regional increases to occur reflecting the current concentration of dairy in the south and east.

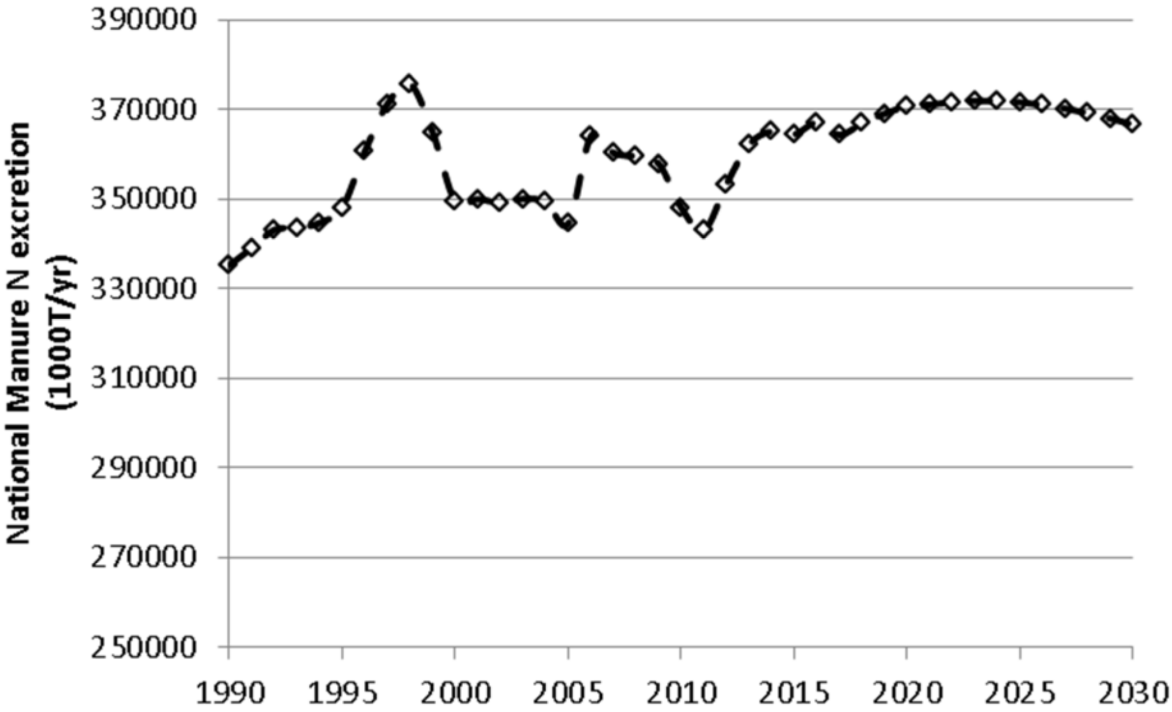

Figure 3.3. National manure N excretion rates (1000s T/year) from 1990 to 2015 (actual) and 2016 to 2030 (projected).

Nitrogen Fertiliser

In recent years fertiliser use has been quite volatile, varying by as much as 10 to 15% from year to year. This makes it challenging to determine what could be considered as a normal level of fertiliser use for the current level of production and in turn this makes it more difficult to project how the usage of fertiliser might change in the future. While fertiliser use is projected to increase, the growth in the level of total fertiliser application is quite limited under the SG scenario (Fig 3.4). While the more fertiliser intensive dairy sector increases its production, the area allocated to dairy also increases, so that the overall stocking rate exhibits little change. In addition, the price of feed relative to fertiliser declines, making purchased feed marginally more attractive economically than grass as an energy source and limiting the increase in the intensity of fertiliser use on a per hectare basis.

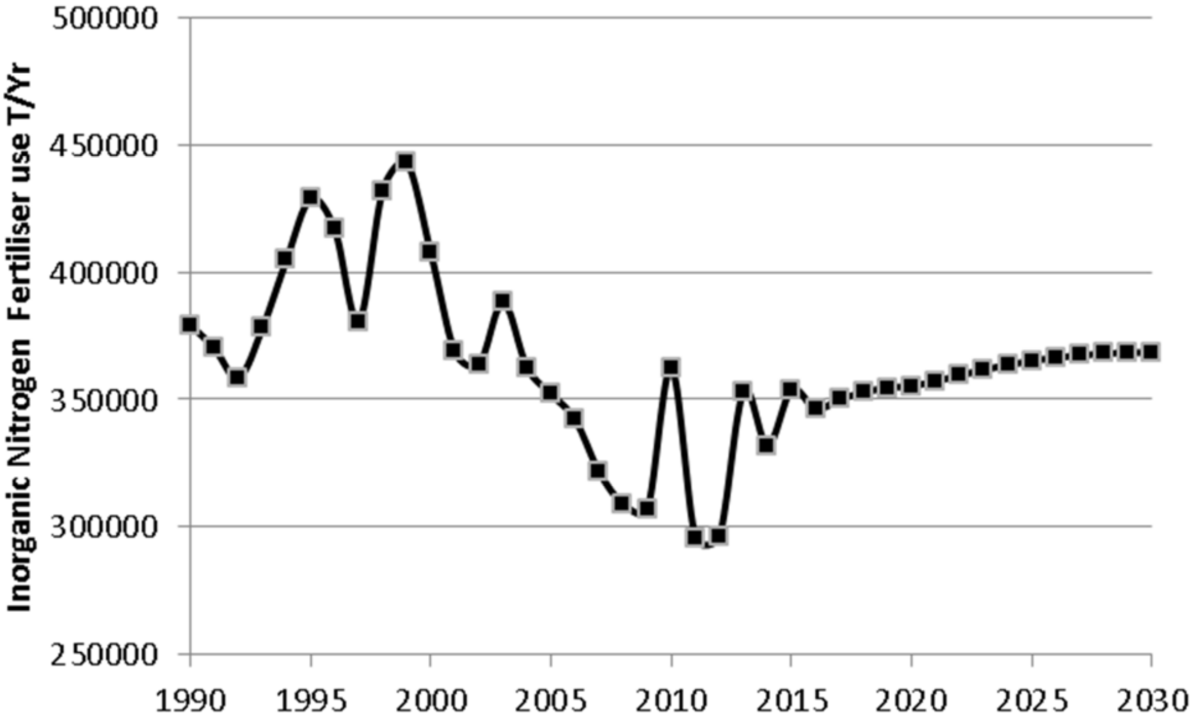

Figure 3.4. National nitrogen fertiliser use (T nitrogen/year) from 1990 to 2015 (actual) and projected fertiliser use 2016 to 2030.

Part 4. Proposals regarding changes to the GAP regulations

4.1. Proposed rationalisation of calculations of maximum fertiliser N and P allowance

Context

The introduction of S.I. 378-06/S.I. 101-09/S.I. 31-14 has brought about far-reaching changes to nutrient management on all farms. Nutrient applications are strictly regulated , and each farm is required to calculate the precise amount of nutrients that may be imported on to the farm , based on , inter alia, stocking rates , livestock movements, nutrient supply from soil and organic manures , as well as P imported onto the farm in the form of concentrate feeds. The fundamental principles underlying these calculations are:

- P-application rates should be based on farm P-balances, i.e. should be aimed at replacing farm P exports with farm P imports.
- Where soil P deficiencies occur (P indices 1 and 2) and have been identified through soil testing, build-up applications of P may be applied to raise the soil test P to index 3 over a reasonable time frame.
- Where excessive soil P (P index 4)) have been identified, no external P may be applied, allowing soil test P to decline to Index 3 over time.

Under the GAP regulations 2014, the total maximum permitted usage of chemical N and P fertilisers on the whole farm must be calculated using the maximum permitted rates of total available fertiliser, taking into account the contribution to total available fertiliser of both home produced animal manures (N and P), imported and exported animal manures/ fertiliser (N and P), and concentrate feeds (Fig 4.1 shows the actual nutrient inputs and outputs from a farm).

The deduction of N and P from home produced animal manures is also dependent on the region in which the farm is located with regards to the slurry storage capacity requirements. Farms that have longer slurry storage periods are assumed to produce greater volumes of slurry with a pro-rata increase in organic N and P produced and therefore are allowed lower rates of chemical N and P as a result.

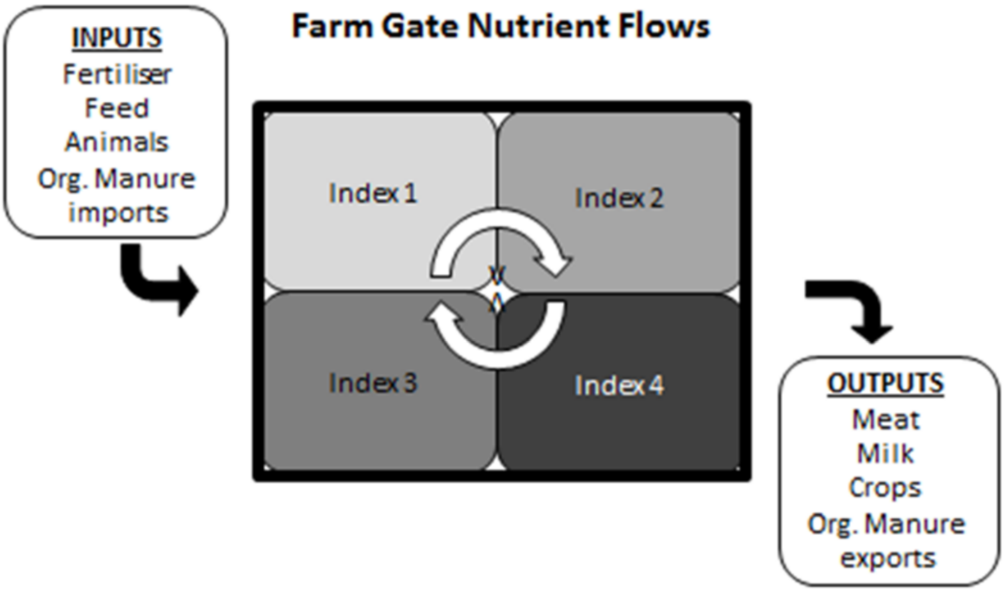

Figure 4.1. Farm gate nutrient flows, the nutrient balance is equal to nutrient inputs minus nutrient outputs. Note: Irish farms typically neither import nor export organic nutrient sources operating a closed system. No new P is produced and therefore manure P produced on the holding does not contribute to the farm gate P balance.

Summary of the issue

The inclusion of imported and exported manures and the concentrate feed usage are valid considerations as they affect the input and output of nutrients from the farm system. However, the inclusion of home – produced manures that are recycled within the farm, into the calculation of maximum permitted chemical fertiliser allowance, unnecessarily complicates the calculations and can seriously compromise the future soil fertility (soil P) and productivity of the farm. The variation in maximum chemical fertiliser N and P allowances between regions with different storage capacity requirements is not in agreement with nutrient advice or with farm nutrient balance.

While Teagasc subscribes to the underlying principles, the implementation of the P-regulations in S.I. 378-06 / S.I. 101-09 / S.I. 31-14 has posed many significant practical and logistical challenges for farmers, agricultural advisors and the farming industry. Based on the past and present experience of Teagasc's Nutrient Efficiency Research Programme and Environment, Dairy, Beef, Sheep and Tillage, Knowledge Transfer Programme with the application of the "Teagasc Nitrates Calculator" and the newly developed "NMP online system", it is Teagasc's view that the precise format of the implementation of the P regulations may be overly complicated and difficult to understand, imposing a significant and unnecessary administrative burden on farmers and their agricultural advisors. There is a fear of the GAP regulations at industry level and persons working within these regulations find it very hard to understand. This has had a negative impact on principles of good fertiliser planning and is at odds with Teagasc's national fertiliser advice (Wall and Plunkett 2016).

Most significantly, there is now a significant body of evidence based on large, long-term data sets collated by the Teagasc Nutrient Efficiency Research Programme, the Agricultural Catchments Programme and Teagasc's National Knowledge Transfer Services, that there is an increased prevalence of soil P deficiencies on Irish farms, resulting in loss of productivity, and in extreme cases, in animal P deficiencies.

Background

Teagasc, has developed conclusive scientific evidence on the increasing prevalence of soil P deficiencies on commercial farms (Courtney et al. 2017; Kavanagh et al. 2015; Mihailescu et al., 2015; Ruane et al. 2016), Agricultural Catchments Programme farms (Wall et al. 2013; Murphy, et al. 2015; McDonald et al., 2016) and Teagasc National Soil Fertility Database (Plunkett and Wall, 2016).

Listed below are the three main factors contributing to this problem identified by Teagasc:

1. **Slurry P deduction** - The calculations of maximum P allowed on a holding, includes the deduction of P contained in organic manure (mainly slurry), from the overall P allowance to balance P offtakes in meat, milk and crops. The P in slurry has been produced from feedstuffs grown inside the farm gate (predominantly silage or hay, and may include a small quantity of P in concentrate feed also). Therefore, by deducting the P in organic manure produced over the mandatory storage period (16, 18, 20 or 22 weeks) the quantity of fertiliser P allowed onto the holding is reduced proportionally, and this has the potential to create an overall P deficit on the farm under the current calculation methods (i.e. P exports are likely to exceed P imports in some situations) based on maintenance P requirements. This method of calculating maximum farm P allowances breaks the first fundamental principal of the P regulation calculations (*S.I. 31 of 2014*) that "P-application rates should be based on farm P-balances, i.e. should be aimed at replacing farm P exports with farm P imports".

2. **Slurry storage period influence** - The probable maintenance P deficit, caused by the organic manure P deduction from the P fertiliser requirement, increases with the length of the mandatory storage period as you move from 16, 18, 20 or 22 weeks, because it is assumed that the contribution of P from slurry is increasing with storage period length (i.e. more slurry collected). However, this assumption is incorrect as at a given stocking rate and production system there is no difference in farm-gate P-balances (i.e. P inputs and offtakes) between farms in different zones irrespective of how long, and what quantity of, excreted P from animals on the farm is collected.

3. **Precautionary approach limiting P imports** - There is evidence that farmers may be spreading less P fertiliser than allowed, to ensure that they are not in

breach of maximum P fertilisation rates. Maximum P fertilisation rates are currently calculated at the end of the year, taking into account records of stocking rate, and P imported onto the farm in the form of concentrate feeds. Since these calculations are based on year-end records, the amount to be imported onto the farm cannot be calculated in absolute detail, as this amount depends on inter alia, dates of livestock movements and variations in concentrate feed usage which are dependent of weather conditions, neither of which are fully predictable. As a result farmers may not spread their full allowance of P fertiliser estimated at the start of the year, in order to ensure they retain sufficient P allowance for unexpected purchase of concentrate feeds or stocking rate changes at the end of the year, to cater for worst-case scenarios. For these reasons, the fertilising planning software NMP-Online has a build in plan safety option which allows farmers and advisors choose slightly lower P fertiliser rates than is allowed on the farm, to ensure they stay under the maximum P limit for the farm. This is further evidence that the regulation calculations may be contributing to the increasing P deficiency.

It is clear that the current format of implementation of the P regulations is unnecessarily complicated and may give rise to inherent anomalies in P-budgeting on individual farms. In these cases, compliance with the GAP regulations may result in significant P deficits in relation to maintenance on farms.

Farm Example: P balance calculations

This example is based on a hypothetical farm of 50ha all under grassland with all soils at P Index 3, requiring maintenance P applications only. The farm has 100 milking cows, feeding 500kg of concentrate feed per cow (amounting to 50 tonnes). For simplicity of calculations in this case all calves (100) are sold at birth, and 20 cull cows are sold at the end of each year. 20 replacement heifers are purchased each year for the milking herd. All cows produce a milk yield of 5500 l milk per annum, which is close to the national average milk yield (NFS 2015).

Table 4.1 shows the actual farm gate P exported and P fertiliser requirements to balance these exports for this farm.

Table 4.1. Actual P export and adjusted structural P deficit requirement for a typical dairy farm used in this example.	
P Exports at farm-gate level	**Exported P (kg)**
P sold in milk (= 5500 litres/cow x 100 x 0.001 kg P / litre milk)	550
P sold in liveweight (calves) (= 100 calves x 55 kg x 0.01 kg P /kg)	55
P sold in liveweight gain (heifers to cull cows) (= 20 cows x 225 kg x 0.01 kg P /kg)	45
P other *(not accounting for losses or P fixation by soil)*	
Farm-gate P Export Total *(agricultural products)* *Average on a per hectare (50 ha) basis*	**650** *13.0 kg/ha*
P Imports required at farm-gate level	**Imported P (kg)**
Maintenance grassland fertiliser P application to balance exports (= 13.0 kg/ha P x 50 ha)	+650
Adjustment for P imported in concentrate feed as per *S.I. 31 of 2014* (=50 t – (0.3t x 100 LU)) x 5kg/t P	-100
Adjusted Fertiliser P requirement *Average input on a per hectare basis*	**550** *11.0 kg/ha*

Table 4.2 shows the current maximum fertiliser P allowance calculation for this farm under current GAP regulations according the different slurry storage zones.

<table>
<tr><th colspan="8">Table 4.2. Calculation of total allowance of chemical P fertiliser, for this for a typical dairy farm, under current GAP regulations</th></tr>
<tr><td colspan="2">P Index</td><td>1</td><td>2</td><td>3</td><td>4</td><td colspan="2">All</td></tr>
<tr><td colspan="2">Max Available P Fertiliser rate (kg/ha) (S.I. 31 of 2014)
Area of land farmed</td><td>41
0</td><td>31
0</td><td>21
50</td><td>0
0</td><td colspan="2">
50</td></tr>
<tr><td colspan="2">Total Available P Fertiliser allowed (kg)</td><td>0
(a)</td><td>0
(b)</td><td>1050
(c)</td><td>0
(d)</td><td colspan="2">1050
A=a+b+c+d</td></tr>
<tr><td colspan="6">P assumed from Concentrate feeds (kg) as per S.I. 31 of 2014
= (50 t – (0.3t x 100 LU)) x 5kg/t</td><td colspan="2">B (100)</td></tr>
<tr><td colspan="6">P assumed from slurry (kg) Zone A (16 weeks = 400 kg P)
P assumed from slurry (kg) Zone B (18 weeks = 450 kg P)
P assumed from slurry (kg) Zone C (20 weeks = 500 kg P)
P assumed from slurry (kg) Zone D (22 weeks = 550 kg P)</td><td colspan="2">C_A (400)
C_B (450)
C_c (500)
C_D (550)</td></tr>
<tr><td colspan="6">Maximum Chemical Fertiliser P allowance (kg) (S.I. 31 of 2014)</td><td colspan="2">=A-B-C_x</td></tr>
<tr><td colspan="2">Zone A
550
11 kg/ha</td><td colspan="2">Zone B
500
10 kg/ha</td><td colspan="2">Zone C
450
9 kg/ha</td><td colspan="2">Zone D
400
8 kg/ha</td></tr>
<tr><td colspan="8">Farm P deficit
(= P allowance – P requirements)</td></tr>
<tr><td colspan="2">0
0.0 kg/ha</td><td colspan="2">-45
-0.9 kg/ha</td><td colspan="2">-95
-1.9 kg/ha</td><td colspan="2">-145
-2.9 kg/ha</td></tr>
</table>

On this dairy farm, with a typical stocking rate, the GAP regulations result in a P deficit of between 0 and -145 kg P per annum depending on the zone for mandatory slurry storage (Table 4.2). This equates to a small P deficit across the farm of 0.0 kg/ha P per annum in Zone A, and larger P deficits of -0.9, -1.9 and -2.9 kg/ha in Zones B, C and D respectively. This increasing P deficit with increasing slurry storage requirement is created because it is assumed that the contribution of P from slurry is increasing with storage period length (i.e. more slurry collected). However, this assumption has no logical basis and is incorrect as there would be no differences in farm-gate P output for this farm if it were in a different zone (see Fig 4.1 and Table 4.1).

Table 4.2 shows the current GAP calculations and adjustments for P in slurry on this farm equates to 400 kg P in Zone A and 450, 500 and 550 kg P in Zones B, C and D respectively. This example demonstrates that the current system of adjusting for P in slurry can substantially limit the P availability on the farm with longer mandatory storage requirements and can create a larger P deficit than can be satisfied under the total farm fertiliser allowances. Phosphorus in slurry/manure is generated from feedstuffs generated within the farm (i.e. grass silage) and should not be counted as a P import at the farm gate level; therefore this method for calculating maximum fertiliser P allowances on a farm does not make sense and creates unnecessary confusion. Including slurry in these calculations also prohibits farmer's advisors and farmers from using the Teagasc, National Fertiliser Advice (Wall and Plunkett, 2016)

Proposed solution

Removal of stored organic P from the calculation of farm P balance and for calculating maximum chemical phosphorus allowed onto a holding.

This change will make nutrient management on farms more understandable for all concerned; adhere to the underlying nutrient management principles; and facilitate the correct calculation of farm P balances. When P recycling in organic manure produced on the farm (i.e. manure produced by livestock on the farm and not imported) is removed from the standard GAP calculations this allows an accurate P balance to be calculated for the farm by subtracting the total P imports and from the total P exports.

These proposed changes to the standard GAP calculations makes nutrient management planning effective, less complicated and more logical for farmers, advisors, inspectors and industry stakeholders. It also removes calculation barriers for advisory and qualified personnel within trade industries (e.g. agronomists, merchants, etc.) to provide field specific nutrient management advice for particular farm situations with knowledge of a few key pieces of information supplied by the farmer (farm stocking rate, soil test results, crop type etc.)

Environmental impact of proposed solution

Teagasc acknowledges the underlying fundamental principles of the regulations with regard to phosphorus, namely that:

- P-application rates should be based on farm P balances, i.e. should be aimed at replacing farm P exports with farm imports.
- Where soil P deficiencies occur (P index 1 and 2) and have been identified through soil testing, build-up applications of P may be applied to raise the soil test P to Index 3 over time.
- Where excessive soil P (P index 4) have been identified through soil testing, no external P may be applied, allowing soil test P to decline to Index 3 over time.

Teagasc does not seek to propose changes to these underlying principles. The proposed amendment addresses the farm gate P deficit and the overall structural P deficits that are arising on Index 1, 2 and 3 soils and therefore prevents the undesirable long term decline in soil fertility. The amendment will;

- Promote the attainment of optimum soil P levels, thus improving nutrient use efficiency.
- Not result in external P applications on Index 4 soils
- Not increase the prevalence of Index 4 soils
- Not result in a positive farm balance (P surplus)

Therefore, the proposed amendment will not have a negative environmental impact and facilitate better nutrient management practice leading to better environmental and economic outcomes.

4.2 Adoption of appropriate phosphorus build-up rates for farmed soil

S.I. No. 31 of 2014 states:

PART 3
NUTRIENT MANAGEMENT

Interpretation, commencement etc
(5) A reference in this Part to the "nitrogen index" or the "phosphorus index" in relation to soil is a reference to the index number assigned to the soil in accordance with Table 10 or 11 of Schedule 2, as the case may be, to indicate the level of nitrogen or phosphorus available from the soil.

Duty of occupier in relation to nutrient management
(1) An occupier of a holding shall take all such reasonable steps as are necessary for the purposes of preventing or minimising the application to land of fertilisers in excess of crop requirement on the holding.

(2) (a) For the purposes of this Article the phosphorus index for soil shall be deemed to be phosphorus index 3 unless a soil test indicates that a different phosphorus index is appropriate in relation to that soil.
(b) The soil test to be taken into account for the purposes of paragraph (a) in relation to soil shall, subject to paragraph (c), be the soil test most recently taken in relation to that soil.
(c) Where a period of five years or more has elapsed after the taking of a soil test in relation to soil the results of that test shall be disregarded for the purposes of paragraph (a) except in a case where that soil test indicates the soil to be at phosphorus index 4.

(3) Without prejudice to the generality of sub-article (1) and subject to sub article (4), the amount of available nitrogen or available phosphorus applied to promote the growth of a crop specified in Table 12, 13, 14, 15, 16, 17, 18, 19, 20 or 21 of Schedule 2 shall not exceed the amount specified in the table in relation to that crop having regard to the relevant nitrogen index or phosphorus index, as the case may be, for the soil on which the crops are to be grown. In the case of crops not identified in the tables listed above fertilisers shall be applied in accordance with the national agriculture and food development authority's guidance as approved by the Minister for Agriculture, Food and the Marine.

Context

Over the last decade soil P levels in Irish farmland have been declining. The proportion of soils tested that have sub-optimal P (P Index 1 and 2) has increased from an, already high, level of 40% in 2007 to 62% in 2016. This is, most likely, a consequence of the generally inadequate levels of P fertiliser application on Irish farms. Under the current GAP regulations the maximum chemical allowances do not meet the replacement of P offtakes on animal grassland systems which has results in large structural P deficits on these farms. As these P application levels are substantially lower than required to replace P offtakes, they also prevent soil P fertility build up to optimal soil P levels (P Index 3). Recent increases in production intensity, especially of dairy farms, which result in increased nutrient offtakes, will exacerbate this problem. This issue is dealt with in more detail in the above (Part 3, Soil Phosphorus, pg. 35).

The continuing decline in soil P and the persistence of these low P levels, when combined with sub-optimal soil potassium (K) and pH levels has resulted in a situation where approximately 10% of Irish soils that are tested have optimum status for all three parameters. This poor soil status threatens the environmental and economic sustainability of Irish farming as in these sub-optimal conditions N and P use efficiency is reduced. Low overall soil fertility provides a poor return on fertiliser expenditure and results in limiting of crop growth conditions and increased risk of nutrient loss to the environment.

Sub-optimal soil P levels thus lead to an erosion of Ireland's competitive advantage, especially in grass-based production, which, when operating efficiently is a highly sustainable system. As well as damaging sustainability at farm level, the loss in efficiency brought about by sub-optimal soil P levels has a knock-on effect on the national economy as increases in output planned under FW2025 and FW2025 are more difficult or impossible to achieve.

Summary of issue

The current GAP regulations **(**S.I. 31 of 2014) allow small P applications in excess of nutrient balance/crop requirement for soil P build-up where STP is suboptimal (i.e. P Index 1 and 2). For grassland and cereal crops an additional 10kg/ha/year in excess of crop requirement is allowed at P index 2 while an additional 20kg/ha/year is allowed at P index 1. For tillage crops, other than cereals, generally larger quantities of P are allowed for build-up at P index 1 and 2 as these crops are more sensitive to low soil P supply (Wall and Plunkett 2016).

At low soil P Index levels the soil P supply may not be sufficient to meet crop growth requirements resulting in reduced yield and/or nutritive quality. By applying additional fertiliser P in excess of nutrient balance, this P helps to build up soil P fertility reserves to agronomically optimal and environmentally sustainable levels (i.e. P index 3) over time. Soil P build-up usually takes many years of repeated build-up P applications and for soil at P index 1 status it can take more than 10 years under current build-up allowances. The current P applications rates for build-up of 10 and 20 kg/ha/yr were adopted from early nutrient management advice, at a time when production levels were lower and for older grass and crop varieties with shorter grazing season length. In the current era these levels of soil P build-up have been shown to be much too low to achieve significant increases in soil P levels within a reasonable time frame. The very slow rate of increase potentially achieved under the current soil P build-up allowances is a serious impediment to correcting low soil P levels and greatly exacerbates the problems with sub-optimal soil nutrient status as described above.

Scientific Background

Several studies carried out in Ireland have shown that the mean annual build-up application of P required to raise Morgan's soil test P (STP) by 1 mg/l STP was on average 66 kg/ha for P index 1 soils and 44 kg/ha (Table 4.3: Culleton et al., 2002; Courtney et al., 2017; Fox et al., 2015; Pettit et al. 2017). In a long term grassland study (17 years), Sheil et al., (2016) calculated the requirement for fertiliser P applications during the build-up phase of 56 kg P/ ha/year at Index 1 and 40 kg P/ha/year at Index 2 to maintain the STP levels. Herlihy et al., 2004, reported relevant unit change ratios (P surplus:STP change) of 40-70:1 for acidic soils and 20-30:1 for limestone soils. Generally, the ratio was significantly higher in the low compared with the high P Index soil groups

Table 4.3. Studies showing the soil test P response to build-up P applications

Study	Land Use type	P build-up required to achieve 1mg/L STP
Culleton et al. 200. 30 yr study Cowlands, Johnstown Castle	Grassland (grazing – beef)	59 kg/ha P (average of P application rates over the 30 years study period)
Sheil et al., 2016, Long term P fertiliser study	Grassland (simulated grazing)	56kg/ha P for Index 1 40 kg/ha for Index 2
Herlihy et al., 2004,	Grassland (cutting)	40-70 kg/ha P for acidic soils 20-30 kg/ha P for limestone soils
Courtney et al., 2017, Heavy soils study	Grassland (grazing - dairy	76 kg/ha at P Index 1 50 kg /ha at P Index 2
Fox et al., 2015 ACP sites	Grassland (cutting)	63 kg/ha at P Index 1 41 kg /ha at P Index 2
Pettit et al., 2017, BETTER Tillage Farms study	Tillage (cereals)	26 kg/ha at P index 2

For example, soils with depleted STP levels, currently at mid-point of P Index 1 (1.5 mg/l STP), would require, at least, 250 kg/ha of applied build-up P to bring that soil to the mid-point of Index 3 (6.5mg/l STP) over a number of years. Similarly soils with STP at the mid-point of P Index 2 (4.0 mg/l STP) would require, at least 125 kg/ha of build–up P to bring that soil to the mid-point of Index 3 (6.5mg/l STP) over a number of years.

At the application rates allowed in the current GAP regulations, in the Index 1 case above, it would take, on average, 21 years to move the soil from P index 1 to 3 based on adjustments with soil sampling, and in the Index 2 case above would take 12.5 years. For soils at lower levels within these indices the time spans are even longer. For example, a soil with a P level of 1.0 mg/l STP, the lower end of P Index 1, would be expected to take, on average, 24 to 25 years to reach P index 3.

The rates of change in soil P outlined in the examples are, clearly, much slower than is feasible for a modern, sustainable farming sector. These types of lags in achieving optimal P status greatly hinder the development of the sector and expose farmers to increased financial risk as they are prevented from achieving efficient levels of production. At the same time land at sub-optimal P status is rendered more vulnerable to nutrient loss since crop growth and nutrient uptake (N, P, K, S etc.) is impaired.

Proposed Solution

Based on the latest scientific studies using modern grass and crop cultivars and encompassing a range of Irish soil types (Table 4.3) we propose that the P allowances for build-up be substantially increased from the current levels. Under this proposal, for soils at P Index 1 the maximum build-up allowance, in addition to crop requirement, would be 50kg/ha. For soils at P index 2 the maximum build-up allowance would be 30kg/ha.

These allowances would be applicable for four years based on current soil analysis. After this four-year period has elapsed either a new round of soil analysis would be completed and used to plan nutrient application for a further four years or the farmer could assume Index 3 for the whole farm (i.e. revert to maintenance P applications = P balance applications). In either case the proposed maximum build-up application rates would, at most, lead to a change of P index from 1 and 2 to 3.

Environmental impact of proposed solution

While this proposal leads to an increase in the chemical P fertiliser permitted on the farm for build-up, it will be targeted towards soils that have depleted STP levels as it is based on soil testing and will therefore only impact specific fields within farms. However, there would be no negative environmental impact of this solution. It has been identified in the original formulation of the regulations that soils within or below the agronomic STP range (i.e. ≤ P Index 3) are at low risk of P loss to waters, where P application rates equal to soil and crop requirements. The proposed solution will not increase the P application on these low P soils to levels above soil and crop requirements, but merely enable farmers to build-up their soil fertility steadily within a reasonable time frame (~ 4-5 years).

<u>Build-in safety margin</u> - to ensure the risk of P loss to water is minimised the proposed build-up rates for P index 1 and 2 (50 kg/ha and 30 kg/ha respectively) are set at 80% of the maximum required to build soil P levels to the top of the P Index 3 band (8.0 mg/L over the four-year soil testing interval. For example, to move a soil with a P level of 5.0 mg/l STP (top of P Index 2), to the top of P Index 3 (8.0 mg/l STP) would, on average, require 150kg/ha of P (50 kg/ha for each 1mg/l STP increase). Over four years this equates to an annual application of 37.5kg/ha of P. Allowing for a 20 % safety margin below the 37.5kg/ha rate gives a figure of 30kg/ha (80% of 37.5).

Similarly, assuming soil with a P level of 3mg/l STP (top of P index 1), on average, 62.5kg/ha of P would be required over four years to raise soil p levels to the top of P index 3. By applying the 20 % safety margin the 50kg/ha figure is arrived at.

Time limited - these allowances will only be available on fields with P Index 1 and 2 over a 4 year soil testing interval. This allows for a maximum increase in STP of approximately 2.5 mg/l STP at P Index 2 and 4mg/l STP at P Index 1. In either case these levels of increase will leave the soil, at most, within the P Index 3 range. At that point the farmer must either complete another round of soil analysis and use the results to plan P applications as specified in the regulations, or assume P index 3 for the whole farm and apply crop requirement only.

Achieving optimum soil nutrient status – by increasing the P build-up allowance and facilitating farmers to improve their soil nutrient status at a reasonably rapid rate risk of nutrient loss should be reduced. Well managed soils with optimum status for P, K and pH will provide conditions for optimum crop growth leading to better nutrient use efficiency as well as more nutrient uptake and offtake.

Sensitivity towards soil P availability/mobility thresholds – Recent studies of soil P mobility in river catchments in Ireland showed that the threshold for P availability/mobility across these grassland soil types was within the STP range from 5.9 to 8.7 mg/l (Morgan's P) (Daly et al., 2015). This threshold range was further confirmed in a study by McDonald and Wall, (2016) across the Agricultural Catchments Programme site. On a range of Irish tillage soils, Regan et al. (2014) concluded that the critical STP threshold range for soils to comply with the phosphorus EQS standards (0.035mg DRP/L) for surface waters was 7.83 to 11.31 mg/L Morgan's P. These P mobility threshold ranges sit above the current Index 3 range (5.1 to 8.0 mg/L) for grassland and within that for tillage crops (8.1 to 10.0 mg/L). This indicates that building soil P levels within the P index 3 range and even to the top of P Index 3 provides agronomic and environmental sustainability for the farming system.

4.3 Basing nutrient management plans on previous year's data

Summary of Issue

As part of the NAP each farmer is required to have a nutrient management plan by the 31st March of the relevant year for his/her farm setting out the limits of chemical fertiliser that can be applied on that farm. In the case of farms applying for a nitrates derogation the requirement is for a yearly application to be submitted to the Department of Agriculture Food and the Marine (DAFM) and a comprehensive plan must be on file with DAFM and updated at least every four years. Applicants must also submit records of chemical fertiliser use.

The requirements in relation to nutrient management plans are based on S.I. No. 31 of 2014 (EUROPEAN UNION (GOOD AGRICULTURAL PRACTICE FOR PROTECTION OF WATERS) REGULATIONS 2014) and set out in details in the guidelines issued by DAFM.

In the period since the introduction of the first NAP in 2006 the majority of farmers have had nutrient management plans prepared for them. However, in the same period substantial problems with nutrient management have emerged. There has been a dramatic fall in the soil fertility levels on Irish farms and a failure by many farmers to utilise fully the plans prepared for them to manage actual nutrient application on the farm. Teagasc has developed NMP Online with a combined aim of meeting regulatory requirements and improving the level of understanding and precision of implementation of plans by farmers.

In examining the procedures for preparing a nutrient management plan it was evident that there is some scope for simplification of the process which would lead to a better understanding of the plans and, at the same time, improve nutrient management at farm level. One change that could deliver substantial benefits would be to allow the utilisation of previous year's data for the computation of the stocking rate on the farm on which the maximum levels on N & P fertiliser are based. These benefits are described below.

The administration on the NAP at farm level has two main components (1) A planning process to determine the maximum levels of N & P that are allowed on the farm and (2) an inspection process which checks the record of usage on the farm against the amount allowed.

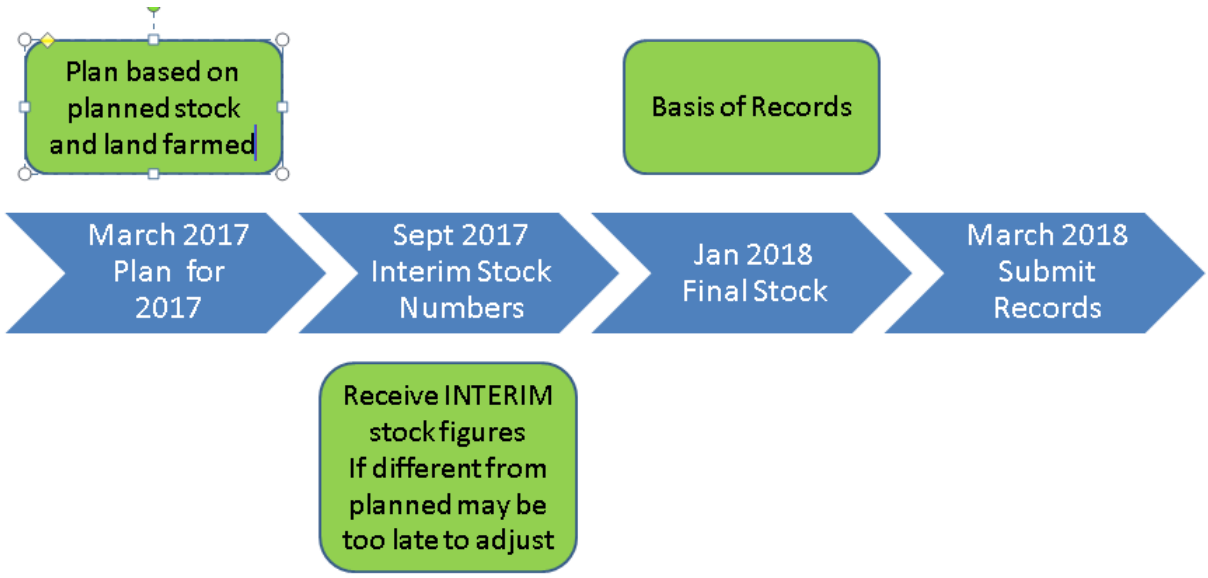

Figure 4.2. Timeline for planning and recording of Nutrient Application

Background

The current system based on the use of the actual year's records has a number of difficulties associated with it which cause problems for farmers and planners.

1. To be effective, nutrient management planning needs to be carried out ahead of the decisions to purchase fertiliser. Therefore an NMP for the farm needs to be done before the end of the closed period. This will allow the purchase of fertiliser in advance to meet crop requirements. A plan completed in the first quarter (start Feb to end March) may be too late to inform the purchase of fertiliser and the early applications. In fact increasing numbers of farmers want to forward buy fertiliser at the end of the year and ideally this should be based on a nutrient management plan.

2. In planning, farmers are risk averse and fearing penalties, are being cautious – the amount of fertiliser allowed is based on the stocking rate – (livestock units/ha). This caution is one of the factors contributing to the fall in soil fertility. If either the amount of livestock or the land base changes during the year the actual stocking rate could be different from planned levels; which could affect fertiliser allowances in the same calendar year. This can change the amount of chemical N and P permitted and where a farmer has proceeded with a fertiliser plan prepared earlier in the year; this could lead to a sanction/fine for over application. To reduce this risk at farm level, advisers generally advise clients to plan for lower application levels than allowed (or required) on a precautionary basis.

3. Currently most farmers wait until final annual N and P per hectare figures from DAFM are available in the end of January before having their NMP Plans prepared. For derogation farms this is reinforced by the requirement for fertiliser records which are based on a calendar year and generally prepared based on final end of year statements from suppliers relating to the purchase of chemical fertiliser. In general the planning and records are carried out together. This process leads to most NMP's, being created after the end of the closed period.
4. Currently if any stock changes take place during the year this will affect the kg/ha Org. N which affects the available N and P permitted on the holding. If stock numbers reduce or increase and puts the farm into a different band for total permitted N or P then the NMP prepared at the start of the year is incorrect. In this situation farmers may need to correct the stocking rate to planned levels and adjust the NMP during the same calendar year to allow the farmer to adjust the chemical fertiliser to be bought for the remainder of the year. However, in practice there is little action that can be realistically taken after the problem is discovered.
5. This on-going NMP adjustment to changing stock numbers is rarely done due to time involved for the farmer and the Agricultural consultant and limited options for corrective action. The alternative for practitioners is to take a risk adverse approach in recommending a safety net of reduced chemical N and P fertilise thus compounding the issue in section 2 above.

Proposed Solution

There are three distinct components to proposed solution which individually can improve aspects of the problem but which in combination would lead to a significant simplification of planning and control processes and lead to a higher quality nutrient management process.

1. <u>Use most recent complete N and P figures</u> - it is proposed that farmers would be able to use the most recent complete year's stocking rate figures (N and P statement) to determine their maximum N and P fertiliser allowed onto their holding rather than be compelled to use current year figures. This would allow for more certainty in the process and would facilitate more effective planning ahead of the fertiliser purchasing season. The import and export of organic manures for the planning year should also be based on the previous year's stocking rate figures.

2. <u>Change of dates for stocking rate calculation</u> - it is proposed that the dates of the computation of the stock on the farm for the purpose of calculation this stocking rate would shift for the current calendar year to an October 1st to September 30th basis. As well as being a more accurate reflection of actual nutrient loading for the year (given that for most of this period animals are housed and manures

utilised at a later stage) this would allow for early nutrient planning based on certainty of stocking rate on which actual allowances are based.

3. Change of dates for fertiliser accounts - it is proposed that the fertiliser accounts year would also be based on an October 1st to September 30th basis. As chemical N and P cannot be applied in the Oct to December period this proposal has no regulatory disadvantage. However from a practical perspective it has two main advantages. It will enable the combined process of Nutrient Management Planning and fertiliser records to be carried out from early November. This puts the process ahead of forward purchases of chemical fertiliser and early applications of organic and chemical manures which are currently taking place before plan completion. It will also reduce the current problem caused by forward purchases in the records process where records of forward purchases have to be reconciled in closing stocks though these stocks will not be on the farm.

These changes would lead to more accurate fertiliser planning and would remove the risk associated with changes in stocking rate during the year. There is precedent for this position in the use of previous year's figures for concentrate feed use. These changes would not lead to increases in the N and P fertiliser allowances on farms on a rolling year basis. Its only impact will be to introduce a time lag and facilitate farmers to applying fertilisers with certainty and within the permitted limits. In contrast to N, P is a "slow" nutrient within the annual time frame and therefore P application rates can be aimed at replacing last year's exports, rather than projected farm P exports for the year ahead without any adverse agronomic or environmental impact.

The change to the previous year stocking rate basis would deliver three main benefits in relation to the import and export calculation for organic manures Firstly it would allow for accurate planning of the import or export of organic manures. Secondly, in an instance of higher than expected stocking rates giving rise to the need for manure exports this exportation can be carried out in a planned manner rather than in a hurry at the end of a year at an inappropriate time for application. Thirdly, it would allow for improved certainty in relation to the importation of pig and poultry manures making it easier for exporting farmers to identify, plan and operate with farmers importing these manures. This would be especially important in areas with high concentrations of pig and poultry enterprises.

Environmental impact of proposed solution

There would be no negative environmental impact of this solution since the overall objectives of farm P balance remain unchanged in the long term (lag of 1 year). This proposal does not impact on the maximum allowed application levels of N and P in fertiliser or imported manures but focuses on reducing uncertainty and risk and thereby allowing farmers to safely apply both chemical and organic manures where appropriate in a more planned and environmentally sustainable manner. The main impacts of the proposal will be:

- To improve the nutrient management planning and control processes, simplify its administration and provide clearer understanding amongst all stakeholders
- To safely allow farmers apply permitted levels of N and P in order to improve soil fertility levels while minimising risk of N and P loss to waters.
- To facilitate for the orderly and effective recycling of Pig and Poultry manures to land where N and P is required.
- To facilitate planning ahead for farmers to buy chemical fertiliser when prices are low to meet crop requirements.
- To facilitate DAFM and Agricultural Consultants to start the NMP's for farmers during non-peak workload periods. This will allow Nitrates Derogation deadlines to be met without having to be extended. It would allow a more efficient and effective workload for all stakeholders and increase the quality of work completed.

4.4 Using specific organic fertilisers (pig and poultry manure and spent mushroom compost) to substitute for chemical fertilisers up to a limit of 250 kg N_{org}/hectare

Context

Intensive agricultural sectors such as pigs, poultry and mushrooms can supply manures and composts to reduce chemical fertiliser inputs for customer farmers. In the context of environmentally friendly farming and the sustainability of these intensive agricultural sectors, it is very important to clearly recognise and positively encourage a preferred order of priority for the sourcing of plant nutrients by farmers who require fertilisers to grow grass and crops. In circumstances where several regulators and state agencies consider that too much chemical nutrients are being imported into the country, a rational preferred order of priority ought to be as follows:

1. Nutrients generated within the farm, followed by:
2. Nutrients available from other farming enterprises in the local area, followed by:
3. Nutrients available locally from processors of agricultural produce, followed by:
4. Nutrients imported into the State and acquired from the chemical fertiliser industry. These can be used as the “last resort” source to top up shortages and imbalances in the combined mix of local, natural and organic materials in 1 to 4 above.

The inefficient utilisation of sources 1 to 3 above inevitably results in an unnecessary over-dependence on imported chemical fertilisers and an increase in the overall nutrient surpluses at farm and national scale.

At present there are approximately 600 intensive livestock producers (pigs and poultry) and approximately 80 mushroom producers in Ireland, with pig and poultry manure accounting for approximately 4.5 % of the national production of organic N (N_{org}) by livestock. Although this represents a relatively small proportion of national N_{org}, the management of manures from these enterprises has created some difficulties for these producers in the past.

In managing the manures and organic fertilisers (collectively referred to as manures from here on) from these enterprises, the objective of the producer is to secure sufficient demand from farmers to take these manures and manage them in such a way that the nutrients are utilised by crops as efficiently as possible. The objective of the farmers receiving the manure is to offset the quantities and costs of chemical fertilisers brought onto the farm.

Summary of Issue

At present, tillage crops are being targeted as being the most suitable home for these manures due to these crops having, in general, higher nutrient requirements than grassland, and having no organic inputs into the soil from grazing animals. However, given the low total proportion and geographical concentration and distance of these tillage crops from the farms producing these manures, a significant proportion of these materials, especially pig manure, is applied to grassland that is more local to the manure producer.

Farmers receiving these manures must account for their contribution in offsetting chemical fertiliser N and P applications. In theory, there are potentially 3 limiting factors to importing these manures, namely 1) total N_{org} application (must be <170 kg/ha); 2) Chemical N allowance on the farm; and 3) chemical P allowance on the farm. However, in reality, the chemical N allowances are rarely a limiting factor. The total N_{org} is usually the limiting factor where stocking rates on the farm are already high, while the chemical P limit is usually the limiting factor on farms with low stocking rates. The existence up to 31 Dec 2016 of transitional arrangements for pig manure, poultry manure and spent mushroom compost to allow surplus P application was a temporary solution to overcome this issue where chemical P is the limiting factor to manure import.

All farms have an N_{org} limit of 170 kg/ha across the holding, either by direct deposition by grazing livestock or by manure application. In terms of nutrient requirements, it is the farms that operate at the higher end of this ‘stocking rate’ that have the highest nutrient offtakes, and hence the highest requirements for nutrients such as N and P. However, since the volume of manure that can be imported and applied on the holding decreases with increasing stocking rate because of the 170 kg/ha limit, the potential for manure import decreases while the requirement for nutrient imports (and hence the potential to use manures) increases. This outcome is contrary to the overall objective whereby manure nutrients should be targeted to soils or fields that have a nutrient requirement.

On farms that have more than 80% grassland, a farmer can apply for a derogation to permit an average organic N application rate up to 250 kg/ha. While this is widely used by grassland farmers to carry higher stocking rates of grazed animals, the conditions of the derogation prohibit the application of imported organic fertilisers on ‘Derogation farms’. However, these farms are the grassland farms that have the highest requirements for nutrients, and hence in the context of nutrient usage, would provide a suitable location for manure application. The inverse relationship between N and P requirements and current ability to import pig manure is illustrated in Figure 1. In summary, the restriction on the organic N application is the limiting factor to these manures being available as a potential nutrient source on these farms that have a high nutrient requirement to replace offtakes.

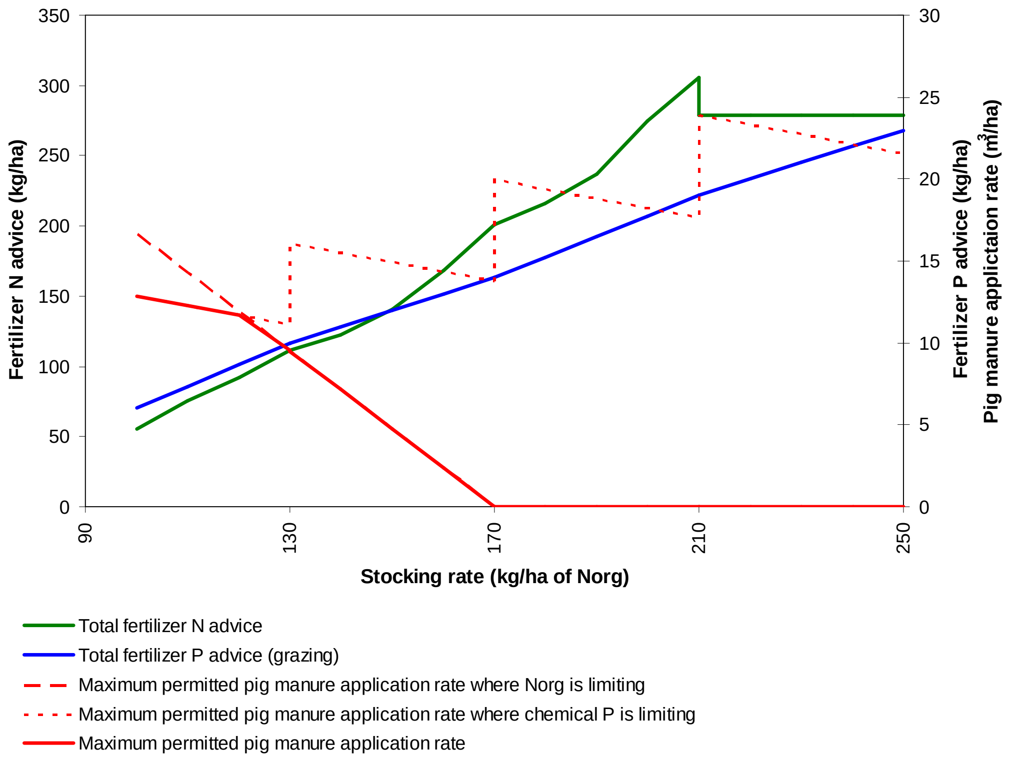

Figure 1. Graph illustrating the inverse relationship between the maximum permitted manure (pig manure in this case) application rate and typical N and P fertiliser advice for grazing for a dairy farm with a 16 week slurry storage requirement at different stocking rates. The use of concentrate feeds, and provision for silage are omitted from source calculations.

Proposed solution

It is proposed to amend the regulation to introduce a permitting system to facilitate the substitution of locally available organic N and P sources for chemical fertiliser. This amendment would allow farmers to exceed the 170kg/ha N_{org} limit through the importation and application of pig manure, poultry manure and SMC onto their farms. Farmers seeking this permission from DAFM would be required to fulfil whatever conditions are deemed appropriate by DAFM. At present grassland farms with stocking rates less than 130 kg/ha of N_{org} are the most suitable grassland farms for these manures given that the N_{org} load is sufficiently low to permit application of reasonable quantities of organic fertiliser. Farms stocked above 130 kg/ha are more restricted in the quantities of manures that can be imported.

By facilitating import of these manures onto farms with N_{org} loadings of 130 up to approximately 210 kg/ha, farms that have a higher requirement for chemical N and P, and therefore greater scope to utilise the manure nutrients most efficiently, could be brought into the network of available lands to efficiently utilise these manures. The overall limit of 250 kg/ha of N_{org}, consistent with the current derogation will remain. The imported manures would supply fertiliser nutrients in accordance with Tables 7 to 9 (including Table 9A where appropriate) of Schedule 2 of S.I. 31 - EC Good Agricultural Practice for Protection of Waters Regulations (2014).

The advantages of this proposal are as follows:

- The grassland farms with the highest nutrient requirements would be permitted to use locally produced organic fertilisers and reduce their usage of imported chemical fertilisers.
- It overcomes the tendency of the current system to encourage these manures to be applied on farms where crop nutrient requirements are lowest (i.e. farms with low stocking rates).
- Farmers who would avail of such a derogation would be automatically required to monitor soil fertility by way of mandatory soil testing every 4 years and engage in more detailed nutrient management planning and recording for their farm (consistent with the existing requirement on derogation farms).

Environmental Impact assessment

It is accepted that the use of the locally available organic material must, like chemical fertilisers be in compliance with EC Good Agricultural Practice for the Protection of Waters (S.I. 31 of 2014), including the conditions pertaining to the derogation. This proposal will not increase the N_{org} loading on farms beyond that which is currently permitted under the existing derogation. In fact the adoption of this proposal on a derogation farm would actually reduce the overall N loading in the case of importing pig manure compared to a farm stocked to an equivalent total N_{org} with grazing cattle, as the N imported in the manure would impact on the maximum chemical N permitted on the farm to a greater extent than that of home produced manure (N availability of pig manure is 50%, compared to 40% for cattle slurry).

Under this proposal, by allowing the use of specific “organic” manures up to an N_{org} load of 250 kg/ha, it is likely that most manure from intensive livestock farms will be used on grassland farms where the existing stocking rate generates an N_{org} of less than 170 kg/ha, but where the derogation will be sought to permit the importation of the manure. Under such circumstances the import of N_{org} up to a total load of 250 kg/ha will result in a net decrease in the chemical fertiliser N and P applications, since the maximum permitted chemical N and P rates will remain unchanged, given that importation of these manures does not impact on the calculated grassland stocking rate.

4.5 Allowing the carry-over from one year to the next of "organic fertilisers" on farms that import them

Introduction

Organic manures are a valuable source of major plant nutrients (N, P and K). Where possible farmers are encouraged to use them to replace expensive chemical fertilisers, especially on tillage farms, and thereby increase nutrient resource use-efficiency. Over the last decade both research and knowledge transfer has demonstrated the fertiliser replacement value of a range of organic manures through research in combination with on farm validation and demonstration studies. This has resulted in the increased use of organic manures at farm level (replacing chemical fertilisers) and an increase in the land area in receipt of organic manures (including more effective distribution of nutrients). Organic manures include cattle and pig slurry, poultry manures and mushroom compost.

Tillage crops have a large requirement for nutrients (N, P and K) and timely application ensures that the nutrients in manures are available at the correct time, correct rate and correct place for either winter or spring cropping. This offers dual benefits for both manure producers (exporters) and farmers importing these manures as it widens the window of application and facilitates a more planned approach for the efficient utilisation of the nutrients supplied. For clarity the "exporter" is the farmer sending organic fertiliser out of his or her holding. The "importer" is the farmer taking the manure onto his holding.

Current difficulties

Under certain circumstances organic manures that are transported onto either grassland or tillage farms may or may not be applied to land immediately depending on the time of year e.g. if transported onto the farm during the winter "closed spreading period" in preparation for spring application or when pig slurry is mixed with cattle slurry to help reduce problems with agitating cattle slurry (which has a higher dry matter content). Where these manures are not applied in the year of import currently they must be accounted for in that year (i.e. year of import) for fertiliser planning purposes. For the two parties involved, the manure producer (exporter) and the recipient farmer (importer) the manure movements are recorded on the DAFM Record of Movement of Organic Fertilisers Form (Record 3). http://www.agriculture.gov.ie/media/migration/ruralenvironment/environment/nitrates/2017/2017Record3MovementForm040117.docx.

Under such circumstances where imported manures are not applied in the year of import this creates serious issues for the farmers involved as there is no facility to explain or document the circumstances on the Record 3 form. It is currently assumed that the manure was used in its year of manure import and there is nothing to allow this assumption to be challenged. Thus such circumstances prohibit farmers from importing and storing manures in a timely manner (i.e. previous year) for the forthcoming growing season.

Likewise there is a recommendation that tillage farms (grant aided under TAMS 2) should construct slurry stores on their farms to allow the "timely" use of "organic fertilisers" during the growing of tillage crops. This means that the transport of the organic fertiliser does not hinder its application over the relatively narrow window of optimum application time – allowing manure use during the crop growing season. There are also other instances when it may be more agronomically and environmentally beneficial for organic fertilisers might be carried over into the following year.

Proposed Solution

It is proposed that the following questions are added to the Record of Movement of Organic Fertilisers Form (Record 3) used by farmers to report "export" and "import" of organic fertiliser at the end of each year to facilitate effective allocation as per fertiliser planning year. See below proposed changes required to Record 3 form:-

The questions below are proposed in addition to current Record 3 format to allow for the "carry-over" from one year to the next:

Please answer the following 2 questions
If these are not answered it is assumed that all the slurry / manure imported was used on the holding in the year of import.

Question 1	Was all imported slurry / manure used in 2015?	Yes / No
Question 2	If not – How much was carried over?	M^3

The farmer importing organic fertilisers should have adequate storage facilities for the imported manure if he/she intends carrying it over into the following year.

Benefits of organic manures

1. Reduces the need for expensive artificial fertilisers
2. Increases the efficient utilisation of organic manures and the nutrients they contain as they will be applied in spring when crops are actively growing. This could also prevent organic manures being applied to stubble ground.
3. Increase the land area for spreading manures such as pig/ poultry and mushroom compost which will aid more effective distributions of nutrients.

4. Enables tillage farmers to maximise the utilisation of manures for tillage crop production.
5. Increases the use of manures in the spring time of the year to maximise N utilisation.
6. Widens the window of application for manure application. This increasing the number of crops that can effectively receive organic manures.
7. Incentive for farmers to import manures at a more opportune time and to transfer/ record the nutrients contained to calendar year of application.
8. Reduces issues for advisory staff in relation to the recording and fertiliser planning of livestock manures.

4.6 Changes in fertiliser N recommendations for potato crops

Context

Fertiliser nitrogen (N) recommendations for potato crops were drawn up by staff at Teagasc based on field trials and data from potato advice in the UK. Over the last 3 decades potato varieties have changed and have been development to meet specific market requirements and end uses. This has resulted in more specific variety N management requirements for example where high tuber quality / dry matter is required lower levels of N are recommended. In addition new crops such the salad potato has developed and consumption is growing. There was no N advice available for this crop in the 3rd edition of the Teagasc 'Green Book' and has now been added to the 4th edition of the Teagasc 'Green Book' (Wall and Plunkett, 2016).

Summary of Issue

With the introduction of new potato groups and modern high yielding varieties more specific N advice was required to meet variety crop N requirements during the growing season plus satisfy specific market requirements in terms of tuber quality and end uses.

Proposed Solution

Teagasc fertiliser N advice for potatoes has not been altered in the last 2 reviews (2004 & 2008) of the Teagasc 'Green Book'. Over the last number of decades N trials have been conducted on new and existing potato varieties with more limited research work for new potato groups such as salad potatoes. In the recent review of the nutrient advice for potato crops in the Teagasc 'Green Book' 4th edition potato advice these trial results have been have been aligned with recommendations in the UK Fertiliser Manual RB209 to generate the new potato N advice.

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The new N advice system for potatoes now classifies varieties into 4 groups based on haulm longevity. This new system gives more specific N advice based on length of growing season and crop maturity to meet specific market / processing requirements. For example for a high yielding variety such as Rooster it recommends not to apply more that 170kgN/ha because of high soil N utilisation while for British Queen it recommends 150kgN/ha because the variety has medium soil N utilisation. New salad potato advice was taken from RB 209 based on variety type and haulm longevity.

It is proposed that the allowable N and P limits for vegetable crops are brought into line with the fertiliser recommendations for field vegetables as per the Teagasc Green Book (Wall and Plunkett 2016).

Environmental impact of proposed solution

The new recommendations for N on potato crops are based on the latest potato N response research and adheres to the principal of optimum N fertiliser application is equal to efficient N uptake and recovery by the crop, thus minimising N loss to the environment. The new potato N advice is targeted based on the growth habits of different potato variety groups and production systems (crop growth length). Therefore, this new advice provides more efficient N recommendations to farmers, hence protecting the environment in terms of nitrate leaching and N_2O emissions The Central Statistics Office survey for June 2016 records a total area under potato cropping of 9,000ha, which represents approximately 2.6% of the total tillage area or just 0.02% of the total agricultural area of the country. Given this small area used for potato production it is expected that the impact of the proposed changes on the environment will be minimal.

4.7 Changes in fertiliser recommendations for vegetable crops

Context

The fertiliser recommendations for vegetable crops were drawn up by the staff at the Kinsealy Research Station in the 1960's partially based on trial work but mainly on data from other countries, more than likely the UK. And they have been largely unchanged since that date. The fertiliser recommendations in the 1984 handbook for vegetables were based on an Index system for soil P and K that was slightly different from the new Index developed at Johnstown Castle, and it was decided to propose an amended index system that would be compatible with both the Johnstown Castle Index system and the vegetable fertiliser recommendations. Hence, this resulted in 5 Index ranges for P and K for vegetable crops. This was subsequently changed back to 4 Index ranges when S.I. No. 378 of 2006 was published. The knock on effect of this was a recommendation of 20 kg/ha P at Index 4 (> 10 mg/l Morgans P) for most vegetable crops, in order to account for the recommendation of 20 kg/ha at the old Index 4 (10.1-15.0 mg/l). However, when the old P Index 4 and 5 recommendations were amalgamated into the current Index 4, this allows the application of 20 kg/ha P to soils with soil test P levels above 15mg/l (Morgans P) Therefore the current P advice for vegetable crops grown on soil with very high soil test P levels is not agronomically or environmentally sustainable and does not fully protect water quality

Summary of Issue

Because of the changes in the Index system and the lack of review over the decades anomalies had become evident when the recommendations were closely scrutinised. For example, the K recommendation for Index 2 and 3 for a number of crops was 180/170 kg/ha respectively which is unnecessarily close. This anomaly relates back to 2002 when the original K Index 2 (50-150 mg/l) recommendation of 175 kg/ha was split into the current Index 2 (50-100 mg/l) and Index 3 (100-150 mg/l) - at the time 5 kg/ha was added and subtracted to give 180/170. In relation to P, if you compare our recommendations at Index 1 with what is recommended in the UK (RB209), our P recommendation of 60 kg/ha is too low at very low soil P readings. For example, in RB209, the vast majority of vegetable crops have a recommendation of 88 kg/ha at a Morgan's soil reading of 0-1.2 mg/l. And as previously stated we are recommending too much P at high soil test P levels. In comparison to RB209 some of our K readings seemed to be excessively high e.g. onions and salad onions.

Proposed Solution

Given that the Teagasc fertiliser recommendations for field vegetables haven't been altered to any degree since the 1960's and also the fact that Teagasc haven't carried out any trial work in the area, it was felt that the best approach was to align the

Teagasc recommendations to RB209, which is the basis of all vegetable fertiliser recommendations in the UK. In relation to P, it is recommended that the standard recommendation for most vegetables of 60, 45, 35 and20 kg/ha for Index 1-4 respectively be changed to 65-45-35-20 kg/ha and for 0 kg/ha when the soil reading is >15 mg/l, for reasons stated above. In relation to K, some of the Index 4 recommendations have been adjusted downwards to align with RB209, the recommendation for Index 2/3 of 180/170 kg/ha was changed to 200/170 kg/ha which aligns it with RB209, and when the soil reading is >250 mg/l recommend 0 kg/ha. In relation to N few changes were made. The maximum N for leeks was increased from 200 to 300 kg/ha to reflect grower uptake of hybrid varieties which require more N than the old open pollinated varieties. The figure of 300 kg/ha aligns with RB209 and in recent nitrogen trials in the UK (HDC FV 350 Nitrogen requirements for leeks), the results supports that particular recommendation. For swedes an additional topdressing allowance of 30 kg/ha has been to ensure sufficient N availability to meet market requirements.

It is proposed that the allowable N and P limits for vegetable crops are brought into line with the fertiliser recommendations for field vegetables as per the Teagasc Green Book (Wall and Plunkett 2016).

Environmental impact of proposed solution

The Central Statistics Office survey for June 2016 records a total area of vegetables of 3,600 ha, which represents approximately 1% of the tillage area or just 0.008% of the total agricultural area of the country. It is expected that the impact of the proposed changes will be minimal for the environment, given that vegetable production is so small in the over context of agricultural output.

4.8 Autumn phosphorus application for winter barley

Context

The area of winter barley grown has increased considerably in recent years such that it is now the second most important cereal crop grown in Ireland. Application of phosphorus fertiliser to cereal crops is regulated by S.I. 31 2014 which limits the amounts of fertiliser P that can be applied and also restricts the dates when chemical fertiliser can be applied to cereals. Specifically chemical P applications are not permitted after September 15th which, in practice, means that chemical P cannot be applied to the majority of winter barley crops at sowing. Good early growth of barley crops is required to produce the required number of tillers to produce high yields and early restrictions to growth can lead to yield reductions.

Summary of issue

Chemical P applications are prohibited after September 15th. The majority of winter barley is sown after this date with an optimum sowing date of late September/early October. Therefore it is not possible to apply chemical P to winter barley around the time of planting, when it could be incorporated into the soil and aid early growth of the barley plant. This is likely to be restricting early growth of winter barley, particularly where soil P index is low (Index 1 +2), and ultimately leading to yield reductions.

Background

Phosphorus is an important nutrient for growth of crops. A supply of readily available phosphorus is particularly important during the early stages of growth. Studies have shown that P deprivation in the early stages of growth can have lasting deleterious effects on plant growth that are not overcome by subsequent application of adequate levels of P (Green et al 1973). Soils with a low P index will have low levels of available P early in the growing season. This combined with a small root system, means that plants can experience early P deficiency in these soils where no fertiliser P is applied at or before sowing. The benefits of early P application for barley yields where soil P index are low have been well documented. Wall et al. (2013) found that at low soil P indices barley yields were increased substantially by the application of P, with the application of P with the seed being more effective than surface broadcasting the fertiliser after sowing. In these studies, the application of starter Pat sowing time increased the overall P recovery and P use efficiency by the crop compared to broadcast applications of fertiliser P. Similarly a number of other authors have reported that P placed with or near the seed is more effective than broadcast P (Peterson et al 1981; Randall and Hoeft, 1988)

Proposed solution

It is proposed that where the phosphorus is incorporated into the soil at or before sowing, that an application of 20 kg/ha of fertiliser P would be permitted to be applied to winter barley at Soil P index 1 and 2, where such application takes place before October 31st.

Environmental impact of proposed solution

The proposed solution involves altering the timing of application of chemical P rather than the amount of P applied; the maximum permitted amount of P that can be applied will not be affected by this change. The change involves permitting the incorporation of a portion of the total recommended amount of fertiliser P into the soil between Sept 15 and Oct 31 on soils that have low P status. The main loss pathway for P is by overland flow when dissolved P or P attached to soil particles is carried by water moving over the surface of the soil to water bodies. This suggests that fertiliser P that is incorporated into the soil, which will therefore not be concentrated at the soil surface, will be less prone to loss to water bodies than surface applied P. This has been verified by a number of studies. Withers et al. (2005) reported that losses of P from an arable soil were lowest when P fertiliser was incorporated into the soil in the autumn compared to surface application at other times of the year. Kleinman et al. (2002) reported that incorporating P into the soil reduced losses of dissolved reactive P to levels comparable to where no fertiliser P was added. Baker and Laflen (1982) also showed that incorporating fertiliser P into the soil reduced P losses in runoff substantially compared to broadcast applications. In a modelling study Gildow et al. (2016) found that incorporation of P had the greatest potential for reducing P loss to a susceptible water body. Therefore it is concluded that the proposed change will have negligible environmental impact in terms of P loss.

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Glossary

ACP	Agricultural Catchments Programme
BER	Break-even ratio
BOD	Biological oxygen demand
C	Carbon
DAFM	Department of Agriculture, Food and the Marine
DM	Dry matter
DHPCLG	Department of Housing, Planning, Community and Local Government
EPA	Environmental Protection Agency
EQS	Environmental Quality Standard
EU	European Union
FAS	Farm Advisory Service
FADN	Farm Accountancy Data Network
FH2020	Food Harvest 2020
FW2025	FW2025
FYM	Farmyard manure
GAEC	Good Agricultural and Environmental Condition
GAP	Good Agricultural Practice
K	Potassium
LU	Livestock unit
MAC	Maximum Admissible Concentration
MRP	Molybdate Reactive Phosphorus
N	Nitrogen
NAP	Nitrates Action Programme (also known as National Action Programme)
ND	ND
NFS	National Farm Survey
NFRV	Nitrogen Fertiliser Replacement Value
NH_4	Ammonium
NH_4-N	Ammonium nitrogen
NO_3	Nitrate
Nopt	Optimum nitrogen application rate
P	Phosphorus
RBDMP	River Basin District Management Plan
REPS	Rural Environment Protection Scheme
SEA	Strategic Environmental Assessment
SFP	Single Farm Payment
SFI	Science Foundation Ireland
SI	Statutory Instrument
S.I.378-06	European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2006
S.I.101-09	European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2009
S.I. 610-10	European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2010
SMC	Spent mushroom compost
SPS	Single Payment Scheme
TON	Total Oxidised Nitrogen
TP	Total Phosphorus
TRP	Total Reactive Phosphorus
WFD	Water Framework Directive