Teagasc Submission made in Response to the Consultation Paper on

4th Review of Ireland's Nitrates Action Programme

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Prepared by:

Teagasc Water Quality Working Group:

Spink, J. (chair), Buckley, C., Burgess E., Childs, S., Fenton, O., Horan, B., Humphreys, J., Hyde T., Meehan N., Mellander P.E., Murphy P., Ó hUallacháin, D., Plunkett, M., Richards, K., Shalloo, L., Wall, D.

Editors:

Spink, J., Wall D.P., and Tobin, C.

Teagasc

Agriculture and Food Development Authority

Oak Park, Carlow

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Introduction

This submission responds 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 4th Review of Ireland's Nitrates Action Programme in 2020. It has been prepared by Teagasc's Water Quality Working Group in consultation with the Gaseous Emissions Working Group. These working groups have members drawn from both the Knowledge Transfer and Research Directorates of Teagasc. It was prepared following consultation with colleagues across Teagasc using their collective knowledge and expertise in agri-environmental science and practice and the implementation of the Good Agricultural Practice (GAP) and Nitrates Derogation Regulations.

Teagasc has and continues to pursue a comprehensive research and advisory programme to address knowledge gaps on the interaction between agriculture and the 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 supported by the Department of Agriculture, Food and the Marine (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 Nitrates Directive - National Action Programme (NAP) measures, has been funded by the DAFM since 2008 and is currently in its fourth four-year phase. Its outputs contribute significantly to the efficacy of current NAP measures and to this submission.

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) and 2017 (Shortle et al., 2017) and 2019 (Spink et al., 2019) which support Irelands NAP and Nitrates Derogation. This submission considers developments in farm practices that have potential to positively impact water quality, but also on greenhouse gas (GHG), ammonia and habitats & biodiversity published since the last NAP. Technological and management changes affecting farm productivity and environmental sustainability are reviewed. Teagasc has responded to the guiding questions posed in the public consultation document and proposes how the NAP and Nitrates Derogation can be supported, based on the outcomes of its environmental research programme, supported by reviews of the current scientific literature.

The objectives of these proposed amendments are:

- To achieve more effective protection of the rural environment.
- To improve efficiency of agricultural production
- To rationalise and simplify the operation of the Nitrates Directive - NAP and Nitrates Derogation regulations.
- To reflect relevant measures in Teagasc's greenhouse gas and ammonia Marginal Abatement Cost Curves (MACC).
- To ensure that relevant measures maintain, or, enhance above ground and below ground biodiversity and natural and semi-natural habitats on agricultural land.

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

1. All proposed amendments, technologies or knowledge transfer (KT) methods are based on solid scientific research from published sources;
2. All proposed amendments, technologies or KT methods have been assessed in terms of their environmental impact, with emphasis on the impact on water quality, and with cognisance to potential impacts on biodiversity, greenhouse gas and ammonia emissions;
3. All proposed amendments/technologies or KT methods have been cross-evaluated against each other to ensure consistency and synergy between all proposed amendments.
4. All proposed amendments, technologies or KT methods have been assessed in terms of their cost effectiveness as costs of implementation, upkeep and administration were considered as part of the cost benefit analysis.

The Agricultural Catchments Programme

The Teagasc, Agricultural Catchments Programme (ACP) established in Ireland in 2008 aims to: i) monitor the effectiveness of the Good Agricultural Practice measures, initially for compliance with the Nitrates Directive (ND) and since 2014 with the Water Framework Directives (WFD), ii) provide a scientific basis for policy review, and iii) to monitor the effects of the nitrates derogation on nutrients balances and water quality in Ireland. Six catchments (4 – 30km^2) have been monitored within ACP for the last 12 years. They were selected to represent intensively managed agricultural land on different physical settings and dominating land use, and therefore different types of risk for nitrogen (N) and phosphorus (P) loss in terms of vertical drainage or lateral runoff risk. The programme is funded by the Department of Agriculture, Food and the Marine.

The high frequency monitoring of nutrient (N and P) concentration and nutrient and sediment load leaving each of the catchment outlets has shown that not only the nutrient concentrations, but also the dynamics varied across the catchments. Results from the six ACP catchments have not shown a clear link between the percentage of land being managed under Nitrates Derogation and stream water concentration of NO_3-N. For example, the catchment with the highest stream water NO_3-N concentration has only 5% of the land stocked above 170 kg/ha organic N loading (Jordan et al., 2012; Mellander et al., 2012; Shore et al., 2016). In other catchments that have similar organic N and P loading the water quality, in terms of N and P concentrations, was different at the catchment outlets. Despite similar source loading, one catchment with poorly drained soils and a “flashy hydrology” had three times higher total P loss than a well-drained mostly groundwater driven catchment (Mellander et al., 2015). Further complexity has been found in catchments with similar soil drainage, where nutrient loss was influenced by processes associated with the soil chemistry. Iron-rich soils led to more P loss to the stream via leaching to shallow groundwater in comparison to a free draining catchment with calcium rich soils, where P was largely retained.

In general across these catchments there is a weak link between NO_3-N leached to the groundwater and the concentrations of NO_3-N monitored at the catchment river outlet. For example, in one of the catchments the NO_3-N concentration in the shallow groundwater reached highly elevated levels of 23.9 mg/L local to the field where ploughing and pasture reseeding had taken place in the previous months. However, this locally high NO_3-N concentration was not detected in the river due to the high N removal capacity in the local near-stream zone and mixing of deeper groundwater with lower NO_3-N concentrations (Mellander et al., 2014). In the Timoleague catchment there was a high annual organic N stocking rate from the outset of the ACP, which further increased from 134 kg/ha organic N loading in 2008 to 182 kg/ha organic N loading in 2018. However, no temporal trend in groundwater NO_3-N concentration was detected during the 2010-2016 period. In contrast, the Castledockerell catchment had a much lower annual organic N loading of between 35 to 45 kg/ha during the 2008-2018 period. However, the groundwater NO_3-N concentration was higher than that in the Timoleague catchment, with an increasing trend from 2010-2016 (McAleer et al., in review).

Other factors beyond farm management also play a significant role in nutrient loss and water quality trends. During 2018 a nation-wide drought caused a build-up of a soil N pool due to poor grass growth and enhanced soil N mineralisation. That pool of N was flushed out and transferred to the stream in the rains in November causing elevated NO_3-N concentrations. This weather extreme was clearly seen in the ACP catchments and is representative of the long-term shifts in weather patterns and more frequent extreme weather events. The North Atlantic Oscillation index expresses this and was shown to influence both N and P concentration differently across contrasting catchments (Mellander et al., 2018).

In summary, Ireland has a large variety of soil types and geology. The heterogeneous physical settings influence the nutrient transfer pathways and the associated transformation process along those pathways. The expected impact of increased source pressure (stocking rate) can be overridden by the physical setting, resulting in a poor link between nutrients leaving the root zone and nutrients monitored in the stream water. Leaching of N is not a steady state process and there are many factors controlling NO_3-transport and transformation. Such factors include both static (e.g. soil and bedrock type, thickness and permeability) and dynamic factors (e.g. weather, soil moisture deficit, farm N loading and depth to water table) which are spatially and temporally variable across any farming landscape.

Responses to Public Consultation Questions

Responses to the questions put forward in the public consultation are as follows. Here we summarise the latest knowledge and propose what amendments, technologies and KT methods and supports are needed to achieve positive outcomes to these questions and to support Ireland's Nitrates Action Programme. Each of these responses is supported by scientific knowledge and based on existing science and data, and the publications are provided in the reference section.

Part 1. Response to Review of Current Requirements

1.1. Cattle Access to Watercourses.

The current regulations prevent cattle access to watercourses, effective from 1st January 2021, on farms with a grassland stocking rate of 170 kg N/ha or above. The measure requires watercourses to be fenced 1.5 metres from the top of the river bank or water's edge as the case may be. Should the current requirements of farms be extended and if so, to what extent?

Protect water quality by limiting cattle access to watercourses

There is a significant body of scientific evidence to suggest that exclusion of cattle from watercourses has a number of environmental benefits including, reduced inputs of faecal matter (Kilgarriff et al. 2020), sediment (O'Sullivan et al., 2019) and bacterial contaminants (COSAINT, 2019), into watercourses; along with reduction in riparian and riverbank impacts (O'Callaghan et al., 2018).

However, efficient policy design dictates that extension of this mitigation measure to farms beyond the 170 kg/N/ha be assessed on a cost effectiveness (or cost-benefit) basis. For example, findings from Kilgarriff et al. (2020) indicate that stocking rate interacted with area of land adjacent to a watercourse is a highly significant determinant of the cost effectiveness of this mitigation measure. This study notes that although some farms might have higher amounts of land adjacent to a watercourse, if agricultural intensity is low, the cost effectiveness of the measure is diminished.

Farms of low agricultural intensity tend to be associated with livestock production (cattle and sheep). These farm types are also associated with low level of income from agricultural production (Donnellan et al., 2020). Access to watercourses is of particular importance to some of these farmers as it provides a cheap, low-maintenance source of water for their livestock. Provision of an alternative water source for grazing livestock on these farms maybe beyond their economic scope or capacity. Madden et al. (2019) postulated that current GLAS incentives to exclude bovines from watercourse were likely to be insufficient to cover the costs of land removed from production and fencing costs when the costs of provision of an alternative water supply are included. However, farmers could be better supported to carry out fencing of watercourses and associated measures to supply alternative drinking water sources for animals by re-examining the incentives and payments for works completed on farms in future agri-environmental policy or under the targeted agricultural modernisation scheme (TAMS). Experience from the ASSAP programme bears this out as this measure has encountered significant resistance when presented to farmers by ASSAP advisors. The

COSAINT report highlighted that incentivising provision of alternative water supplies, to avoid the need for cattle to access watercourses for drinking water, could be considered in future revisions of the Common Agricultural Policy.

In summary, efficient policy design dictates that an extension of this measure beyond farms of 170 kg N/ha needs to take account of cost-effectiveness analysis criteria and the acceptability and distributional effect on low-income farmers.

1.2. Phosphorus Build-up.

The provision allowing for P build-up on farms with stocking rates of 130 kg N/ha or above was introduced in the most recent review of the Nitrates Action Programme. It allows for landowners to introduce higher levels of Phosphorus onto lands with a Phosphorus Index of 1 or 2 in order to optimise soil productivity.
An assessment of the uptake and effectiveness of this measure will be undertaken as part of this review of the Nitrates Action Programme to determine if it should be removed, retained or expanded in the next NAP.

Adoption of appropriate phosphorus build-up rates for farmed grassland soils

The decline in soil phosphorus (P) levels 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 21% of Irish soils that were tested in 2019 had optimum status for all three parameters (Teagasc 2020). While extensively managed soils and those primarily providing enhanced biodiversity value may not need soil fertility levels within the agronomic optimum range, the large proportion of agriculturally managed soils with poor soil fertility status threatens the environmental and economic sustainability of Irish farming as in these sub-optimal conditions N and P use efficiency are reduced. Low overall soil fertility provides a poor return on fertiliser expenditure on nutrients other than that which is deficient, especially fertiliser nitrogen (N), and results in limiting crop growth conditions and increased risk of nutrient loss to the environment. Where strategies to improve N use efficiency such as adoption of grass-clover swards are taking place, low soil P fertility levels are a major limiting factor to maximising the opportunity for clover establishment and persistence. In addition, on grassland soils where N fertilisers and organic manures are being applied, soil with optimum soil test P (STP), i.e. P index 3, have been shown to have lower nitrous oxide (N_2O) greenhouse gas emissions compared to soil with sub-optimal soil P fertility levels. The dual benefits for agronomy and environment from correcting soil P fertility status are critical for the agricultural sector and this improvement must be achieved in a relatively short time frame if Ireland is to meet the targets set out for water quality and greenhouse gases by 2027 and 2030 respectively.

The adoption of appropriate P build-up rates for grassland soil in SI 605, 2017 have led to improvements in soil P fertility; in 2017 approximately 63% of farms had sub-optimal soil P fertility i.e. P Index 1 and 2, and in 2019 the proportion of soil with very low and low soil P fertility had decreased to 50%. This shows the potential for improving soil P fertility over the 2 years since the higher P build-up rates became available to farmers. There is still much more improvement to be achieved on farms and the adoption of appropriate P build-up rates, based on the latest science, should be maintained to enable farmers to achieve more improvements in their grassland soils and the associated environmental benefits which are critical.

The higher levels of P allowance for soil P fertility build-up are based on several studies carried out in Ireland. These studies show that the mean annual build-up application of P required to raise Morgan's soil test P (STP) by 1 mg/L was on average 66 kg/ha for P index 1 soils and 44 kg/ha for P index 2 soils (Culleton et al., 2002; Courtney et al., 2017; Fox et al., 2016; Pettit et al. 2017; Fox et al. 2016). At the application rates allowed in the current baseline regulation (20 kg/ha for P index 1 soils and 10 kg/ha for P index 2 soils) 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.

Phosphorus build-up allowances for tillage soils

The additional soil P build-up allowances should be extended to tillage soils to help improve soil P fertility levels. Currently 50% of tillage soils have sub-optimal soil P fertility i.e. P Index 1 & 2, and there has been very little improvement in tillage soil P fertility over the last number of years (in 2017, 56% soils tested had sub-optimal P fertility and in 2020, 50% soils tested had sub-optimal P fertility). Improving soil P fertility levels in tillage soils would improve grain yields and increase N use efficiency by the crop, and hence reduce the N surplus in the soil, which could potentially be leached. A recent trial carried out by Teagasc showed that winter wheat grown on soils with optimum fertility (P Index 3) increased grain yield by 1.5t/ha compared to low P fertility soils (P index 1 & 2) given similar applications of fertiliser N. This clearly demonstrates that winter wheat crops are more yield responsive to soil P fertility than to in-season fertiliser P applications. In addition, by extending the P build-up allowance to tillage soils it would encourage greater use of organic manure application for tillage crop production and to build soil P fertility in tillage soils, plus adding valuable soil organic matter to tillage soils.

Phosphorus allowances for grassland on high pH soils

Lower soil P availability for plant uptake and issues related to the overestimation of soil P availability using the Morgan's extractable P method on grassland and tillage soils with high pH ≥ 7.0 may lead to undersupply of soil P for optimal grass and crop production. To overcome this on tillage soils, in the NAP a 20 kg/ha P additional allowance is provided on high pH tillage soils at P index 4 based on current soil test results. A review of P allowances is needed for grassland soils with high pH to assess if a similar P allowance should be specified. Grassland soils with soil pH ≥ 7.0 should have P allowance consistent with the 20 kg/ha P allowed on cereals (i.e. 80% of the Index 3 rate of 25 kg/ha). This would help to reduce significant production and environmental impacts of less than optimal P supply for grass swards on farms with these soils. In addition, a review of soil P test methods for high pH soils and the advice provided based on the soil test results is required to improve the estimation of soil P availability on farms.

Based on the latest scientific studies using modern grass and crop cultivars and encompassing a range of Irish soil types (Culleton et al., 2002; Sheil et al., 2016; Courtney et al., 2017; Fox et al., 2015) the current soil P allowances for build-up enables farmers who opt in for build-up allowances to apply up to 50 kg/ha P for increasing soil P fertility on index 1 soils and up to 30kg/ha P on index 2 soil. While this P build-up allowance leads to an increase in the chemical P fertiliser permitted on the farm it is targeted towards soils that have depleted STP levels only, as the allowance is based on soil testing and will therefore only impact specific fields within farms. There is limited or no negative environmental impact of this solution as 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 low risk of P loss to waters, where P application rates are 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).

Mandatory training requirement – to ensure that farmers opting to avail of the P build-up allowances manage the nutrient applications in a sustainable and environmentally friendly manner they must attend P build-up training course. These courses provide training and the latest knowledge to farmers on key aspects of nutrient management, agronomy, water quality protection, reducing gaseous emission losses, maintenance of biodiversity and health and safety on the farm.

Built-in safety margin - 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 minimum required levels 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 150 kg/ha of P (50 kg/ha for each 1 mg/L STP increase). Over four years this equates to an annual application of 37.5 kg/ha of P. Allowing for a 20 % safety margin below the 37.5 kg/ha rate gives a figure of 30 kg/ha (80% of 37.5). Similarly, assuming soil with a P level of 3 mg/l STP (top of P index 1), on average, 62.5 kg/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 50 kg/ha figure is arrived at.

Time limited - these allowances will only be available on fields with P Index 1 and 2 over the 4 year soil testing interval (maximum duration that the soil sample is valid and a new soil sample is required). 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, the overall 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 MAC (0.03 mg 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.

1.3. Record Keeping

Management, maintenance and submission of records is becoming a more important element of demonstrating compliance with the GAP regulations. At present all farmers are required to maintain up to date paper records and failure to produce these records during an inspection can lead to significant penalties for farmers. A more streamlined process may be required to ensure more farmers are able to manage their records and free up additional time for farm advisors, whose time is often taken up with record-keeping on behalf of farmers. In addition the need for a regime similar to that for pesticides where sales are recorded on a farm by farm basis will be considered.

Streamlining the process of recording and submitting farm records

The management, maintenance and submission of farm purchase and usage records in accordance with the GAP regulations presents challenges for farmers and farm advisors in terms of the time demands and administrative burden to complete these tasks throughout the busy farming season and at the year-end prior to submission of these records to DAFM. This process of record keeping needs to be streamlined and a level of automation may provide an avenue for achieving this. Similar to sales records for milk and meat etc. which can be electronically collated and reported, fertiliser purchases could also be collated electronically removing some of the administrative and time consuming tasks for farmers and advisors. Teagasc have previously developed a fertiliser tracker App to help farmers, agri-professionals and merchants ensure compliance with fertiliser limits based on a nutrient management plan (NMP). Assisting farmers in recording, tracking and decision making around NMP's will encourage best practice around NMP and on-farm decisions to maximise optimal soil fertility.

Promote the use of protected urea

Helping farmers manage the fertiliser purchases and to assess if the optimum mix of N, P, K & S etc. is available to optimise soil fertility and nutrient efficiency on the farm is important to achieve agronomic, economic and environmental sustainability. Grassland yields respond strongly to supplemental nitrogen (N) addition, including from mineral fertilisers. The switching from CAN and straight urea to protected urea is a critical measure in both the greenhouse gas MACC (Teagasc, 2018) and the ammonia MACC (Teagasc 2020) for reducing gaseous emissions to comply with national and international obligations. It is important that this is reflected in all policy and regulations to ensure that there is a rapid switch to protected urea as early adoption will result in greater cumulative reductions in N_2O over the period 2021 to 2030. Automated record keeping at national level provides the verifiable activity data for national greenhouse gas inventory compilation so that farmers can be sure that they can get credit for their use of protected urea and the environmental benefits that accrue from its use.

Protected urea has been shown to have the same agronomic performance as CAN and a greater nitrogen use efficiency compared to urea. Protected urea has verifiable greenhouse gas and ammonia reductions which are included in the national inventories. Support is required by all parts of the agri-food industry to ensure that farmers have access to protected urea and are encouraged to use this technology. The difficulties encountered by farmers in purchasing protected urea needs to be addressed through wider availability of the product. Quality assurance is required to ensure that when farmers purchase protected urea that it complies with all required standards. As more low emission fertiliser products, bio-fertilisers and bio-stimulants come to the market it will be important that there are verifiable emission factors for these fertilisers. The emerging fertiliser technologies need agronomic, environmental and safety factors to be quantified and accounted for. Clearly there is a need to ensure that farmers are provided with appropriate, timely and accurate information around the available protected urea products and their approval and potential to be counted within national gaseous emissions inventories. Including a record of fertiliser type on farm in an automated system might provide an opportunity for individual farmers to benefit from being able to demonstrate their own environmental credentials.

1.4. Training (for farmers and advisors).

Knowledge transfer, both from advisor to farmer and peer-to-peer, has clear benefits in sharing best practices and helping to develop farmer's knowledge of the requirements of the GAP regulations. It also provides farmers with a better understanding of environmental protection in general and the impacts poor farming practices can have on local watercourses. A requirement to participate in training programmes specified by DAFM is included for farmers engaging in P build-up, and, from January 2020 for any farmer wishing to avail of a derogation. Do you think increased requirements to participate in training courses or knowledge transfer events for all farmers would have an impact on Water Quality?

Provision of training courses and KT events for farmers and advisors

Participation in training courses for farmers, advisors and agronomists, merchants and agri-industry personnel has demonstrated benefits in terms of building understanding of the requirements of the GAP regulations, GHG and Ammonia targets, improving habitats and biodiversity etc. Training coupled with education and awareness raising helps farmers and the wider industry adopt best practice management that will improve the environmental sustainability of their farms and to tailor management for their soils and farming systems appropriately.

Training and education can be improved as follows;

i. Farmers with stocking rate >170 kg/ha organic N loading currently have a requirement for training under the current NAP. These farmers need an on-going training process which builds an understanding of the potential impacts of farming on water quality and possible mitigation measures,
ii. Training needs to be tailored to address local water quality source pressures, be they phosphorus and, or, sediment, and, or, nitrogen and, or, pesticides,
iii. An extensive advisory upskilling programme is required to enable advisors to deliver this programme backed up by appropriate research. Currently new Teagasc advisors are enrolled in Advisory Development Programme (ADP) training. In addition training events are available to private advisors, agronomists and agri-professionals through Teagasc ConnectEd which provides structured access to Teagasc research, education, knowledge resources and online tools.
iv. A network of suitable sites to demonstrate mitigation need to be established to show best practice. These sites include the ACP sites, research farms and farms that have engaged with the ASSAP advisors. In 2021 the Signpost farm initiative will provide a network of farms, linked with the agri-food industry where best practice in agronomy and agri-environmental measures for maximising nutrient efficiency, protecting water quality, reducing gaseous emissions and enhancing on farm habitats and biodiversity will be demonstrated and disseminated.
v. Over the last 4 years, a number of training events on "The Precise Application of Fertilisers" were organised and delivered by the Teagasc and the Fertiliser Association of Ireland. These events were held regionally (southeast, southwest, middle, north and west of Ireland) to train and upskill agricultural contractors and agri-merchants on the accurate and precise application of fertilisers. In the future similar events will be planned to deliver training as new fertiliser spreader technologies and products emerge.

1.5. LESS Slurry Spreading.

Low emission slurry spreading (LESS) has been demonstrated to ensure less nutrients are lost to run off and that atmospheric emissions of Ammonia from slurry-spreading are reduced. This method of slurry spreading is a requirement for all derogation farmers from 2020.The environmental benefits of LESS methods are well documented. How can these methods be further implemented to improve fertiliser management practices going forward?

Promote low emission slurry spreading (LESS) methods for reduced ammonia and greenhouse gas emissions

The adoption of low emission slurry spreading (LESS) technology, such as trailing shoe or trailing hose has led to reductions in ammonia-gas and GHG emissions from livestock farms in Ireland. Slurry N losses in the form of ammonia (NH_3) emissions are potentially the largest loss of reactive N on Irish farms (Burchill et al., 2016), with manure spreading responsible for a quarter of all NH_3 losses in Ireland (Duffy et al., 2018). The method of slurry application will have a large effect on these N losses. When applied using LESS methods (i.e. trailing shoe/band spreader) the manure is placed closer to the soil surface or in narrow bands reducing the slurry surface area that is likely to emit NH_3 gas. Shallow injection may also be an appropriate LESS method in some Irish soils which are have flat topography and are stone free. Shallow injection places the manure in shallow slots in the soils further reducing the ammonia emissions. The acidification of slurry during storage or at land-spreading has been shown to be highly effective in reducing ammonia emissions and improving the N availability from slurry in other European countries. Further research is underway to assess the potential impacts on soil quality and the extent of N use efficiency (NUE) gains that can be achieved at farm level across Irish soils.

Therefore LESS is an effective technology for abating NH_3 emissions. Teagasc studies show that the efficacy of LESS for reducing N losses is less affected by weather and soil conditions at slurry spreading times compared to the traditional splash-plate application method. Slurry applications during warm, sunny and windy weather such as during summer, is more susceptible to N loss however, using LESS during these periods (typically post silage harvest) can have the largest NH_3 abatement potential. In such conditions trailing hose and trailing shoe can reduce NH_3 by 40% and 60%, respectively (Dowling et al., 2010), with no negative trade-offs on nitrous oxide emissions (Meade et al., 2011; Bourdin et al., 2014). Simultaneously, reducing NH_3 emissions from land-spreading by switching from splash-plate to trailing shoe increases slurry nitrogen fertiliser replacement value (NFRV) from 30% to 40% in spring and from 15% to 25% in summer (Wall & Plunkett, 2016) leading to GHG emission reductions where N fertiliser are optimised in conjunction with LESS.

Further adoption of LESS has the potential to help improve farm NUE and reduce on-farm N surpluses. This can be achieved by the following approaches.

i. To achieve the targets set in Ag-Climatise a significant number of farmers need to adopt LESS by 2022 and a gradual increase in the adoption levels beyond then is required
ii. Broader implementation of LESS on its own will not achieve significant water quality improvements. The management and application of LESS must be incorporated into a farm specific nutrient management plan, where the slurry can be targeted to fields at the appropriate timing and application rate to match nutrient uptake by the grass or crop and

to replace chemical N and P where appropriate. This will help reduce nutrient loss to the environment, reduce nutrient surpluses and in turn protect water quality.

iii. The focus needs to be on improving the temporal and spatial management of slurry application. This will involve reducing application when there is a risk of loss to water, with appropriate consideration of soil moisture deficit, temperature, weather forecast and predicted growth. Achieving this will require significant KT focus with the use of tools such as a Sustainability Planning System and nutrient management plans.

iv. Given the large quantities of slurry being applied by agri-contractors (approximately 50% ; Hennessy et al. 2011) and its likely increase, measures to support contractors should be considered. Farmers that are dependent on contractor services for slurry application are not in full control of the application method, depending on the availability of equipment within the pool of locally available contractors. More widespread adoption of LESS is dependent on the availability of equipment from contractors in addition to farmer-owned equipment.

While lack of availability of LESS equipment in some areas has caused a lag in uptake on some farms to date. Grant aiding the purchase of this equipment by DAFM through the targeted agriculture modernisation scheme (TAMS) has helped farmers adopt this technology more quickly and should be extended. In addition, further training of farmers, farm advisory services and contractors will help to achieve the associated agronomic and environmental benefits from using LESS to increase slurry N use efficiency, reduce chemical fertiliser applications and costs while simultaneously reducing emissions of N to the environment. Training and advice for farmers around slurry management during storage is also needed to help to reduce other technical issues with LESS technology such as increased working downtime due to machinery blockages due to bale silage, plastic and other foreign objects entering the slurry tank.

1.6. Nutrient Management Planning.

Nutrient Management Planning (NMP) is one of the most efficient means of ensuring a farmer maximises the value of their chemical and organic nutrient inputs. NMP is also a cornerstone of compliance with the derogation requirements. The advent of online nutrient management planning tools in recent years has greatly simplified this task and many farmers that are not in derogation are also using these tools to maximise their nutrient usage.
Mainstreaming the use of these tools will be a key component of any successful NAP and will be linked to the training programmes specified by DAFM.

Soil sampling & nutrient management planning for optimum soil fertility on farms

Currently farmers receiving a Nitrates Derogation and farmers participating in agri-environment schemes such as GLAS are required to take regular soil samples (every 4 years from an area of 4 ha, with maximum area of 5 ha per sample where soil types and cropping of lands were similar) to monitor soil fertility changes over time. This is a key part of efficient nutrient management planning as these soil test results guide nutrient application rates and timings. It is essential that soil samples are taken correctly and Teagasc has a team of trained professional soil samplers, associated with their regional advisory offices, to ensure representative and reliable soil test results are produced for fertiliser planning purposes. In addition it is critical that the correct laboratory soil testing methods are used; methods that have been calibrated to the national nutrient advice for grassland and crops in the Teagasc “Green Book” of Major and Micro nutrient advice (Wall and Plunkett 2020), that are approved in the NAP.

Optimising the soil pH to ≥ 6.3 through the application of lime on acidic mineral grassland soils is a critical step in correcting soil fertility and ensuring efficient use of the N, P & K nutrients applied as fertilisers and organic manures. At optimum soil pH the soil N supply capacity of grassland soil is maximised and the uptake and efficiency of fertiliser N is improved. In addition at the optimum pH the availability of soil nutrients for grass uptake is increased and the efficiency of freshly applied P as either slurry P or chemical P (Shiel et al., 2015). Where soils are maintained within the optimum soil pH range, productive grass species and clover persists for longer and higher overall NUE can be achieved, especially where N fertilisers are appropriately managed. Improving NUE is a key measure in both the greenhouse gas and ammonia MACC analyses. The improvement of soil fertility on farms can reduce emissions where N fertiliser is reduced to account for the associated additional yields.

Advisory services nationally utilise the Nutrient Management Planning (NMP) Online system, developed by Teagasc. NMP Online is a key tool in the delivery of farm fertiliser plans for farmers annually. The programme delivers user friendly advice for all major nutrient sources (lime, organic fertilisers & chemical fertilisers). This advice can be delivered in tabular form or in the form of colour coded maps of the farm with field by field advice on them.

It also ensures that farmers meet farm cross compliance requirements based on current nutrient legislative limits. The nutrient management planning tool continues to evolve based on user requirements and will be key to the uptake and adoption of farm fertiliser plans by farmers.

- NMP Online delivers that latest nutrient advice for all crops as per the Teagasc Green Book (Wall and Plunkett, 2020)
- NMP Online delivers user friendly lime advice to show annual lime application requirements for a farm. This allows farmers to plan lime applications on a field by field basis. Lime application maps are available to help lime contractors apply accurately & efficiently.
- The programme tailors farm fertiliser plans driven by the Teagasc Green Book, the advisors knowledge and interaction with the farmer depending on farm system and soil type.
- The programme will generate farm soil fertility maps to help ensure organic manures are allocated to the parts of the farm depending on soil test results and crop type to maximise the return from slurry nutrients and ensure the farms soil fertility is kept in balance. In future versions of the system critical source areas will be highlighted such as water ways, slopes etc.
- The programme will provide field by field nutrient advice and formulate a sustainable fertiliser programme selecting the most suitable forms & rates of N fertiliser (Protected Urea) to reduce emissions.
- Identify the most suitable fertiliser blends (N-P-K) to best supply N, P K at key times during the growing season.
- The programme will formulate a fertiliser 'shopping list' for each farm and equips farmers with vital information on the correct fertiliser types for the soils and farming system.
- The system can record planned stock numbers and in turn stocking rate for the farm enterprise.
- The system can record the volume of organic manure storage on the farm. The volume of slurry and farm yard manure produced. The purchase of straw and other bedding.
- Slurry imports and exports are also recorded in the system.
- NMP Online in the past has been under appreciated as a dissemination tool. Policy changes or updated scientific findings can immediately be included in the system and brought to advisors and in turn to farmers.
- Future plans for the software (including a Green Book App and NMP Online App) aim to make these findings even more available to the farmer, farm staff and contractors alike. The uptake of digital devices across all demographics presents an opportunity to offer soil fertility maps, fertiliser plans, and lime recommendations etc. in graphical formats on mobile devices for farmers to access when they need to make soil related decisions.

More advisor time is required in the preparation of Fertiliser Plans and the updating of Fertiliser Plans during the growing season to take account of soil, weather and grass growing conditions. Administering best nutrient advice on farms is especially critical in spring when soils are colder and wetter and there is increased risk of water movement from the soil to ground and surface waters. Advice will ensure farmers make informed decisions in relation to fertiliser and manure applications which have been proven to yield production, environmental and economic benefits. In 2021 and into the future, Teagasc plan to launch regular N fertiliser advice through the Grass 10 programme particularly focused on spring grass and this will provide advisors and farmers with improved advice which takes account of predicted growing conditions. This will be followed by grass growth predictions being available on a farm by farm basis for users of PastureBaseIreland (PBI) in future allowing better fertiliser management.

Other actors (Merchants / Co-Ops / Fertiliser sales personnel) giving fertiliser advice should be appropriately trained in sustainable nutrient management advice and have access to the farmers fertiliser plans generated with NMP-Online. The Teagasc ConnectEd programme can be leveraged to reach these other actors with information and training in relation to sustainable fertiliser planning and advice. This would enable better tailoring of fertiliser programmes in line with fertiliser product ranges that are available in different locations and helping to ensure the efficient and compliant use of applied N, P & K.

Teagasc generates regular communications (Phone / Social media / campaigns e.g. Grass 10 / newsletters and popular press) with farmers on the most suitable timings (weather / soil conditions) during the key months for fertiliser and nutrient applications on farms and will promote sustainable nutrient management practices in future. Additionally, targeting training opportunities in Nutrient Management focusing on reducing loss pathways and improving efficiency could play a significant role in achieving required improvements.

1.7. Assessment of Tables in Schedule 2.

Schedule 2 of the 2017 GAP regulations includes 22 tables that set out various criteria as to storage capacity and nutrient management. These include several tables relating to permitted fertilisation rates, animal excretion rates, slurry storage capacities, etc. While some of this information was updated or introduced during the last review of the Nitrates Action Programme, a full assessment of the robustness of the information contained in the tables is being considered. This assessment must take account of improvements in scientific knowledge relating to nutrient management, climate change data and climate adaptation measures.

Availability of Scientific Data and Information to Inform Changes in Tables in Schedule 2 of the GAP regulations

Teagasc has reviewed the tables in Schedule 2 and based on the latest science and considering factors and information required to improve the utility of the GAP regulations to provide guidance for farmers and farm advisors for improving nutrient management and the protection of water quality responses have been provided in Table 1.

Table 1. Availability of new scientific data and information to inform changes in the schedule 2 tables.

Schedule 2 table number and description	Response detailing availability of new data and information to inform changes in each table
Table 1 Slurry storage capacity required for sows and pigs	No new data available to inform changes
Table 2 Slurry storage capacity required for cattle, sheep and poultry	In general, there is no new data available to inform changes in the manure production and consequently the slurry storage capacity for the animal types according the different zones nationally. In new dairy parlour set-ups the water use and quantities of dairy washings may be different – Herringbone vs Rotary vs Robotic. This information would inform the quantities of soiled water that needs to be stored and to be applied to land during the development of NMP.
Table 3 Storage capacity required for dungstead manure	No new data available to inform changes
Table 4 Average net rainfall during the specified storage period	Met Eireann may have up to date information on average net rainfall quantities over the last decade. This information could be used to assess if changes to Table 4 for open tanks where freeboard must be included.

Table 5 Storage capacity required for effluent produced by ensiled forage	No new data available to inform changes to Table 5.
Table 6 Annual nutrient excretion rates for livestock	New average annual nitrogen excretion figures for dairy cow (89 kg/ha organic N) need to be updated in the tables. For poultry litter production there are no figures in these tables. Standard values would help farmers and advisors to estimate quantities of poultry litter available during Nutrient management planning.
Table 7 Amount of nutrient contained in 1m3 of slurry	New figures from research (Berry et al., 2012) sampling slurry on Irish farms can be used to update the nutrient levels (dry matter%, total N , total P and total K) in cattle slurry (Table 7) This information has been disseminated in the Teagasc "Green Book" of Major and Micro Nutrient Advice (2016 & 2020) (Table 9.1)
Table 8 Amount of nutrients contained in 1 tonne of organic fertilisers other than slurry	Table 8 needs to provide clarity, where non-animal manures are imported onto the holding, as to the requirements when developing an NMP. For example, would certified analysis of material on a fresh weight basis to establish N and P availabilities be acceptable? Such average book values for N and P for such material be included in Table 9. New available nutrient values for poultry broiler manure has been included in the Teagasc, Green Book. In addition new research has been conducted using layer manure to provide the N input for spring barley production (2 years work)
Table 9 Nutrient availability in fertilisers	The adoption of LESS technologies will affect the availability of N applied to agricultural land. Current slurry N availability levels (40% fertiliser N replacement value) specified in the SI 605, 2017 are appropriate for the trailing shoe application method. Therefore this is currently taken into account for NMP's and fertiliser allowances
Table 9A Nutrient availability in compost	The quantities of digestate coming from anaerobic digesters that will be land spread is likely to increase in future. Information on digestate may need to be included in tables 8 and 9. Depending on feedstock the N and P availability for digestate needs to be defined as livestock manure or non-livestock manure. New information has been disseminated in the Teagasc "Green Book" of Major and Micro Nutrient advice (2016 and 2020)

	Table 9 may need to define compost in more detail in order to prepare official NMP. Could the available N & P be based on certified analysis of the compost material?
Table 10 Determining nitrogen index for tillage crops	New research has been completed to evaluate the soil N supply in arable soils. This work showed that previous cropping history and soil mineral N in spring were two variables explaining most of the variation in soil N supply. This information was used to assess the current N index and will support minor changes according the previous crops in the rotation (Walsh et al. 2015)
Table 11 Phosphorus index system	There is a potential issue with reduced soil P availability on high pH grassland soils (pH ≥ 7.0). Coupled with this the Morgan's soil test (effective for acid soil types) and corresponding P index system which has been co-opted into the regulations may indicate higher potential P availability than in reality in these high pH soils. As the fertiliser P allowance is linked with the soil test further evaluation and assessment of research data and information for grassland P requirements for high pH grassland soils is needed. This information will inform Table 11 and Tables 13A/B.
Table 12 Annual maximum fertilisation rates of nitrogen on grassland	New N fertiliser advice for grass-clover swards (>20% annual white-clover content in the sward) have been included in the Teagasc "Green Book" of Major and Micro Nutrient Advice (2020). This information can be reviewed and used to inform Table 12.
Table 13A Annual maximum fertilisation rates of phosphorus on grassland	No new data available to inform changes
Table 13B Annual maximum fertilisation rates of phosphorus on grassland adopting increased P build-up application rates	These P build-up allowances for P index 1 and 2 soils are based on the latest science and has suitable environment impact assessment measures associated with it. The P build-up allowance is discussed in detail in point 2 above.
Table 14 Annual maximum fertilisation rates of available nitrogen on grassland (cut only, no grazing livestock on holding)	No new data available to inform changes

Table 15 Annual maximum fertilisation rates of phosphorus on grassland cut only	No new data available to inform changes
Table 16 Maximum fertilisation rates of nitrogen on tillage crops	Review of the current SI 605 2017 there are a number of crops missing, with lesser agricultural land area devoted to them. The inclusion of maximum N and P fertiliser application guidance for these crops would provide clarity when preparing fertiliser plans for farms. Nutrient advice based on relevant research for many of these crops has been included and disseminated in the Teagasc "Green Book" of Major and micro Nutrient Advice for productive agricultural crops, Chapter 22. Arable and forage crops: Triticale (spring & winter), Winter rye and Arable silage, Westerwolds, are not included. These crops potentially have emerging distillery & feed markets. A review and clarity is required for fertiliser (N & P) allowances where double cropping is carried out on a farm to provide clarity for advisors and farmers when drawing up NMP's and to ensure compliance with GAP regulations.
Table 17 Maximum fertilisation rates of phosphorus on tillage crops	Similar for max P rates for tillage crops, see response to table 16 above
Table 18 Maximum fertilisation rates of nitrogen on vegetable crops	Based on the latest scientific research on nitrogen application rates for potatoes new advice has been disseminated in the Teagasc "Green Book" of Major and Micro Nutrient Advice (2016) and has been implemented in SI 605 2017
Table 19 Maximum fertilisation rates of phosphorus on vegetable crops	Similarly the max P rates for vegetable crops has been updated in 2017, see response to table 18 above.
Table 20 Annual maximum fertilisation rates of nitrogen on fruit/soft fruit crops	Based on the latest scientific research on nitrogen application rates for fruit/soft fruit crops new advice has been disseminated in the Teagasc "Green Book" of Major and Micro Nutrient Advice (2016) and has been implemented in SI 605 2017
Table 21 Annual maximum fertilisation rates of phosphorus on fruit/soft fruit crops	Similarly the max P rates for fruit/ soft fruit crops has been updated in 2017 see response to table 20 above.

Table 22 Phosphorus excess limits Article 34	The transitional arrangements for application of pig manure expire in 2021. This will reduce the quantities pig manure that can be applied on agricultural land from 2022 onwards and may create difficulties for farmers who have been unsuccessful in finding suitable additional spread lands for pig manure during this transitional period up to end 2021. We propose to extend the transitional provision (as cited in Article 34 of SI 605 of 2017) for a 3 year period to promote the use of pig manure applications on farms as a substitute for chemical fertiliser N & P sources. The advantages of this are as follows: • This promotion will encourage a change in farmer behavior and help reduce the reliance on imported chemical fertilisers on Irish farms. • Teagasc is developing Demonstration and Sign-Post farms to improve the "sustainability" credentials of our food producers. The use of pig manure to replace chemical fertiliser will be assessed under the "carbon foot-print" heading and the farming community will be more informed of the benefits of such a substitution. The proposal to extend the Transitional Provision would be seen as a very positive move to support this, • Using locally produced pig manure to reduce their usage of imported chemical fertilisers is in keeping with the Green Deal Goals as recently advocated by the European Commission, • The benefits of using pig manure over a number of years in a tillage situation has multiple benefits for soil fertility, soil quality and environmental sustainability. While the use of pig manure each year may replace the requirement for some chemical fertilisers the long term benefit is an increase in soil organic matter (SOM) and improved soil structure.
Schedule 1 Soil Test Analysis for Phosphorus	The NAP stipulates that *"the Morgan's extractable P test shall be used to determine the Soil P Index".* A review of the soil P analysis methods and P fertiliser advice based on the soil analysis results is required to ensure that the soil P availability in high pH soils can be optimised to meet both agronomic and environmental targets for fertiliser P use. Further details of issues regarding soil test P are described in Section 1.2 Phosphorus build-up. This is important so that there is harmonisation between statutory soil testing methods and those potentially used in the National Soil Sampling Campaign announced by the Government in late 2020.

Schedule 1 Soil Test Expiry of fertiliser allowances for high pH tillage soils based on soil testing	Clarity is needed within these tables and the SI that where soil samples expire, on high pH soils that any P allowances for tillage crops cease until new soil samples become available?

Review of dairy cow excretion rates

Scientific evidence is currently available to demonstrate that the excretion rates for the dairy cow should be updated.

Representing future dairy cow excretion rates in a planned manner

The Minister for Housing, Local Government and Heritage and the Minister for Agriculture, Food and the Marine, announced a new dairy cow excretion rate of 89 kg of organic N per cow from January 2021 onwards. A review of the dairy cow organic N figure per cow was completed based on data between 2010 and 2017. The previous dairy cow N excretion figure of 85 kg organic N per cow does not represent the current situation on commercial dairy farms in Ireland as milk production and consequently N excretion per cow has increased since 2013. In order for the dairy cow excretion rate to be more representative of the current national situation it has been increased to 89 kg of organic N per cow based on the average organic N per cow between 2013 and 2017. This review process should be repeated every five to seven years with the previous five years organic N output figure set for the next period. This will allow the figure to move with productivity while allowing farmers to plan for changes as they occur.

1.8. Slurry Storage Requirements incl. soiled water.

It has become clear in the past number of years that the slurry storage available on farms is not always sufficient. This is linked to a variety of factors, not least of which is changed rainfall patterns brought about as a result of climate change. Cost of installation of storage infrastructure is also an obvious factor.

Grants are available for installation of additional slurry storage on farms and DAFM always encourage farmers to ensure that they future-proof their storage requirements during design and installation.

The storage periods in Schedule 3 of the GAP regulations will be examined by the Nitrates Expert Group as part of this review of the NAP.

Ensuring slurry storage capacity and best management of organic manures

Livestock manure is a valuable nutrient source that is routinely recycled back to soils on grassland farms. In order to increase the efficiency and enhance the environmental sustainability of manure management on Irish farms, all aspects of the manure management chain need to be considered. First farmers should assess their livestock manure storage requirements to ensure they have the required capacity to store the quantities of this valuable resource produced over the winter closed period and the nutrients it contains. In order to protect water quality, manure storage and collection facilities, including yards etc., must be in good working order and managed in a manner that nutrient loss through runoff or leakage does not occur. When this manure is being recycled back to grassland soils during land spreading, it should be applied during the spring period to soils with the largest nutrient requirement, minimising the total requirement for chemical fertiliser. Finally the use of low emission slurry spreading (LESS) methods will minimise potential N losses during land-spreading and reduce the ammonia emissions associated with slurry. These best management practices for livestock manure can be implemented on farms to minimise environment impact and are described further as follows.

Slurry storage capacity - ensure storage capacity matches planned stock numbers

The requirement for slurry storage for farmers is outlined in the GAP Regulations (SI 605, 2017), Part 2, sections 5 – 14 and schedules 3 & 4. The regulations require farmers to have in place sufficient organic manure storage for all livestock over the winter housing period. The location of the farm (Closed spreading period zone) and the number of livestock over the winter period determines the volume of storage required. The Teagasc NMP-Online system includes calculations to advise the volumes required for an individual farm and will indicate if there is sufficient storage available for the livestock on a farm.

Compliance with organic manure storage conditions also ensures that farmers can comply with the requirements of the GAP Regulations (SI 605, 2017), Schedule 4; Periods when application of fertilisers to land is prohibited. Full compliance by farmers with the existing requirements ensures that organic manures are applied at appropriate times and reduces risk of nutrient losses to waters. Farmers should assess any concerns about adequate organic manure storage requirements on their farms in consultation with their agricultural advisor. Promoting compliance with the regulations and best practice e.g. apply spring slurry applications on low risk fields for nutrient transfer, through advisor/ farmer engagement and other Knowledge Transfer mechanisms, is the best way to ensure impacts on the environment from nutrient loss are minimised.

<u>Maintenance of farm yards and slurry storage facilities to minimise point nutrient losses</u>

As per the GAP Regulations (SI 605, 2017) farmers are obliged to minimise the amount of soiled water produced on their farms from livestock on concrete yards. The best way to achieve this is by a high standard of management at farm yard level to prevent and reduce the level of livestock faecal deposition and dirty yards.

Farm yard management and the minimisation, control and storage of soiled waters is a key part of the ASSAP farm assessment, and part of all farm advisory work when preparing the farm derogation plan using NMP Online. Currently ASSAP advisors engage farmers on a one-to-one basis to provide them with a better understanding of the issues involved. With an improved understanding, farmers are better able to implement and adhere to the GAP requirements on soiled water.

Initial indications from the ASSAP suggest that through improved advisor/farmer engagement and knowledge of issues involved, there is scope for improvements to be made on implementation of existing regulations that will yield a reduction of nutrient loss from farm yards. Additionally there is also potential for ammonia loss reductions from housing and hard standings to be gained from this new advisory intervention on farms.

1.9. Drinking Water Source Protection.

The protection of drinking water sources is a key element of the GAP Regulations, and the regulations include several measures to protect drinking water sources from contamination by agricultural pollutants and pathogens. These can be caused by poor slurry or chemical fertiliser application practices (i.e. application timing, rates, types) or by applying slurry or fertiliser too close to the water source.
This is an area of the NAP that needs to be strengthened and it also needs to link with ongoing source protection work under the Water Framework Directive and the provisions of the recast Drinking Water Directive, which is expected to be published later in 2020.

Identify and manage drinking water source abstraction points and adhere to set-back distances for nutrient applications

The requirement for buffers / non-application zones for fertilisers are outlined in the GAP Regulations (SI 605, 2017), Part 4, Section 17. These requirements for farmers are aimed to reduce the pollution of waters caused by nitrates and phosphorus arising from agricultural land and farm yards. While the existing set back distances can greatly improve the protection of waters where risks of nutrient loss are present the 'one-size-fits-all' approach needs to be re-examined at field, farm and catchment scales on a risk based approach. Using the whole catchment risk based approach for identifying pressures and pathways can be further improved using farm scale assessment of critical source areas and connectivity and has the potential to lead to a more targeted and effective use of setback distances and consequently 'break the pathway' of nutrient (and sediment) losses and would be more cost effective for the farmer. The Teagasc Agricultural Catchments Programme (ACP) has used digital terrain mapping (DTM) developed using LiDAR technology to map overland flow pathways for water and hence the identification of critical source areas for nutrient loss potential (Thomas et al., 2015). While high resolution DTM information (through LiDAR) is not currently available at a national scale this could be made available in future to aid in identification of critical source areas (CSA's) for nutrient mobilisation and loss and to guide the optimum locations to retain or introduce mitigation measures to break nutrient loss pathways.

Teagasc NMP Online has been updated with the latest data layers and maps for soils (identifying areas of mineral vs peat soils) and the pollution impact potential (PIP) maps for P (and very shortly for N) from the EPA. These data layers and maps are being used by advisors and farmers to identify areas of their farms with higher risk of nutrient loss or connectivity with water bodies (potential CSA's) and coupled with nutrient management planning is an effective tool and communication method to promote the protection of drinking water sources and more generally surface and ground waters in agricultural landscapes. Credit should be given to farmers adopting this risk based approach. There also needs to be alignment with other agri-environmental policy to ensure farmers are not penalised for implementing this approach through loss of payments due to land eligibility issues. Improvements in management of critical source areas and subsequent water quality improvements could form the basis for future environmental schemes.

Part 2. Response to Potential Additional Requirements

2.1. Liming.

The 2020 Good Agricultural Practice (Amendment) Regulations introduced a requirement for farmers availing of a derogation to incorporate a liming programme into their fertilisation plan. The control of soil pH through application of lime is a common practice on many farms, however, it had not previously been prescribed in the regulations until the recent amendment. The uses and benefits of liming will form part of the discussions around the NAP review and the input of stakeholders will be key to these discussions.

Promotion of lime applications and nutrient management planning on farms

The majority of Irish soil types are naturally acidic due mainly to the acidic parent material they are derived from and the effect of relatively high annual rainfall leaching basic cations from the upper topsoil layers. Currently 41% of Irish grassland soils tested have pH levels below the optimum soil pH 6.3 (Plunkett, Murphy and Wall, 2020). A smaller proportion of soils nationally may not need to be maintained within the agronomic optimum pH range of ≥ 6.3, such as those providing habitat for biodiversity, those with very extensive management and peat soils which have a lower agronomic pH target range (5.5 -5.8). However, agricultural soils of an acidic nature that receive organic and chemical fertiliser applications on an annual basis need regular lime applications to neutralise acidity and mitigate agronomic and environmental impacts arising.

Maintaining mineral soils within the optimum agronomic optimum pH range for grassland swards of 6.3 to 6.5 and grass-clover swards 6.5 to 6.8 is essential to enhance soil nutrient supply from organic matter pools through mineralization processes and to maximise fertiliser nitrogen (N) and phosphorus (P) use efficiency by the grass sward. Mineral soils maintained in the agronomic optimum soil pH range have capacity to mineralise up to 70 kg/ha/yr N. This additional soil N supply can help reduce farm N requirement and can offset some of the chemical fertiliser N on the farm. Soils with optimum soil pH will improve soil health and improve biological activity of soils leading to a better functioning soils to supply major nutrients during the growing season. The application of lime for the maintenance of soil pH above 6.3 has also been shown to decrease the emissions of N_2O from management of grassland soils but this has not yet been included in the National inventory. Optimising soil pH is a management practice in the greenhouse gas MACC (Teagasc 2018) based on the reduced requirement for chemical N fertiliser through liming.

A requirement since 2020 for farms in receipt of a Nitrates derogation is to develop a liming programme for the whole farm based on the most recent soil analysis. Teagasc NMP Online has the capacity to generate a farm-specific liming programme on a field-by-field basis for all farms, including farms not in receipt of a Nitrates Derogation, this system and the lime planning function will be promoted by Teagasc KT and advisory services to ensure that farmers receive practical and easy to understand liming advice for their farms. Soil pH should be optimised in the first 3 years after developing and implementing a fertiliser plan. Correcting soils with low soil pH, especially those with pH <5.8, to the target level (≥6.3 for grassland) has the potential to increase soil nutrient supply and grass production and has been shown to offer a typical return on investment of 7:1 (€7 return in grass growth and nutrient efficiency for every €1 invested). Since 2014, when 63% soils tested had low soil pH, Teagasc have heavily promoted lime use on farms and this soil fertility campaign has led to an improvement in soil pH nationally (2019, 41% soils had low soil pH). However, more improvement is needed on farms and Teagasc will continue to promote the use of lime to farmers through advisory services, discussion groups, events and media outputs.

2.2. Soils.

Optimising soil fertility to ensure efficient use of nutrient inputs will be a key component of the next review. The proportion of soils tested with levels of soil fertility at the agronomic optimum (pH >6.3, P and K > Index 3) remains low at approximately 18% in 2018. Balancing both macro- and micro- nutrients to meet optimum soil fertility will be reviewed.

Increased adoption of NMP-Online fertiliser recommendations and best practice nutrient management guidelines on farms

Optimising soil fertility will be central to improving the efficiency of N use at farm level. Over the last 5 years we have seen an annual improvement of 2% in soils with optimum pH (>6.3), P & K (Index 3). Building soil fertility is a slow process and takes time but the continued improvement in soil fertility will improve nutrient efficiency and reduce nutrient losses to both air and water. When soil testing analysis of secondary and minor nutrients will be important to ensure all soil nutrients are in balance to ensure efficient use of applied N and P organic and chemical fertilisers.

The continued use of soil test results and annual preparation and updating of farm fertiliser plans will continue to build-up soils with optimum soil fertility in the years ahead. It is recognised that not all soils on farms need to have soil fertility levels at the agronomic optimum as the priority in some areas of farms is to provide other soil functions or ecosystem services, rather than production *per-se,* such as, areas of habitat and enhanced biodiversity. Therefore the preparation of farm fertiliser plans using nutrient management planning online (NMP On-line) will provide field-by-field advice for nutrient inputs (lime, N, P, K, S) capturing all farm information that impacts on final crop nutrient recommendations. These farm-specific fertiliser plans show soil fertility levels on colour coded maps which easily identifies areas of the farm with high, optimum or low soil nutrient (pH, P and K) status. This valuable information can be used to target cattle slurry to fields that have high N, P & K requirements, for example silage fields, and away from fields with high soil P status (i.e. P index 4) or from risky areas for nutrient loss i.e. critical source areas (CSA's). These field-by-field fertiliser plans should be prepared for each derogation farm and discussed with the farmer through an advisory consultation to ensure the efficient use of N, P & K at the correct time during the growing season. On the NMP-Online system these fertiliser plans can be updated or tailored during the growing season. This is important to account for changes in fertiliser product types (following interaction with Agri-merchants/Co-Ops/Fertiliser sales personnel) or fertiliser management due to unforeseen weather events etc.

Greater emphasis on the fertiliser planning recommendations is needed and increasing advisory contact time with farmers, especially those who operate moderate to intensive farming systems, to provide follow up advice and guidance during the growing season in order to help increase the efficient use and appropriate timing of fertiliser applications across farms. For example, text message alerts in spring time to identify suitable timing of early N applications / reminders to apply additional nutrients to build soil P & K levels, for example application of K in the autumn.

2.3. Grazing Intensity

Grazing intensity relative to whole farm stocking will be reviewed. This will be reviewed based on most recent research available.

Optimising stocking intensity to meeting agronomic and environmental objectives on farms

Across the 6 ACP Catchments no clear link was observed between the percentage of land being managed under Nitrates Derogation and stream water concentration of NO_3-N was found. The heterogeneous physical settings largely influence the nutrient transfer pathways and the associated transformation process along those pathways. These settings can override the source pressure resulting in a poor link between nutrients leaving the root zone and nutrients monitored in the stream water.

Stocking rate (SR) is the key strategic decision for pasture-based dairy farms and is generally defined as the number of animals allocated to an area of land (i.e., cows/ha). Although the beneficial impacts of SR on grazing system productivity have been widely reported (McCarthy et al., 2011), the impact of SR on environmental efficiency must also be considered. Previous studies have indicated that where increased SR are associated with increased chemical fertilizer and supplementary feed importation, nutrient surpluses increase, and nutrient-use efficiency is reduced, resulting in increased losses to groundwater and the general environment. Contrary to these findings, both McCarthy *et al*., (2015) and Roche et al. (2016), investigated the direct effect of SR on nitrate leaching; while both studies reported relatively high levels of nitrate leaching overall across all SR treatments, the levels of nitrate leaching were stable or declining with increasing SR where no additional N fertilizer or supplements were introduced at higher SR. Similarly, in the ACP Timoleague catchment, the organic N loading increased from 134 kg/ha organic N loading in 2008 to 182 kg/ha organic N loading, however, no temporal trend in groundwater NO_3-N concentration was detected during the 2010-2016 period.

As grazing farms intensify it is also recognised that a number of changes to management practices are required to maintain low levels of nutrient loss. These include, increased grazed pasture utilisation, greater use of organic manures to replace chemical fertilizer, more strategic use of chemical N, reduced cultivation reseeding, improved grazing management and nutrient budgeting, and, importantly, the preferential management of areas with higher risk of nutrient loss on the farm. The appropriate SR for individual farms varies considerably due to differences in land type, pasture management and soil fertility and therefore no overall SR will be appropriate to all individual farms. A maximum limit for whole farm stocking rate of 170 kg/ha organic N for standard farms and up to 250 kg/ha organic N for farms that apply for a Nitrates derogation constrains the total number of livestock on the whole farm. However, within farms stocking rates across the different parcels of land will vary due to different biophysical, management, fragmentation and accessibility factors. It would be administratively arduous and very complex to calculate or implement a within-farm maximum stocking rate intensity. In addition defining the boundary of the grazing platform would be difficult as the area used is likely to change seasonally depending on grass growth levels, areas closed for silage and when the grazing season is being extended early and later in the season. On that basis, Teagasc recommends that SR per se should not be used to regulate within-farm practice. It is preferable that increased emphasis is placed on increasing nutrient use efficiency (NUE; N outputs /N inputs) and reducing N balances at farm level in order to reduce N losses. This can be achieved by further integrating pasture, supplement and milk production data for individual farms to achieve increased milk production per unit N applied as part of more rigorous nutrient management planning on individual farms. The compilation of N fertiliser and feed inputs for individual farms would enable such approaches to be developed resulting in both increased farm system performance and reduced losses of N from grazing systems.

Promotion of grass measurement and efficient grazing management on farms

The number of grassland farmers using PastureBase Ireland (PBI) has increased from 2,393 in 2017 to 3,664 in 2020; while over the same period the number of grass cover measurements has increased on average from 14 to 19 per farm per year. Annual grass DM production in 2019 on dairy and drystock farmers using PBI was 13.5 and 10.1 tonnes DM/ha respectively; this compares to 10.7 and 7.9 tonnes of DM/ha estimated on national average dairy and cattle rearing farms respectively. Over 90% of the grassland farmers participating on PBI are dairying, with the remainder being beef and sheep. A large proportion of dairy farmers that regularly use PBI also apply on an annual basis for derogation from the Nitrate Directive. In recent years, PBI has under gone significant developments. One major development that has greatly enhanced PBI usage was the launch of the offline 'PBI Grass' app in mid-2018. Today, over 1,700 farmers have this app downloaded on their smart device; this is available on Google Play and App Store. This app makes data collection (grass covers, graze dates, fertiliser applications, spring rotation planner etc.) much easier for the farmer. Over 50% of grass covers are now uploaded from the offline app. New tools have been developed which include the projected wedge, weekly grazing planner, grass budget and fodder budget, these features will contribute significantly to farmers' ability to tailor fertiliser plans to the requirements for forage and the likely grass demand for nutrients. Another aspect of PBI development in recent years was linking up with other companies to add value to data already being recorded by farmers. One major success was the link up with 13 milk processors; Arrabawn, Aurivo, Bandon, Barryroe, Centenary, Dairygold, Drinagh, Glanbia, Kerry, Lakeland, Lisavaird, North Cork and Tipperary. When milk is collected from a farm the details are sent to PBI the day after. In PBI litres per cow, kilograms of milk solids per cow, kilograms of milk solids per hectare are calculated and displayed. This information adds huge value to data in PBI. Farmers can see the inputs (grass and meal) and the output (kg milk solids).

2.4. Zero Grazing

Zero grazing is a practice being adopted more and more at farm level and a review on best practice for grazing and nutrient management will be undertaken as part of this review.

Considerations for the incorporation of zero grazing in farming systems

The increased prevalence of zero grazing on intensive farms is acknowledged. The practice of zero-grazing has allowed farmers on fragmented land holdings to greatly increase the utilisation of outside land blocks to provide high quality home grown feed to maintain animal performance in spring and autumn when grass- growth rates are low relative to animal feed requirements. Zero grazing also provides for a more even redistribution of recycled slurries on grassland across fragmented land holdings and reduces the risks of N losses from urine patches on free draining soils particularly during autumn. However it is generally associated with increased stocking rates on the milking platform, which has the potential to create nutrient loss hotspots as these milking platforms are operated at very high stocking rates. Increasing the amount of manure generated through reduction in grazed grass could potentially increase ammonia emissions and this needs to be considered when reviewing the potential of zero grazing. As a widespread mitigation practice for N loss, the potential of this approach to Irish grazing systems must also be considered in terms of the additional economic costs associated with substantially increased mechanical handling of both feed and slurries when compared to grazing *in situ*. From an economic perspective, Dillon et al. (2008) has reported a strong positive relationship between the amount of grazed pasture in the diet of the dairy herd and milk production costs while the full economic costs of zero grazing are similar to the costs of grass silage conservation (Finneran et al., 2012). Moreover, an increased reliance on zero-grazing will also require increased slurry storage and on farm mechanisation both resulting in significant cost increases in addition to increased ammonia emissions. In cases where slurries are not recycled evenly across the entire land area, the practice of zero-grazing can result in increased N surpluses and losses on the main grazing platform. At the same time, the further confinement of animals for zero-grazing will also result in a reduction in grazing season length on farms which is an area of increasing animal welfare concerns for the European dairy industry (Nalon and Stevenson, 2019).

2.5. Exports of Livestock Manure.

Over 4,500 farms export livestock manure to remain compliant with stocking rate limits in the regulations. The impact of these farmers and potential additional controls will be examined. Some additional measures were introduced by the GAP amendment regulations (SI 40 of 2020) however, the practice of exporting livestock manure is one which needs a full assessment. The Nitrates Expert Group review of the NAP in 2019 recommended the introduction of further measures for these holdings.

Promoting nutrient management planning to maximise the efficiency of nutrient inputs on farms exporting and importing organic manures

Farms exporting slurry to remain compliant with stocking rate limits in the GAP regulations (SI 40 of 2020) currently have to do a liming plan only where there are valid soil samples on farm. To promote better use of slurry and chemical fertiliser nutrients within these farms soil sampling and nutrient management planning should be promoted to improve targeting of organic manure and compliance with N and P allowances across the fields on the farm, in particular, maximising the recycling of nutrients in organic manures to silage fields

On farms that import organic manures the development of a full nutrient management plan, including soil samples, can help to identify the quantities of organic manures required across the farm and to target the imported slurry nutrients to low fertility soils (P and K index 1 and 2). The information provided to the farmer in the nutrient management plan will help to increase the substitution of chemical fertilisers on these farms while increasing the sustainability of total nutrient inputs across the farm. Importing organic manures especially on tillage farms can improve organic matter levels within soils and increase nitrogen use efficiency. Farmers should be encouraged to import organic manures under whole farm best practice nutrient management planning. Offsetting chemical fertilisers with imported organic manures which are targeted at low P and K index soils has many potential environmental benefits.

2.6. Large Herds.

There is an increasing disparity between those with the largest herds in the country and those other farmers that are running average-sized herds. With the intensity of these large operations having the potential to put significant pressures on the water quality and quantity in their local catchment, should additional measures be considered to address this issue?

Relationship between large herds and increased pressure water quality and quantity

Teagasc are not aware of any published relationships between herd size and environmental impact on pasture based livestock systems. While herd size and stocking rate are not always mutually exclusive, the size of the herd on a farm may not be closely related with stocking rate. In practice and under existing GAP regulations, large farms are required to have increased pasture area availability for feed production and manure management in order to stay within the maximum stocking rate limits i.e. up to 170 kg/ha Organic N loading for standard intensity farms and up to 250 kg/ha Organic N loading for farms applying for a Nitrates derogation. Within each stocking rate band farmers must comply with the rules and regulations set out and therefore, farms with larger herds present no greater risk to nutrient loss than farms with smaller area and consequently fewer animals. On that basis, and while it is imperative that all farms follow the guidelines of good farm practice, Teagasc believe that it would be inequitable to require any additional requirements on individual farms solely on the basis of scale.

2.7. Interim Review of the Action Programme.

The existing Nitrates Action Programme (NAP) sets out the requirements for managing agricultural nitrogen and phosphorus for a 4-year period. While a similar period is expected for the next NAP it is proposed to undertake an interim review of the programme nationally towards the end of Year 2 of the programme to assess progress nationally in achieving the objective of reducing pollution from agricultural sources. Where considered necessary for the purpose of achieving this objective amendments to the programme will be proposed.

Guiding expectations for water quality improvement over the NAP period

To guide our expectations for water quality improvement in Irish river catchments due to imposed programmes of measures the gap between review periods (interim of 2 versus 4 years) should be cognisant of both man-made and natural delays. Practice change and water quality response is not immediate. Various components of time lag have been identified in the literature e.g. man-made delays pertaining to policy, regulation and implementation & practice adoption of measures. Further components of time lag are, firstly, the physical movement of water and pollutants (hydrological time lag) and, secondly, the transformation of these pollutants before they affect water quality (biogeochemical time lags) (Melland et al., 2018), and thirdly, lag-time in ecosystem response (Meals et al., 2010). Within agricultural catchments these time lag components interact and are influenced by the soil, the subsoil and the geology. When it comes to nitrogen (and specifically nitrate) natural time lags in well drained continuums can range from months to years but this time range increases in moderately drained equivalents (Fenton et al., 2011; Vero et al., 2017; Vero et al., 2018). Time lags in completion of monitoring data review, new research (typically conducted in 4 year cycles) and the availability of new data and scientific evidence also need to be considered for supporting reviews of the NAP through evaluating existing policy and potential new measures.

2.8. Compliance with Birds & Habitats Directives.

Compliance with the Birds and Habitats Directives is an integral part of the development of any plan or programme, including reviews of those plans or programmes. While the overall NAP review will be subject to a high-level appropriate assessment, this assessment must be detailed enough to incorporate impacts at a ground level on each individual holding.
One of the main concerns in this regard is the derogation process, and ensuring that derogation from the stocking rate limits of the Nitrates Directive does not result in non-compliance with the Birds and Habitats Directive or the WFD.
A screening for Appropriate Assessment (AA) in accordance with the European Communities (Birds and Natural Habitats) Regulations 2011 will also be undertaken as part of this review of the Nitrates Action Programme.

Nitrates Acton Programme and Appropriate Assessment

The *UN Global Assessment Report on Biodiversity and Ecosystem Services* highlighted that managing landscapes sustainably can be better achieved through multifunctional, multi-use, multi-stakeholder and community-based approaches. Sustainable practices can be enhanced through well-structured regulations, incentives and subsidies, removal of distorting subsidies, and integrated landscape planning.

The *Farm to Fork* and the *EU Biodiversity Strategy for 2030* have set ambitious targets, for biodiversity, water quality and climate. From a water quality point of view, the *EU Biodiversity Strategy for 2030* has highlighted the need to reduce pollution and restore freshwater ecosystems as key strategic actions, highlighting the potential synergies between water quality and biodiversity strategies. In addition, Ag-Climatise the national climate & air roadmap for the agriculture sector has set out pathways to reduce emissions and an ambitious vision for reach climate neutral agriculture by 2050.

Natural links frequently exist between measures to protect the environment, e.g. land-based climate change and mitigation activities can be effective and support conservation goals (e.g. supporting the objectives of the *Birds* and *Habitats Directives*). However, the *UN Global Assessment Report on Biodiversity and Ecosystem* Services report highlighted that inappropriate implementation of specific practices (e.g. afforestation of non-forest ecosystems) can have negative side effects on biodiversity and ecosystem functions (including water quality). Thus strategies should recognise the potential multi-functional impact (positive or negative) of implementation measures, rather than from the perspective of a single ecosystem service such as water quality.

An example of aligned policy and the recognition of the multi-functional benefits of measures include protection of landscape features. This has contributed to the retention of these *eligible* habitats within the landscape (Roser et al., 2021), supporting the delivery of multiple ecosystem services. E.g., landscape features such as hedgerows support biodiversity; store carbon and can play an important role in water quality, for example in relation to sediment interception and retention (Sherriff et al., 2019). The Teagasc Agricultural Catchments programme which was established to evaluate the Irelands NAP linked with water quality has recently been expanded to include measurements and monitoring of greenhouse gas and ammonia emissions and will also encompass biodiversity and habitat assessments and monitoring going forward. By evaluating and monitoring the multiple functions of agricultural land more holistic insights to trade-offs and synergies between measures can be gained and the identification of optimum management practices and systems can be developed in future.

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