Which factors influence farmers' intentions to adopt nutrient management planning?

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Abstract

Nutrients not converted to agricultural products are at risk of being lost to the environment and can contribute to environmental degradation. The adoption of nutrient management planning (NMP) can lead to win-win outcomes in terms of both improving productivity and reducing the environmental impact of farming, yet adoption remains below expectations globally. Few studies specifically focus on the adoption of NMP and the majority overlook psychological factors in their analysis. This study examines the factors which influence Irish farmers' intention to adopt NMP as defined by intention to apply fertiliser on the basis of soil test results. An expanded version of the theory of planned behaviour is used as a framework for analysis. The influence of policy is also accounted for by this study which requires certain farmers in Ireland to adopt soil testing on a mandatory basis. The results for the national sample (n=1009) show that attitudes, subjective norms (social pressure), perceived behavioural control (ease/difficulty) and perceived resources are significant and positively associated with farmers' intentions. In terms of the voluntary sample (n=587), only attitude, perceived behavioural control and perceived resources are significantly and positively associated with farmers' intentions. Whereas, for the mandatory sample (n=422), subjective norms, perceived behavioural control and perceived resources are significantly and correlated in a positive direction with intentions. A number of farm and farmer characteristics were also significantly associated with intentions. We argue that psychological issues must be addressed by initiatives designed to encourage further uptake of NMP. Furthermore, initiatives must account for the heterogeneity in the factors which influence farmers to adopt, which may be influenced by motivations for adopting soil testing, such as voluntary or mandatory purposes.

1. Introduction

The past five decades have seen a rapid increase in demand for food, owing to a persistent increase in the global population and a dietary shift towards a larger share of meat and dairy products (Lassaletta et al., 2016). To meet this demand, food production has intensified, with crop production per unit of area increasing due to increasing inputs of nutrients among other factors (Sutton et al., 2013). Nutrients, such as nitrogen (N), phosphorous (P) and Potassium (K), are essential for the continued growth of global agricultural production however nutrients not converted to agricultural products have the potential to cause environmental degradation (Schröder et al., 2004; Cherry et al., 2012). Global concerns over the nutrient enrichment of both ground and surface waters and the direct emissions of nitrous oxide and ammonia into the atmosphere have led to the simultaneous regulation of nutrient use on farms in various countries (Sutton et al., 2011) and the promotion of management practices that increase productivity which can in turn reduce environmental damage (Gebrezgabher et al., 2015; Hyland et al., 2018).

Effective nutrient management can improve productivity and farm income while reducing the risk of nutrient loss to the environment (Goulding et al., 2008). The purpose of nutrient management is to allocate the optimal amount of nutrients to crops which require them, using the right source, in the right quantities and when they are required (Roberts and Johnston, 2015). A key method that can be used to achieve the objectives of nutrient management is to adopt nutrient management planning (NMP). According to Beegle et al. (2000), NMP is a process which begins by collecting site specific information which is then used to devise a nutrient management strategy unique to the farm situation, usually with the aid of an agricultural advisor. The final step is to execute the plan. Research has demonstrated that the appropriate adoption of NMP can lead to reductions in the risk of nutrient loss to the environment (Bishop et al., 2005; Koelsch, 2005; Rao et al., 2009) and improvements in financial returns from nutrient inputs (Epp and Hamlett, 1996; Valentine, 1999).

Despite the benefits of adopting NMP, it is often found that farmers adopt certain practices associated with NMP, such as the collection of site specific data, but fail to fully translate these data into decision making surrounding nutrient applications (Buckley et al., 2015). This potentially forgoes some of the benefits that otherwise could be gained. Despite the fact that various technologies, practices and information sources[1] are available to help farmers to adopt NMP, there remains an international challenge in the adoption of NMP on a wider scale (Osmond et al., 2014; Bruyn and Andrews, 2016). Research has shown that the adoption of NMP

[1] Examples of technologies and practices that aid NMP include soil, manure and plant tissue testing, calculating optimal stocking rates and nutrient budgets. Agricultural advisors are also available to help farmers to formulate a nutrient management plan.

can be constrained by a lack of financial benefits observed by farmers which have been found to vary on a farm-by-farm basis (Ribaudo and Johansson, 2007) and often dependent on intensity of production (Price et al., 2011). However, this variance can often be contingent on factors which are under the control of the farmer such as the extent of adoption and management skill (Oenema and Pietrzak, 2002; Roberts et al., 2017).

Very few studies have examined the determinants of adoption of NMP. Most of the literature focuses on the factors which influence the adoption of individual nutrient management technologies or practices (Bosch et al., 1995; Caswell et al., 2001; Monaghan et al., 2007; Ribaudo and Johansson, 2007). Thus, less attention is given to NMP which involves the simultaneous adoption of a given nutrient management practice and its translation into on-farm decision making. Furthermore, previous studies have primarily focused on examining the influence of farm and farmer socio-economic factors on adoption of nutrient management practices and, as such, the underlying psychological factors (beliefs and social pressure) which affect farmer behaviour are often overlooked. Some authors have argued that a failure to account for the influence of psychological factors on behaviour may lead to an incomplete understanding of farmers' intentions towards management practices (Borges et al., 2014; Wauters et al., 2010; Zeweld et al., 2017). Following these authors, we extend the literature by developing a conceptual framework based on the Theory of Planned Behaviour (Ajzen, 1991) in order to advance our understanding of the factors which influence farmers' intentions to adopt NMP. This will help policy makers to better target initiatives at the factors which hinder and drive the uptake of the NMP.

This study seeks to add to the literature by examining which factors which influence the adoption of the NMP, which has seldom been studied. In order to achieve this objective, we first establish the intentions of farmers towards adopting NMP. Secondly, we determine which factors influence farmers' intentions to adopt NMP. This study, to the best of our knowledge, is also the first of its kind in relation to NMP for the country under investigation (Republic of Ireland, henceforth Ireland), and it, therefore, provides novel recommendations for encouraging the further adoption of NMP. Furthermore, the paper contributes to the limited literature on the adoption of NMP which takes into account psychological issues.

The remainder of this paper is organised as follows. Section 2 presents an overview of NMP in Ireland. Section 3 details the conceptual framework. Section 4 outlines the methods. Section 5 presents the results, section 6 discusses these results and the final section offers some conclusions.

2. NMP in Ireland

Agriculture is important to the Irish economy and in terms of environmental impacts, especially on water quality, associated with agricultural nutrients (Mockler et al., 2017). Production is concentrated on milk and beef export, benefiting from low-input costs by using grass based feeding systems (Hyland et al., 2018). While there exists an assumption that only intensive agriculture with high fertiliser inputs and high stocking rates and/or tillage can pose a threat to the aquatic environment, research in Ireland has demonstrated that extensive agriculture can also pose a high risk of nutrient loss with a lack of NMP (Roberts et al., 2017). Thus, the Irish government has a focus on encouraging all farmers to further improve their level of NMP as a means to increase food production, reduce the risk of nutrient loss to water and improve soil fertility levels (DAFM, 2015; Shortle and Jordan, 2017). One key area of focus has been the promotion of soil testing and the targeting of nutrient applications based on recommendations made by the results of soil analysis (Shortle and Jordan, 2017; Micha et al., 2018).

Soil testing is a diagnostic tool which helps farmers to assess current soil fertility and pH levels of individual fields and make nutrient application decisions based on these (Adusumilli and Wang, 2017). Data gathered from soil analysis can help to make informed decisions in relation to the source, quantity and placement of nutrients to a particular field or crop (Beegle et al., 2000). Absent soil analysis, the risk of applying nutrients not in line with crop demand and to fields with suboptimal soil pH levels can increase (Robert, 1993) . This can increase the risk of nutrient loss to the environment, underperformance of crops, an increase in the risk of soil erosion and a financial loss to the farmer (Sharpley et al., 2003). In Ireland, farmers are encouraged to soil sample every 2 to 4 hectares of land every 3 to 5 years (Wall and Plunkett, 2016). The most commonly used test is for P, K and pH and costs around €25 per sample. General recommendations for nutrient applications, including liming requirements, are provided in a soil analysis report by registered soil testing laboratories. Some of the benefits of following these recommendations[2] include increased yields, improved crop quality and efficiency of input use (Robert, 1993). However, following recommendations made by soil test results can incur additional costs and risk such as the need to increase fertiliser and lime inputs and changes to nutrient management strategies which can increase risk (Sheriff, 2005). For these reasons farmers may be averse to stringently following recommendations by the results of soil analysis.

There are several factors which drive the adoption of soil testing in Ireland. These include water quality policy, agri-environmental scheme entry and farm management. In Ireland, the adoption of periodic soil testing is mandatory for farmers who receive a derogation to farm at a higher stocking rate under Nitrates Directive (ND) regulations and those who apply to enter and receive subsidy payments under the ‘Green Low Carbon Agri-environment Scheme’ (GLAS) (Image, 2016). However, there is evidence which suggests that these groups of farmers often undertake soil testing for policy compliance purposes and do not actually consult the results when making nutrient management decisions (Buckley et al., 2015). On the other hand, farmers who adopt on a voluntary basis typically do so with the primary aim of facilitating nutrient management decisions, but still may not follow recommendations stringently. Thus, policy makers are keen to understand the factors which influence farmers to not only conduct soil testing but also to translate the results into practice (Shortle and Jordan, 2017). For this reason this study examines the simultaneous adoption and application of one key NMP practice: farmer intentions to apply fertiliser on the basis of soil test results.

3. Conceptual framework

In order to examine the factors which influence farmers’ intentions to apply fertiliser on the basis of soil test results, we developed a conceptual framework based on the Theory of Planned Behaviour (TPB), formulated by Ajzen (1991) to explain human behaviour. According to the

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[2] If a farmer soil tests with the primary aim of aiding production decisions, then it is typical for him/her to refine the recommendations with an agricultural advisor to reflect, for example, soil type, topography, weather, crops and rotations. For the purpose of this study we do not strictly limit the definition of following recommendations to a soil analysis report.

TPB, intention is an appropriate predictor of actual human behaviour. Intention, in turn, depends on the beliefs held by the individual towards a particular behaviour which are based around three constructs. These include attitudes towards the behaviour, the perceived social pressure from significant others to perform the behaviour (subjective norms) and perceived behavioural control, which incorporates the perceived ability to perform the behaviour.

The TPB framework has been validated and shown to provide a structured yet flexible framework that can explain farmer decisions to adopt agricultural practices (de Lauwere et al., 2012; Läpple and Kelley, 2013; Borges and Lansink, 2015; Lalani et al., 2016). The TPB is flexible because it is allows for the inclusion of additional variables if they improve the models predictive power and can be shown to be conceptually independent of the models constructs (Ajzen, 1991). As the TPB leaves a substantial percentage of variance with no explanation in intention and behaviour (López-Mosquera et al., 2014), we extend the model by including a number of additional variables.

Our first addition to the model is the predictor ‘perceived resources’. In the context of the TPB, we follow Zeweld et al. (2017) in defining perceived resources as the degree to which a farmer perceives that he/she owns or has access to the necessary resources (e.g. finance, labour, time) and technical infrastructure (information) to support him/her in adopting NMP. Resources are an important component of NMP and, as discussed previously, adopting soil testing and applying fertiliser on the basis of soil test results can require additional resources to facilitate the process (Beegle et al., 2000). Previous research has shown that resources have been found to constrain adoption of NMP (Monaghan et al., 2007) and therefore it is important to capture this variable in our model.

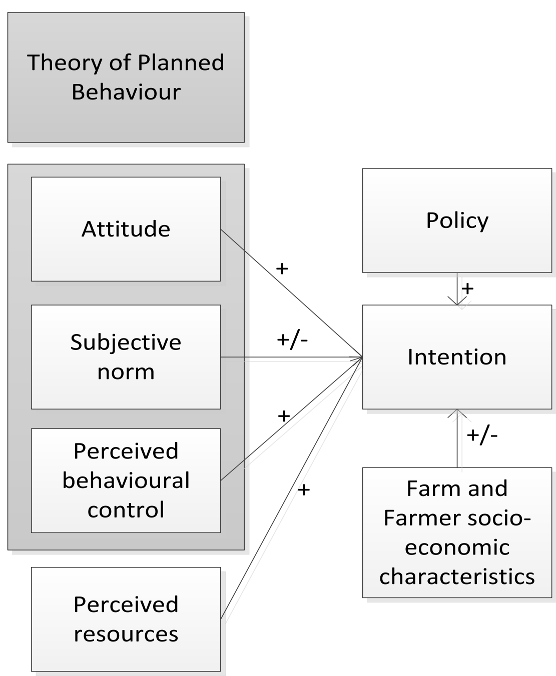
In the TPB, socioeconomic characteristics and background variables such the policy environment, are assumed to influence intention through attitude, subjective norms and perceived behavioural control. Yet, the TPB has been criticised for not accounting for such variables explicitly (Beedell and Rehman, 1999). A number of authors have addressed this limitation by explicity inclduing socioeconomic and background variables in their extended model of the TPB to explain farmer intentions (Area et al., 2012; Micha et al., 2015; Borges and Lansink, 2015). Based on previous research, discussed below, we also include a number of additional variables in our conceptual model to explain farmer intentions to apply fertiliser on the basis of soil test results. These include farm size and system, farmer age, both formal and agricultral education, contact with an agricultral advisor and participation in a discussion group. A policy variable is also included in the analysis.

In terms of farm characteristics, farm size is frequently hypothesised to positively influence the decision to adopt due to issues associated with economies of scale. Ribaudo and Johansson (2007) found farm size to be positively and significantly associated with the probability of soil testing. Intensity of production is also generally found to be positively associated with the adoption of management practices because higher intensity farms tend to use larger quantities of inputs and therefore the scope for using practices that lead to potential costs savings such as NMP is greater. Monaghan et al. (2007) showed that cost, complexity and compatibility with the current farm system to constrain the adoption of various nutrient management practices.

In relation to farmer characteristics, age is typically hypothesised to negatively influence the adoption of management practices because older farmers tend to be more risk averse. Buckley et al. (2015) found that the frequency of adoption of nutrient management practices, including soil testing, decreased with age. Higher levels of both formal and agricultural education have been found to positively increase the likelihood of adoption of management practices (Knowler and Bradshaw, 2007). Furthermore, contact with extension services such as an advisor or discussion groups have also been found to increase the likelihood of engagement of management practices. Pan (2014) found that farmers who based fertiliser application on the basis of soil test results were more likely to be in contact with agricultural extension. We incorporate these variables into our conceptual framework to explain farmers' intentions towards applying fertiliser on the basis of soil test results.

Due to the importance of policy in relation to the adoption of soil testing in Ireland (see section 2), we include an additional variable to capture the potential effect of policy on farmers' intentions to apply fertiliser on the basis of soil test results. Here we assume that farmers who have conducted soil testing to comply with policy may have a propensity to use the results as they are available to them. However, research has found that policy aimed at promoting the adoption of nutrient management practices on a mandatory basis may stimulate a negative attitude towards such practices which may prevent farmers from fully implementing the practices they adopt (Macgregor and Warren, 2006; Barnes et al., 2009). Furthermore, Barnes et al. (2013) found that farmers not affected by nutrient management policy were more likely to adopt certain voluntary water quality measures than farmers who were affected by the policy. As such, the potential drivers of adoption of NMP may differ between farmers operating under mandatory and voluntary circumstances. We, therefore, attempt to capture these potential differences in our study.

Figure 1 Conceptual framework based on the theory of planned behaviour used for the purpose of this study.



4. Data and methodology

Survey

The data used in this study was derived from a structured survey of over 1000 farmers across Ireland. A survey company was hired to carry out a face-to-face survey with farmers during the period January to April 2017. A quota controlled sampling procedure based on the Teagasc National Farm Survey (NFS) 2015 quotas[3] was set in place to ensure that the survey was nationally representative by farm system (beef, dairy, sheep and tillage) and size (hectares) for the farming population aged 15 years and above (Hennessy & Moran, 2016). It was ensured that the key decision maker on the farm participated in the interview. The quotas used here were based on known population distribution figures in relation to specific farm types taken from the Irish Central Statistics Office (Hennessy & Moran 2016). In order to obtain a nationally representative sample of farmers, the survey company initially stratified the target sample of farmers by Electoral Divisions. At each sampling point, the interviewer adhered to a quota control system based upon the known number of farm types and population distribution figures within each area (Howley et al., 2015). Interviewers then proceeded to interview farmers until they filled their quotas. The final sample size consisted of precisely 1009 farmers.

A review of the literature, expert consultations, farmer interviews and a pilot study were used to develop the survey. The final survey was divided into three sections. First, questions were used to collect data on farm (e.g. farm size and system) and farmer characteristics (e.g. age, education and contact with an agricultural advisor) for use as independent variables in the analysis. The second section collected information on farmers' motivations for adopting NMP practices, such as regulation or participation in an agri-environment scheme, for the identification and classification of farmers as 'voluntary' or 'mandatory' adopters. In the final section, farmers were asked to evaluate various statements on a five point-likert scale, from strongly disagree (1) to strongly agree (5), designed to reveal their beliefs and intentions towards applying fertiliser on the basis of soil test results. Five point-likert scales have also been utilised in previous agricultural research (Gorton et al., 2008; Adnan et al., 2017).

The statements on farmer beliefs (appendix 1) were predicated on information gathered from the survey development phase and were designed to capture the three aspects of the TPB (attitudes, subjective norms and perceived behavioural control) and the additional component 'perceived resources' which was measured in the same style as the TPB components. Thus, for farmer intentions to apply fertiliser on the basis of soil test results, farmers had to evaluate nine statements regarding personal beliefs, four statements regarding subjective norms, four statements regarding perceived behavioural control and six statements regarding perceived resources.

Explanatory variables

Information in the survey pertaining to the statements used to elicit farmer beliefs towards applying fertiliser on the basis of soil test results, was simplified using a principal component

[3] The Teagasc NFS is collected annually as part of a requirement to supply farm level data to the European Union Farm Accountancy Data Network requirements. A comprehensive set of farm accounts and enterprise level data are recorded on a random representative sample of farms across Ireland (Buckley et al., 2016).

analyses (PCA). This method was also applied in order to confirm the conceptualised TPB components (attitude, subjective norms and perceived behavioural control) and the additional component, 'perceived resources' (figure 1). If responses to the statements designed to capture these components are highly correlated, they are essentially 'saying the same thing' and PCA identifies a reduced number of similar components that account for most of the variation in responses (Jolliffe, 2002). The reduced number of components can then be used as explanatory variables in a regression analysis without losing meaningful variation in the original data (Jolliffe, 2002). The varimax rotation method was chosen and components extracted where eigen values were greater than one (Hair et al., 2010). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was also estimated where Kaiser (1974) recommends accepting values greater than 0.5. All KMO values were higher than 0.67 in this study. Items were included in a component when they presented a PCA coefficient loading of greater than 0.3.

Appendix 1 shows the results from the PCA which indicates that the statements used to elicit farmer beliefs have been reduced to four principal components. The first component is attitude, which reflects personal beliefs towards the outcomes of applying fertiliser on the basis of soil test results. This component had high component loadings on statements such as "increases profits" and "increases productivity". The second component (subjective norms) relates to farmers' perception of the level of social pressure to apply fertiliser on the basis of soil test results. Some examples of statements that produced this component when farmers were asked what most people think were: "think that I should" and "encourage me to do so". The third component (perceived behavioural control) consisted of statements reflecting the level of ease a farmer feels that he/she can conduct the behaviour. Such statements include "I am confident in my ability to do so" and "it is under my control to do so". Finally, the fourth component comprised of statements reflecting the farmers' perceptions of resources (perceived resources). This relates to the farmers perception of whether he/she has adequate resources, such as time and finance, to adopt the practice in question. The components from each PCA were used as explanatory variables in regression analysis designed to examine if these factors influence farmer's intentions to apply fertiliser on the basis of soil test results.

Based on the literature discussed previously, a number of socioeconomic and background factors are expected to influence farmer intentions to apply fertiliser on the basis of soil test results. The chosen variables include farm size and system, farmer age, formal and agricultural education, contact with an agricultural advisor, participation in a discussion group and policy. The smallest category of farm size (<20ha) was selected as the reference group for analysis of the effect of farm size on intention. This is because smaller farms generally cannot achieve the same economies of scale to engage in management practices that large farms can (Knowler and Bradshaw, 2007). In order to examine the effect of farm system on intentions, the sheep system was selected as the reference group for analysis. In Ireland, sheep farms are considered as the least intensive and generally use the least amount of fertiliser (Renwick, 2013) and, therefore, applying fertiliser on the basis of soil test results is not always considered a priority on such farms. In relation to farmer age, the oldest category of farmer (65+) was selected as the reference category for analysis because older farmers tend to be more conservative when it comes to the adoption of management practices (Prokopy et al., 2008). A dummy policy variable was developed which included farmers who participate in GLAS or receive a derogation under the Nitrates Directive. As discussed previously, both of these policy instruments make it compulsory for farmers to conduct periodic soil testing in Ireland.

Data analysis

The dependent variable for this study is farmer intention to apply fertiliser on the basis of soil test results. As the statement designed to measure this variable was based on an ordered five-point likert scale, it is typical to use an ordered regression model to analyse the data as there are more than two categories of response (Greene, 2008). However, due to insufficient responses in the first three response categories (strongly disagree, disagree and unsure), it was not possible to decompose these categories. Therefore the responses "strongly disagree", "disagree" and "unsure" were grouped into the category "do not intend" and labelled as 0 and the responses "agree" and "strongly agree" were grouped into the category "intend" and labelled as 1. As there are now only two levels of response, the following binary logistic model is employed to explore the relationship between the hypothesized psychological and additional variables on the probability that a farmer indicates a "yes" response (positive intention) to apply fertiliser on the basis of soil test results, which can be expressed as follows:

$$In[P_i/(1 - P_i)] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} \quad (1)$$

Where, subscript i denotes the i-th observation in the sample, P_i is the probability of the outcome, β_0 is the intercept, β_1, β_2, …, β_k are regression coefficients of variables X_1, X_2, ..., X_k, respectively (Timprasert et al., 2014).

Multicollinearity between the independent variables was tested for by using the variance of inflation factor (VIF) where a VIF factor of 10 is used as a cut off value (O'Brien, 2007). The maximum VIF was 3.57 which suggests that multicollinearity was not an issue in our analysis.

As discussed previously, policy requires certain farmers in Ireland to conduct periodic soil testing and therefore it was deemed necessary to account for this influence by splitting the full sample into 'voluntary' and 'mandatory' adopters. For the purpose of the analysis farmers who participate in GLAS or receive a derogation under the ND were classified as 'mandatory' adopters (n=422). The remaining farmers were grouped as 'voluntary' adopters (n=587), this group also includes farmers who do not necessarily conduct soil testing currently.

5. Results and Discussion

Descriptive statistics

Table 1 provides a description of the variables used in the regression models. The following descriptive statistics are for the full sample of farmers (n=1009). Cattle farms[4] represented 51% of the sample whereas dairy accounted for 26% followed by sheep at 17% and tillage comprising 6% of the sample. The median farm size was 31-50ha whereas the median farmer age category was 51-64. These figures are in line with national averages (Dillon et al., 2017). Furthermore, 54% of farmers have at least a second level education or higher whereas around 69% have some level of agricultural education. The descriptive results further indicate that around 63% of farmers are in contact with an agricultural advisor whereas only 29% participate in a discussion group. About 42% of farmers stated that they adopt soil testing on a mandatory basis. Finally, 63% of farmers currently soil test within national recommendations (at least every 5 years) (Wall

[4] For a definition of how farms were classified, readers should refer to (NFS, 2015).

and Plunkett, 2016). This result is similar to Buckley et al. (2015) who found from a sample of Irish farmers that 66% were conducting periodic soil testing.

Table 1 Variables used in the regression analysis.

Explanatory variables	Description	Mean	Std. deviation
Attitude	Latent variable based on ordinal responses (5-point likert scale)	0	1
Subjective norm	Latent variable based on ordinal responses (5-point likert scale)	0	1
Perceived behavioural control	Latent variable based on ordinal responses (5-point likert scale)	0	1
Perceived resources	Latent variable based on ordinal responses (5-point likert scale)	0	1
Size[a]	Farm size (1 = <20ha, 2 = 20-30ha, 3 = 31-50 ha, 4 = 51-100ha, 5 = 101+)	2.78	1.22
System[b]	Main system of farming (1 = Cattle, 2 = Dairy, 3 = Sheep, 4 = Tillage)	1.78	0.94
Age[c]	Age of farm operator (1 = under 35, 2 = between 35 and 44, 3 = between 45 and 50, 4 = between 51 and 64, 5 = 65+)	3.65	1.21
Formal education	Highest level of formal education received by farm operator (1 = some secondary and above, 0 = otherwise)	0.54	0.50
Agricultural education	Has some level of formal agricultural education (1 = some secondary and above, 0 = otherwise)	0.69	0.46
Advisor	Farm operator is in contact with an agricultural advisor (1 = yes, 0 = otherwise)	0.63	0.48
Discussion group	Farm operator participates in a discussion group (1 = yes, 0 = otherwise)	0.29	0.45
Policy	Participation in the Irish GLAS agri-environmental scheme and/ or received a derogation (1 = yes, 0 = otherwise)	0.42	0.49

Notes: [a] Farm size under 20ha as reference group, [b] Sheep as reference group, [c] Age 65+ as reference group.

Farmers' intentions

Table 2 provides a descriptive overview of farmers' intentions to apply fertiliser on the basis of soil test result. The result is higher than actual adoption rates of soil testing alone which may be due to the use of behavioural measures which are the farmers' own perceptions of their behaviour and so are subject to acquiescence biases. This means that farmers' may provide responses to questions in a 'socially desirable' way (Beedell and Rehman, 1999; Armitage and Conner, 2001). Furthermore, farmers conducting periodic soil testing on a mandatory basis do not display a 100% level of intention to apply fertiliser on the basis of soil test results. This may suggest that farmers may adopt soil testing to comply with policy but do not intend to use the results from soil analysis to influence decision making, this concurs with the findings of Buckley et al. (2015).

Table 2: Farmers' intentions towards applying fertiliser on the basis of soil test results.

	Intention[a] (% of farmers)		
Practice	National (n=1009)	Voluntary (n=587)	Mandatory (n=422)
Farmer intention to apply fertiliser on the basis of soil test results.	79	70	92

Notes: [a] as per the method, 0 = no intention, 1 = positive intention.

Factors influencing farmers' intentions to adopt apply fertiliser on the basis of soil test results

National sample (n=1009)

In the first analysis, the factors which influence farmers' intentions to apply fertiliser on the basis of soil test results are examined on a national basis (table 3). Results for the national sample highlight that intentions are influenced significantly and in a positive direction by the psychological factors attitude (1% level), subjective norm (10% level), perceived behavioural control (1% level), and perceived resources (1% level). A number of socioeconomic variables were also significantly associated with intention. Dairy farm system was significantly (5% level) and positively related to intention. In terms of farmer characteristics, the age groups 45 to 50 and 51 to 64 were significant at the 1% and 10% levels in explaining farmers' intentions. This means that these groups of farmers are more likely than their older counterparts (65 and over) to have an intention to apply fertiliser on the basis of soil test results. The coefficient for contact with an agricultural advisor is positive and significant at the 1% level. Finally, the effect of the contextual policy variable was significant (1% level) and positively correlated with intention.

The overall goodness of it of this model, as measured by $Pr > Chi^2$, is 0.0000 which implies significance at the one percent level. The r^2 value of the model was 0.45, which shows that the model has good explanatory power.

Next, the sample is divided into the two farmer groups, voluntary and mandatory adopters. Results show that different variables become significant across the regressions, that is, there is heterogeneity in the factors which influence intentions. A likelihood ratio-chow test was performed to test the null hypothesis that none of the model coefficients vary between the groups. The likelihood ratio-chow statistic test was significant at the 3% level and therefore we can reject the null hypothesis. This means that the two different groups should not be aggregated but instead should be examined separately.

Voluntary sample (n=587)

Table 3 also illustrates the factors which influence farmers' intentions to apply fertiliser on the basis of soil test results who are classified as voluntary adopters, i.e., those who do are not required to adopt periodic soil testing on a mandatory basis. The psychological factors, attitude, perceived behavioural control and perceived resources were each significant at 1% level and positively associated with intention, however subjective norms failed to reach significance. In terms of socioeconomic factors, similar to the national sample, dairy system was correlated in a positive direction with intention and significant at the 5% level. The age group 45 to 50 was found to be significant at the 10% level with a positive effect on intention to adopt. As discussed previously, this means that farmers who fall into this age band are more likely than older farmers (65 and over) to have an intention to apply fertiliser on the basis of soil test results. Finally, contact with an agricultural advisor was found to have a statistically significant (1% level) and positive effect on intention.

The regression model has a good fit with a by $Pr > Chi^2$ of 0.0000 which implies significance at the one percent level. The r^2 value of the model was 0.31, which reflects adequate explanatory power.

Mandatory adopters (n=422)

The results pertaining to the factors which influence the intentions of farmers who adopt periodic soil testing on a mandatory basis are also shown in table 3. As can be seen, there are differences between these results and the results of the full and voluntary samples. Here, the psychological variable attitude did not have a significant influence, suggesting that mandatory adopters may or may not apply fertiliser on the basis of soil test results regardless of their opinion towards the outcomes of performing this behaviour. Unlike the voluntary sample, subjective norms had a significant (10% level) and positive influence on intentions, suggesting that social pressure is an important determinant of whether a farmer decides to apply fertiliser on the basis of soil test results for this group. Perceived behavioural control and perceived resources both displayed a positive and significant correlation with intentions at the 5% level. The variables pertaining to farmer age (age under 35, 35 to 44, 45 to 50 and 51 to 64) were all positively associated with intentions at the 1%, 10%, 1% and 5% levels respectively. This means that each of these groups were more likely to adopt than their older counterparts (over 65). Finally, the parameter for agricultural education was significant at the 10% level, with a positive effect on intentions.

This model was significant, as measured by $Pr > Chi^2$, at 0.0000 which implies significance at the one percent level. The r^2 value of the model was 0.47, which is illustrates good explanatory power.

Table 3 Results of the binary logistic regression for the prediction of farmer intention to apply fertiliser on the basis of soil test results.

	Farmer intention to apply fertiliser on the basis of soil test results					
	National sample (n=1009)		Voluntary sample (n=587)		Mandatory sample (n=422)	
Explanatory variables	Coefficient	Std.err	Coefficient	Std.err	Coefficient	Std.err
TPB						
Attitude	0.27***	0.06	0.403***	0.0828	0.163	0.104
Subjective norms	0.17*	0.09	0.144	0.102	0.320*	0.183
Perceived behavioural control	0.40***	0.08	0.487***	0.110	0.275**	0.138
Additional TPB style variable						
Perceived resources	0.45***	0.09	0.380***	0.114	0.440**	0.204
Farm characteristics						
Farm size 20-30ha [a]	0.12	0.28	-0.106	0.324	0.548	0.643
Farm size 31-50ha	0.42	0.30	0.334	0.366	0.131	0.592
Farm size 51-100ha	0.36	0.37	0.188	0.458	0.188	0.703
Farm size 101+ha	0.68	0.65	0.781	0.897	0.0360	1.018
Cattle system	0.42	0.27	0.458	0.332	0.807	0.536
Dairy system	0.75**	0.36	0.957**	0.436	0.494	0.675
Tillage system	0.55	0.49	0.676	0.606	1.100	0.974
Farmer characteristics						
Age < 35[c]	0.37	0.56	-0.371	0.598	16.99***	1.359
Age 35-44	-0.02	0.36	-0.414	0.432	1.610*	0.963
Age 45-50	1.23***	0.41	0.833*	0.490	2.397***	0.896
Age 51-64	0.47*	0.25	0.266	0.307	0.901**	0.443
Formal education	0.24	0.25	0.422	0.309	-0.113	0.519
Agricultural education	0.22	0.23	-0.114	0.293	0.743*	0.430
Agricultural advisor	0.60***	0.23	0.788***	0.287	0.0753	0.435
Discussion group	0.35	0.31	0.333	0.453	0.264	0.518
Contextual variable						
Policy	0.50***	0.18	-	-	-	-
Validity statistics						
Constant	-1.54**	0.74	0.623	0.402	0.312	0.688
Model chi-square	167.1		120.3		339.34	
Prob > chi2	0.0000		0.0000		0.0000	
Loglikelihood	-285.7		-191.7		-81.2	
Pseudo R^2	0.449		0.468		0.313	
% correctly classified	90.19		87.56		94.31	

Notes: Significance levels *** p<0.01, ** p<0.05, * p<0.1 [a] reference group for farm size is <20ha, [b]reference group for farm system is sheep system, [c] reference group for age is group 65+, [d]Includes farmer who have a derogation and farmers participating in GLAS agri-environmental scheme.

6. Discussion

This study uses a modified TPB approach to understand which factors influence farmers' intentions to adopt NMP which is defined as intentions to apply fertiliser on the basis of soil test results. The results from the regression analysis indicate that there are both similarities and inconsistencies in the significance of variables across the regressions. This suggests that there is heterogeneity in the factors which influence intentions to apply fertiliser on the basis of soil test results which may be dependent on underlying motivations (voluntary or policy compliance) for adoption. The significance of the policy variable in the regression analysis for the national sample provides further evidence to suggest that policy is an important driver of intention. To this end, this section focuses on discussing the significant results for the voluntary and mandatory groups only.

The first TPB variable, attitude, has a positive and significant influence on farmers' intentions to apply fertiliser on the basis of soil test results for the voluntary sample, however this effect is not noted for the mandatory sample. This means that farmers unaffected by policy are more likely to adopt the practice if they evaluate the outcomes of performing the behaviour more favourably than their counterparts. A possible explanation for this result is that certain groups of farmers who voluntarily intend to engage with the practice are more aware of the benefits that can be gained from doing so than other farmers within this group. This result is in line with previous TPB studies which found attitude to be a significant predictor of intention to adopt voluntary agricultural practices (Wauters et al., 2010; Martínez-García et al., 2013).

It is suggested that social norms influence people's intentions and behaviour because people do not conduct decisions independently from social and cultural influences and, instead, they are constantly referring their behaviour back to important reference groups (Burton, 2004). However, our results only partially support this assertion as subjective norms is only found to significantly influence the intentions of farmers classified as mandatory adopters. This means that farmers within this group who feel a larger degree social pressure are more likely to translate the results of soil analysis into practice. One possible explanation for this result is that a fear of further regulation, or fear of penalties if not operating within the regulations, within the farming community may be stimulating farmers to behave in a way that is perceived as 'socially desirable' to gain social acceptance and avoid further regulation in the future (Welch and Marc-Aurele, 2001).

In theory, farmers who have a strong belief in their own capability to apply fertiliser on the basis of soil test results should be more likely to do so (Ajzen, 1991). Our results support this assertion as perceived behavioural control is found to be statistically significant and has a positive influence on farmers' intentions, for both farmers classified as voluntary and mandatory adopters. This means that farmers who perceive it to be easy to apply fertiliser on the basis of soil test results are more likely to do so. Recommendations made by soil analysis laboratories in Ireland are based on national average fertiliser recommendations (Wall, and Plunkett, 2016) and therefore a level of technical expertise is required to refine the recommendations to suit the particular farm situation. Increasing levels of awareness and engagement with support available to farmers may help to increase levels of control and thus raise farmers' ability to apply fertiliser on the basis of soil test results on their individual farm.

The additional hypothesised component, perceived resources, significantly and positively influences both groups of farmers' intentions to apply fertiliser on the basis of soil test results. This means that farmers who believe that they have the necessary resources such as time, finance and labour to adopt the practice are more likely to do so. Whilst this result is contrary to the finding of Zeweld et al. (2017), who did not find a significant relationship between perceived resources and farmers' intentions to adopt sustainable practices, it conforms to expectations as the practice can require changes in practices such as applying additional fertiliser, increased frequency of application, or to fields that may be difficult to access with machinery. Such practices often require additional finance, time and labour to which a farmer may not have access and which may hinder adoption (Sheriff, 2005). Initiatives designed to encourage further adoption must acknowledge disparities in resources available to farmers before making recommendations.

The results of this study also demonstrate that several farm and farmer characteristics influence intentions. The dairy system was significantly and positively associated with intention for the voluntary sample. A possible explanation for this result is that dairy farms in Ireland receive the majority of their income from the market and inputs are relatively higher compared to other systems (Dillon et al., 2017), therefore the incentive is greater to optimise returns from nutrient inputs versus other systems through the use of NMP (Beegle et al., 2000).

Younger farmers are said to be more likely to adopt management practices (Weaver, 1996; Rahelizatovo and Gillespie, 2004). The results for the regression analysis for the mandatory sample strongly support this assumption and demonstrate that the younger cohorts of farmers compared to their older counterparts (65 and over) are more likely to have an intention to apply fertiliser on the basis of soil test results. Encouraging younger farmers within this group of farmers to participate in NMP could help to increase uptake levels. In terms of education, Lambert et al., (2006) found that education was positively associated with nutrient management practice adoption, our results for the mandatory sample in relation to agricultural education concur with this study. A possible explanation of this result is that agricultural education raises farmer awareness of the benefits of NMP, which may lead to further adoption.

The positive influence that agricultural advisors can have on the adoption of agricultural management practices has been well established (Baumgart-Getz et al., 2012). In our study, the role of an agricultural advisor was significantly and positively associated with intention to apply fertiliser on the basis of soil test results for the voluntary sample. This result is consistent with Ingram (2008) who found that agricultural advisors were critical to helping farmers to improve soil management decisions. Extension services can help farmers to implement management practices by providing knowledge and technical expertise, which can help to explain our result.

7. Conclusion

This study sought to determine which factors influence farmers' intentions to adopt NMP. Most previous studies of this nature tend to focus on the adoption of individual nutrient management practices but few examine NMP as a process which requires both adoption and implementation of practices, as such, this study addresses a gap in the literature. Furthermore, we build on the literature further by also incorporating psychological variables into the analysis which have seldom been explored in relation to NMP adoption. Our results are in line with previous TPB studies within an agricultural context which have found support for the psychological constructs under study (Borges et al., 2014; Läpple and Kelley, 2013; Senger et al., 2017) and other studies which do not account for the effect of psychological variables (Bosch et al., 1995; Caswell et al., 2001; Monaghan et al., 2007; Ribaudo and Johansson, 2007).

The results from the regression analysis showed that there are both similarities and differences in the drivers of intention to adopt NMP depending on which group (voluntary or mandatory) farmers belong to. In terms of psychological variables, intention under both groups was influenced by perceived behavioural control and perceived resources. However, attitude was only significant for the voluntary group whereas subjective norms were only significant for the mandatory group. Furthermore, farm system and contact with an agricultural advisor were significant factors influencing intention for the voluntary group whereas age and agricultural education were important for the mandatory group. The study concludes that intention is shaped by psychological, farm and farmer characteristics as well as policy. These results suggest that in order to encourage further uptake of NMP there is need for interventions focussed at the factors that influence farmers' intentions towards NMP.

Nationally, efforts should be made to encourage farmers to engage with technical support and to address gaps which may exists in advice given. This may help to increase the levels of control that farmers feel over the NMP process. National initiatives must also further acknowledge the diversity of resources farmers have available to them to adopt NMP, especially when delivering key messages. In terms of encouraging adoption among farmers who do not have to adopt periodic soil testing on a mandatory basis, an emphasis on highlighting the benefits of adopting NMP should be made in order to reinforce positive attitudes. On the other hand, in order to encourage farmers operating under mandatory policy requirements, efforts should be directed at increasing the level of social pressure for farmers to incorporate the result of soil analysis into decision making. This can be achieved by further encouraging farmers to join group learning environments which can include farmer led knowledge exchange platforms which have a specific focus on NMP (Blackstock et al., 2010).

Finally, it is important to note some of the key limitations of this study. This study only examines intentions rather than actual adoption levels. Nevertheless, previous studies have shown that intentions have a strong direct effect on future behaviour (Bamberg, 2003). A future study could examine whether farmers actually acted on their intentions. Indirect relationships between variables were also not considered in this study (e.g. between attitude and subjective norms or farm system and perceived behavioural control). Such influences have sometimes been studied and used to develop a more detailed understanding of farmer decision making (Borges and Lansink 2016; Zeweld et al. 2017). Despite these limitations, this study provides fresh insights into identifying what determines the decision making-behaviour of farmers and possible ways of encouraging further adoption of NMP.

Appendix 1

PCA result for farmer intentions to base fertiliser application on soil test results.

Latent variable	Attitude	Subjective norms	Perceived behavioural control	Perceived resources	KMO index
Increases productivity	**0.3805**				0.94
Produces better quality grass/crop	**0.3876**				0.94
Increases profits	**0.3521**				0.95
Reduces input costs	**0.3297**				0.92
Saves time	**0.3304**				0.93
Helps to protect the environment	**0.3288**				0.97
Improves soil fertility	**0.3336**				0.96
Soil testing increases knowledge about your fields	**0.345**				0.67
Think that I should do so		**0.5218**			0.91
Encourage me to do so		**0.4991**			0.90
Would approve if I do so		**0.4963**			0.94
Most farmers I am aware of base fertiliser application on recommendations from soil test results		**0.465**			0.90
A clear understanding of			**0.3011**		0.93

how to do so					
I am confident in my ability to do so			**0.3879**		0.94
It is under my control to do so			**0.4500**		0.94
It depends entirely on me and not on factors enabling or preventing me from doing so			**0.4257**		0.93
It is easy to do so			**0.3349**		0.95
Is expensive				**0.5123**	0.67
Enough time to do so				**0.3738**	0.94
Access to enough labour to do so				**0.3816**	0.94
Enough financial resources to do so				**0.5086**	0.94
Eigen value	10.21	1.72	2.01	1.20	-

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