The Adoption of Management Technologies: The Irish Dairy Sector

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Declaration

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Table of Contents

Abstract

Why do farmers adopt new practices? This thesis explores agricultural adoption. Drawing on prior research that has used economic, sociology and social psychology literature to describe and explain the social phenomenon of the adoption of a new technology. This thesis uses a mixed methods approach to examine grassland management and nutrient management practices by Irish dairy farmers. Understanding the adoption of these specific practices is important because of conflicting political and policy interests: the objective of increasing production, while simultaneously achieving sustainable farming. The research is organised into three separate studies making a number of distinct contributions. This work extends the current agricultural adoption literature by using literature and concepts, beyond agricultural economic theory, to explain the process of adoption. Specifically, the use of the evolutionary theory of the firm provides an alternative perspective to agricultural adoption. As such, this work provides a deeper explanation of the adoption process. The first study highlights the impact of mandatory adoption of practices through participation in agri-environmental schemes. Highlighting the ineffectiveness of mandatory schemes for innovation; it identifies the adoption-innovation gap. Second, the application of the Technology Acceptance Model in study two indicates the comparative strength of farmer perception, with variables more traditionally used in the agricultural adoption literature for predicting intention to use practice. It also identifies a social influence variable and groups of influential social actors. In terms of context, the thesis presents the first application of the TAM to a nationally representative sample of Irish farmers. The third study is one of a limited number of empirical applications of the organisational routines literature. It is to the knowledge of the author the first application in the dairy sector and the second in the agricultural sector internationally. It deepens the understanding of agricultural adoption by drawing on this literature specifically for land management practices in the dairy sector.

Introduction

The objective of this thesis is to examine the adoption of management practices by Irish dairy farmers. This thesis uses primary and secondary data sources and is structured as three studies. To support the approach taken, diverse theoretical frameworks have been applied using distinct literatures in each study. The rationale for three distinct studies is a reflection of the complexity of technology adoption. The area of technology adoption has been extensively studied in agriculture, the questions asked of it however, are not varied enough to fully explain the process of adoption. Discrete research questions provide the foundation on which the research is based.

Study one focuses on a single management practice soil testing, study two and study three examine two suites of technologies grassland management and nutrient management respectively. Soil testing is a key decision making tool used in both suites of technologies. Testing of soil plays a functional role in management activities, providing information to farmers on nutrient levels in the soil and consequently, potential output.

The distinct research questions that form the basis of each study are outlined below:

- Study one aims to identify who or what groups of Irish dairy farmers are likely to adopt soil testing. It addresses the voluntary and involuntary adoption of practice. Using a binary logit model it asks: What are the farm and farmer characteristics of those adopting soil testing?

- Study two aims to explore farmer perceptions and identifies influential social groups relating to six grassland management practices. It examines the performance of socio-economic and demographic variables in the prediction of intention to use with variables measuring perceptions and goals of farmers. Using the Technology Acceptance Model study two addresses two questions:

    - Are latent factor social variables more appropriate in predicting intentions to use practice than more traditional observable variables?

  - What type of social influence impacts adoption of practice and who are the most influential social groups?

- Study three explores the nutrient management practices of 20 Irish dairy farmers. It details the implementation of practices on their farms specifically how the adoption of these practices occur. Through semi-structured qualitative interviews it asks: How are nutrient management practices implemented at farm level?

Study One

Study one uses a mainstream economics approach exploiting available secondary data in a quantitative analysis to explore adoption of soil testing as a binary decision. Using logistical regression analysis it utilizes data to model groups of the population who are likely to adopt soil testing. The variables chosen in this model follow traditional economic studies, which view adoption as a binary activity. In traditional economic literature, farmers are viewed as price takers operating in a perfectly competitive market structure. The reduction of costs and the use of practices which are cost positive, is therefore a priority, soil testing is one such practice. The rates of adoption for the sample of dairy farmers, was high; 70% tested soil on a regular basis. The statistical analysis is conducted in two stages, first using t-tests and then using regression analysis.

The t-tests examine the statistical differences which exist between users and non-users, in relation to a farm and farmer characteristics; t-tests compare the means of relevant continuous variables (Table 1.4). The findings from these t-tests reveal a significant difference between the two groups for several variables. Users have larger farms, higher income (gross margin and gross output), larger dairy herds and more livestock units and are largely younger. The t-tests however, indicate there is no significant difference between the two groups in relation to number of days grazing, dairy gross output and dairy gross margin, overall direct costs, fertilizer expenditure and concentrates expenditure (variables derived on a per hectare basis). Users of soil tests are expected to be better managers of their nutrient input costs, specifically expenditure on fertilizer. However, there is no significant difference between the groups, with users spending on average €13 per hectare more on fertilizer than non-users. This may reflect a higher input system. However, users of soil tests are assumed to be better managers of input costs (expenditure on fertilizer).

The regression analysis identifies salient farm and farmers characteristics in the prediction of adoption. Two regression models are conducted; one predicting characteristics of the population and the second for the voluntary participants only.

The first model examines the population using eleven variables (Table 1.2). The analysis shows, policy is a key driver in adoption (Table 1.5). In schemes where adoption of soil testing is mandatory there is an involuntary effect. Discussion groups members are twice more likely to adopt than non-members, age negatively affected the odds of adoption as did quality of soil, those with better soil are less likely to test. Farm size also positively impacts likelihood of adoption.

The second model uses eleven variables (Table 1.3) to examine adoption of voluntary participants (Table 1.7) of which of 45% soil tested on a regular basis. T-tests of the voluntary population shows, users have: larger farms, higher income (gross margin and gross output), larger herds and more livestock units and are younger. In addition, voluntary users on average have significantly more days of grazing than non-users. For the voluntary population, users are four times more likely to have formal agricultural training than non-users; farm size is also significant and positively impacting odds of adoption.

The results from both logit models are largely as expected and in line with the literature. However, high rates of adoption of practice, coupled with falling fertility rates (Donnellan, Hanrahan and Lalor 2012) are surprising. These unanticipated findings formed the focus for study three.

Study Two

Study two uses a survey based approach to quantitatively identify dairy farmers' perceptions towards the use of six grassland management practices (Table 2.3). TAM perception is measured using seven items, on Likert scales. All seven TAM items are positive statements and a balanced scale was used (See Appendix B). All participants in the survey were asked to indicate their perceptions of six practices: users and non-users. The nationally representative (Table 2.2) survey is designed using a social psychology model, the Technology Acceptance Model (TAM). TAM is designed to elicit responses from a user perspective on perceptions of using a technology.

The rationale for this study emerged from existing secondary data which identified low levels of adoption of grassland management practices, by dairy farmers. Nationally, 80% not completing a formal grass cover and 85%, not completing a formal grass budget (NFS 2009[1]). Based on National Farm Survey (NFS) data there was need to understand the low adoption rates of the technology. Findings indicate there has been a significant increase in rates of adoption (Table 2.3) of practice over the period 2009-2013.

The TAM model has been criticized for its failure to account for social influence (Bagozzzi 2007). Social influence is important for a number of reasons. Firstly the impact of policy and regulation on mandatory adoption from findings in study one, second is the introduction of financial incentives for farmers to join discussion groups this is an important issue for technology adoption on Irish dairy farms. Discussion groups are the main extension tool used by Teagasc to transfer knowledge on technology to farmers. This is measured using a Kelman (1958; 2006) social influence framework and influential social groupings are also identified.

The findings in study two are presented in three stages. The first stage examines the characteristics of the population and the farming objectives. Three farming objective factors are identified: experimental, conservative and productive (Table 2.6).

The second stage contains the main findings of the study: the comparative regression analysis, which is presented in three sets of regressions models with final a comparative analysis.

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[1] The National Farm Survey (NFS) is carried out annually by the surveys department of Teagasc and is a nationally representative sample, (Connolly 2010), more information, results and reports are available at http://www.teagasc.ie/nfs/ [Accessed 01/12/13].

- The first set of models uses all variables: the TAM and objective variables and the socio-economic and demographic variable. Across six models (Table 2.11) findings indicate the strong predictive power of the TAM perceptions in predicting a positive intention to use practice, consistent for all practices.

- The second set of models use socio-economic and demographic variables only (Table 2.12). These models show the strongest predictive factor is membership of a discussion group or participating in the dairy efficiency programme, in five of the six models. The detailed findings of each model are discussed within study two.

- The third set of models use the TAM perception factor and the three farming objectives to predict intention to use each practice. Again the predictive power of TAM was consistent across all six models (Table 2.13).

- The final section of stage two contains the comparative analysis. It compares the predictive power of model set 2 and model set 3 with actual outcome. First a visual comparison is made (Figures 2.1-2.6) and secondly the study statistically compares the predictive probabilities with intention outcome (Table 2.14). Findings indicates for all six models

The third stage of findings in study two is social influence. Findings indicate social groupings are consistent across practices. Family and discussion groups are most influential, followed by the farmers own personal management decision. This study indicates the importance of understanding adoption from the prospective of end users and what is important for them. Although this study gives greater insight into adoption than study one, identifying perceptions and social influences, it does not address change avtivities. Study one identifies the characteristics of users; study two identifies the perceptions and social influences of users, study three details implementation activities.

Study Three

Following on from study one and two, study three takes a qualitative approach to advance understanding of adoption activities of dairy farmers. This approach gives the opportunity to the farmer, the end user, to present their experience with using particular technologies on their farms. It permits research to ask: *why* characteristics or groups are more likely to adopt and *why* such influences exist and in what way for a particular farmer? This approach allows for rich contextual detail to be gathered on the nutrient management activities of dairy farmers. The study uses the routines concept from the evolutionary theory of the firm. The questions asked of farmers are influenced by this concept, it is used as a loose framework to structure the interviews. An inductive approach to interviewing is taken, what could be more accurately described as a purposeful conversation. The aim of the study is to identify how practices are implemented and to identify their experience with using by asking, 'how' and 'why' decisions are made. It allows farmers to frame the implementation of practices through their experience with using.

The analysis of the data uses two aspects of the routines literature to frame the experiences of farmers, the ostensive and performative aspects of the nutrient management routine. The importance of past, present and future for decision making is evident. The success of implementation is seen generally by farmers as a direct relation to farm outputs (physical rather than financial). Financial indicators are important to farmers; however, these are not the only factors, resources and outputs are of much greater importance. Specifically in relation to required output for the farm grass and nutrient availability, farmers conduct experiments to determine what is required and rely on past experience. Decision rules are also based on local knowledge and understanding the land as well as financial indicators. The use of the routines concept in understanding decision making concerning nutrient management, the findings indicate, is more fitting than the mainstream economics view of profit maximising as the key decision making rule. This is based on the experiences of the twenty farmers interviewed. While making money is a priority other issues are of equivalent importance overall. The utilization of resources, and understanding resource, mainly land management, is of key importance in terms of nutrient management decision making; these finding are discussed further in study three.

Summary

These management practices aim to improve the utilization of resources at farm level, namely grass and soil. Grassland management is focused on maximising grass usage through scientific methods of measurement. Nutrient management aims to encourage more efficient use of nutrients and is the internationally recognised approach to address farm nonpoint source (field) nutrient losses (Beegle, Carton and Bailey 2000). They are discussed in detail in the next section. Secondary data suggests successful uptake of practice is poor.

The thesis is structured in three sections as follows. Section I outlines the development of the literature in agricultural economics examining technology adoption. It defines the approach taken in this thesis, and the philosophical grounding of the research. It provides the rationale for the each empirical study and positions the research in the context of legislative requirements and policy aims. Section II contains the three empirical studies, as outlined: study one, two and three. Section III discusses findings, contributions, limitations and areas of future work.

Section I

Approaches to Researching Technology Adoption

Economics: Decision Making

In order to establish the epistemological approach of this thesis, this section briefly reviews theoretical frameworks from the economic literature relevant to understanding how economists have viewed decision making generally and more specifically in relation to technology adoption in agriculture. The decision making process within the firm is subject to a non-exhaustive number of variables. Economists view this process through the application of various theories of the firm. The orthodox economic theories of the firm continue to have an influential bearing on how the decision making process is understood and researched.

The remainder of this section is structured as follows. First the literature describes the assumptions of orthodox economists and discusses alternative theories presented. In particular what is of interest to this literature review is how economics addresses technical change. It then discusses technical change in the agricultural literature and specifically the technology adoption literature both internationally and in the Irish context.

Secondly it examines the philosophy of social science and the approach taken in this research. Each empirical study is then discussed in terms of their research objectives and research questions and the data sources employed by each study. The final section addresses the Irish context and the policy implications of the research.

Orthodox Economics

Most orthodox economic models are grounded in the concepts of equilibrium and maximisation and are executed using sophisticated mathematical techniques. This approach tends to look at production functions of firms. It aggregates activities of individual firms. This could be national, regional or sector performance, but is generally not at firm level. Performance of these aggregate groupings rests on the assumptions of uniform organisational goals and profit maximisation conditions under general equilibrium. These underpin the neo-classic theory of the firm and mainstream economic analysis. The neo-classical theory of the firm offers a singular perspective. It is important for research to explore other perspectives also. Given the complexity associated with decision making and technology adoption this is important. The assumptions and interpretations made on the basis of neo-classical theory alone are monolithic ignoring all other influence beyond the three core variables: *inputs, outputs and prices*.

It is not unreasonable to assume all organisations aim to be economically viable. However, profit maximisation is not the sole rule by which organisations make decisions (Penrose 1959; Nelson and Winter 1982). This is a fundamental principle of the study of social phenomena, in mainstream economics. The core assumptions of rationality of actors under conditions of perfect information, maximising conditions and constraints, based on a given set of choices remain keystone assumptions. The optimisation of choice is assumed. There is no deviation from rationality for the *homo economicus* actors who operate under these conditions. Some economists concede to the inadequacy of the firm as a rational actor in explaining decisions (Nelson and Winter 1982). The inadequacy of this assumption relates to the definition of the rational man as: a self-interested actor, unaffected by social state, with desire to possess wealth, and holds the judgement of choosing the most efficient means for obtaining such a desired end. Secondly the inadequacy relates to the ability to always act as such. However, the link between the individual and the firm is treated as homogeneous in mainstream economics. It is assumed that the addition of each unit of labour gives an equal return to productivity in the firm.

Further examination of rational choice models highlight that rational action is not explained, but rather it is taken for granted (Vanberg 2002). More recently, rational choice theory is described as unrealistic for economists and policy makers as behaviour of 'ordinary people' is not always as prescribed by that theory (Metha 2013). Simon questioned this approach by asking if the theory of the firm is reflecting how firms "*do"* behave or how they "*should*" behave (Simon 1955).

Neo-classical theory treats the firm as a 'black box', modelling maximising behaviour using production functions. The essence of neo-classical economics is the reduction of price, input and output in determining solutions generally through using mathematics. By contrast other theories of the firm, the behavioural and evolutionary theorists, including Simon (1955; 1979), Cyert and March (1963), and Nelson and Winter (1982), focused on opening up the 'black box'. They focused on activities within the firm discussed later in the section.

The rationale for adoption or non-adoption of a technology varies considerably. Such decisions are frequently made by actors with best reason (Geroski 2000, p. 610). If one is to encapsulate fully where the influence emerges within firms, institutions, individuals, systems for example, then it is necessary to move away from the rational actor and look at what drives individual's and systems and why. A more relevant aspect of the literature for this research is that of technical change.

Technical Change

A fundamental challenge for neo-classical economics is its failure to deal adequately with or account appropriately for technological advancement. Technological change is not clearly demarcated in production functions; it is rather labelled as a residual that growth cannot account for (Himmelweit, Simonetti and Trigg 2001). Variations in output are related to supply curve shifts, technological advancement is considered exogenous to the firm. This approach to technological change does not encapsulate how the change has occurred. In looking at technology, there are five factors which affect supply, the price of a good and the price of related goods, the cost of production, the current state of technology and factors outside the control of the supplier.

The supply function may rise or fall as a result of a change in the five factors highlighted, the only exception is the state of technology, as it is an assumption that as the state of technology does not fall. On the assumption that technological improvements increases supply, and so increased efficiency, it is thought all enterprise choose to adopt technology. This is not always the case as many empirical studies in agriculture suggest adoption rates are low with many farmers choosing not to adopt (Leeuwis 2004).

This theory does not account for endogenous change and innovation. Technology traditionally is viewed as an exogenous variable in economic models. Neo-classical economists see individual economic agents as the fundamental building blocks of the economy (*ibid*), where the economy is characterised by scarcity and technology is taken as a given. The neo-classical theory of the firm operates on the premise of a purely profit maximising behaviour independent of time, geographic and social environment. This assumption of a purely exogenous phenomenon of technical change accompanied by other abstract theoretical assumptions of rational actors, perfect information and optimized behaviour, facilitated the development of "*neat*" formal economic models for determining optima and equilibriums (Balzat 2006).

As stated, the performance of the firm in neo-classical theory is largely reflected in change in production functions. The 'change' residual remains unexplained, failing to account for endogenous change and innovation. Innovation studies examine this change. The ideas of Joseph Schumpeter (1934), considered the father figure of innovation, remain a pillar for modern day studies. Schumpeter differentiated between invention and innovation, and as such, disregarded the association of 'newness' with innovation. The definition of innovation engages with change and how change occurs. The process was important for Schumpeter as "it is not possible to explain *economic* change by previous *economic* conditions alone" (Schumpeter 1934, p.58). The innovative happenings or changes not only occur as a result of external influence, but also by its own initiative, from within the firm (*ibid*, p.63). Innovation in the 'new combination' of materials in production occurs with minor adjustments to bring about change and this innovation brings about economic success. Schumpeter was interested in this fundamental analysis of "*change*" (*ibid* p.65).

Alternative Theories

There has been much critical reflection of the assumptions surrounding the decision making of economic actors in neo-classical economics since the 1950s. A cohort of researchers moved beyond conventional utility maximising frameworks. The questioning neo-classical economic assumptions of perfect information (Simon 1955) and profit maximisation (Penrose 1959) lead to the formation of new paradigms; with alternative views of firm behaviour. In economics, the richness of alternative theories available to replace the classical and neo-classical theory was identified (Simon 1979), recognising the shortcomings associated with using maximising theory (Simon 1978; 1979) and rational economic actors (Nelson and Winter 1982). There was much to be learned from other disciplines in seeking out additional ways of problem solving (Greenberg, Goldstucker and Bellenger 1977). The economics literature was also exploring the behavioural foundation which underpins economic theory (Sen 1977). The period of critical reflection in the 1970s and 1980s lead to further theoretical development such as management theory.

Herbert Simon (1955; 1979) proposed decisions of actors to be based upon 'bounded rationality'. The presence of 'organisational slack' is described as a firm operating far from optimum, 'slack' operates between the environment and decisions made by a firm (Simon 1979). Furthermore the resource based view of the firm emerged from the seminal work of Penrose (1959) who based her theory of growth on resources in the firm. Such approaches explored the internal dynamics of the three core variables of orthodox economics. Through broadening the definition of the "inputs" variable this allowed a deeper understanding of the variation which exists in "outputs" and "prices" for goods and services between firms, rather than attributing this to the unexplainable "black box". The redefining of inputs to include human capital and the stock of existing knowledge as resources, and also the appreciation that an organisation holds a particular environment which can also enable and constrain activities gives greater insight to decision making in organisations.

Activities are carried out within an administrative organisation rather than within a market (Penrose 1959). Activities in the firm are essentially the building blocks of capabilities. A capability is an expertise within the firm[2]. Capabilities are 'invisible'. However, by identifying associated activities, researchers can identify a capability. An activity is not just a singular action, but rather ongoing activities that are continually being improved and altered as experience and learning contribute to the capability of the firm. A capability compromises of bundles of interacting routines. Routines are defined by Nelson and Winter (1982) as ways of doing things and ways of determining what to do. There are potentially parameters within which activities

[2] An organisation's knowledge, experience and skills (Richardson 1972)

are based; these are a function of resources. Resources are categorised by their characteristics. Resources maybe homogenous across a number of firms; however, the services rendered from those resources may be quite different (Penrose 1959). A firm's resources are both tangible and intangible. Penrose (1959) views the services yielded from resources as a function of the way in which they are used. In that vein it can be seen that services rendered by resources is a function of the routines of the firm.

Building on behavioural theorists such as Herbert Simon, James March and Richard Cyert who provided the orthodox economists with a new vision of the organisational world Nelson and Winter (1982) focus on economic change within firms. Nelson and Winter (1982) develop a theory of evolutionary economics. In recognising economic change is important and interesting they suggest reconstructing the foundations of economics as a discipline in order to understand change. In the evolutionary theory, firms are "*treated as motivated by profit and engaged in search for ways to improve their profits, but their actions will not be assumed to be profit maximising over well defined and exogenously given choice sets"* (Nelson and Winter 1982, p.4).

This is proposed as an alternative means of understanding economic change. In evolutionary theory firms are assumed to have capabilities and decision rules, given by 'routines'. There is general agreement on the definition of the firm in this literature. What is central to the firm's economic performance is a continuous learning process of the firm, learning is based on firm resources (Canëls and Romjin 2005). Resources are the human skills, knowledge, physical assets and organisational routines stored in the firm (*ibid*). Placing such a high value on human capital equating it with the value of physical assets is one aspect of this theory which is of interest in an agricultural context. Many firms in agriculture are operated solely by one person who fulfils multiple roles; who is the decision maker at every level of the business, from input to end product.

The evolutionary economic approach and the resource based view of the firm focus on knowledge and capabilities relating to technical change. The general focus is on technical change within the firm. Both view technical change as based on the nature of existing resources. Evolutionary economic theory and resource based views are identified as being specifically suited to the study of micro processes of innovation and learning (Canëls and Romjin 2005). Nelson and Winter (1982) view routines as resources that are built upon; Penrose (1959), examined resources as a function of growth of the firm. The essence of Penrose's theory is resources. These resources are viewed not as factors of production, but rather differentiated resources in terms of the *services rendered* from them. These frameworks form the basis of study three and are influential in the overall thesis contributions. There is much to be gained from using alternative perspectives to the neo-classical view in the study of technology adoption.

Innovation, Diffusion and Technology Adoption

Within the broad area of innovation and technological change lies a sub-set of research examining technology adoption. It emerged from rural sociology in the 1940s extending to other fields of sociology by the 1950s (Ruttan 1996). Two broad literatures relate to agricultural adoption, the natural scientific and social scientific. Two distinct types of studies are undertaken in social science adoption research, diffusion studies and practice specific studies. Diffusion studies examine patterns of adoption, using an aggregate approach to look at the spread of adopters over time. Practice specific studies often include groups of practices for example, precision agriculture (Khanna 2001; Tozer 2009). This thesis uses the latter approach. It uses aspect from the natural scientific perspective to examine the practices and the social scientific literature to examine activities surrounding practice adoption which is the main focus of the thesis.

The areas of adoption and diffusion of an innovation overlap in many respects and research has been criticised for the inadequacy of definitions that distinguish 'innovation' from 'adoption' (Kremer et al. 2001). Such a distinction is of less importance to this research, as its primary focus is on adoption. In this research 'adoption' is defined as the uptake of innovation by individuals (Leeuwis 2004). The strand of the literature drawn upon broadly is adoption and use of innovations. Diffusion is discussed, but to a lesser extent. Critical reflections of the adoption literature led to a questioning of the suitability of methods used. Seminal contributions in economics Griliches (1957) and Mansfield (1961) emerged from neo-classical schools of thought and so to a certain extent did not diverge from that school of thought[3].

The first model of adoption-diffusion was outlined in a U.S report "How Farm People Accept New Ideas" (Beal and Bohen 1955)[4]. This heuristic model was validated (Beal, Rogers and Bohlen 1957) and formed the basis for the now classic work of Everett Rogers (1962). This first model of adoption in 1955 contained three assumptions about the development of human personality and how individuals respond to stimuli: man is telic, acting and an organising being (Bohlen 1967). Rogers (1962) examines rate of adoption and characterised adaptors using five categories[5]. This approach only applies to *when* or *how soon* individuals adopt, not engaging with extent of continued adoption (Bach 1989). The basis for the Rogers model was diffusion based on time rather than extent.

The social science literature on best practice adoption stems from rural sociology and agricultural economics[6]. The seminal contribution of economics to the technology adoption literature was in agriculture (Griliches 1957)[7]. A second branch of literature emerged from sociology stemming from the work of Everett Rogers in the 1960s. The economics and sociology literatures approach adoption from two distinct perspectives. Orthodox economic theory views adoption decisions in terms of

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[3] Both authors examining technical change using static economic models to determine behaviour in agriculture (diffusion) and industry (imitation) respectively.

[4] Beal and Bohen made a flannel board presentation to the US Department of Agriculture in 1955 on "How Farm People Accept New Ideas" which is summarised in "The Diffusion Process" available at http://ageconsearch.umn.edu/bitstream/17351/1/ar560111.pdf [Accessed 20/08/13]. The original report was reprinted in 1988 and is available at http://ufdc.ufl.edu/UF00082062/00001 [Accessed 20/08/13].

[5] Innovators, early adopters, early majority, late majority and laggards.

[6] Traditions of research on diffusion in anthropology, geography and other disciplines also exist (Ruttan and Hayami 1973) but they are not the focus of this thesis.

[7] Griliches (1957) used logistical growth functions to determine the *origin*, *slopes* and *ceilings* of technology diffusion.

conditional causal statements, “if X then Y” statements, conferring causal logic on the adoption decision.

Rural sociology is focused on the process of adoption examining the impact of communication (interaction) and resistance (cultural) to innovation with economics focused on profits (Ruttan and Hayami 1973). Since the seminal work of sociologists Ryan and Gross (1943), the process surrounding adoption has had a key impact on research. The rationale for their work, based on the speed of diffusion of hybrid seed relative to other practices, remains relevant today. The rationales were both economic and physical. The rapid diffusion among farmers was attributed to the financial success of the crop, in terms of crop output, but also the ease by which the new crop could be adopted, currently still of interest. The ease of use which Ryan and Gross (1943) highlight, was attributed to minimal change required with adoption; in terms of routine and equipment. This finding is now more developed in broader literatures which use resources (Penrose 1959), proximity (Boschma 2005) and routines (Nelson and Winter 1982) to explain firm activities. The financial rationale introduced by Ryan and Gross (1943) has been developed further in economics, mainly in the context of exploring monetary return to technology. However, less of a focus has been placed on the physical ease of use for the end user. The characteristic of technologies, rather, has been studied in relation to their abstract characteristics. What is required of end users is less well studied. The focus is largely on the financial and scientific returns to adoption.

Various classifications have been given to the adoption of an innovation, in the agricultural literature. Agricultural adoption is viewed from two perspectives: micro or macro (Feder and Umali 1993). This distinction refers to the approach taken. Micro studies focus on individual adoption of the firm, as opposed to, macro studies that focus on trends in adoption. The latter, is generally referred to as, the study of diffusion (Rogers 1962). This distinction extends to how studies classify innovations, the depiction of an innovation as a discrete choice or as a continuous variable. This distinction highlights, how researchers think about adoption of innovations.

Adoption of innovation can also be classified based on what the firm requires in order to adopt the innovation. Depending on the type of investment required, financial capital or investment in human capital, a technology could be classified as management-intensive or capital-intensive. Most technologies fit into a number of these categories (Sundig and Zilberman 2001). The technologies studied in this thesis can be classified as management intensive technologies. They relate specifically to how the farmer manages land, in relation to grass and nutrients, with little or no capital investment.

In agriculture technologies are generally introduced as packages with distinct bundles of complementary technologies. Farmers face choices in adopting the whole package or specific aspects of the technological package (Feder, Just and Ziberman 1985). Similarly the management-intensive practices in this thesis are presented as bundles. This thesis views adoption as part of an innovation process. It is a step towards innovation and if adoption results in improvements or achieves perceived benefits it is successful and so the adoption has been innovative. Innovation is a function of how adoption occurs. It is not an automated result of adoption. Adoption does not necessarily result in innovation.

Agricultural Economics and Adoption

Despite the accepted complexity associated with the social phenomena the economic approach has been dominated by a strong quantitative approach. In quantitative agricultural adoption studies, the relative importance of individual and technology characteristics, are based on mathematical applications, mainly through econometric modelling. However, the assumption that a technology is available and directly transferable is a crucial limitation in understanding diffusion through disregarding ecological variations and factor endowments inhibiting transfer (Ruttan and Hayami 1973).

This limitation has been lessened somewhat with the availability of large data sets and the inclusion of wider reaching variables and with more sophisticated modelling techniques. Data on ecological variables or factor endowment such as soil type or region are often included in adoption studies which control for variation (observable variables). Econometric modelling is based on the assumption of direct transferability between organisations. This is based on the existence of homogenous variables (available). This at best gives a partial understanding into adoption of technology, given the complex nature of decision making and structures within firms. Penrose (1959) views the services rendered from these resources of greater importance than the resources themselves.

Early traditional economic approaches focused on how observable economic variables impacted adoption and diffusion (Griliches 1957; Mansfield 1961). Agricultural economics focusing on this measured approach have largely used observed on-farm variables looking at the farm and the farmer, but external variables including prices have also been included in modelling decision making at farm level. A large body of empirical studies confirmed the findings of Griliches (1957) that profitability has a positive impact on the diffusion of innovations (Feder, Just and Zilberman 1985; Sundig and Zilberman 2001). Alternative empirical models have also been employed such as threshold models (Olmstead and Rhode 1993) which changed the focus of research from diffusion studies to adoption behaviour of individual farmers as a source of heterogeneity using duration data or discrete choice models (cited in Sundig and Zilberman 2001) maximising utility through the decision to adoption or not adopt.

Many economic adoption studies, describe at a point in time, variables which explain a binary decision. Many empirical studies examining decision making use efficiency measures to make distinctions between groups in a population. Modelling allows for the identification of entry (exit) points for change, but does not give insight into the process of change (Leeuwis 2004). Most do not go beyond using biographical variables such as level of education, to make such distinctions (Rougoor et al. 1998). There is a lack of awareness and evidence investigating the process of adoption. The change activities of individuals within the firm is not given enough attention in the literature. The relative importance of decisions on farm is not always considered. Exceptions include academics using broader literatures including social-psychology literature, (Flett et al. 2004; Willock et al. 1999). Since the 1980s a substantial body of knowledge has emerged in the adoption of best management practices.

Geographically the United States, New Zealand and Australia are major contributors in this field. Studies aiming to synthesise research in the United States have failed to identify universally explanatory variables (Prokopy et al. 2008), due to inconsistencies in approaches and measures used (Baumgart-Getz, Prokopy and Floress 2012). However, quality of information, financial capacity and networks are three variables that have been identified as having the largest impact on adoption (*ibid*).

The focus of more recent work has changed from solely using tangible observations to the use of intangible variables through incorporating psychology approaches from which a new genre of research emerged in the agricultural adoption literature, discussed in the next section. The assumption of homogeneity between organisations based on available observable data alone may only be part of the story as Ruttan and Hayami (1973) highlight.

Social Psychology

The exploration of goals and values of farmers raises questions for economics, in terms of, how motivations are treated in explaining behaviour (Gasson 1973). Why do individuals make the decision to adopt a technology or not? What motivates any individual in the agricultural sector to make a decision? There are numerous variables discussed in the traditional agricultural literature including risk, information asymmetries and production inputs and outputs. However, in order to establish a meaningful explanation it is essential to look further than these explanatory variables.

Gasson (1973) identified linkages between social psychology and economic behaviour in order to develop an understanding of the decision-making processes of farmers. She uses the social psychologist, Kurt Lewin's, definition of behaviour as being "*a function of the person in his environment*". In contrast to the orthodox economic theory which, largely concentrates on constant variables for the purpose of behavioural analysis, Gasson uses various classes of variables (Gasson 1973, p.522). These classes of variables are identified as being: the *person* with goals, his or her aspirations directing behaviour towards a desired end and the *environment* as the farmers' perception of resource and material constrains/means to attain desired end (*ibid*). Despite the seminal contribution of Gasson, the classification of goals, values and the non-economic factors (social, cultural) in decision-making continue to be viewed as an add-on element of rational models (Burton 2004).

Studies incorporating social influence variables generally use social psychology models[8] with a focus on the attitude of the users. Attitude is defined as an individual's favourable or unfavourable evaluation of an object, a belief represents the information they hold about the object (Ajzen and Fishbein 1975). The social psychology area of research focuses on attitudinal variables in assessing technology adoption.

Many such studies have incorporated psychology literature to complement the strict profit maximising framework of earlier research (Lynne, Schonkwiler and Rola 1988). Studies on technology adoption from the field of social psychology suggest that income alone is not the primary motivator for adoption and decision making (Lynne and Rola 1988; Gillmor 1986). Studies in agriculture, explored goals and values (Gasson 1973), and more recently approaches focus on attitudes (Willock et al. 1999) and the use of social psychology models (Beedell and Rehman 2000; Burton 2004; Rehman et al. 2007). Such approaches determine links between attitudes and beliefs of farmers to an outcome: adoption behaviour.

Traditionally these unobservable variables (attitude and intention) became quantifiable through incorporating parallel literatures and methods[9] from psychology. The use of previously unobservable data in main stream economic research using normative measures of individual evaluation developed into a separate area of research within the broader adoption literature.

Patterns within ones value system, beliefs and attitudes often are conflicting, not always as expected (Bohlen 1967). Such attitudes are measured using Likert scales. Likert scales are widely accepted in the social science literature. The formats of

[8] For comprehensive account of such studies see study two

[9] Mainly Likert scales

scales are debated (Weijters, Cabooter and Schillewaert 2010). Attitudinal evaluations are widely used in much of the economics and interdisciplinary work in economic decision making (Willock et al. 1999).

These models aim to predict behaviour based on attitudes and intention; however, an intention-behaviour "gap" remains[10]. The introduction of the first social-psychology model the Theory of Reasoned Action (TRA) in 1975 gave a structure to the area of behaviour and decision making. The agricultural technology adoption literature found economists had much in common with the problems faced by social psychologists as they looked at probability of behaviour (Lynne 1995).

Technology Adoption: Irish Agriculture Literature

Early Irish studies examined information sources of farmers (Bohlen and Breathnach 1970) the spatial diffusion of innovation (Walsh 1992). This research occurred in a context of an agricultural sector driven by production increases. More recent studies have focused on green technologies looking at conversion of agricultural systems (Läpple 2012) and participation in agri-environmental schemes (Hynes and Garvey 2009). However, there is no study investigating the adoption of groups of technologies. Research found media sources used by Irish farmers more influential at early stages or pre-adoption stages (Bohlen and Breathnach 1970). This need for accessible quality information is still a requirement for decision makers (Baumgart-Getz, Prokopy and Floress 2012). The need for the provision of information beyond making initial change is viewed as salient in potentially preventing discontinued adoption (Läpple 2012). This is less well developed in the literature.

There are a number of researchers actively working in the area of agricultural technology adoption in Ireland (Table I.1). Many such studies view adoption as a dichotomous decision and focus on characteristics of adopters (Hynes and Garvey 2009; Buckley 2012 (a); Läpple 2012; Hennessy and Heanue 2012; Howley et al. 2012). These studies have addressed specific questions in relation to Irish agricultural adoption spatial diffusion (Walsh 1992), participation in schemes (Hynes

[10] For a detailed discussion see study two.

and Garvey 2009; Hennessy and Heanue 2012) or straight adoption (Howley et al. 2012). Researchers have also used social-psychology focusing on willingness to adopt (Buckley 2012a) or focusing on less well researched areas in the literature: reversal of an adoption decision (Läpple 2012).

Table I.1 Selected Published Studies: Irish Research Technology Adoption

Authors	Publication Year	Research Area
Bohlen and Breathnach	1970	Sources of information
Walsh	1992	Adoption and diffusion Irish mechanisation
Hynes and Garvey	2009	Modelling participation of REPS[11]
Buckley	2012	Nitrates directive a view from the farm
Buckley	2012a	Willingness to adopt riparian buffer zones
Läpple	2012	Adoption and abandonment of organics
Hennessy and Heanue	2012	Discussion group participation
Howley et al.	2012	Artificial Insemination

Internationally, earlier scholars thought of adoption as a singular activity (Griliches 1957; Mansfield 1961) while more recent agricultural scholars view adoption as a social process (Rogers 2003; Leeuwis 2004). However, the notable absence of social factors in earlier research is still evident in current Irish research (Läpple, Hennessy, and O'Donovan 2012; Patton et al. 2012) on grassland management. These Irish studies are examples of the lack of consideration for wider social factors when examining economic change with a focus on the economic and biological efficiencies. In ignoring factors such as the farmer's objectives or abilities, part of the story is missing.

Similarly to the wider literature, practice specific studies relating to precision agriculture[12] focus on the economic benefits of adoption, and farm attributes, while

[11] Rural Environmental Protection Scheme (REPS) for more detail see study one

[12] Considered as a suite of technologies, precision agriculture is a management strategy using information technologies to bring different data from multiple sources on crop production decisions. A key difference between conventional and precision agriculture is the application of modern

social factors are often ignored (Kutter et al. 2011). As social factors are often difficult to capture, in economics there is a tendency to focus on measurable observables specifically restricted in modelling.

The agricultural management literature has engaged with individual decision making through drawing on the psychology literature (Öhlmér, Olson and Brehmer 1998; Burton 2004). This is aimed at an individual level rather than the organisational level (Penrose 1959; Nelson and Winter 1982). Four phases of decision making[13] and five characteristics of the decisions[14] indicate there is a matrix of relationships in decision making at farm level (Öhlmér, Olson and Brehmer 1998). It also indicates that alternative theories may have the potential to explain these phases and characteristics of decision making at farm level looking at why these matrix of relationships exist in agriculture.

This thesis draws on a number of theoretical approaches in order to seek a better understanding of decision making in agriculture in relation to, adoption of technology. The focus is on the central role of technology in economic change. Furthermore it goes beyond the economics theorists by using theories of decision making (social psychology) and alternative theories of the firm (evolutionary theory and the resource based view) to frame the analysis. This thesis suggests information and supports at the implementation stage of adoption is the most salient in terms of innovation, in realising successful social or economic change (conversion/adoption).

Study one uses a traditional economic approach to identify the farm and farmers characteristics of users, who are likely to adopt soil testing. The social psychology literature informs the approach taken through making distinctions between voluntary and involuntary adoption. Study two draws on a behavioural approach using a social

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information technologies to provide, process and analyse multisource data of high spatial and temporal resolution (Precision Agriculture in the 21st Century: Geospatial and Information Technologies in Crop Management, 1997).

[13] Problem detection, problem definition, analysis, choice and implementation.

[14] Farmers: Continually update plans, prefer qualitative approach, prefer quick simple solutions, avoid risk through incremental implementation and checking cues during implementation

psychology model to identify farmer perceptions towards using grassland management practices. In study three the organisational routines literature is used to structure interviews and uncover the activities of Irish dairy farmers. This approach gives a deeper understanding of how change occurs on participating farms at a more abstract organisational level. The empirical focus of this thesis, grassland management and nutrient management are suites of practices which improve the utilisation of resources at farm level. As this thesis is structured using three studies addressed three specific research questions, it is important to clarify the overarching approach taken in the research. The perspective used to structure this thesis is discussed in the next section.

Philosophy and Social Science Research

The purpose of philosophy for social science research is as structural support. The three levels of analysis, ontology, epistemology and methodology function as a guide to research. By identifying a position within and between each of these three levels a researcher should unearth a paradigm for their particular area of research. Within research itself there are many debates among the paradigms. Guba and Lincoln (1994) identified four competing paradigms of inquiry positivism, postpositivism, critical theory and constructivism, and more recently they added a fifth participatory/cooperative paradigm (Guba and Lincoln 2005). This list of paradigms is not definitive, as paradigms evolve (Morgan 2007); however, it is important to identify the range of existing paradigms. They are the basis upon which research is conducted. A paradigm is defined by Guba and Lincoln (1994) in a general sense as: a basic set of beliefs that guide inquiry.

We can distinguish between these paradigms on the basis of their suppositions about the nature of reality and whether that reality is observable or not. Theses suppositions influence how inquiry is carried out within each paradigm. The positivist paradigm is generally characterised by viewing reality as an objectively accessible world, measurable through observables, generally (not exclusively) characterised by the use of quantitative methods. This is the dominant paradigm in economics. The interpretivist paradigm is dominated by qualitative methods of inquiry which is demarcated by a sense of unity with reality. Such studies emphasise sense making aiming to represent others' life worlds as fairly as possible (Symon and Cassell, 2006).

Historically, mathematics is associated with certain exactness with a push towards the measured way of conducting research accessing reality in an objective manner eliminating subjectivism. As a result positivism has been enshrined as a dominant paradigm in the physical and social sciences since the mid-late 1500s.

The paradigm within social science is not as clear as the natural sciences. Kuhn (1971) argued that the social sciences are in a pre-paradigm state. Described as a multi paradigm discipline with definite cohesion, but not to the extent that one paradigm overturns the other, Kuhn defines the paradigm as standing for the entire constellation of beliefs, values, techniques etc, shared by members of a given community (Kuhn 1971). As thought within a paradigm evolves, the paradigm shifts which in turn leads to the introduction of a new paradigm and a new way of exploring existing problems, in order to gain new knowledge.

The fundamental beginning of modern philosophy is epistemology, the theory and nature of knowledge. Primarily the purpose of all science is to answer specific questions about specific phenomena. There are two broad approaches to generating knowledge: inductive and deductive. The biggest critique of inductive knowledge is causality. Can we bridge the gap between cause and effect in getting closer to the truth and is that useful for the progression of knowledge? The epistemology of positivists is based on objective knowledge, observed in objective reality and based on laws of probability. Mainstream economists have been criticised for restricting themselves to methods of mathematic deductive modelling, forcing theorisation, isolated from social reality (Lawson 2004). Lawson interprets mainstream economics with a comparison to medical research:

> *'…that uses only one rather narrow method determined in advance of the study… in neglect of available insights into the nature of the object of study…(one) should not be too surprised if it is found to be* highly limited *in…advancing understanding.'(ibid p.333).*

The quotation highlights the dominant paradigm which currently exists in economics. This perspective does not consider the social phenomenon being studied. In this thesis the process of technical change is of key importance. In failing to consider the phenomenon under study it is difficult to gain understanding of the process. It abstracts from non-measurable influences. A positivistic approach to inquiry can answer certain *what* questions, but can never answer *why* questions. The research questions asked of any phenomenon should be a key determinant of how knowledge is gathered on that subject. The dominant positivistic approach in economics assumes the natural and social sciences can utilise similar methods to create knowledge. The approach does not allow for a reflection on current understanding availing of the most appropriate tools to answer the research question asked.

The chosen philosophical approach in this thesis is that of pragmatic realism. Classical Pragmatism is historically associated with the works of Charles S. Peirce 1839-1914, William James 1842-1910 and John Dewey 1859-1952. All held that that the primary aim of science is to solve problems, although there are distinct differences in their approaches to knowledge formation. In general, however, pragmatism warrants the use of unobservables in research and theory, which comes from the ontology of realism, as distinct from the positivists' exclusive use of 'observables'. For pragmatic realists there exists a dynamic world with one objective reality the focus is on problem rather than the theory or methods.

Pragmatism fits within a more heterodox approach to economics, while the positivist paradigm fits with the mainstream thinking in economics. These two positions differ greatly. Pragmatic realists recognise unobservables as well as observables in explaining and describing. Positivists solely explain through observables. The paradigms also differ epistemologically. Positivists create knowledge through generating universal laws, generally (not exclusively) using quantitative methods. In contrast pragmatists use the most appropriate methods to address a particular issue. For pragmatists the methods employed are of lesser importance. In contrast to the positivist orthodox economists who, Lawson (2004) describes as, restrict themselves through the use of mathematical deductive modelling.

For pragmatists the appropriate answering of the research question is of greater importance than the methods employed. Research driven by (methodological) predispositions, rather than abstract inquiry (Morgan 2007) is not conducive to discovery. This may lead to a lack of deeper understanding of a social phenomenon. It seems it is not a case of declaring the numbers to be wrong, but rather the measure (inferences) to be inexact. It is for these reasons the pragmatic approach to research fits best with the current study of management practices in the Irish dairy sector. In the social sciences, questions asked of data holds greater importance, than the methodology employed.

Mixed method is an approach characterised by the use of both quantitative and qualitative methods. This thesis uses a mixed methods approach to answer specific questions on the issues which exist in the agricultural technology adoption literature. Kivinen and Piiroinen (2006) argue pragmatic philosophy is an appropriate tool in assisting social scientists in problem focused research. This thesis engages with three problem focused studies, the philosophy of pragmatism best describes such an approach.

Philosophical Approaches in Economics

Social science is the study of society. Economics is a social science and is, in its broadest definition, the study of economic actors in society. The laws and assumptions of neo-classical economics have its philosophical underpinnings solidly positioned in positivism. Although this positivistic epistemology remains a stronghold in economics, it is gradually being eroded in favour of theories that are characterised by activities within firms. Mainstream economics evolved virtually independently of methodological analysis (Dow 1997) and there has been little critical reflection on methods. However, this is changing. Alternative theories and models with a more realistic view of the world are evident in recent literature across many domains including economics (Vanberg 2002).

The psychology literature shares the ontological approach taken in the economics literature. However, what is measured is fundamentally different in both. The middle ground between these areas is social-psychology, which takes a psychological approach to research on social phenomenon through measurable variables.

Decision Making

While different approaches are taken to decision making, in particular the evolutionary economic theory Nelson and Winter (1982) and Penrose's (1959) resource based view, (to traditional orthodox economic theory) there are similarities between these alternative views now discussed.

The evolutionary theory treats firms as being motivated by profit and searching for ways to improve profits. However, they are not assumed to be profit maximising over given choice sets. Similarly the resource-based view in explaining growth assumes firms seek profit through investment opportunities to make money. However, owner-managers view the firm as their life's work; they have a desire to increase total long-run profits (Penrose 1959). Profit as an output is measured on inputs however, these theories treat inputs differently. The resource based theory does not necessarily use the term as it is "*never*" the resource itself which is an input into the production process, but rather the services rendered from these resources. This highlights the potential bias in treating resources as equivalent across all firms.
The evolutionary theory treats routines as a central resource of the firm: these routines are the building block of capabilities within a firm. Through using aspects from a variety of theories a more holistic understanding of the adoption of management practices is understood from this thesis. This thesis uses aspects from the mainstream orthodox view and the alternatives discussed: social psychology; evolutionary theory and the resource based view.

The philosophical position taken in this thesis is most appropriately described as a pragmatic realist approach. This thesis uses three different approaches to understand the phenomenon of technology adoption in agriculture. Each study is outlined in the next section, in terms of the research objectives and research questions.

1. Soil Testing on Irish Farms: An Investigation of the Differences in Adopters

2. Perceptions of Irish Dairy Farmers: Toward the use of Grassland Management Practices.
3. Organisational Routines in Nutrient Management Decision Making.

This thesis examines rates of adoption using prescriptive methods in study one and two and examines extent of adoption using a heuristic approach in study three.

Research Objectives

For traditional technology adoption studies using the static approach, the assumption of *ceteris paribus* holds in examining the adoption of a new practice. The rate of adoption is the static measure. It is often used to indicate diffusion, focusing on the spread of adoption. This epidemic model assumes the unidirectional movement towards the adoption of a practice. It does not consider motivation or the extent to which adoption has occurred. Adoption of the key decision making tool, soil testing is viewed as a binary decision in study one. However, to address policy issues surrounding the mandatory adoption of practice, the objective of this study is to use the social psychology literature in making distinctions within the population focusing on voluntary users.

Study two identifies the perceptions of farmers towards using grassland management technologies. Again using a prescriptive model intention to use six grassland management practices is predicted. This approach digs a little deeper into what is important for users. Using the Technology Acceptance Model (TAM) (Davis 1989) seven items relating to the characteristics of the technology, the objective of this study is to predict intention to use practice. It allows farmer to identify what is important for them in terms of technology usage rather than positing profits as the main driver. A further objective is to compare the use of the TAM and three farming objective variables (Willock et al. 1999) with more traditional economic indicators in predicting intention to use. The final objective of this study is to identify social influence using Herbert Kelman’s (1958; 2006) social influence framework and influential social groups on adoption of grassland management practices.

In investigating paradoxical behaviour of *homo sapiens* it is beneficial to ask more probing *why* questions in investigating decision making. Study three allows research to develop rich contextual detail on the social phenomena of adoption. Farmers will not act in precisely the same way in repeated trials, activity is based on resources available, and these include: environment, past experience, future plans. Study three explores this using the routines literature, how adoption and non-adoption occurs. This is based on farmers experience with the technology. The objective of this study is to identify the implementation activities of the farmer moving beyond identifying who adopts and their attitudes towards adoption to why they adopt and the reasons for the activity.

The objectives of each empirical study are highlighted as follows. The objective of study one is to identify the farm and farmer characteristics of farmers who use soil testing on a regular basis using a binary logit model. Soil testing is a core decision making tool in nutrient management practices. The aim of study two is to identify the attitudes of dairy farmers to the use of grassland management practices. Using two attitudinal measures, perceived usefulness and perceived ease of use, it extends the model to incorporate the level of commitment to using this practice based in the Irish context. Study three focuses on nutrient management practices and their implementation at farm level. It uses the concept of routines to understand the nutrient management practices at farm level. This approach gives an insight to on-farm decision making and use of practice.

Research Question

In understanding the decision then it is possible to influence change or the introduction of a method of intervention. Such interventions must act as supports for decision making in understanding the diverse nature of decision making. Philosophy offers social science a structure to guide inquiry. The economics discipline traditionally takes a predominately positivistic view of the world. Many scholars accept this position without looking further at alternative approaches to researching social science phenomenon. The philosophy of pragmatic realism places the research question at the centre of the work. It is the question which dictates the approach taken. The following research questions are asked in each study:

Study One

- What are the farm and farmer characteristics of Irish dairy farmers who soil test?
- What are the farm and farmer characteristics of those who regularly soil test on a voluntary basis?

Study Two

- Are latent factor social variables more appropriate in predicting intentions to use practice than more traditional measurable variables?

- What type of social influence impacts adoption of practice and who are the most influential social groups?

Study Three

- What are the commonalities and differences influencing existing nutrient management routines at farm level?
    - How are nutrient management practices implemented at farm level?

Discrete sets of literature are used to explore technology adoption, presented in three studies in this thesis. This section outlines the general economic approach taken to technology adoption giving an overview of the trends in the literature focusing on agriculture where much of the research has been carried out. It links literatures and discussions from each study of the thesis. The research presented in this thesis complements existing research on technology adoption by employing a mix of approaches. Study one, a typology study examined characteristics using a traditional economic approach. It quantitatively identifies the characteristics of adopters. Study two, an attitudinal study focusing on the farmer, quantitatively identifies perceptions and social influences of end users. Study three, an implementation, study uses a practice approach to investigating technology adoption it qualitatively explains activities at farm level. It is a mixed-methods thesis. The choice of methods employed is a function of the research questions in each study.

The following section outlines the scientific practices used as the context for this research. It outlines their importance in the achievement of current policy targets and obligations.

Policy and Land Management Practices

This thesis as outlined examines two suites of practices: Nutrient Management Practices and Grassland Management Practices. The focus is of this research is on agricultural farm practices for three reasons. The first reason is the importance of the Irish agriculture to the economy. Secondly it is a major contributor to emissions and could potentially hinder Ireland meeting international climate change targets. Finally nationally production targets have been set for the dairy sector.

In light of the opportunities anticipated with the removal of milk quotas in 2015 improving competitiveness is imperative. However, the challenge is to achieve such targets in an environmentally friendly manner. This green approach to increased production is a paradox itself. However, these management practices (See study two for more details) are tools which are identified as aids to achieving this objective. The green approach to increases in production may be realised through increased grazing days using appropriate grassland management practices, but also reducing costs and potential pollution through nutrient management practices. Of the total agricultural area used in Ireland 76% is in grassland close to 3.8 million hectares (CSO 2010).

Agriculture is a very important industry for Ireland, exports for the food and drink exports reached €9 billion for the first time in 2012 and the dairy sector alone it is estimated, for Irish dairy and ingredient exports, contributed to €2.66 billion of that (Bord Bia 2013[15]). The competitiveness of the sector is critical to Ireland's economic performance. The dairy sector is an integral part of this and is seen as the most valuable sector in agriculture currently, domestic milk intake by creameries and pasteurisers increase 8.2% on the same period in 2012 (CSO 2013[16]). It is estimated

[15] Available at http://www.bordbia.ie/industryinfo/agri/pages/default.aspx [Accessed 23/12/2013].

[16] Available at http://cso.ie/en/releasesandpublications/er/ms/milkstatisticsaugust2013/ [Accessed 3/10/13].

the primary agricultural sector (agriculture forestry and fisheries) employ 5% percent of the total workforce (DAFM 2013[17]).

The Irish agricultural sector is responsible for 32% of Irelands greenhouse gas (GHG) emissions (EPA 2011)[18]. Internationally it is recognised climate change effects agriculture more than any other economic sector based on its reliance on natural resources: agriculture uses 80% of the world's fresh water (Rajalahti 2012). The opportunities for Ireland to reduce GHG emissions by 2030 was highlight in a Mc Kinsey report (2009) commissioned by the Sustainable Energy Authority of Ireland (SEI). This report conducted detailed analysis of the agricultural sector in which opportunities and issues were highlighted. The report stated that the opportunities presented in agriculture are small in comparison to current levels and also to potential identified in other sectors of the economy (McKinsey 2009). The largest opportunity identified for the sector relates to land management for Ireland's beef and dairy sector relating to farming practice (*ibid*). The report identified three opportunities

- Growing clover: reducing need for nitrogenous fertilizer.
- Extending the grazing season: reducing need for feed supplement.
- Optimal timing of slurry application: reducing the need for nitrogenous fertilizer.

Ireland's total greenhouse gas emissions are calculated on the basis of participation in the EU Emissions Trading Scheme (ETS)[19] and the non-ETS. Agricultural emissions are classified as non-ETS. Agriculture accounted for 30% of total emissions in 2013 (EPA 2013[20]). Total emissions from agriculture are as follows:

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[17]Available at http://www.agriculture.gov.ie/publications/2013/compendiumofirishagriculturalstatistics2013/tableofcontents/ [Accessed 3/10/13].

[18]Available at http://www.epa.ie/irelandsenvironment/climatechange/#tab_3 [Accessed 24/07/13].

[19] Regulates installations emitting large quantities of greenhouse gases (ESRI 2012).

[20] Available at http://www.epa.ie/pubs/reports/indicators/agriculturefactsheet.html [Accessed 28/12/2013].

enteric fermentation the major contributor 47%, manure management and nitrogen account for 28% and 20% respectively, and the remaining 5% of emissions attributed to combustion of fossil fuels (EPA 2011[21]). The McKinsey report (2009) highlights some issues associated with these emissions. The first is the difficulty in empirically measuring methane emissions. It also states the benefits of dietary changes, improved grazing management or vaccination would not necessarily be recorded without changes to the inventory system (McKinsey 2009). There is a call for a system to verify implementation of nutrient management best practice to support an environmentally friendly expansion in the sector towards 2020 (ESRI 2012). Current international research into chemical additives to prevent decomposition of nitrogenous fertilizer is a long way from commercialisation (McKinsey 2009).

The three recognised opportunities for reducing emissions in the sector relate to farm practice. There is a need for extension to support such changes at farm level. This is already happening through encouraged adoption of best practice largely through discussion groups[22]. However, an increased rate of adoption may be insufficient for innovation. The implementation of a technology is crucial for the benefits of the technology to be realised.

In Ireland, 90% of total agricultural output is based on a grassland system the management and fertilizing of grass is consequently of grave importance (Culleton 2013). The focus on these suites of technologies is of key importance for the dairy sector for the following fundamental reasons, economic competitiveness and meeting policy targets. Our competitiveness is based on the low cost grass-based system where maximising grass as a resource is based on its management in term of required inputs and outputs. Specific environmental policy targets are set for agriculture, similar to other sectors, to reduce emissions and to protect water quality. Production

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[21] Available at http://www.epa.ie/pubs/reports/air/airemissions/EPA%20GHG%20Emission%20Projections_FINAL.pdf [Accessed 28/12/13].

[22] For an examination of the characteristics of members and financial return of participation to discussion groups see Hennessy and Heanue (2012).

targets have also been set for the dairy sector by 2020 so the challenge exists to achieve production targets while meeting environmental obligations.

Through focusing on these suites of technologies Ireland's ability to achieve targets may be improved. However, this thesis advocates that increases in the 'use' of these technologies are not sufficient. The examination of the rates of adoption is the first step in the adoption of an innovation. The change occurs in the second stage which is the implementation of the technology. It is at this stage where decision making occurs. It is at this stage where communications is vital to support farmers in how they implement these technologies on their farms given their resources, routines and capabilities.

Section II

Empirical Studies

1. Study one: Soil Testing on Irish Farms: An Investigation of the Differences in Adopters

1.1 Introduction

Soil is the foundation for almost all land uses (Herrick 2000). It is a vital non-renewable natural resource that requires sustainable management to ensure the production of food and fibre; furthermore its nutrient retention forms an essential component of the future water cycle (Creamer et al. 2010). For farmers the need to efficiently use nutrients on farms stems from the positive potential it holds for increasing production. It also offsets possible adverse environmental effects of nutrient transportation off farm on water quality. Knowledge of the soil is an essential element in maintaining soil quality, soil fertility and sustainable soil management. This study investigates the use of a key decision making tool, soil testing, among Irish farmers.

This study answers two main research questions. First what are the farm and farmer characteristics of the Irish dairy farmers who soil test? Second, what are the characteristics of farmers who soil tests voluntarily? This study uses a binary logit model to analyse data from the Teagasc National Farm Survey (NFS) focussing on the core decision making tool soil testing on dairy farms. This type of analysis identifies the various farm and farmer characteristics, affecting the probability of an event occurring. The event in this case is soil testing.

The quantitative results are generally as expected; soil test users are more profitable, have larger farms and as a group are younger. When focusing on voluntary behaviour disregarding those for whom it is compulsory to carry out soil tests, formal agricultural education is of much greater importance for this group. Contrary to expectations, there is no significant difference between adopters and non-adopters in terms of cost savings. Soil testing is a cost positive technology:[23] generally adopters should save money through improved management of required inputs, mainly

[23] Two exceptions exist. On nutrient surplus farms costs may be incurred in exporting excess nutrients and secondly on nutrient deficient farms, where increased inputs are required (Beegel et al. 2000).

expenditure on chemical fertilizer, but also through more efficient use of on-farm nutrients.

The remainder of this study is structured as follows. The next section 1.2 details soil testing in the Irish context. It presents information on the three main reasons why farmers might soil test: economic competitiveness, legislative and environmental obligations and national production targets. The second section outlines in more detail the issues concerning soil testing, soil quality and policy towards soil testing. Section 1.3 reviews the focal literature on agricultural technology adoption which underpins the empirical analysis. Section 1.4 outlines the research question, section 1.5 details the data and methods used. Section 1.6 contains the results and discussion and the final section is a conclusion.

1.2 Soil Testing: Context

Why soil testing? The testing of soil is a critical tool in nutrient management decisions. Theoretically farmers test soil to improve the fertility in their soil, reaping the production benefits and informing nutrient management routines relating to application: its timing, quantity and type. In the literature it is established that farmers use an array of knowledge in managing soil (Ingram 2008; Ingram, Fry and Mathieu 2010; Raymond et al. 2010).

Soil is a unique medium and variability is a problem for soil scientists (Wollum 1994). The salience of nutrient management in agriculture is reflected in environmental legislation and production efficiency. Nutrients exist on farms in two main forms organic[24] or chemical. These nutrients are applied to the land to enhance soil quality for crop production. However, as soil is permeable it has the potential to leach nutrients to groundwater, rivers and lakes resulting in environmental damage and potentially financial losses.

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[24] Commonly referred to as slurry, the material contains mainly dung and urine potentially waste water (washings) collected in large tank at farm yards during periods of animal housing (Winter). It is applied onto fields during the growing season excluding the closed period as stipulated by the nitrates directive.

At a European level, the Water Frameworks Directive[25] and the Nitrates Directive[26] contain the main programmes of measures to mitigate the potential for agricultural activities impairing water quality in river basin districts (Fealy et al. 2010). These directives have been incorporated into Irish legislation (SI 101, 2009) and are intended to effectively manage the potential losses of nitrogen and phosphorus into surface water and groundwater *(ibid*). The nitrates directive is concerned with the quality of drinking water and the water framework directive targets water quality in rivers, lakes and coastal waters. Breech of these regulations results in penalties. Water quality is of utmost importance in an Irish context given the Food Harvest 2020 strategy for the development of the agri-food and fisheries sector. This report has set targets for the dairy sector to increase milk production by 50% by 2020. The challenge is to increase production whist maintain environmental (water) standards.

Nationally: Soil Management

The Irish dairy sector has an advantage in terms of the environmentally sustainable grass-based production system compared to our European counterparts. Grass is a low cost feed for animals both environmentally and economically by comparison to the European high input system of feeding concentrates, which represents a financial cost coupled with a high carbon emissions factor, relative to grass. The production and efficient use of grass therefore is a vital resource, through extending the numbers of days animals are at grass.

Every Irish farm receives a phosphorus (P) and potassium (K) statement annually from the Department of Agriculture Food and the Marine (DAFM). This statement is based on a number of variables including: livestock units per hectare, soil nutrients and pH[27] of soil. The statement gives recommendations to each farmer on the type and quantity of fertilizer to be applied on the farm. The base nitrogen allowance is increased in the case of those intense dairy farmers who apply for derogation.

[25] WFD; Official Journal of the European Community, 2000

[26] European Council, 1991

[27] The pH level is a measure of acidity in the soil which is neutralized by the use of lime generally.

Derogation is applied for at a European level and in the event of deterioration of Irish water quality such derogations may be reconsidered by the EU.

In the case of farmers who do not soil test, the DAFM estimate soil nutrient level to be the optimum level (an index of 3). The assumption is made in order to calculate and recommend application levels of phosphorus (P) and potassium (K) on the farm for the purpose of P and K statements issued by the DAFM. With only 30% of samples taken[28] actually at the desired index of 3, this is a major issue for the DAFM estimates. It is not required that all farmers soil test. However, each farmer is legally responsible for the quantity of fertilizer applied on the farm. In the Irish context, some farms are required to adopt soil testing while others are voluntary users. It is compulsory for farmers who participate in the Rural Environmental Protection Scheme (REPS) and those farming intensely who apply for derogations.

The national body for agricultural research Teagasc provides the farming sector with a procedure like approach to carry out these nutrient management activities. These include a number of programmes and campaigns to improve soil fertility. The following is a five step plan for improving soil fertility and overall nutrient management as outlined by Teagasc (Plunkett 2012):

1. Soil Testing (*Current Status*)
2. Soil pH and Lime (*Fertilizer Efficiency*)
3. Target Index (*Low 1&2, Optimum 3, High 4*)
4. Slurry and Manures (*Where and When*)
5. Nutrient Balance (*Choose Appropriate Minerals*)

Soil testing in Practice

Testing of soil is a well-established practice. It is a diagnostic technique used to gather nutrient data and analyse its spatial variability at field level (Khanna 2001). Soil testing has two main functions (Table 1.1), to determine nutrient status and pH of the soil (Gallagher and Herlihy 1963). Having an appropriate pH level in the soil

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[28] Teagasc client samples.

ensures the efficient uptake of the major nutrients. The pH level is indicative of levels of soil acidity and is neutralised using applications of lime. Soil testing is a management tool and an important indicator used in soil quality measures. The index for available nutrients in soil ranges from 1-4[29]. Soil in category 1 or 2 is considered to have low fertility. To optimise grass growth it is necessary to have the macro nutrients[30] available for plant growth at index level 3.

Table 1.1 Functions of soil testing

Soil Testing	***pH Level***	***Nutrients Range [1-4]***
Optimum Level	6.2 - 6.5	3

Techniques developed in the United States in the early 1940s were used in Ireland in the 1950s. At that time Irish soil fertility was very poor, with 91% of phosphorus and 93% of potassium at index 1 which was reduced to 44% and 29% respectively by 1960 (Coulter 2000). The key to optimising crop returns is the capability of farmers to manage the nutrients in their soil and, therefore, optimise soil fertility and growth.

This is an important factor for technologies studied in this thesis, and in particular with respect to soil testing. Given the abolition of EU quota in 2015 there is an opportunity for expansion and investment in the dairy sector. The efficient use of resources in agriculture is an area where potential improvements can be realised. The production and efficient use of grass hence is a vital resource, and therefore, soil fertility, as set out in the rationale for this study. The challenge for the Irish dairy sector is to achieve the production targets set out in the Food Harvest report 2020 with minimal environmental impacts potentially achieved through improved soil quality.

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[29] Developed by Teagasc Johnstown Castle (Conway 1986) through extensive studies carried out these have been refined and changed in the years since. For a detailed report on changes in soil advice and management in Ireland see Coulter (2000). Since then field studies (Schulte and Herlihy 2007) and a review (Schulte and Lalor 2008) have led to further changes in the parameters (Coulter and Lalor 2008).

[30] Potassium (K) and Phosphorus (P)

The importance of soil testing is clear as it informs wider nutrient management activities, in particular nutrient application: timing, quantity and type. Given the legislative background, the distinction between voluntary and involuntary adoption is important as it moves beyond looking at rates of adoption to motivational factors. Motivation to change or adopt technology may form part of an incentivised scheme and so resulting in a compliance effect. Schemes such as the Rural Environmental Protection Scheme (REPS) and the Nitrates Directive mandated soil testing for participating farmers in Ireland, discussed in the next section. The rationale for focusing on soil testing is based on economic competitiveness, legislative and environmental obligations and national production targets.

Economic Competitiveness

Soil testing provides the farmer with key information about the nutrient status of soil. This information allows for optimum decisions to be made about critical inputs such as, organic and chemical fertilizer. Expenditure on fertilizers represents a significant cost to dairy farms. Cost reduction is a key objective on any farm as it results in increased profit. Utilizing resources through nutrient management and soil testing is one way of improving this efficiency. Soil testing is a particularly important management tool for Irish farmers. Irelands' uniquely temperate climate generates very high yields in arable crops and ideal conditions for growing grass, the key input to low-cost livestock production. Dairy competitors in Europe increase output through increases in concentrate feed usage, achieving high output per animal. In contrast, Irish farmers can capitalise on their competitive advantage to grow grass. Irish grass based farmers can reduce costs and achieve increases in their productivity. The challenge for Irish dairy farmers is to increase productivity in a sustainable manner, and soil fertility is vital for its achievement (Culleton 2013).

Legislative and Environmental Obligations

EU legislation[31] imposes restrictions on nutrient application. The European council directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC) stipulates the restriction.

[31] Water Frameworks Directive (WFD; Official Journal of the European Community, 2000) and the Nitrates Directive (European Council, 1991)

The Nitrates Directive, as it is commonly known, states that for each farm or livestock unit, the amount of livestock manure applied to the land each year, including by the animals themselves, this shall not exceed 170kg of organic nitrogen per hectare. Ireland applied for and was granted derogation from this on the 22nd October 2007 (2007/697/EC) [32]. Irish farmers may apply to Irish authorities on an annual basis to receive such derogation for their holding. Successful derogations applicants are permitted to apply a maximum of 250 kg nitrogen per hectare. The derogation is conditional on a farmer having a nutrient management plan, which includes a soil test.

Soil testing is also compulsory for farmers who participate in REPS. The Irish government introduced REPS in response to European Council Regulation 2078/92, which was designed to reward farmers for farming in an environmentally friendly manner and to bring about environmental improvement on farms. Each member state designed national programmes, operated over four years; Ireland ran four REPS programmes. REPS operated from 1994-2009, it was replaced by the Agri-Environmental Option Scheme (AEOS) in 2010. Each farmer is responsible for the quantity of fertilizer applied on the farm. According to Irish legislation (SI 101 2009) it is the duty of the farmer to ensure compliance with the regulations. EU legislation, environmental schemes and current soil fertility trends are salient in this study. Using social a psychology concept, the voluntary distinction is used to differentiate users, and non-users of the practice.

National Production Targets

Trends in soil test results from Teagasc clients show falling levels of phosphorus (P) and potassium (K) in Irish soils (Donnellan, Hanrahan and Lalor 2012). Furthermore a recent study shows the average pH of Irish grassland mineral soil at 5.4 while the target pH is recommended to reach 6.2 for optimum grass growth (Tunney et al. 2010). In Ireland production targets for Irish dairy farmers are currently set out in the Food Harvest 2020 report (DAFM 2010). It explicitly states that given the abolition of EU milk quota in 2015 there is a real opportunity for the Irish dairy

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[32] European Commission 2007. Commission Decision 2007/697/EC. Granting derogation permits application of chemical to a higher threshold (250 kg N/Ha) as stipulated under regulation.

sector to expand and to increase milk production by 50% by 2020. This target is based on average growth from 2007-2009. The achievement of this target will require greater utilisation of resources. One of these resources is soil. The ability of soil to produce grass is a function of many factors one major factor is the nutrient available for the plant. This is given by soil results.

There are two key indicators in soil tests results: the nutrient level and the pH level. The macro nutrients, P and K, and pH level, are the primary concern[33]. The falling trend in soil P and K results is not driven by any particular sector and is reasonably consistent across regions (Donnellan, Hanrahan and Lalor 2012).

Trends show over the period 2001-2011, the percentage of soils in very low to low fertility have increased from approximately 15% to 55% overall, steadily increasing since 2007 (Plunkett 2012). Plunkett (2012) highlights approximately 25% of Teagasc soil tests in 2011 at the optimum index. The greatest increase in this trend has been from 2009-2011 with unprecedented numbers of samples (54% (P) and 54% (K)) in the low categories in the final year of data. Trends in sales of fertilizer and usage have been studied using the NFS and from DAFM figures in Ireland (See Appendix A). There has been a considerable decline in fertiliser sales over the period 2001-2011 (Donnellan, Hanrahan and Lalor 2012). Fertilizer prices accelerated over the same period peaking in 2008; there was a decline in 2009 and 2010, but an increase in 2011, raising concerns regarding the volatility of this input price (Breen et al. 2011). These factors form the context for this empirical study for Irish farmers. Internationally the soil and soil quality are also of key importance to the agricultural sector. These are discussed in the next section.

Soil Quality and Policy

The concept of soil quality emerged throughout the 1990s with increasing emphasis on sustainable land use and sustainable soil management (Karlen, Ditzler and Andrews 2003). The widely accepted definition of *soil quality* used by the Soil

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[33] The micro nutrients and trace minerals fine tune fertility of soil. See the next section for more information on

Scientists Society of America is: the ability of soil to function within ecosystems boundaries to support healthy plants and animals, maintain or enhance air and water quality, and support human health and habitation (Karlen, Ditzler and Andrews 2003, Wander and Drinkwater 2000). This definition has also been used by soil research in New Zealand (Lilburne, Sparling and Schipper 2004). The definition of soil quality and sustainable agriculture are parallel (Herrick 2000).

Sustainable agriculture has been an objective of the European Union (EU) since the Amsterdam Treaty of 1999. Europe recognises the multifunctional role agriculture plays with three-quarters of EU land mass agricultural land or woodland[34]. Sustainable agriculture became an environmental concern for the European Union due to the intensification of farming, incentivised by the earlier Common Agricultural Policy (CAP). CAP encouraged increased productivity based on technical progress and the optimum use of the factors of production. There have been a number of amendments to the CAP scheme since its introduction in 1958. The first major amendment, the MacSharry reform in 1992, saw a shift from market supports to direct payments. The second essential element of this reform was the introduction of an environmental scheme for agriculture. Since then agriculture in the EU has increasingly been viewed as being part of the wider rural community, and the key for future policy is the sustainability of European countryside (Wilson 2001).

The public good element of agriculture and the environment is an issue for farmers and the wider rural community. Dairy farmers have a responsibility to be aware of the potential harm caused by leaching of soils and potential run-off of chemicals into waterways. Water quality is of utmost importance in an Irish context. In Ireland, the Agricultural Catchments Programme funded by the Department of Agriculture Food and the Marine (DAFM) and run by Teagasc, is implemented by a team of researchers, advisers and technicians working closely with farmers. Their main objective is to monitor water quality at the spatial scale of river catchments. The excess application of chemical fertilizer and organic manure have harmful

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[34] (European Commission 1999/C 173/02, available at http://eurlex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&lg=en&type_doc=COMfinal&an_doc=1999&nu_doc=22) [Accessed 26/12/2013].

environmental effects, while maintaining sufficient levels of nutrients in the soil, essential for re-growth. The rationale for chemical fertiliser application is to increase output through productivity, leading to improved profitability. When the plant (grass) is harvested the nutrients are harvested with it, and the potential productivity of soil decreases (Fertilizer Europe 2010[35]). This results in a constant requirement for fertiliser application after harvest. Soil testing indicates the appropriate levels of fertiliser application with any given crop so as to minimise detrimental environmental impact, given the porous nature of soil.

Soil Characteristics

Any material entering the soil, (including animal manure, pesticides, fertilisers) is decomposed and recycled by the soil organisms: the soil 'biomass', through mineralisation (Griffiths 2008). Through the mineralisation cycle, recycled nitrogen feeds the soil biomass which subsequently recycles that nitrogen for plant growth. The supply of nitrogen released by the biomass for plant growth is dependent on soil type, nutrient management history, and soil ecosystems (*ibid*). The science of soils recognises the importance of historical management. Knowledge of the soil and its nutrient history is vital for decision making on the farm. Decisions surrounding fertilizer application should be based on soil test results so that optimum grass growth on the farm is achieved. This optimum growth however, may not achieve the objectives of the farmer: for example, in certain cases the optimum may result in surplus grass and wastage. The optimums presented in Table 1.1 are maximising positions, scientifically proven to give optimum results. However, it is known not all farmers produce at the optimum.

There are two important characteristics of soil: one is the inherent characteristics of the soil given by soil formation, and second is the dynamic characteristics of soil, which change with human decisions and management practices (Karlen, Ditzler and Andrews 2003). Soil management practices are of significant importance, any material entering the soil effects soil characteristics. The impact of practices on soil functions can be identified through a soil quality index (Fernandes et al. 2011).

[35] 'Fertilizers Europe' formally known as the European Fertilizers Manufacturers Association (EFMA)

The Fernandes study used an American framework, developed by Karlen and Stott (1994), using three soil functions to access soil quality. Soil capacity for root development, water storage capacity and nutrient supply capacity. Nutrient supply capacity determined 46% to 61% of the overall soil quality index; the variation was dependent on system. This shows the importance of the nutrient supply for overall soil quality. Providing the essential nutrients for a plant allows it to grow to its full potential. The main elements in soil are nitrogen, the essential plant protein, phosphorous, containing the acids and lipids and potassium, which perform a multi-functional role in plant growth including metabolism and photosynthesis. The underlying principle of an effective fertilizer programme is; to precisely match the nutrient inputs with the requirements of the plant, this maximises nutrient usage, ensuring better use of organic waste and avoids losses to the environment (Fertilizers Europe 2010).

Soil Plant

The soil-plant relationship is complex (Figure 1.2).

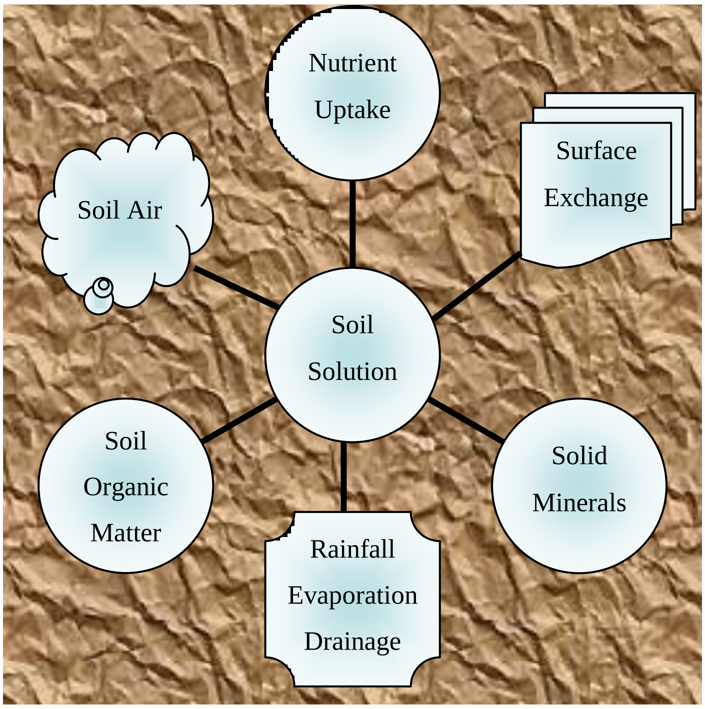

Figure 1.2 Components that influence plant nutrition concentration (*Adapted from Havlin et al. 2005*).

It is the interactive exchange of physical, biological and chemical properties in soil which control plant nutrient availability (Havlin et al. 2005). As a plant absorbs nutrients the concentration in the soil decreases (*ibid*). The nutrient concentration in the soil solution involves twelve interactions of, microbial reactions, ion exchange, and absorption and desorption as depicted in Figure 1.2. The scientific detail is complex and concentration in the soil is not a function of any one singular entity rather an intricate web of scientific relations.

These scientific exchanges impact nutrient availability. They are important for nutrient management and for understanding the knowledge used to assess soil quality. About 50% of soil compromises of solid materials, water and air occupying the rest (*ibid*). The challenge is to find the correct balance in maintaining productivity levels through monitoring fertility of the soil ensuring optimum output, without adverse effects on the environment.

Relevance of Soil Fertility

The rate of consumption of agricultural food and natural resources is of increasing concern internationally in recent years with world population predicted to rise. The agricultural sector worldwide is under pressure as climate change and food security are of grave importance. An investigation of Irish expansion capacity deems Food Harvest targets for the dairy sector as ambitious compared to other targets and unlikely to be achieved given current land in dairy production and also the potential for further restrictive environmental policies (Läpple and Hennessy 2012).

For Irish agriculture perennial ryegrass accounts for approximately 95% of forage grass seed sold currently: other grass varieties include Italian ryegrass and white clover (DAFM 2011[36]). Irish dairy farmers use a pasture based system with the potential to feed animals outdoors for up to 270 days (Patton et al.2012). Using a grass based system is a more lucrative alternative than feeding concentrates.

[36] Available at http://www.agriculture.gov.ie/media/migration/farmingsectors/crops/seedcertification/cropvarietyevaluationcvepublications/GrassCloverRecomListVarieties2011.pdf [Accessed 26/05/2012].

Extending the grazing season is a cost saving practice on all dairy farms. In order to optimise grass growth it is essential to apply fertilizer according to soil requirements.

The appropriate fertilizer application is essential for grass growth (Table 1.1), according to Teagasc specialist: *"the desired pH level for soil is 6.3 for optimum grass growth and for maximum uptake of potassium and phosphorus. It is estimated that the uptake of potassium and phosphorus will be three to four times more effective if pH is correct",* (Dairy Specialist in the Knowledge Transfer Department, Teagasc).

The over application of fertilizer, results in the inefficient use of resources in terms of increased direct costs and its potentially damaging effects to the environment. Land management practices such as nutrient management and grassland management are specifically focused on increasing the returns from an existing resource. Soil testing ensures the quality and management of soil can be quantified monitored and improved upon.

1.3 Current Literature

The literature on agricultural technology adoption is published in many fields of research[37]. Quantitative approaches seek to predict adoption rates and level of adoption within populations. Technology adoption analysis can range from a broad assessment of trends, to looking at the adoption of specific practices. This literature review takes the latter approach and focuses on specific research in the area of soil and the adoption of soil testing. The literature relating to soil relates to a broad range of global concerns such as soil erosion, tillage practices largely classified as conservation practices. Given the interest in sustainable agriculture over the past ten years and the relative importance of soil in production, this is an extremely important area of research for the agricultural sector. Globally, soil productivity is a concern coupled with the environmental effects of conventional practice (Knowler and Bradshaw 2007). The protection of the environment, including water, is a priority in sustainable food production and so the efficient use of resources. Input agriculture is

[37] Including: Agriculture, Economics, Sociology, Management, Geography and the Environment.

no longer an option for environmentally sustainable production. Soil testing is a key decision making tool and is the focus of this study.

Much of the literature on soil testing and conservation relates to tillage farms. Many soil conservation studies use discrete choice models to identify factors distinguishing farmers who use conservation practices from those that did not (Prokopy et al. 2008). There was a significant push on soil conservation research in the United States in the late 70s and early 80s, Ervin and Ervin (1982) identifies three main reasons: an increased demand for food, the realisation that government conservation programmes were not reaching objectives and finally the introduction of legalisation to improve water quality. The current rationales for focusing on soil in Ireland are similar to those in the United States: national production targets, a worrying concern soil programmes are not achieving goals of increased fertility and legislation to protect water quality.

Studies have outlined factors such as: credit, information availability, risk and farm size as the focus of many studies (Feder and Umali 1993). Khanna (2001) identified factors effecting technology adoption of soil technologies as relating to scale, human capital, innovativeness, land ownership, soil quality, and costs of adoption. However, the identification of universal explanatory variables to predict adoption in agriculture has proved difficult for research (Feder, Just and Zilberman 1985; Feder and Umali 1993; Knowler and Bradshaw 2007). Prokopy et al. (2008) condensed variables used in United States best management adoption studies to four broad categories: capacity, awareness, attitudes and farm characteristics. However, findings have been inconsistent. This has been attributed to the collection of data and inconsistent measures based on studies in the United States (Baumgart-Getz, Prokopy and Floress. 2012).

Soil testing is described as a scale neutral technology (Khanna 2001) although; farm size or scale variables are identified as influential in other adoption studies. The size of the farm is most commonly associated with, availability of financial resources and the ability to invest. However, soil testing does not require large investment. Certain studies examine rates of adoption (Norris and Batie 1987; Bell et al. 1994) while other studies examine intensity of adoption (Sureshwaran, Londhe and Frazier 1996). Variables may be significant in more than one study, but this could be for a variety of reasons mainly due to variable measurement and how adoption is measured. This reflects the complexity associated with the literature of adoption of agricultural innovations (Kremer et al. 2001).

This study focuses on, variables affecting the incidence of technology adoption. Studies show that age and education influence adoption with older farmers less likely to use soil conservation practices (Prokopy et al. 2008). Other factors include financial indicators, perceptions, farm size (Ervin and Ervin 1982; Feder, Just and Zilberman 1985; Norris and Batie 1987; Prokopy et al. 2008). Studies have been criticised for including ‘local’ area specific variables circumventing a more general conclusion being drawn (Ervin and Ervin 1982). By contrast, more recent environmental literature embraces ‘local’ approaches focusing on farmers attitudes. An example in relation to soil conservation legislation in Ireland is Buckley (2012), focusing on farmer opinions. Another is Reimer, Weinkauf and Prokopy (2012) which focus on perceptions of farmers towards conservation practices.

Historically, the practice of soil testing is well established and with the exception of REPS and derogation farmers, its use is voluntary. The voluntary versus involuntary element of the practice is of interest, as the key to successful adoption (soil testing) is the implementation (results). Innovative activities are affected by interventions such as price, government policy, regulation and internal organisational structures. However, for the purpose of this study, the focus is on the characteristics of the population, and the impact of policy and regulation, through looking at voluntary and involuntary adoption. Institutional structures may have a role to play in the provision of: product demonstration, information and education, also to demonstrate efficiency in local conditions, in reducing risk associated with adoption (Sundig and Zilberman 2001). The practices studied in this thesis may seem less ‘risky’ with no investment of capital required. However, the importance of soil in farm production is outlined in this study, as such, changes to how soil is management are risky.

There is a large body of Irish studies published in the natural scientific field with regard to soil and water, some salient Irish publication include: Coulter (2000), Schulte and Lalor (2007), and Coulter and Lalor (2008)[38]. The volumes of these studies have been increasing since the introduction of the Agricultural Catchments Programme. The social sciences however, have not been actively researching soil and soil conservation in Ireland. This study aims to fill this gap by focusing on the primary soil management tool, soil testing. This study identifies the personal, physical, and economic characteristics of Irish dairy farmers who are likely to soil test. Given the current government programmes (REPS) and legislative policies (Derogation) that require farmers to soil test, voluntary users are examined in a second model.

1.4 Research Question

It is important for reasons outlined above to improve fertility in an environmentally friendly way. As the testing of soil is suggested as a first key step in response to achieving required soil fertility it is then pertinent to identify who are likely to adopt such practice. Using a logit model it is possible to do this.

The aim of this study is: to identify who are the cohorts of farmers who are more or less likely to soil test on a regular basis. In 2009 the National Farm Survey (NFS) asked the following: Do you soil test on a regular basis? The response option was a binary Yes or No. This study first identifies the rate of adoption in the Irish dairy sector. It also identifies the farm and farmer characteristics of adopters, using odds ratios to identify groups of farmers who are more likely to soil test on a regular basis.

The research questions are as follows:

- What are the farm and farmer characteristics of the Irish dairy farmers who soil test?
- What are the farm and farmer characteristics of those who regularly soil test on a voluntary basis?

[38] For a more comprehensive list of wide ranging Irish studies visit Teagasc website, available at http://www.agresearch.teagasc.ie/johnstown/publications.asp [Accessed 21/12/13].

1.5 Methodology

Data

The empirical data used in this study is a nationally representative sample of Irish specialist dairy farmers, using the Teagasc 2009 National Farm Survey (NFS). The NFS contributes Irish data to the European Farm Accountancy Data Network (FADN). This data set is used mainly by the European Commission along three dimensions: region, economic size and type of farming. The main aim of the network is to gather accounting data from farms in determining incomes of agricultural holdings[39].

Sample used in analysis

The total population is 231 specialist dairy farmers, 70% of which soil test on a regular basis. Table 1.4 contains the descriptive statistics for the population. The population is split into adopters (165) and non-adopters (66) showing the mean and standard deviation for each variable. The purpose of the division is to test if there is a statistically significant difference between the groups using two sample t-tests[40]. These tests are used to compare the means of normally distributed interval dependent variables, for two independent groups. The logit analysis identifies the probabilities of use based on farm and farmer characteristics. The strength of these probabilities is given by the odds ratios. The odds ratios are used to compare the probabilities between groups.

Deciding whether or not to test soil in a voluntary capacity is a significant factor when examining the decision to use a practice. For these reasons, the analysis of quantitative data is carried out in two steps. First, adoption of the whole population is examined and secondly, the analysis focuses on the voluntary users only.

Logit Analysis

The analysis uses a binary logit model to examine the adoption of soil testing. The binary dependent variable has two values: one, representing farmers who conduct a

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[39] Available at http://ec.europa.eu/agriculture/rica/concept_en.cfm [Accessed 26/12/2013].

[40] Null hypothesis assumes the difference between the groups is zero.

soil test on a regular basis and zero, representing farmers who do not. Given the dichotomous nature of the decision, the model is non-linear with a cumulative distribution function, the estimated conditional probabilities will lie between zero and one. The relationship between the probability (Pi) and the variable (Xi) is non-linear. This requires a non-linear functional form. A more intuitive specification would be an s-shaped curve "*one which approaches zero at a slower and slower rate as Xi gets small and approaches one at a slower and slower rate as Xi gets very large*" (Gujarati 2003). The model fit is estimated by maximum likelihood (ML). The likelihood function indicates: how likely it is that the data reflects the population parameters (Long and Freese 2006).

The conditional expectation of Yi given Xi,

$$E(Y_i|X_i)$$

can be interpreted as the *conditional probability* that the event will occur given Xi. That is:

$$\Pr(Y_i = 1|X_i). \text{ If } Y_i = 1$$

The probability of an event occurring that is P_i and the probability of an event does not occur:

$$Y_i = 0$$

then probability is:

$$(1 - P_i)$$

Logit models are used to identify probabilities of individuals with certain characteristics to be in a binary grouping. In this study the logit is used to identify farmers who use soil tests on a regular basis and those who do not based on their farm and farmer characteristics.

Variables in the study

The variables chosen in this study (Tables 1.2-1.3) can be categorised by economic variables, which include, financial results of the farm and structural variables. In the agricultural adoption literature there are no universally accepted set of explanatory variables used (Prokopy et al. 2008). However there are four types of variables identified by Prokopy et al. (2008) in a review of 25 years of US literature, these are identified as capacity, awareness, attitude and farm characteristics. In this study variables are chosen based on Prokopy et al. (2008) and a soil study (Khanna 2001).

The 2009 NFS is the empirical setting in Study 1 and the availability of variables are based on two, of four categories suggested by the Prokopy et al. (2008) review: capacity of individual (age, income, education) and farm characteristics (size, per hectare expenditure). Soil specific variables are also included as per Khanna (2001).

Omitted variables identified as salient by Prokopy et al. (2008) include three types of networking capacity. Local (homophilous relations: farmer to farmer), agency (heterophilous), (Rogers 2003) and business (heterophilous relations with an economic nature) networks. Variables such as attitudinal factors and environmental awareness are identified by Prokopy et al. (2008) as relevant from their review of the literature. Such are not included due to unavailability of data so are consequently omitted.

Table 1.2 Variables in Logit 1

Explanatory Variable	Hypothesised
REPS/Derogation	+
Dairy Platform	+
Age	-
DG Membership	+
Soil Quality 1	-
Soil Quality 2	-
Soil Quality 3	+
Lime/UAA	-
Fertiliser/UAA	-
FarmGM/UAA	+
Cashflow	+

Relevant variables for the technology included specific cost variables (direct costs/ha, fertilizer expenses/ha), a physical environmental variable of the farm (soil quality) and a measure of intensification (total lu[41]/uaa[42]). This is highly correlated with expenditure on fertiliser per hectare and so it was dropped from regression.

In the second model, the mandatory adopters were dropped from the model, leaving only those acting in a voluntary capacity. This model captures the impact of voluntary adoption. The existence of incentivised schemes (REPS/AEOS), in which it is compulsory to test, is the essence of the population split.

In the second model, eleven variables were chosen to reflect voluntary behaviour including: formal agricultural education, a scale variable (size of the dairy platform), soil quality variables, financial indicators and other complementary practices, reseeding of land and completion of grass covers.

Table 1.3 Variables in Logit 2

Explanatory Variable	Hypothesised
Dairy Platform	+
Formal Ag. Training	+
Soil Quality 1	-
Soil Quality 2	-
Soil Quality 3	+
Lime/UAA	-
Fertilizer/UAA	-
FarmGM/UAA	+
Cashflow	+
Grass Covers	+
Reseeding	+

In summary eleven variables are used in each model, eight variables are common to both: diary platform, three soil quality variables, expenditure on lime and fertiliser, gross margin and having a cashflow. Having a cashflow budget suggests, the farmer is conscious of costs (fertiliser) and planning, so it is hypothesised to have a positive effect on adoption. Farmer age and level of education are strongly negatively

41 LU is standard notation in agriculture for number of livestock units which varies with each type of animal

42 UAA is the utilizable agricultural area in hectares (ha)

correlated; age was used in the first model, while education was used, for the voluntary population in the second model. Education, scale and income variables are hypothesised to have a positive impact on adoption (Prokopy et al. 2008).

Participation in REPS, discussion groups and those with a formal agricultural education, may exhibit a positive environmental attitude or awareness towards a practice, which Prokopy et al. (2008) hypothesised will also have a positive effect on adoption. It is hypothesised, based on previous research (Khanna 2001), that soil quality would only have a positive impact on adoption if soil quality was poor, while age would have a negative impact on adoption. Furthermore, adopting reseeding and grass covers is hypothesised to have a positive effect on the likelihood of soil testing.

1.6 Findings

Step 1: T-tests Model: Soil Testing

The full population (231) was divided into testers (165) and non-testers (66) showing the mean, standard deviation and t-tests for each variable.

Who tests?

In line with technology adoption literature it can be seen that soil testers generally:

- Have higher incomes in terms of gross margin (t=3.35, p=0.00) and gross output (t=2.98, p=0.00) per hectare.
- Be younger (t=3.11, p=0.00).
- Have larger farm size (t=-2.64, p=0.00)
- Have larger dairy herds (t=-3.21, p=0.00)
- Have higher total livestock units (t=-2.50, p=0.01).

What are the benefits of testing?

Famers who soil test should be saving money through spending less on fertilizer application. The average spending on fertilizers per hectare represents 18% of dairy farm direct costs. The actual difference in nitrogen usage between the testers and non-testers is significant (t=2.34, p=0.02), but not large. The difference in the mean quantity of chemical nitrogen used is 17.3kg per UAA which may not appear to be a large difference. However, in a farm of average size 57.6ha, this would amount to almost 1000kg of nitrogen, representing additional expenditure in the region of €300. The quantity of nitrogen used on a per hectare basis, is higher for testers than non-testers. There is a strong positive correlation (z=0.5699) between intensity and nitrogen use. This indicates more intensive farmers, on a per hectare basis, use greater quantities of nitrogen.

Table 1.4 Descriptive Statistics Total Population

Variable	**Population #231 Mean (Std Dev)**	**Users #165 Mean (Std Dev)**	**Non-Users #66 Mean (Std Dev)**	**T test Diff!=0**
FarmGM/UAA	1227.48(476)	1292.5 (468)	1064.87 (460)	**0.00**
Gross Output/UAA	2203.9 (754)	2295.7 (770)	1974.29 (664)	**0.00**
Size of Dairy Herd (Avg)	64.1 (36)	68.9 (36)	52.1 (34)	**0.00**
Age	50 (10)	48.7 (10)	53.4 (11)	**0.00**
Farm Size	57.6 (31)	60 (28)	49.1 (36)	**0.00**
Dairy Grazing Platform	33.6 (18)	36.8 (19)	25.7 (13)	**0.00**
REPS Payment	2596.9 (3729)	3347.1 (3911)	721.6(2372)	**0.00**
Total LU	106.9 (63)	113.4 (59)	90.5 (71)	**0.01**
Nitrogen (Kg)/UAA	100 (51)	105 (53)	87.7 (44)	**0.02**
Grazing Days	227.1 (26)	229 (24)	222.3 (24)	**0.08**
Dairy GO(€)/UAA	1345.5 (602)	1388.1 (614)	1238.8 (561)	**0.09**
Dairy GM(€)/UAA	661.3 (354)	684.7 (345)	602.8(371)	**0.11**
Direct Cost(€)/UAA	976.4 (426)	1003.2 (446)	909.4 (367)	**0.13**
Fertilizer(€)/UAA	164.8 (67)	168.6 (69)	155.2 (60)	**0.17**
Concentrates/UAA	344.8 (210)	351.4 (217)	328.3 (192)	**0.45**

What is surprising is the insignificant t-tests for the overall cost variables[43]. Soil testing is presented as a cost positive technology, yet there is no significant difference between the groups in relation to direct cost and fertilizer cost per hectare. This raises questions concerning motivations for adoption in light of the fact that

[43] The calculation of continuous variables are standardised on a per hectare basis

adopters should benefit in terms of reduced cost on fertiliser. However, this is not the case and soil testers on average spend more on a per hectare basis.

What drives the use of tests?

The following econometric analysis uses a logit model; it highlights agricultural policy as a key driver in the adoption of soil testing[44]. This is as a result of farmers being mandated to soil test as part of incentivised schemes (REPS) or complying with regulation (Nitrates Directive derogation). Eleven variables are used in the model[45] with only significant variables displayed in Table 1.5.

- The age of the participant impacted negatively on odds of adoption with a ratio less than one. For each additional increase in age the odds of soil testing falls by a factor of 0.9, displaying the diminishing returns to adoption as you age (Khanna 2001). Age is associated with non-adoption of technologies as individuals find it difficult to change behaviour.

Table 1.5 Logit Model 1 Population

Explanatory Variable	**Estimated Coefficient**	**Standard Error**	**Odds Ratio (e^b)**	**95% CI**
REPS/Derogation	2.447 ***	0.417	11.5578	[1.620762 3.245148]
Dairy Platform	0.041**	0.014	1.0414	[.0134333 .0691278]
Age	- 0.054**	0.019	0.9465	[-.0912248 -.0158624]
DG Membership	0.859*	0.482	2.3608	[-.0646831 1.816524]
Soil Qual 1	-2.124**	0.742	0.1195	[-3.578212 -.6707495]
Soil Qual 2	-1.686*	0.756	0.1853	[-3.167251 -.2043723]
Log pseudolikelihood -5534.69 Pseudo R2 0.39				

Num of Obs 231. *p<0.1, **p<0.05, ***p<0.001

The soil quality variable also impacted negatively on the likelihood of soil testing. Those with better quality soil are less likely to soil test. Soil is a key resource on farms, the results show farms with widest ranging soil use (soilqual1) are less likely

[44] A weighted sample was used in the analysis based on the NFS 2009 (Connolly et al. 2010).

[45] Including expenditure on fertilizer and lime, farm gross margin and having a cashflow statement.

to test by a factor of 8.37 and the moderate range soil use (soilqual2) by a factor of 5.4. The soil with limited use (soilqual3) was automatically dropped from the logit because of multicollinearity between the other two soil quality variables. However, if included in the model with no other soil quality variables there is a positive association between it and the dependent variable. Soil testing is a site-specific technology; Khanna (2001) recognises the rationality of non-adoption of such a site-specific technology, given other factors such as soil quality. This may reflect a search routine. Farmers, who have problems with poor soil quality, seek out a solution through testing, while farmers with high quality soil are less likely to test.

In summary soil test users are more likely to:

- Participate in REPS/Derogation: z=5.87, p=0.000
- Have larger dairy platforms: z=2.79, p=0.005
- Be younger: z=-2.88, p=0.004
- Member of a discussion group: z=1.78 p=0.075
- Have soil which has not wide ranging use: z=-2.86, p=0.004
- Have soil which has not moderate range use: z=-2.23, p=0.026

Step 2: Voluntary Participants

The characteristic with the strongest predictive power for soil testing on a regular basis in the first model is participation in schemes where use of soil tests is compulsory. To investigate the effect of policy on adoption the population is split into classifications based on these findings. The classification was taken from the social psychology literature using; voluntary and involuntary users. Volitional behaviour has been a key component of social-psychology models looking at behaviour since the 1970s[46]. The voluntary use of testing is an issue which needs to be teased out, as two conflicting motivations for voluntary testing may exist: increasing production or reducing the negative environmental impact from the inappropriate application of fertilizer. Farmers are motivated by production, but also in they must be environmentally aware. To achieve a balance between these two objectives is the challenge. Therefore, it is important to understand why individuals

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[46] See for example Fishbein and Ajzen (1975)

choose to use these practices in a voluntary capacity. First the mandatory soil testers (REPS and derogation farmers) were dropped. Through eliminating the involuntary participants, the sample was reduced to 86 participants, 39 testers and 47 non-testers. Within the voluntary population, the rate of usage is much lower at 45%, compared to 70% adoption for the total sample of farmers (Table 1.4 and 1.6).

Who tests?

Again in line with the technology adoption literature and the total sample soil testers:

- Have higher incomes in terms of gross margin (t=-2.52, p=0.01) and gross output (t=-2.73, p=0.00) per hectare:
- Have larger farm size (t=-2.87, p=0.01)
- Have larger herds (t=-3.68, p=0.00)
- Have more livestock units (t=-3.09, p=0.00)
- Are younger (t=2.09, p=0.04)

Table 1.6 Descriptive Statistics Voluntary Population Users and Non-Users

Variable	**Population #86** **Mean (Std Dev)**	**Users #39** **Mean (Std Dev)**	**Non-Users #47** **Mean (Std Dev)**	**T test** **Diff! =0**
Gross Output/UAA	2043.9 (713.6)	2266.3 (727.3)	1859.2 (653.5)	**0.00**
Size of Dairy Herd (Avg)	61.4 (36.8)	76.4 (32.7)	49 (35.7)	**0.00**
Nitrogen Grazing(Kg)	5770.6 (4172.3)	7865.6 (4470.5)	4032.1 (2974.6)	**0.00**
Total LU	107.2 (73.2)	132.7 (60)	86 (77)	**0.00**
FarmGM/UAA	1121.1 (492.5)	1263.8 (476.9)	1002.7 (478.4)	**0.01**
Farm Size	59.8 (38.8)	72.5 (32.8)	49.3 (40.6)	**0.01**
Grazing Days	226.5 (28.7)	234.2 (24.9)	220 (30.4)	**0.02**
Age	50.5 (12)	47.6 (11.2)	53 (12.2)	**0.04**
Fertilizer(€)/UAA	163.5 (70.1)	179.6 (78.7)	150.2 (59.7)	**0.05**
Dairy GO(€)/UAA	1259.7 (549.5)	1371.1 (547.9)	1167.3 (539.1)	**0.09**
Direct Cost(€)/UAA	922.7 (369.0)	1002.5 (384.6)	856.5 (345.8)	**0.07**
Dairy GM(€)/UAA	632.9 (362.7)	702.4 (332.6)	575.3 (379.8)	**0.11**
Concentrates/UAA	326.7 (188.7)	337.5 (182.1)	317.7 (195.5)	**0.63**

The descriptive statistics for the voluntary population (Table 1.6) shows; the difference in mean fertilizer expenditure between users and non-users of soil testing, is on the border of significance (0.05). Furthermore, similar to the first model, the mean spend on fertiliser is bigger for the users of the practice than the non-users. For the voluntary population the difference in average fertiliser expenditure, for an average farm holding of 57.6 hectares, is in the region of €1700 for the year.

What is surprising for this analysis again is that costs per hectare (expenditure on fertiliser and overall farm direct costs) are larger for users than non-users. In the first model for the population the mean difference in expenditure between users and non-users is not significant using t-tests (0.17).

The variables chosen for the second logit model were chosen for the purpose of analysing voluntary behaviour. The remaining 86 farmers act in a voluntary capacity choosing to soil testing or not to soil test (Table 1.7).

Only significant results of the second logit for voluntary participants are displayed in Table 1.7. It highlights the importance of formal agricultural education. Farmers with formal agricultural education are almost four (3.69) times more likely to soil test. Farm size (measured by dairy platform) also has a positive impact on the likelihood of soil testing. For each additional (hectare) increase in the size of the dairy grazing platform there is a 5.5% increase in the odds of testing.

Table 1.7 Logit Model Two Voluntary Behaviour

Explanatory Variable	**Estimated Coefficient**	**Standard Error**	**Odds Ratio (e^b)**	**95% CI**	
Dairy Platform	0.0535**	.0195407	1.055	[.0152667	.0918649]
Formal Ag. Training	1.3074**	.6422673	3.696	[.0486439	2.566285]
Log pseudolikelihood -2343.51 Pseudo R2 0.27					

Num of Obs 78. *p<0.1, **p<0.05, ***p<0.001

Summary voluntary soil testers are more likely to:

- Have larger dairy platforms z=2.74 p=0.006
- Have formal agricultural education z=2.04, p=0.042

What does this tell us in terms of adoption decisions? With 70% of the population carrying out soil tests on a regular basis, but on average the users spending more on fertilizer than non-users of the practice, firstly the technology is not delivering its potential cost positive benefit. It is possible that testing of soil is viewed as a problem solving tool dealing with on-farm issues.

1.7 Discussion

What does this tell us in terms of adoption decisions by Irish dairy farmers? The objectives of this study surround the adoption of a core nutrient management tool: soil testing. It first highlights the farm and farmer characteristics of users and non-users in population. Secondly, it uses social psychology literature to identify, farm and farmers' characteristics of voluntary users in the population.

Furthermore, the descriptive findings highlight two anomalies. One is the average expenditure on fertiliser; it is higher for soil testers than non-testers. Second is the high rate of adoption coupled with low levels of fertility. These findings highlight an important issue on adoption: the adoption-innovation gap. This occurs where, the benefits of the technology are not being realised by users, and questions remain concerning the implementation of practice and the associated management decisions.

In Ireland 70% of dairy farmers test soil; 50% of Teagasc samples tested have low fertility (Figure 1.1). This raises questions left unanswered from this analysis. These questions surround the implementation and use of soil test results; this is explored in study 3 of this thesis.

Examining adoption using a dichotomous Yes or No variable does not reflect the complexities associated with decision-making on farms. As highlighted by the analysis carried out here decisions are not always based solely on profit with those adopting the practice incurring higher costs. For this reason the alternative theories are used in the second and third study. Study two uses the Technology Acceptance Model (TAM), to identify the perceptions of dairy farmers towards the use of grassland management practices. Building from the findings in this study, the evolutionary theoretical framework to guide the qualitative analysis of farmer's use of nutrient management practices: soil testing is a key decision tool (study 3 of this thesis).

Mandated Adoption/Legislation

This study raises questions about the motivations to adopt. Policies to encourage uptake of new practices, should consider end users motivations for adoption to ensure management tools, aid achievement of user goals (Pannell et al. 2006). Such goals and values include economic, social, cultural and environmental (Gasson 1973) and having relative advantage over existing technologies (Rogers 2003). The extent to which this study explores motivation of adoption is defined by examining voluntary and involuntary adoption.

There is also a need for more evidence of the factors which motivate farmers to adopt practices in a volitional capacity rather than in incentivised fashion. A reward system exists in many innovative firms and is seen as a powerful motivator of behaviour (Lawson and Samson 2001). This is important in an agricultural context given the existence of incentivised schemes introduced to encourage adoption of practices. Lawson and Samson (2001) highlighted that a rewards system must have a specific focus otherwise unintended activity blossoms. A firm must be actively engaging and implementing practices to encourage change through wanting to achieve the benefits of that practice.

This study identifies the characteristics of those farmers using soil testing on a regular basis. The findings suggest, participation in schemes which mandate adoption does not perfectly predict use on a regular basis. If participation in such schemes and regular practice use were perfectly correlated the variable would be automatically redundant in the model. This highlights the singularity associated with mandates to adopt. Seminal writers (Griliches 1957; Mansfield 1961) relate adoption to a singular activity however more recent scholars (Rogers 2003; Leeuwis 2004) view adoption as part of a social process (see p.29). This study identifies the characteristics of those adopting, it also identifies the possible impacts of adoption (soil testing) on innovation (soil fertility), highlighting the adoption innovation gap. This presents a need for relevant authorities to place an equal emphasis on implementation as on increasing rates of adoption if successful change is to be achieved through best practice adoption.

The conflicting results presented in this study; high rates of adoption, coupled with low achievement of potential benefits, stresses the importance of moving beyond the examination of rates of adoption and begin to look farmers' goals, and perceptions and ultimately; the implementation of practice. These issues are examined further in study two and three. The adoption of the technologies studied in this thesis; are essentially management decisions: the management of grass and the application of nutrients.

1.8 Conclusion

Using Teagasc NFS data this study indicates 70% of dairy farmer soil test. This high rate of adoption, coupled with low fertility levels questions, the impact of policy and regulation, on implementation and motivation for adoption. There are issues for organisational learning when adoption is mandatory; as with REPS and derogation farmers. In this case it is necessary to question if there is a long term commitment to using the practice or is adoption based on fulfilment of programme requirements?

The impact of mandated policy adoption, on implementation is significant from the findings in this study. These findings have influenced the approach taken in study two and three. Study two further addresses the impact of policy, exploring the impact of social influence, social groupings and perceptions of farmers, towards using grassland management practices.

A second consideration, which could be explored further in the study, is establishing if the benefits of the technology correspond with the objectives of the farm. In a system where it is mandatory to adopt practices this is not considered. Objectives of dairy farmers are explored in study two using a nationally representative survey.

Gains in productivity with adoption may vary with the heterogeneous characteristics of the farms (Khanna 2001) as do the reasons for adoption. This study argues that beyond the characteristics of the farm, the capabilities literature also may have a significant role to play which is explored later in the dissertation. This is extended in study three, using an implementation study.

Land management practices such as nutrient management and grassland management are specifically focused on utilizing land as a resource. This marks a switch away from what is the focus of the majority of agricultural research, financial indicators per livestock unit or her hectare return. The volatility of market prices for fertilizer does little to stabilise farm profits. Particularity, the dairy sector returns are based per cow rather than return from the land itself as a resource. It seems the focus on the farms largest asset, the land, its utilization and appropriate management, is where there is potential to improve efficiency in Ireland.

In this study, soil testing is a management intensive technology. It requires the development of a skill: implementing the soil test results, and furthermore, the development of an overall farm nutrient management capability. Soil testing is a management intensive technology, it is also important to identify cohorts of adopters; as a targeted approach can be taken by relevant bodies to encourage practice uptake. However, based on the findings in this study, it is necessary to develop skills concerning implementation of a technology for innovation to occur. The farmer, who is the end user, is of key importance in terms of adoption and innovation. Study two and study three of this thesis focus on the farmer. Study two focuses on objectives and perceptions of farmers. It uses a social psychology model to quantitative compare the use of farm and farmers characteristics with, farmer objectives and perceptions, in predicting intention to adopt six grassland management practices. Study three focuses on the experience of farmers, using twenty qualitative interviews; it details the implementation of nutrient management practices, at farm level.

2. Study two: Perceptions of Irish Dairy farmers toward the use of grassland management practices.

2.1 Introduction: Perceptions and Social Influence

It is widely accepted in the social psychology literature that perceptions or attitudes are extremely influential in decision making. Traditional economics literature largely ignores this when studying decision making. More recently, aspects from the social psychology literature are used in the agricultural economic literature on adoption. This is the first study to apply the Technology Acceptance Model (TAM) to a nationally representative sample of Irish dairy farmers. The objective of the study is to compare the strength of traditional socio-economic and demographic variables with theorised TAM beliefs in predicting intention to use grassland management practice.

This study identifies perceptions of Irish dairy farmers towards using six grassland management practices. The Irish research on adoption of these practices is scant (Creighton et al. 2011; McDonald et al. 2013). This study uses a nationally representative survey instrument based on TAM (Davis 1989) to examine the proposed constructs which determine usage for a nationally representative dairy population. Socio-economic and demographic information were also gathered and used as a comparative set of variables in this study to predict the same intention variable. The focus is on six grassland management practices (GMP): (1) grass budgeting (2) grass covers (3) reseeding (4) rotational grazing (5) grass wedge and (6) spring rotational planner.

The analysis and results are presented in three stages. The first stage examines descriptive statistics of the population and identifies farming objectives using Principle Component Analysis (PCA) based on 21 statements. The second stage identifies the perceptions and intention of all dairy farmers, towards the use of six grassland management practices. This is carried out using regression analysis, presented as three sets of models. The second stage also contains the comparative analysis is based on correct classification. It uses the predicted probabilities of each model and compares them to the intention outcome, across the models. The third stage addresses social influence.

Stage two contains the main findings of the study. It is separated into two steps. The first step examines six TAM models with ten independent variables including socio-economic, demographic and objective characteristics of farmers to predict the probability of intention to use GMPs. Results conclude the TAM perception factor is a key driver of intention to use. This is a consistent result across all six practices. The second step of analysis uses two separate models to compare the power of the TAM and objective models against models using socio-economic and demographic variables, both predicting intention. Results again indicate the strength of the TAM model in predicting intention to use for all six practices. The probabilities of model residuals are compared using classification tables, comparing prediction with outcome. They indicate the strength of TAM in predicting the intention to use practice.

The third stage of the analysis focuses on the users of the practice. This step measures social influence (Kelman 1958; 2006). It firstly identifies the nature of 'Kelman' social influence (Compliance, Identification and Internalisation) felt by users. Findings indicate the Internalisation effect was most widely felt by farmers for all six practices. Farmers adopted practice because they believed in and wanted to adopt. Secondly, it identifies the social groupings which are influential in the creation of a social pressure to act. Results indicate discussion groups were the most influential social group for most recently introduced practices[47]. While family were most influential for the more established practices[48]. The third step compares the Kelman effect and the two most important social influential groups: discussion groups and family. The compliance feeling, users which felt they had to do practice, identified the family as most influential for all six practices. The identification and internalisation effects are most influenced by discussion groups for the more recently introduced practices.

[47] Grass Budgets, Grass Covers, Grass Wedge and the Spring Rotational Planner.

[48] Reseeding and Rotational Grazing.

This study makes three distinct contributions to agricultural technology adoption literature. Firstly, it is the only Irish application of TAM to a nationally representative population. It is the only application examining grassland management practices. TAM studies have been criticised for failing to account for policy (Bagozzi 2007). This study addresses the impact of policy on intention to use GMPs, using past and current interventions. Lastly it qualitatively identifies antecedents of social influence as social groupings. This provides information on the relative influence of social groupings on adoption.

The consistency of findings recognises the strength of TAM emphasising it as a powerful tool to identify perceptions towards using a practice for the prediction of intention to use. TAM is used to identify general perceptions of dairy farmers toward the use of six grassland management practices. The diversity which exists within the population is controlled for in the models using farmers' self-reported objectives. The TAM construct, however, measuring usefulness and ease of use, is the strongest predictor of intention to use.

In comparing the predictive power of the traditional economic and TAM variables in estimating intention the results clearly support the predictive power of the TAM construct beyond the more traditional variables. This indicates the importance of farmers own personal beliefs in having a positive intention to use practice.

This study tests and deepens the TAM model. The categorical Kelman variable identifies influential social groupings and explores the Kelman effects on TAM perceptions. Furthermore, while exploring moderating demographic variables (Venkatesh et al. 2003) it also includes a policy variable estimating the moderating effect of national policy on intention to use practice. This application of TAM is part of a scarce literature on business-level adoption; generally TAM studies examine individual adoption decisions (Yu and Tao 2009). This distinction is based on adoption by individuals working within an organisation and those operating their own businesses.

The remainder of this study is structured as follows. Section 2.2 contains the literature review. It focuses on three social psychology models: The Theory of Reasoned Action (TRA), Theory of Planned Behaviour (TPB) and the Technology Acceptance Model (TAM). It also details Kelman's theory of social influence and its application in the context. The final element specifically details the GMPs studied. Section 2.3 addresses the research question, section 2.4 contains the methodology, section 2.5 holds the findings, the discussion is in section 2.6 and the conclusion is in the final section 2.7.

2.2 Literature Review

Social scientists have studied farmers in terms of their attitudes and behaviours since the 1920s (Garforth 2010). Research on grassland management has focused on the scientific benefits of the practice (Patton et al. 2012; Läpple Hennessy and O'Donovan 2012) rather than the perceptions of users. This represents an imbalance in the current Irish research in the area. The Teagasc annual National Farm Survey (NFS) reported a low uptake of grassland management practices (Creighton et al. 2011; NFS 2009[49]). By contrast results from this study show adoption rates have more than doubled over the period 2009-2013. The introduction of financial incentives for farmers to join discussion groups in 2010 as part of the Dairy Efficiency Programme (DEP[50]) may have influenced this significant increase. Discussion groups are currently the main extension tool used by Teagasc to encourage the uptake of best practice including grassland management practices.

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[49] Adoption of GMP's by Irish dairy farmers: Creighton et al. (2011) average adoption rate 18%. Grass budgeting and grass covers 15% and 20% respectively (NFS 2009). This study shows an increased to 44% and 40% (2013) respectively, see Table 2.1.

[50] The DEP was designed to promote farmer participation in discussion groups. It was funded through Article 68(1) of Council Regulation (EC) 73/2009 which makes the provision for the use of unused Single Payment Scheme funds to address disadvantages and economic vulnerability affecting dairy farmers. These funds were used to support the DEP. A total of €6m was made available in each of the following years 2010,2011 and 2012. For details on criteria and provisions see Teagasc or the DAFM website [Online] available from http://www.teagasc.ie/advisory/dairy_efficiency/ or http://www.agriculture.gov.ie/farmingsectors/dairy/dairyefficiencyprogramme/dairyefficiencyprogramme-anoverview/ [Accessed on 27/12/2013].

To explore the perceptions of Irish dairy farmers toward the use of grassland management technologies a survey was designed using TAM. This is the first application of the TAM to investigate the use of grassland management practices. TAM is the most widely used model in the information systems (IS) field (Lee, Kozar and Larsen 2003) and have been applied in examining information technology usage. Individual intention to use is determined by two beliefs: perceived usefulness (PU) and perceived ease of use (PEOU). These beliefs are defined as the extent to which using an IT will enhance job performance and the degree to which the use of the IT will be free from effort respectively (Davis 1989; Davis, Bagozzi and Warshaw 1989; Venkatesh and Bala 2008).

Flett et al. (2004) were the first to apply the model to agriculture. There have been five applications in total to the broad agricultural literature. Two in the dairy sector (Flett et al. 2004; McDonald et al. 3013), two applications to use of precision agriculture tool (Adrian, Norwood and Mask 2005; Reichardt et al. 2009) and one agricultural study focused on agricultural students (Hooker et al. 2009). The studies have used a number of methods and have applied various aspects of the model: using structural equation modelling (Adrian, Norwood and Mask 2005) and in a mixed methods study (Reichardt et al. 2009). Both studies support the TAM constructs of PU and PEOU for the use of precision tools. TAM was also used to examine student use of online web-based course management system of an agri-food marketing database for students (Hooker et al. 2009).

The use of TAM in Reichardt et al. (2009) is less well defined while Hooker et al. (2009) define PU and PEOU constructs using a single question. Of the four applications of TAM to agriculture only three are comparable to previous TAM research (Adrian, Norwood and Mask 2005; Flett et al. 2004; McDonald et al. 2013). These studies use a number of items to identify the TAM constructs of PU and PEOU and the questions are clearly defined. The additional of more than one item increases the strength of the scale in measuring the latent factors (PU and PEOU). McDonald (2013) is the only other application of TAM to the Irish context. The thesis study is currently under review for publication. The findings are based on new entrants to dairying, the TAM constructs are supported.

Studies examining adoption of agricultural technologies tend to focus on the scientific and economic benefits without alluding to the role of attitudinal factors. By contrast, this is strength of the TAM. It fails, however, to account for social influence. This study has incorporated a social influence variable as it is generally seen as important in agricultural (Vanclay 2004; Macken-Walsh 2009). Later TAM models have incorporated social influence variables (Venkatesh and Davis 2000). This study uses one variable to identify social influence and another variable to identify the group most influential. The development of the variable is based on the work of Herbert Kelman which was the basis of the more recent TAM work (*ibid*).

The development of a social influence variable in TAM research, using the work of Herbert Kelman, has taken two specific approaches. It has been incorporated into TAM 2 as an antecedent to PU as two variables (Venkatesh and Davis 2000): subjective norm[51] and image. Other studies have viewed it as a psychological attachment to decision making (Malhotra and Galletta 2005) or as a locus of causality[52] (Malhotra, Galletta and Kirsch 2008).

The impact of social influence is one that is of interest in an agricultural context. Capturing the effect of the Irish DEP programme introduced in 2009 was essential. As part of the DEP, attendance at discussion group meetings, which promote the use of grassland management practices, was mandatory. Thus, discussion groups were hypothesised as a potential social influence. In an attempt to capture it, a variable was designed using the theoretical framework of Kelman (1958).

Kelman's theory addresses social influence in terms of a change in opinion. What was of interest to Kelman is the process of attitudinal[53] change. It is only when the

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[51] "Subjective norm" are perceived social pressures to perform (encourage or discourage) behaviour (Ajzen 1991, Rehman et al. 2007).

[52] "Locus of causality" differs from "locus of control", it is concerned with what controls a person's outcomes, "locus of causality" is concerned with why a person behaves (Deci and Ryan 1985 cited in Malhotra, Galletta and Kirsch 2008). For further work on "locus of control" in agriculture see Nuthall (2010).

[53] The term attitude (see Table 2.1) is taken in it's broadest sense to include attitudes, opinions, beliefs and images which all represent "attitudinal variables" (Kelman 1958).

nature and depth of attitude change is known that influence, intention and behaviour can be established (Kelman 1958). The TAM constructs: PU and PEOU are captured, in this study at one point in time and so a change could not be estimated. The Kelman variable was used to capture the effect of social pressure on current perceptions and to identify influential social groupings.

Rules, roles and values are properties of the social system and the individual (Kelman 2006). Kelman (2006) identifies theses as useful concepts for social-psychology analysis they are interrelated, but analytically separable. Each of the components *rules, roles and values* represent a set of standard behaviours of individuals and *compliance, identification and internalization* are in effect, designed to meet each of these standards respectively (*ibid*). A categorical variable was developed as a self-assessment of the adoption behaviour. This variable identified if there was a feeling of Compliance, Identification or Internalisation associated with their decision to adopt a particular practice. Each farmer was then asked to identify a social group to which this assessment was attributed as most influential. These questions are a self-assessment of the level of reasoned feeling for using a grassland management practice and secondly to identify the social grouping which had the greatest influence on this.

Social Psychology Models

Understanding and predicting behaviour at an individual level is the focus of social psychology models. They are used in a wide range of research areas including health (Humphreys Thompson and Miner 1998) consumer behaviour (Thompson and Thompson 1996) education (Greenfield and Rohde 2009) and more recently this methodology had been used in the agricultural literature in the UK (Garforth et al. 2006; Rehman et al. 2007) and Ireland (Läpple and Kelley 2010). The majority of these models focus on an individual's ability to accept new technology within specific conditions (Greenfield and Rohde 2009).

The major constructs of all such models are attitude, intention and behaviour. They are most severely critiqued for failing to account for the intention-behaviour "gap" which exists. The relationship between these constructs is complex and earlier models[54], discussed in the next section, use summative product terms to identify global measures for these constructs. They have been viewed as difficult to interpret given the relative importance of these attitudes and beliefs are unaccounted for in the models[55].

In terms of analysis these data are described using data reduction techniques to evaluate the responses into groupings. In using a theoretical model to structure a survey the more appropriate technique is confirmatory factor analysis (CFA) which is a type of structural equation modelling and is used to explore theorised relationships between observed variable measures (items) and latent (factor) variables (Brown 2006). Exploratory factor analysis is a type of factor analysis: similarly to CFA it explores relationships between items and latent constructs although the relations are not heavily hypothesised a priori.

CFA is more appropriate in testing hypothesised relations when using a model; however, exploratory analysis is normally the first step in accessing the data. The issues of constructs and analysis of data is discussed in greater detail in the next section specifically in relation to the three main models the Theory of Reasoned Action, the Theory of Planned Behaviour and the Technology Acceptance Model.

Theory of Reasoned Action (TRA)

Prior to 1970s much work carried out in social psychology was in the area of attitude-behaviour prediction. The term attitude was *"characterized by an embarrassing degree of ambiguity and confusion...attributed to its use as an explanatory concept"* (Fishbein and Ajzen 1975). The sense of 'frustration' in the literature, having spent decades developing the concept of attitude and behaviour, (Lynne 1995), was rooted in the misapplication of the term. The clarification of the relationship between attitude-behaviour as "*a given action…always performed with respect to a given target, in a given context, at a given point in time*" by Ajzen and

[54] The Theory of Reasoned Action (TRA) and The Theory of Planned Behaviour (TPB)

[55] Bagozzi (2007) summarises the issues placing an emphasis on beliefs. Bagozzi (2007) proposes a shift towards goal setting in identifying predictors of such constructs also highlighting the lack of group, cultural and social effects in decision making.

Fishbein (1977 p.889) is described as an article which saved the literature (Lynne 1995). Many concepts were incorporated within the label of "attitude"; therefore its measurement required clarification (Fishbein and Ajzen 1975). From this work Fishbein and Ajzen (1975) developed the conceptual framework for the first social-psychology model, the Theory of Reasoned Action (TRA).

The TRA gave a framework to the theoretical work of the past. It is regarded as the parent model. Prior to Fishbein and Ajzen (1975) there was no clarity in the literature and often the measure of evaluation (attitude) was specified wrongly as for example: opinion, satisfaction, prejudice, intention, value, belief (*ibid*). Herbert Spencer (1862) was one of the first social psychologists to employ the term "attitude" (Ajzen and Fishbein 1980). The term was developed using psychometric methods applied to the variable and attitude was identified as the potential action toward an object, which may be favourable or unfavourable (Thurstone 1931).

Fishbein and Ajzen (1975) recommended that attitude be measured on bi-polar scales given its definition (favourable or unfavourable evaluation). The psychology literature did not reflect the complexity associated with the concept of attitude, but rather, the widespread agreement (Fishbein and Ajzen 1975). It is such that *affect* is the most essential aspect of attitude (*ibid* p.11).

Table 2.1: Definition of TRA framework

Age-Old Trilogy[56]	TRA	**Operational Definition**
Affect	Attitude	Feelings toward & evaluation of object/person/issue
Cognition	Belief	Knowledge, opinion, beliefs & thoughts about object
Conation	Intention	Action with respect to object

[56] Referred to in Fishbein and Ajzen 1975 pp.11/12. Although attitude theorists tend to agree with these three classifications they seldom use them. The authors take these classifications and apply them to the TRA concepts of Attitude, Belief and Intention. When dealing with the area of attitude there is a concern with predisposition rather than behaviour itself and so the use of the "age old trilogy" underpins the main constructs of the TRA.

Consequently this has an impact on how concepts are measured. In making the distinction between the use of the attitude, belief and intention, Fishbein and Ajzen (1975 p.13) made the following explicit divisions.

1. Attitude should be used when there is strong evidence that measure places an individual on a bi-polar *affective* dimension.
2. Belief should be used when the measure places the individual on a dimension of subjective probability relating an object to an attribute.
3. Behavioural intention represents the probability dimension of the relationship linking the person to the behaviour.

These distinctions gave a solid grounding to the definitions of attitudes as: (1) an individual feeling towards (a general measure), and (ii) a belief about a specific thought (an exact measure). There was an increasing interest in decision making behaviour of individuals in the 1980s which resulted in two dominant social-psychology models emerging from the literature: the Theory of Planned Behaviour (Ajzen 1985; 1991) and the Technology Acceptance Model (Davis 1989). Both emerged from the Theory of Reasoned Action (Fishbein and Ajzen 1975). The psychology literature suggests, users' intention to use, is the best single predictor of actual system usage (Davis and Venkatesh 1996). However, the intention-behaviour assumption is viewed as one of the most uncritically accepted assumption in social science research (Bagozzi 2007).

The TRA is based upon the premise that the individual is free to act. It does not take into account: lack of opportunities or resources such as time, money, skill (Thompson and Thompson 1996) ability, experience and co-operation of others (Sheppard, Hartwick and Warshaw 1988). However, Fishbein and Ajzen (1975) never intended the model to deal with objects goals or outcomes, but rather, to address behaviours under volitional control (Bagozzi 1992). Volitional behaviour is an action that a person is able and intends to perform; furthermore, its execution has no factors to prevent it.

The TRA focuses on the attitude towards the behaviour at the peril of the attitude towards the object. As stated already it is a joint estimation of an attitude relating to a given action, performed with respect to a given target, in a given context, at a given point in time (Ajzen and Fishbein 1977 p.889) cited in (Lynne 1995). The question here is it attitude towards the behaviour (adoption of technology) or attitude towards the object/target (technology) which is of relevance in answering the questions asked in this project? The TRA looks at the decision makers' overall attitude towards performing behaviour given certain constructs (behaviour, target, context, time). It may represent an assessment of the decision overall and the first step in the decision making process where the decision makers identifies his behavioural intention (BI). The second step then is to look at the specifics of the target/object independently, which the TRA has explicitly failed to look at (Ajzen and Fishbein 1980). It has been successfully used in the agricultural literature (Garforth et al. 2006) incorporating principle component analysis to extrapolate the weightings on intention (Rehman et al. 2007), looking at the relative importance of each. This study is interested in eliciting, specific beliefs about a specific object, in this case grassland management practices.

The Theory of Planned Behaviour (TPB)

The TPB is an extension of the TRA, made necessary given the limitations of the TRA in dealing with, behaviour not under complete volitional control. The TPB added a third construct, perceived behavioural control (PBC) (Ajzen 1991). The model has three independent predictors (attitude, subjective norm and perceived behavioural control) which individually contribute to intention behaviour (*ibid*). Behaviour is influenced by other factors outside of attitude and the subjective norm, PBC includes ability and factors which impede or facilitate performance of behaviour (Ajzen 1991). The Theory of Planned Behaviour defined PBC through two theoretical frameworks, facilitating conditions using Triandis (1979) and self-efficacy using Bandura (1977; 1982) cited in Ajzen (1991).

The main focus is on the intention-behaviour relationship as in the TRA, in general: the stronger the intention, the more likely to engage in behaviour. Ajzen (1991) distinguishes three types of beliefs: behavioural (attitude), normative (subjective norm) and control (PBC). The performance of most decisions depends on opportunity and resources, which represent actual control of performing behaviour, for example: time, money, skills (Ajzen 1991) for which the TRA was criticised (Thompson and Thompson 1996).

The development of the three main constructs in the TPB (A, SN and PBC) and consequently the TRA constructs (A and SN) are not without criticism. There are established links between behavioural beliefs and attitude, between normative beliefs and subjective norms, and, between control beliefs and perceived behavioural control, the exact form of these relations is uncertain (Ajzen 1991). The moderate correlations which exist between, individual belief-based measures and global measures of behaviour, may indicate the expectancy-value model does not adequately describe combined individual responses in generating a global response (*ibid p.179, p.198*). The use of these product terms in establishing independent constructs in forming an intention to perform behaviour has limitations. The beliefs sets have been deemed *monolithic* and therefore may not consistently relate to attitude (Taylor and Todd 1995). The belief set referred to looks at the summation of belief on the one hand and an evaluation on the other.

The relationship between attitudes (beliefs, evaluation) subjective norm (belief, motivation) and intention is complex. In determining the separate constructs each term is measured using a bipolar/unipolar scale and the sum of each product term forms the basis of the intention construct. There are difficulties in using such scales to measure constructs. The rankings are successful in identifying major influences on behavioural intent; the relative importance of each intention, however, is unclear (Rehman, et al. 2007). It is at the level of beliefs where the literature can advance in realising the specific factors which induce an individual to engage or not to engage in behaviour (Ajzen 1991) and research going forward should place an emphasis on salient beliefs (Bagozzi 2007).

Technology Acceptance Model (TAM)

Originally, the TAM emerged from a need to evaluate the market potential of emerging Personal Computer based applications, to guide investments in new product development for IBM Canada (Davis and Vanketesh 1996). It is adapted from TRA. Its application in past research has been discussed. This section first addresses the disparities which exist between the TRA/TPB and the TAM. Then it discusses the main TAM constructs. The TRA is the theoretical base for identifying the TAM constructs, two belief constructs: perceived usefulness (PU) and perceived ease of use (PEOU).

The strength of TAM can be seen in its large number of empirical applications in varied disciplines and contexts (Venkatesh, Davis and Morris 2007). The second strength of TAM is its structure, with strong evidence to support the main constructs (PU and PEOU) as determinants of intention (Venkatesh and Davis 2000). Its strength as a model is its parsimony however; it is also its weakness (Bagozzi 2007). One of the biggest criticisms of TAM is the lack of usable knowledge for managers (Lee, Kozar and Larsen 2003). The focus in the literature is now at the level of beliefs.

TAM: Perceived Usefulness (PU) and Perceived Ease of Using (PEOU)

The main constructs of TAM are the belief variables, PU and PEOU. The discussion on perceived usefulness was suggested by the work of Schultz and Slevin 1975 and Robey (1979) cited in Davis (1979 p.320). Davis (1989) found the literatures which support PU and PEOU are self-efficacy, contingent decision behaviour and adoption of innovations as the three main theoretical frameworks from which these constructs emerged. PU is defined as the prospective user's subjective probability that using a specific application system will increase his or her job performance. It has been identified as the most critical belief given its direct effect, (Davis 1989). PEOU is defined as the degree to which the prospective user expects the target system to be free of effort (Davis, Bagozzi and Warshaw 1989). These two constructs have been found to be distinct on two counts as psychological constructs and as statistically distinct dimensions in a number of studies which exert direct effects on acceptance and usage behaviour (Davis, Bagozzi and Warshaw 1989) a technology may be perceived as useful, but not easy to use.

The accumulated body of knowledge from the various fields provide a comprehensive support to the constructs of PU and PEOU although improved measures are needed to gain insight into the nature and roles of the constructs in technology adoption (Davis 1989). Much work has been carried out on the determinant of these constructs (Davis and Venkatesh 1996; Venkatesh and Davis 2000). In terms of the usage and relative importance of the constructs PU has outperformed PEOU in determining intention.

TAM versus TRA/TPB

The direct effect of the constructs in the TAM is a key difference between it and the TRA. The TAM belief constructs are chosen a priori and are designed to be applied across populations. However, the design of the TRA (and TPB), is such that, belief constructs are elicited from the specific population and so are contexts/population specific. The major construct in the TRA model is attitude toward a particular behavioural intention. The intention being completely mediated by the attitudinal constructs (Davis and Venkatesh 1996). In TAM the basic concepts determine intention to use. The constructs of TAM are, as discussed, the individuals considered opinion toward technology usage, in terms of their perception of usefulness (PU) and perceptions of its ease of use (PEOU).

TAM is the only model with which a singular variable directly influences behavioural intention (BI). The BI and actual usage relationship is assumed to be voluntary for farmers as the assumption of Davis, Bagozzi and Warshaw (1989) assumed computer usage would be for managers. Another possibility which could be applicable to the farmer was identified by Bagozzi (2007) in looking at collective intentions where farmers may have to consider others in their decisions on for example, a family farm. The “I-intention” examined by TAM changed to a “We-intention” in the case of a potential user’s self-conception as a member of a particular group (*ibid*). If this is the case then this study assumes an individual who runs a family business will tailor the response accordingly and automatically adjust for their particular situation. The importance of the family in farm business is evident from the literature (Vanclay 2004). It is for this reason this study can be considered part of the business-level adoption literature, rather then, the individual adoption literature.

The Models

The three intention-based models discussed have dominated the social psychology field, applied in a range of contexts. They emerge from the same expectancy value genre as utility theory (Rehman, et al. 2007). The recent criticisms of such models have led to a realisation that, the shortcomings of the neo-classical theory and the expectancy-value formulation may not describe, the process of combining individual beliefs to produce global measures (Ajzen 1991 p.198).

The TRA and TPB models are based upon the summation of product terms in explaining and understanding the intention-behaviour relationship. The use of product terms summed to form one condensed term is difficult to understand in terms of analysis.

Bagozzi (2007) called for the abandonment of summated multiplicative models for four reasons:

1. Current models treat all pairs of beliefs as equal obscuring the differential contributions of salient beliefs.
2. Such constructs fail to allow for underlying structure of salient beliefs existing in memory. The summation of beliefs will not reveal how specific components of knowledge affect the decision making process.
3. Summative terms do not account for relationships among salient beliefs.
4. The terms are not ratio scaled. It is necessary to model the constructs using multiple regression analysis however; this is problematic (independence of variables, measurement error-reliability of product terms, multiplicative model undistinguishable from additive plus multiplicative model)

In choosing a model for examining the adoption of technology it must be noted that all of the models assess a global issue at an individual level. The problem most cited in the works which have been explored in this literature review has been that of self-reporting of beliefs, generally using either bipolar/unipolar scales. The issue being the arbitrariness of the decision made. Flett et al. (2004) suggested using a method to overcome this where a more objective measure is obtained from experts who act as objective raters of the technologies.

TAM was chosen based on its extensive use in the literature its well defined scales and its powerful results beyond the other competing models. TAM has outperformed its parent model TRA and the TPB and its constructs are well defined. The simplicity of its structure and it's elicitation of individual beliefs are its strongest features. The main rationale for choosing TAM is its ability to elicit specific beliefs at the individual level, this is appropriate for owner managers such as farmers.

Social Influence: TAM

The major critique of TAM is the absence of a social influence variable. None of the five agricultural studies using TAM have explored social influence. TAM 2 (Venkatesh and Davis 2000) reintroduced social influence as an antecedent to PU using Herbert Kelman (1958). In the original TAM the Kelman processes: compliance, identification and internalisation, were excluded from the final TAM. Its influence did not impact intention to use beyond PU, a need for further investigating was highlighted based on its difficulty to disentangle direct effects of social influence on behavioural influence, from indirect effects via attitude (Davis, Bagozzi and Warshaw 1989; Venkatesh and Davis 2000).

Subjective Norm (SN) variable was excluded from the final TAM model due to its uncertain theoretical and psychometric status and its surprising lack of significant relationship. This was based on previous research in the IT field which stressed the importance of management support and user involvement. The explanation for this unexpected relationship was based on two rationales. One was a weak SN scale; the other rationale for non-inclusion was the technology itself. Word processor was deemed a personal and individual choice and so may be less driven by social influence. They justified this by comparing Word with, what they describe as a more multi-person application such as, e-mail or project management. Further work on how to generalise their findings was recommended in examining technology usage under various social conditions and within social groupings. The research results on the inclusion of social norm have been mixed in comparing the TPB (Mathieson 1991) and the TRA (Taylor and Todd 1989) to TAM. It is incorporated into an extended TAM2 model as two social influence processes (SN and image) (Venkatesh and Davis 2000) described as antecedents of perceived usefulness with three other cognitive instrumental processes[57].

The composition of the latent factors in TAM 2 is based on Kelman's (1958) processes of social influence: compliance (C), internalisation (IN) and identification (ID). The latent factors are subjective norm (C, IN) and image (ID). The addition of a social influence to the TAM has been explored in the literature, but from an individual standpoint rather than from a considered group or culture in looking at the social aspects of decision-making and usage (Bagozzi 2007).

Social Influence: Kelman and TAM

Herbert Kelman's (1958; 1974; 2006) social influence theory differentiates between changes that are temporary and superficial and those that are long lasting and integrated into the value system of an individual. Kelman called for a framework to be used when "opinion data" attempts to predict subsequent behaviour (Kelman 1974). The framework suggested, is based on three social influences processes: compliance, identification and internalisation. These processes of social influence meet three social influence standards: rules, roles, and values respectively (Kelman 2006). This framework was used to identify such social influences, but more specifically to identify the social groupings that influence such a feeling.

Conditions for change, induced by social influence, are the basis of Herbert Kelman's early 1950s work. He differentiated between, temporary and superficial change and change that is lasting and integrated into an individual's value system (Kelman 1974). The basis of his framework relates to three social influences: compliance, identification and internalisation. Recognising the importance of social influence occurring within the larger social context, the three processes are reconceptualised within the context of the social system (Kelman 2006). This refers to the society, organisation, or group to which individual acceptance of influence is directed (*ibid*). The addition of a social influence to the TAM has been treated in a unidirectional sense (Bagozzi 2007).

[57] Job relevance output quality and result demonstratability, these relate outputs of the system to individual's requirements.

In a family run business and specifically in the agricultural context, social influence and the influence of family in decision making is important. Farming is considered socially as a way of life rather than an occupation (Vanclay 2004). Viewing the farmer and their associated decision making, as part of a wider social or cultural group, is much closer to reality than from an individual standpoint. It is from this perspective that the TAM was extended to include an adapted social influence variable grounded in the Herbert Kelman (1958) framework. This study examines the perceptions of Irish farmers in the dairy sector regarding the adoption of grassland management technologies using the main TAM constructs. In addition it identifies the Kelman social influence effect. Due to space limitation in the survey, this study could not be measured using three separate questions. It identifies Kelman through using exclusive categories based on the three Kelman processes as a categorical variable. More importantly the use of a categorical variable allows for the identification of influential social groupings and their associated Kelman effects. This is of greater importance for this study as it allows for the qualitative differentiation each social group has on adoption.

The three Kelman processes are: internalisation, identification and compliance. Since the original article 1958 the definitions of these processes have largely remained the same. The theory was extended in 1961 which expanded on the antecedent conditions characterising each construct. These differentiated the basis for behaviour for each social influence. The antecedents for change are as follows:

- What is the basis or importance of change for the individual? Is it a social effect (C), an anchorage in society (ID) or value congruent (IN).
- What is the source of power for induced change? Is it on the basis of control (C), attractiveness (ID) or credibility (IN).
- What is the manner through which change is achieved? Is it limitation of choice (C), delineation of role requirement (ID) or reorganising a means-end framework (IN).

The magnitude of the antecedents may vary. The induced change may be based on varying degrees of importance or an influencing agent with varying degrees of power or extent to which the change becomes a “distinguished path”. The expansion of these antecedents and consequences lead to an inference of motivation or conditions for opinion formation, the aim being to predict the future course of an opinion knowing the conditions under which it was formed (Kelman 1961, p77).

Kelman did however, add a further dimension to the original theory to analyse the relationship between individuals and the social system, in terms of adherence to *rules* involvement in its *roles* and sharing its *values*, the three processes of social influence meet these social influence standards respectively (Kelman 2006 p.12).

Definitions of the processes (Kelman 2006):

- *Compliance*: In accepting influence via this process, an individual is assured continued access to rewards and approval (or avoiding punishment/penalties and disproval). The stability of the decision depends on surveillance by parties, outside powers.

- *Identification*: It reflects the orientation to the role of system member, and/or other roles within the system, not just as a set of behavioural requirements, but as an important part of an individual's self-definition. In accepting influence via this process, members are meeting the expectations of their system roles, thus maintaining their desired relationship to the system and their self-defining relationship as fully embedded in these roles. This is described by Kelman as a pragmatic partnership in which new images and relationships are formed, but remain vulnerable to change, as change may trigger old attitudes.

- *Internalization*: reflects an orientation to system values that the individual personally shares. In accepting influence via this process, members live up to the implications of these shared values, thus maintaining the integrity of their personal value framework. This allows for the internalization of new attitudes, integrating this new or changed value, into their own identities; the decision is less vulnerable to situational changes.

Kelman sought to differentiate between qualitatively different, though not mutually exclusive, groups. The depth and nature of change induced by social influence is what is of interest, it is the level of integrated change. The use of Kelman in this study is explored in two ways. First it is used to investigate if TAM perceptions of respondents differ based on the self-chosen "Kelman effect" (Table 2.15) of social influence to adopt practice. Secondly it identifies the groups who are acknowledged as influential in respect of these perceptions (Table 2.17). The Kelman variable is employed as a categorical variable; it is the focus of this study to identify influential social groupings. The identification of social groupings in respect of the Kelman effect gives insight to influencers of change to target such groups as a vehicle to sway perceptions and intentions to change. Kelman suggests it is not enough to know there has been some measurable attitudinal change it is also necessary to know, what kind of change has taken place. It is only when the *nature* and *depth* of the change is established, can meaningful predictions be made about how this change will influence intention-behaviour (Kelman 1958). This study focused on the use of Kelman given the relative importance of social influence and influential agricultural policy implications.

Kelman and the Irish Dairy Sector

The identification of the Kelman effect is important in examining the potential long-term impact of discussion groups and the Dairy Efficiency Programme (DEP) introduced in January 2010 on the adoption of key practices. Discussion groups are the main tool used to promote the use of grassland management practices. Although they also act as a tool for the promotion of other practices, the main focus is on grassland management practices. As part of the DEP scheme a financial incentive of €1,000 per annum was given to farmers to join discussion groups and implement a work programme. Kelman's framework is used in this study to estimate the type of social influence experienced by adopters of the key grassland technologies. Farmers are asked to identify the biggest influence on, the Kelman effect, through identifying social groupings.

Compliance occurs where a party has power over certain "reward" the other wants. Described by as a means-control relationship where the influencing agent has the ability to supply or withhold material or psychological resources on which the achievement of the individual's goal depends (Kelman 2006 p.4) it is important to estimate if these groups actually did influence the farmer.

The Kelman effect was measured using the following question asked of each practice:

The example given here is grass budgets.

Q. Are you using grass budgeting because:

1. You feel you have to do grass budgeting
2. You feel you should do grass budgeting
3. You believe in and want to do grass budgeting

This follow-on question was asked to identify the social group influencing the Kelman effect:

Q. What is the biggest influence on the reason you just outlined:

1. Family
2. Neighbours
3. Discussion Group
4. Other (Please specify)

This study examines the farmer perceptions, but also attempts to capture the social influence through the Kelman effect.

In conclusion, less attention has been placed on understanding attitudes and perceptions for decision making in the agricultural literature compared to the social-psychology literature. However, the social psychology literature has been incorporated into some decision making studies in the agricultural literature. Within this literature there has been no direct comparison between the use of traditional socio-economic or demographic explanatory variables and the use of psychology variables. In the TAM literature the theory have been incorporated into existing models (Reichardt et al. 2009; Hooker et al. 2009), as additional explanatory evidence to support decision making. Contextual variables have been included into the TAM model (Adrian, Norwood and Mask 2005). The TAM model has also been applied (Flett et al. 2004) directly without formally comparing the strength of explanatory power. The superiority of strength of social-psychology variables is assumed. However, the simple structure of TAM exhibits significant explanatory power given its well-developed scales in explaining intention to use practice. This study compares the strength of predictors of intention using traditional economic variables with farm attitudinal variables using TAM.

2.3 Research Question

Research Question:

- Are latent factor social variables more appropriate in predicting intentions to use practice than more traditional measurable variables?

- What type of social influence impacts adoption of practice and who are the most influential social groups?

The Agricultural Context

This section outlines the agricultural context. It identifies the technologies being studied.

Grassland Management Practices

Six grassland management practices are examined in this study. The GMPs were developed in the 2000s investigating herbage mass measurement (O'Donovan et al. 2002). Proven to increase grass utilisation (Shalloo et al. 2004) and improve overall efficiency (Kennedy et al. 2005, Shalloo 2009), they exhibit low rates of adoption (NFS 2009; Creighton et al. 2011). The introduction of a policy initiative, the Dairy Efficiency Programme (DEP) in 2010 is of interest to this study. The DEP encouraged participation in discussion groups indirectly promoted the adoption of these practices.

Each practice has a functional role to play throughout the grass growing season. They are also interdependent practices. Rotational grazing and reseeding are the two most widely adopted grassland management practices. The least widely adopted practice is the grass wedge.

This section details each practice, it is based on the Farmers Grazing Notebook[58], the Teagasc Dairy Manual, informal discussions with advisors and attending a number of discussion groups as an observer.

1. Rotational grazing is based on the planned movement of herds on a rotational basis from one paddock to another, while the grazed paddocks recover and regenerate. The time animals spend in each paddock is based on the herd size and the ground conditions. In general, during spring and autumn a 12 hour period is recommended. Paddocks may also be fenced off into sections, this avoids damaging the ground and conditions for grass re-growth (poaching). In dryer conditions, paddocks are made larger and animals may spend up to two days in a paddock. The size of paddocks is based on animal numbers.

2. Reseeding occurs when a new grass seed is chosen to replace current seed, which may no longer be producing the required output. Spring is the most appropriate time to reseed with a targeted 60 day turn around between seeding and first grazing, at covers of 600-700 kg DM/ha (see 4. grass covers).

3. The spring rotational planner is used at first date of turning out cows to grass. Generally in early February a proportion of the farm is allocated to the cows daily based on farm cover targets. Farm cover targets (see 4.grass covers) are calculated on a weekly basis for paddocks. The spring rotational plan is a grazing plan. General recommendations are provided as a guide to get cows out to grass as early as possible. Such action represents a daily saving up to €2.70 per cow in the spring time (Kennedy et al. 2005). The saving is represented through substituting grass for alternative feeds.

   The plan has two main elements: (1) to apply urea as soon as is permitted under regulation and (2) to target grazing areas. Urea is a chemical fertilizer similar to nitrogen which encourages grass growth. It is more readily

[58] Available at http://www.agresearch.teagasc.ie/moorepark/Publications/pdfs/Open%20Day%20Moorepark%202009%20Grazing%20Manual.pdf accessed on the 08/09/2013.

absorbed by grass in the spring as the climate is colder and conditions are generally damper. As the year progresses nitrogen is applied as it is more readily available for the plant in dryer conditions. The targeting of grazing areas is the second element. A targeted area of grazing is apportioned to the animals, the area is increased on a daily basis during February and March. These targeted areas are based upon the average farm covers. The example given in the Farmer's Grazing Notebook, begins the first grazing on February 1st. By the end of that week 7% of the farm is grazed and by the last week of March the animals have 100% of the farm grazed. It is recommended the farmer reduce feeding concentrates to animals over this period.

By late March a grass only diet is recommended. The reduction of alternative feeds should be on a gradual basis. The post-grazing height of grass is also an indicator, if height is 4cm or more the herd is over fed and feeding of concentrates should cease. The planned second rotation then begins on the first week of April. There are other conditions and tips given to farmers for such a plan to be successful. It gives the farmer the flexibility to change as the conditions allow. During wet conditions, on/off grazing strategies apply ensuring cows do not damage pasture. It is recommended to stick closely to the increasing targeted grazing area for successful planning. Furthermore, the poorest performing paddocks should be identified for reseeding and the use of clover which is a natural source of nitrogen is recommended to improve grass sward. The use of organic slurry (diluted) is also recommended in the spring with the remainder used for crop (silage) paddocks.

4. Grass covers are based on a representative square meter of grass which is cut and weighted. The weight is multiplied by the estimated dry matter (DM) in the grass. This DM is calculated based on weather conditions, the season, but mainly rainfall: the greater the levels of rainfall the lower the DM in the grass. It is also based on the quality of the grass. The DM will be lower if the sward is green and leafy. To calculate a grass cover a 0.5 meter x 0.5 meter quadrant is placed on a representative area of the grass in that paddock. The

grass is clipped and weighted. This weight is multiplied by the estimated DM and weighted up to the hectare using the following formula:

Weight of grass (kg) x DM% x 40,000 kg DM/ha in the paddock.

There are 40,000 quadrants in a hectare and DM ranges from 12%-23%. These estimated figures are available for farmers on a weekly basis from Teagasc and through the Irish Farmers Journal which give estimated regional figures. The calculation of grass covers feeds into an annual grass budget, but also into the grass wedge and the spring rotational planner. Paddock cover calculation is the key measurement tool in grass management. However, it is generally advocated that measurement is not enough and it is also equally important to anticipate change and project growth rates. This allows for more informed decision making and potentially anticipated demand and supply of grass.

5. Later in the grazing season a grass wedge is recommended to determine the supply of herbage mass per paddock. Ideally paddocks are of similar size. It focuses on yield between 1,100-1,500 kg DM/ha. The grass wedge is an extension of grass cover calculations. It is a more precise tool used during periods of high growth so as to provide the farmer with more accurate information on grass growth. It allows a farmer to record pre and post grazing measurement. On a weekly basis a paddock cover is entered to a software package which creates a visual representation of yield in each paddock and for the overall farm targeted cover. The pre-grazing measurement is then compared to post grazing levels. This automatically calculates the growth rate for that week. The residual is the post grazing figure. This is designed to improve decision making.

   Stock types and relative intake of grass from stock type is accounted for on the day of measurement. It accounts for the level of concentrates given to animals in that week, aiming at increasing grass intake and reducing alternative feed. There are also other options to record fertilizer applications and milk quality in any particular week. The grass wedge is automatically updated as information is inputted. It also records and saves the changes. The main function is to identify the grass demand and project future grass demand a week in advance by entering an expected growth and expected levels of livestock at grass.

6. On a more long term basis a grass budget, beginning on any particular week runs for a 52 week period. Starting out a projected grass cover figure is estimated for the week ahead. The projected covers form a line graph for the year. This line graph is then adjusted according to the actual measurement. A grass budget is a data entry tool using a specialist package. Budgets are estimated, based on stocking rate number of animals at grass and figures available on regional conditions growth and consumption. Weekly the actual grass covers are inputted and automatically impact the projected budget line for the farm. As the weeks progress from spring the numbers of cows at grass increases as the cows calve down and return to milking. The grass dry matter is estimated to increases as the spring moves to summer.

2.4 Methodology

This section first outlines the survey instrument and data collection and then details the analysis of the nationally representative survey in four steps.

Data

The TAM survey (See Appendix B) was designed as part of a wider Teagasc work programme. The survey was implemented, face to face, by Amarach an Irish Survey Company. Amarach were provided with a sampling frame, stratified in terms of region and herd size (Table 2.2). From this sampling frame Amarach filled quotas, to derive a nationally representative sample. Amarach surveyed 389 Irish dairy farmers during the autumn of 2013. The criterion for selecting farmers for interview was based on number of dairy cows. The number of dairy cows on the holding was required to be greater than 50% of all other animals to proceed with the survey.

The questionnaire was designed as part of a larger Teagasc research programme. Data used in this study is based on partial analysis of the wider survey (See

Appendix B). The survey questions were designed in conjunction with the Principle Investigator of the Teagasc work programme, Dr. Kevin Heanue. The questions were based on the TAM and Kelman's social influence literatures. Questions on farming objectives were designed using 21 statements adapted from Willock et al. (1999) and Flett et al. (2004).

The only other input to the questionnaire design was from Amarach. This was in relation to the number of points used on the Likert scale. They recommended, due to redundancy of responses in previous work in the agricultural sector, a five point scale as opposed to the seven point scale used in the original TAM (Davis 1989) scale. The data was returned in a spreadsheet where the data cleaned. This included individually checking variables and scanning data for inaccuracies and checking the sampling code frame. Thereafter the initial descriptive statistics were carried out.

Table 2.2 Region and Number of Dairy Cows

Region	<= 24	25-35	36-51	52-69	70+	Total
1	15	14	8	7	7	51
2	0	0	1	0	1	2
3	3	8	7	7	11	36
4	2	4	4	7	14	31
5	13	7	8	10	4	42
6	12	15	11	14	15	67
7	30	32	33	32	23	150
8	3	2	3	0	2	10
Total	78	82	75	77	77	389

1= Louth, Leitrim, Sligo, Donegal, Monaghan

2= Dublin excluding NFS farms due to small sample.

3= Kildare, Meath, Wicklow

4= Laois, Longford, Offaly, Westmeath

5= Clare Limerick, Tipperary N.R.

6= Carlow, Kilkenny, Wexford, Tipperary S>R>, Waterford

7=Cork, Kerry

8=Galway, Mayo, Roscommon

Methods

Logit analysis is used to identify the probability of a farmer to: have a positive intention to use practice or not. Success is indicated by having a positive intention to use the practice. The binomial distribution is based upon the success or failure of an event occurring. Bernoulli trials estimate the probability of success (s) is one minus the probability of a failure (p), denoted s = 1 – p. The probabilities are based on a number of independent variables controlled for in the model. A mix of variables were chosen from the survey using socio-economic and demographic variables which rely on more traditional economic theory, but also variables used the social psychology literature including TAM (Davis 1989) and farming objectives (Willock et al. 1999), described in the next section.

Six logit models were carried out. The first set of models use a stepwise regression to identify significant variables, when using both socioeconomic and demographic, and the latent factor variables. The choice was based on eliminating any bias in choosing variables. As there are ten variables chosen it was decided not to simultaneously include all variables it was thought a stepwise regression was a better alternative than subjectively choosing and eliminating manually. The limitations in using stepwise regression models are well documented. Such include the overestimation of parameters as an automated best fit is chosen. The procedure of forward selection, backward elimination to fit the best subset selection is conducted automatically. A stepwise regression model was used across all six model, all six were subject to the same methodological biases. The sample and variables used are consistent in all six models. The chosen variables are well established based on existing literature. In conducting the logistical regression simultaneously the results would not change the conclusions drawn. The latent factor variables are far superior predictors. Goodness-of-fit post-estimation tests determine whether variation in the model residuals are small, follow the model specification and are not systematically clustered. Hosmer et al. (1997) identify three assumptions by which model fit is specified:

1. Logit transformation is the correct function linking the covariates with the conditional mean

2. The linear predictors are correct (inclusion of additional variables, transformations or interactions)
3. The variance is Bernoulli distribution

Pearson's chi-squared examines the sum of square differences between observed and expected cases per covariate pattern, divided by the standard error (Archer and Lemeshow 2006). The statistic is dependent on the number of covariate patterns and the number of independent covariates in the model. When continuous variables are used in the model, this test is not effective since the number of distinct covariate patterns can be equivalent to the sample size (Archer and Lemeshow 2006). The distribution of the covariate pattern is a function of the controlled variables.

Hosmer and Lemeshow (1980) developed a test to overcome this issue through grouping on deciles of risk. This is the percentiles of the estimated probabilities in the model: the differences between observed and estimated frequencies in cells. This is estimated using the Pearson chi-squared statistic which displays contingency tables displaying expected frequencies less than one (Hosmer et al. 1997).

The Hosmer and Lemeshow test groups participants. A chi-squared test is then estimated using the amalgated cells (Archer and Lemeshow 2006). The major concern with this test is the procedure in choosing numbers of groups. The standard or default number of groups set is 10. By changing the number of groups specified, the results change dramatically. The statistic depends on the choice of cut points used to define the groups (Hosmer et al. 1997).

The results of a non-significant goodness of fit test should not be evaluated in isolation. Rather it is an indicator of fit which may prompt the researcher to search for more appropriate models (Evans and Hosmer 2004) particularly in relation to the test assumptions (Hosmer et al. 1997). For this study the observed and estimates predicted values are compared for each model. They are estimated by STATA using the *estat* command. The observed and predicted values are compared using classification of the probabilities as stated below which indicates how well the model correctly predicts the outcome (Long and Freese 2006).

Predicted probabilities range from 0-1.Each model predicts individual probabilities based on the controlled variables in the model. These predicted probabilities are visually and statistically compared for each practice, in Figures 2.1-2.6. A binary variable is generated to compare the number of predicted cases compared to the number of actual outcomes. By defining the predicted probabilities as:

$$\hat{y}_i = \begin{Bmatrix} 0 \; if \;\; \pi_i \; \leq \; .5 \\ 1 \; if \;\; \pi_i \; \geq \; .5 \end{Bmatrix}$$

Where π_i is the predicted probability of the i the individual. This permits the comparison of predicted probabilities from each model with the actual outcome. This gives an indication of the overall model fit of the predicted probability accurately predicting outcome.

2.5 Findings and Discussion

This section details the findings from the survey in three stages. The first stage identifies the characteristics of the population in terms of their socio-demographics and adoption rates of grassland management practice. This section also identifies the objectives of Irish dairy farmers using principle component analysis. The second stage analysis uses the TAM construct in a regression analysis. It identifies the probability of intention to use grassland management practices chosen. The third stage focuses on users only. It focuses on social influence, based on Kelman's theory it identifies the level of social pressure on action. It also identifies social groupings which have had the most influential impact on the social pressure to act.

Stage 1: Survey Profile and Farming Objectives

Socio Demographic

All participants are owner operators of specialist dairy farms, with the number of dairy cows greater than 50% of all other animals on the holding, 92% are male.

Almost 60% of households have no person under 18 years of age with 52% of houses having 3 persons in the house, 30% of farmers had identified a successor. As regards the future, 13% plan to exit or an unsure about dairy in the future, a total of 48% of farmers intending to increase milk output post quota removal in 2015. The reasons for not intending to expand related to satisfaction with current output (18%) or no access to land (15%). A further 10% refer to the required increase in labour with increased output. These findings are in line with NFS findings. The next section compares most recent NFS rates of adoption of GMP with adoption rates from the TAM survey, the empirical setting for this study.

Table 2.3: Descriptive Characteristics

Variable	Mean	Range	Frequency (%)
Farm Size	52 (32)	9-283	
Dairy Platform	30 (19)	.4-182	
Age	52 (11)	22-79	
Num. Cows	58 (48)	10-450	
Yrs. Farming (main holder)	27 (13)	1-60	
Agri-Education			68
Teagasc Client			58
Discussion Group			42
Dairy New Entrant			8
Received Derogation			73
Successor identified			30
Employment (off-farm)			18
(N 389)			

Adoption of Grassland Management Practices (GMPs)

The results in Table 2.4 indicate rotational grazing and reseeding are the most widely adopted practices. The adoption of measurement practices: grass covers and grass budgets from the NFS are in line with Creighton et al. (2011) however, adoption rates from this study shows considerable increase in adoption.

A total of 78% of participants use both rotational grazing and reseeding practices. While 37% are using both grass budgeting and grass covers, 30% are using both the spring rotational planner and the grass wedge.

Table 2.4 Usage: Specialist Dairy Farmers

Practice	Using (%) NFS 2009	Using (%) TAM Survey 2013
Rotational Grazing	93[†]	85 (n= 386)
Reseeding	54[°]	81 (n= 383)
Spring Rotational Planner	-	51 (n= 381)
Grass Budgeting	15	44 (n= 387)
Grass Cover	20	41 (n= 384)
Grass Wedge	-	35 (n= 382)

[†] NFS question: How do you allocate grass to cows controlled grazing? Controlled grazing included the use of paddocks (30%), 12-48 hour grazing (23%) or 12 hour strip grazing (40%).

[°] NFS question: Have you reseeded 10% or more of the holding in the last three years?

There appears to be a significant increase in the adoption of the measurement of herbage mass (grass budgeting and grass covers) from these two separate surveys carried out in the years examined (Table 2.4). These separate surveys (NFS and TAM) both use a nationally representative sample of Irish dairy farmers. The definition of what constitutes a dairy farmer is as follows. The definition of a specialist dairy farmer according to the NFS classification is based on EU farm typology as per Commission Decision 78/463 using standard gross margins (SGM) for each type of farm animal and each hectare of crop. The definition of a specialist dairy farmer is based on the proportion of the total SGM of the farm which comes from the main enterprise after which the system is named. The name refers to the dominant enterprise. The NFS is an annual survey carried out on a sample of Irish farmers. The sample can change from year to year however it largely is remains the same.

The TAM survey was carried out in August 2013 on a nationally representative sample of dairy farmers. The sample selected based on a sampling frame devised by the Teagasc Surveys Department and quotas met, stratified by region and size (see Table 2.2). The TAM survey defines a dairy farmer as one if their inventory of dairy cows is greater than 50% of all other animals on the farm.

The apparent increasing trend in the usage of GMP as seen in the two sets of survey results (Table 2.4) could be attributed to the increased numbers of farmers participating in discussion groups. This has increased by 10% from (NFS 2009) to forty two percent according to the TAM survey (2013). This is also based on the introduction of the DEP scheme in 2009, which required farmers to conduct a specific work package relating to management of grass through discussion groups, this also had an impact on usage.

In terms of multiple practice use, there is a strong positive relationship between some groups of technologies, for example the more established practices reseeding and rotational grazing. The strongest relationships are highlighted in Table 2.5. The correlation only gives an indication of the groups or types of practices that are used by farmers.

Table 2.5 Correlations among practices

	Grass Budgeting	Grass Covers	Rotational Grazing	Reseeding	Grass Wedge	Spring Planner
Grass Budgeting	1.000					
Grass Covers	**.799****	1.000				
Rotational Grazing	.284**	.319**	1.000			
Reseeding	.311**	.282**	**.629****	1.000		
Grass Wedge	**.620****	**.695****	.280**	.301**	1.000	
Spring Planner	.443**	**.534****	.298**	.275**	**.507****	1.000

The interrelationships between the use of practice is likely to relate to their complementarily. The use of grass covers to generate grass budgets and consequently a grass wedge is evident in the strength of the correlation between the practices. The generation of a grass cover also feed into the planning of rotations in spring.

Farming Objectives

The identification of farmer objectives allows the analysis to investigate the differences which exist between like-minded farmers groups, based on responses to statements in the survey sample.

In this study, attitudes[59] of farmers are used in conjunction with traditional economic variables and social psychology variables to identify predictive power of intention to use. First farmers were asked to attribute a level of importance to 21 statements (Table 2.6) using a five point Likert scale ranging from: Not very important to me-extremely important to me. These statements are then grouped. Using data reduction methods: Principle Component Analysis (PCA) groups statements together based on similar responses from farmers.

The top five objectives relate to land maintenance and structure. The objective with the highest mean ranking was preventing pollution. The mean ranking of statements however, provides limited information. To identify farmers' objectives in terms of grouped variables the PCA is used in the second stage of objective analysis. The farmers individual objective scores are grouped together reflecting the factors. These factors compromise of objectives which load together for the sample. Each participant is attributed a factor score based on his scoring of individual objectives.

PCA was conducted on these data. It assumes a common variance and does not discriminate between shared and unique variance (Costello and Obsourne 2005). There are two types of rotation orthogonal and oblique. The former produces factors that are uncorrelated while oblique rotation allows factors to correlate which is more likely in the social sciences. The first rotation used all 21 farming objectives as items, using an oblique rotation assuming the items are correlated.

Prior to the factor analysis data are scanned. If multiple items from the correlation matrix are below .3 then exclusion should be considered (Field 2009). The correlation matrix indicates patterns of relationships between the items in this case farming objectives. If any of the correlations are excessively large, nearing singularity there is a need again to consider removal.

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[59] The term "attitudes" is used here to describe the response (positive or negative) of farmers towards a group of statements which load together. The statements reflect their farming objectives.

Table 2.6 Objectives

Farming Objectives	Mean	Std. Deviation
Preventing pollution	4.61	0.65
Leaving land in as good a condition as you received it	4.55	0.68
Producing high quality products	4.54	0.60
Minimising risk in farming	4.53	0.75
Keeping debt as low as possible	4.46	0.81
Maximising profit	4.43	0.77
Utilising your resources fully	4.37	0.77
Having the best livestock/pastures	4.29	0.70
Being environmentally friendly	4.26	0.85
Spending time with the family	4.25	0.85
Maximising production	4.25	0.88
Using chemicals sparingly	4.17	0.96
Meeting challenges	4.06	0.86
Having the respect of other farmers	3.97	1.06
Reinvesting in the farm	3.86	1.08
Being innovative by using new technologies/practices	3.85	1.09
Having up-to-date equipment and machinery	3.72	1.18
Having a successfully diversified farm	3.36	1.32
Expanding the business	3.35	1.26
Trying new varieties of livestock/crops	3.05	1.28
Entering and winning competitions/shows	2.12	1.31
Valid N (389)		

The Kaiser-Meyer-Olkin (KMO) measuring sampling adequacy ranges from 0-1 and is recommended to be a minimum of .5 (Kaiser 1974). The KMO (.890) and Bartlett's test of Sphericity (x^2 =3069 p=.000) both indicate the data is suitable for factor analysis.

When factors are rotated using these 21 objectives, three factors emerge. These factors reflect the common variance between items in the data, compared to the starting position of PCA which assumes a common variance of 1. The communalities for the data indicate item fit. Low values of <.3 could indicate an item does not fit well and is also reflected in the factor loadings (Pallant 2010). None of the communalities presented were below the threshold.

The rotation identifies the factors or linear components in the data set. They are called eigenvectors. These represent the weights of each variable and they provide loading for each vector on a factor. Eigenvectors and eigenvalues describe the shape (height and width) of data (Field 2009). The factors loadings for each objective are then compared. These loadings are linear components (eigenvectors) within the data before extraction. Therefore, there are 21 eigenvectors for these data. The eigenvalues determine the importance of each eigenvector[60].

Initially two rotations were conducted on the data. Both rotations, oblique and orthogonal, revealed a three factor model. Each factor represents the variance explained by that particular linear component given as percentage of the total variance explained. The rotation has an optimizing effect on the variance explained, the factor structure indicates the relative importance of each factor is equalized (Field 2009).
The reproduced correlation matrix compares the original correlations with the reproduced correlations presented by the model. The residual correlations between the observed and the model are below the threshold of 50% (Field 2009). If the model was a perfect fit the residual would be zero as correlations would be equal. SPSS provides a summary statistic for a good model. The residuals should be below 0.05 (Field 2009), for this model 44% of the correlations are >0.05, passing the threshold of 50%.

The model reveals the shared variance between factors. The three factors in this model using Kaiser criterion, were retained. The factors explain 51% of total variance. The first factor accounts for 31% of variance, after rotation the factor structured are optimized; this equalisation addresses the relative importance of factors (Field 2009). The common variance explained by factor items, which prior to rotation is assumed to

[60] The default in SPSS is the Kaiser criterion. It retains factors with a value greater than 1.

be one, are the communalities. These are produced after rotation. Communalities indicate an accurate variance for each item. All items were retained.

Table 2.7 Factor Component Matrix

Farming Objectives	Factor 1 Experimental	Factor 2 Conservative	Factor 3 Productive
Q43_29 Having a successfully diversified farm	**.731**	.029	.098
Q43_17 Trying new varieties of livestock'/'crops	**.699**	-.009	.021
Q43_35 Expanding the business	**.690**	-.090	.341
Q43_34 Entering and winning competitions'/'shows	**.651**	-.115	-.253
Q43_15 Having up-to-date equipment and machinery	**.602**	.257	.226
Q43_26 Being innovative by using new technologies/practices	**.602**	.130	.437
Q43_19 Reinvesting in the farm	**.596**	.205	.404
Q43_30 Meeting challenges	**.584**	.171	.378
Q43_20 Having the respect of other farmers in the community	**.506**	*.484*	.025
Q43_9 Keeping debt as low as possible	-.018	**.706**	.052
Q43_21 Using chemicals sparingly	.224	**.703**	.063
Q43_23 Leaving land in as good a condition as you received	-.019	**.673**	.342
Q43_10 Being environmentally friendly	.201	**.647**	.118
Q43_13 Minimising risk in farming	.008	**.632**	.300
Q43_25 Preventing pollution	-.110	**.605**	.223
Q43_12 Spending time with the family	.086	**.430**	*.418*
Q43_5 Maximising profit	.226	.075	**.734**
Q43_6 Producing high quality products	-.003	.371	**.649**
Q43_1 Utilising your resources fully	.060	.188	**.632**
Q43_32 Maximising production	*.442*	.102	**.620**
Q43_3 Having the best livestock'/'pastures	.157	.280	**.539**
Valid N (389)			

These factors scores were saved for use in further analysis. It is assumed the factor scores are correlated and are saved using regression method scores are used as weights in an equation (Field 2009). Each individual is scored for each factor. Table 2.7 is the rotated component matrix which identifies the items and respective factor loadings.

Three factors represent attitudes of dairy farmers. The factor names were chosen by the author, reflecting the groups of statement items. The factors are identified as: experimental, conservative and productive which relate to their farming objectives. This is a self-selection process where farmers rank a number of statements on the relative level of importance of each statement (Appendix B).

Each individual is then is given a score weighting for each statement. The high factor loadings are highlighted in bold. Three items had high cross factor loadings in italics, maximizing production (32), spending time with the family (12) and having the respect of other in the community (20). These factors were retained on theoretical grounds.

Orthodox economic literature would suggest maximizing production is a key objective and the wider social science literature recognizes the importance of family and community in the farming context. These factors are scored and used as variables in the regression analysis to examine the relationship between farmer's objectives and their intention to use grassland management practices.

Having identified the objective factors the TAM latent factor perception variables are derived. Through using factor analysis the theorised TAM perception variables, Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), are discussed in the next section. These variables are used in predicting intention to adopt with the objective factor variables.

Stage 2: Logistical Regression Analysis Intention to use practice

The factor analysis from this study suggests the theorised TAM factors are measuring one construct not two. The two structure model (PU and PEOU) does not exist as suggested from wider TAM literature (Lee, Kozar and Larsen 2003) in this study. Previous applications in the dairy context (Flett et al. 2004; McDonald 2013) and precision agriculture studies (Adrian, Norwood and Mask 2005) show factors to load as separate constructs.

This latent factor is called the TAM perception factor, and is used in the regression analysis. GMP involves a certain level of specialist skill, there may be conflicting characteristics associated with this technology; its concept of managing grass on the farm is quite simple. It is currently being implemented at some level on most, if not all farms. The design of the technology is very scientific and it is complex in its implementation. This TAM survey examines this relationship between the usefulness of the grassland practices and the ease of use of these practices as one TAM perception factor.

There are two measurement reasons relating to survey design which may present a rationale for this unanticipated result in this study. One is the weakness of the second PEOU latent factor, measured using two items as per Flett et al. (2004). It is recommended multiple indicators are used to measure concepts[61] when no direct measurement is available (Bryman 2008). The introduction of more item indicators may have improved the strength of the global PEOU factor. Six items were used in the original Davis (1989) scale. The second weakness in the measurement of these scales is the format of the scale itself. Generally the formats of scales vary in terms of three areas, the number of categories, the labelling of categories and the use of a midpoint (Weijters, Cabooter and Schillewaert 2010). A five point scale was used to measure each TAM construct. Given the weighted positive responses to the scale items for all practices, this unwillingness to report a negative response may suggest a positive oriented scale may have been more suitable. The pilot carried out by the survey company was not indicative of this as a potential issue.

Based on the exploratory factor analysis the seven items are measuring one factor. This is called the TAM perception factor and is used in regression analysis as a variable. The approach taken in the analysis used a logistical regression model to identify the probability of adopting a grassland management practice using the TAM perception and intention factors as explanatory variables. The factors in a logit analysis investigate the impact of the TAM constructs on the probability to adopt a practice. Based on these variables for all practices the TAM constructs were positive

[61] The categorisation of common features in observations or ideas is generally thought of as a concept (Bryman 2008).

and significant as was membership of a discussion group. The first step is to use a logistical regression model to estimate the probability of chosen variables on the positive intention to use a technology. The rationale for using intention to adopt is based on the TAM. It is theorised that intention to adopt in the next 12 months is used rather than actual use, as it reflects your future intentions. Ten variables[62] were used in the regression analysis. Based on these variables for all practices the TAM construct was positive and strongly significant as was having access to specialist grassland management advice.

TAM Perception latent factor (PU and PEOU)

Each scale is checked to indicate the reliability of its items. The primary checks on scales relate to the internal consistency of each scale, it examines the degree to which each item accounts for the overall. Each perception scale had strong internal consistency across practices. Reliability given by Cronbach's alpha also indicates strong scale measure. The degree to which each item correlates to the overall PU is given by the corrected item-total correlation (Table 2.8).

Reliability

The item total correlation (ITC) matrix indicates items are measuring the same characteristic to the overall perception factor. The item total statistic gives an indication of how much each item correlates with the overall score for that practice.

The lowest correlated item is saving time; this is as expected and is consistent across all six practices. The item saving time if removed from reseeding and rotational grazing scale would improve the Cronbach's alpha marginally; however, it was left in as it did not impact on reliability of the scale. The high Cronbach's alpha suggests good internal consistency for each scale in the sample. Reliability of scores indicates item suitability for summation in attaining the overall TAM perception.

[62] Perception, total lu/ha, third level education, farming experience, off farm job, heir, gmp advantage, intention to stay in dairying and expand, hours working on farm and income.

Table 2.8 TAM: Item Total Correlation

Practices TAM Items	Grass Budget		Reseeding		Rotational Grazing		Grass Wedge		Spring RP		Grass Covers	
	Mean	ITC	Mean	ITC	Mean	ITC	Mean	ITC	Mean	ITC	Mean	ITC
Farming needs	3.7	.823	4.34	.864	4.37	.872	3.44	.904	3.87	.909	3.65	.888
Production	3.8	.855	4.34	.891	4.37	.908	3.47	.936	3.87	.932	3.68	.917
What it replaces	3.72	.887	4.32	.857	4.31	.884	3.47	.913	3.82	.918	3.67	.923
Profits	3.77	.890	4.35	.858	4.35	.877	3.49	.927	3.84	.922	3.65	.886
Saves time	3.54	.764	3.97	.605	4.16	.710	3.40	.880	3.76	.876	3.50	.804
Understand	3.66	.854	4.34	.849	4.35	.876	3.51	.929	3.84	.917	3.65	.887
Use	3.70	.875	4.26	.835	4.30	.874	3.45	.900	3.82	.922	3.63	.922
Cronbach ∝	.940		.943		.957		.976		.977		.969	
Mean (SD)	25.9 (5.9)		29.9 (5.1)		30.2 (4.8)		24.2 (6.1)		26.8 (5.9)		25.4 (6.1)	
N389												

ITC: Item Total Correlation

TAM Perception factor

The mean total score of each scale ranged from 25-30 for the six practices. Given the differences in scores of individual items of the TAM constructs t-tests were carried out for user and non-users. The results in Table 2.10 indicate there is a statistically significant difference in the perceptions of users and non-users for all six practices. All grassland management practices were scored significantly higher for farmers using the technology in terms of their perceptions. This was as expected as users will have experienced the benefits of practice.

Table 2.10 Mean TAM Perception for users and non users.

Practice (n=using, not using) Mean TAM perception	**Using**	**Not Using**	**t-Test (df)**
Rotational Grazing (n=328,58)	31.1	24.9	t (384)= 10.1, p<0.000
Reseeding (n=310,73)	31.3	24.8	t (381)= 11.4, p<0.000
Spring Planner (n=193,188)	30.3	23.3	t (379)=13.9, p<0.000
Grass Budgeting (n=171, 216)	30	22.6	t (385)= 15.5, p<0.000
Grass Cover (n=156, 228)	30	22.3	t (382)= 15.6, p<0.000
Grass Wedge (n=134,248)	29.7	21.2	t (254)=16.7, p<0.001
Average TAM perception			

(Grass wedge not equal variance)

The TAM perception statements are worded positively and the responses of farmers exhibited a very low percentage disagreement with statements (Table 2.9, Appendix B). There is a statistically significant difference in perception, between of users and non users; users have higher average perception for all six practices (Table 2.10). Findings indicate significant agreement with statements from users and large neutral responses[63] largely from non-users. Most widely used practices (rotational grazing and reseeding) have an average neutral rating of 9%-11%, while all other practices have between 31%-48%[64] neutral responses. Those who ranked items as neutral or negative were largely non-users.

[63] Tables 2.9 Appendix B for more details on population responses for items.

[64] Grass budgeting 32%, grass covers 37%, grass wedge 48% and spring rotational planner 31%.

Intention: Logit analysis

Having established the perceptions of farmers towards using a practice, a farmer's intention to use each practice in the following 12 months was also measured. This is called the TAM intention factor. It was asked of all farmers whether using or not using for each practice, measured using a scale variable. Details of item responses are found in Table 2.9 (Appendix B) responses are divided into three categories: negative, neutral and positive. Table 2.11 identifies the number of users and non-users who have a positive intention to use, indicating that between 9%-28% of non-users have positive intentions to use the practices in the next 12 months.

Intention is the theorised dependent variable in the analysis. In identifying the intention of users and non-users the Eta statistic infers the percentage of variance explained by this grouping for each practice. This statistic tests the strength of difference in the intentions of users and non-user, in the next twelve months. The figures suggest there is a significant difference between the two groups. However, the magnitude of the difference is very small for grass wedge and spring rotational planner; this indicates that between 4%-5% of the variance in TAM intention is based on use. There is a moderate effect on intention for reseeding and grass covers (7%-9%). While there is a large effect on variation in TAM intention for reseeding and grass budgeting (12%-15%). This Eta statistic calculates variance as follows:

$$\text{Eta squared} = \frac{t^2}{t^2 + (n1 + n2 - 2)}$$

The distribution of the intention variable as measured from the survey is positively skewed. The responses to the TAM intention collated using Likert scales were collapsed to negative neutral and positive categories and into the binary response[65]. This measured if the farmer had a positive intention to use the practice in the coming year or not. Farmers who agree or strongly agree they will use the practice in the next 12 months as opposed to those who do not. This was used as the dependent variable in a logit analysis.

[65] For information on the seven TAM perceptions in terms of negative neutral and positive categories see Table 2.9 Appendix B.

Table 2.11 Positive Intention to use.

Practice (n=using, not using)	Using %	Not Using %	Overall intention	Eta sq (%)
Grass Budgeting (n=215)	73	27	56%	12 (t= 5.47, p=0.000)
Grass Cover (n=205)	72	28	53%	7 (t= 4.04, p=0.000)
Rotational Grazing (n=330)	91	9	85%	15 (t= 6.43, p=0.000)
Reseeding (n=309)	91	9	81%	7 (t= 4.90, p=0.000)
Grass Wedge (n=157)	77	23	41%	4 (t= 2.72, p=0.007)
Spring Planner (n=224)	76	24	59%	5 (t= 3.63, p=0.000)
TAM positive intention (mean)	**80**	**20**	**63%**	

T-tests indicate the statistically significant difference between users and non-users in terms of their positive intention to use GMPs. Users of the practice as expected have statistically significant higher mean TAM perceptions than non-users. The Eta indicates the strength of this difference.

Logit Analysis

This stage of analysis uses logistical regression analysis to predict the intentions of dairy farmers to use six grassland management practices. The variables chosen include socio-economic and demographic variables, but also social psychology variables. The TAM global measure is used in the analysis as outlined. It is a latent factor variable using seven items. The TAM intention factor is the dependent variable used in the logit analysis. The logit analysis is divided into three set of models. The first set of models use all variables in a stepwise regression. The second stage of analysis then compares the socio-economic and demographic variables with the TAM and objective variables in predicting intention to use. Results indicate the TAM and objective variables are stronger predictors of intention to use.

Variables

Ten explanatory variables used in the model were tested using simple diagnostic tests to access for outliers in the predictor variables. Findings suggest the categorical and binary variables are within specified ranges. The continuous variable age is normally distributed. However, using a histogram, farming intensity is not normally distributed.

***Dependent Variable**: Intention*: originally measured using a Likert scale is collapsed to a binary measure, intention to use. Numerically the number one represents the farmer agreeing or strongly agreeing they will use the practice in the next twelve months. The zero represents farmers who had a neutral or negative response. This variable is used as the dependent variable in the logit regression for all six practices. This is regressed against ten other variables, defined and described below.

Independent Variables

TAM perception: measured using seven Likert scale items. The scale reliability statistics indicate these items are a good measure of the latent factor (Table 2.8). The relationship between perceptions towards using a practice is well established in the TAM literature to have a strong positive effect on intention to use. The Hypothesis is: TAM perception will have a strong positive impact on intention to use.

Total livestock units per hectare: calculated based on age and animal[66]. Farm size is used as a proxy for available resources and the livestock numbers a proxy for intensity. The latter ranges form 0.3-5.9 lu/ha the mean (std. dev.) is 1.7(.68) lu/ha for the population. More intense farmers are assumed to get the most out of their resources and so farm more intensively and consequently have higher stocking rates per hectare. The Hypothesis is: Total/lu/ha will have a positive impact on intention.

Agricultural education: equates to farmers who attended fulltime specialised agricultural training and education. This included attendance at (one year) agricultural college, a full time degree or masters in agriculture or completion of the farm apprenticeship scheme. The Hypothesis is: Third level education will have a positive impact on intention.

Age: of the farmer ranging from 22-79 years. The mean (std. dev.) age of Irish dairy farmers is 52 (11.5). The effect of farming experience is assumed to have a similar

[66] Dairy cows, stock bulls and bloodstock are attributed a value of 1, other cows are calculated at 0.9, in calf heifers and cattle 1-2 years are calculated at 0.7, cattle less than 1 year are given a value of 0.4 and ewes and other sheep are calculated at 0.2. The summative effect gives total livestock units for the farm which is divided by total farm size.

effect as age of the farmer. Adoption literature suggests age has a negative impact on change. The rationale is based on more experienced farmers having established grass management strategies in place and so may chose not to change. The Hypothesis is: Age will have a negative impact on probability of a positive intention to adopt.

Grassland management advantage: farmers who are part of the DEP scheme or otherwise were member of a discussion group. These farmers have received specialised advice on grass management through these groups. The Hypothesis is: GMP advantaged farmers will have a higher probability of intention to use practice.

Future/Expand: captures those who intend to remain in the dairy sector and intend to increase output. Therefore it is assumed such farmers want to increase grass utilisation. Intention to stay in dairying and expand post 2015 is a combined variable (46%). It combines intention to remaining in dairying for the foreseeable future (81%) and those who intend to expand (48%) after the current quota system is removed in 2015. The Hypothesis is: Intention to stay in dairying and expand will increase the probability of intention to use practices.

Income: measured using six categories. Those earning less the €10,000, those earning €10k-€29,999, €30k-€49,999, €50k-€69,999, €70k-€89,999 and those earning over €90,000. This is a before tax figure which does not include the single farm payment. The higher income farmer assumed more likely to use practices. The Hypothesis is: farmers with higher income will increase the probability of intention to use.

Experimental farming objectives: include trial and diversification type statements with which these farmers agreed were congruent with their personal farming objectives of growing the business through investment and exploring new ways of doing and using practices. The Hypothesis is: having a high loading on this group of objectives will have a positive probability on intention to use practice.

Conservative farming objectives: are risk averse; their objectives are reflective of environmental or sustainable way of farming rather than production orientated style of farming. The Hypothesis is: farmers having a high loading on these groups of statement are less likely to have a positive probability of intending to adopt practice.

Productive farming objectives: consist of items which indicate the importance of increased output through utilising resources in the production of a quality product. The Hypothesis is: farmers with a high loading on these statements will have a positive effect on intention to use practice.

The names of the three objective variables (experimental, conservative and productive) were chosen by the author. This was based on the sentiment from grouped statements, identified through the PCA methodology.

Logistical Regression: Analyses

Three sets of model were run using intention to use as the dependent variable. The first models used the entire variable set above in one logit analysis. The results are displayed in Table 2.12 using a stepwise regression. The stepwise regression identifies the strongest predictors of probability of intention to use a practice. For all six models the TAM perception is the only consistent predictor of intention to use practice. TAM perception is statistically significant for all practices at the 1% level.

This findings support the large body of TAM literature which suggests perceptions towards usage significantly impacts intention to use. Through identifying perceptions of individuals the probability of intention is strongly predicted for all models. Those models including TAM have a much lower log-likelihood than models without. The likelihood is the probability of obtaining a set of observations given the model parameters; the log-likelihood is a measure of unexplained variation (Field 2009).

The significance of the TAM variable indicates it may be suppressing the predictive probability of the other regressors. The TAM measure may cause issues of collinearity between the variables. Whilst the VIF factor does not show that multicollinearity is a statistical issue, there is evidence to suggest given the predictive relationship between a number of the individual socio economic regressors and the dependent variable may be an issue for the model.

A second set of models using the traditional variables only confirm this and the hypothesized relationships are validated, the result are displayed in Table 2.13. The final sets of models were run using four variables the TAM perceptions variable and the three objective factors. The results displayed in Table 2.14 indicate the significance of TAM in the prediction of intention to use.

This section details three sets of regression models all predicting the intentions of dairy farmers to use grassland management practices. The last section compares the second set of models with the third set of models to identify the variables which more accurately predict intention to use. Two variables exhibited levels of collinearity, income and intensity. Statistically it was not problematic, but the model fit suggested they were collinear. Therefore income was dropped from the regressions. The rationale for dropping income was twofold. First is the theoretical significance of intensity for the use of management practices over income and second is this is the only variable with missing observations (n=13). The Log-Likelihood chi2 p-value is statistically significant for all models (0.0000) indicating model significance.

Model Set 1: Stepwise Regression

A total of nine variables were used in the first logistical regression Table 2.12. The TAM perception factor was significant across all practices at the 1% level. The stepwise method was used as an indicator of overall model fit. As expected the results for these models indicate TAM to be a significant factor in predicting the probability of intention to use a practice. Given the low log-likelihood and high Pseudo R2, the findings indicate a satisfactory goodness of fit.

Results Overview

- TAM perception variable predicted strongly the intention to use all six grassland management practices.
- The farmers with conservative objectives are less likely to have a positive intention to use any of the grassland management practices.
- Members of discussion groups or the DEP scheme are significantly more likely to have a positive intention to use four of the six practices.

- Having a third level agricultural education is positive and significant (5%) factor in predicting the probability of intention to use grass wedges. This is expected given the technical computer skills required to generate a digital wedge for the farm. It is also significant for rotational grazing which again was expected given choices which must. This based on the wide variety of seeds availability.
- Level of intensity is significant only for the generation of a grass budget. This may be an indicator of a need for increased planning with greater demand for grass in highly stocked farms.

There are unexpected results in the Table 2.12 specifically the relationships between experimental farmers and expansion farmers in terms of their probability to have a positive intention to use a practice. The multicollinarity statistics indicate there is no issue with interrelations between the variables.

Grass Budgeting (GB): TAM perceptions and the objective factors are significant. The effect of TAM perception variable is such that it dwarfs the effect of the other socio economic variables. Farmers with a positive TAM factor are more likely to use grass budgeting by a factor of 1.9. The odds ratios also indicates productive (1.5) and experimental (1.6) farmers more likely to have a positive intention to use budgeting.

Summary farmers with a positive intention to use grass covers are likely to have:

- TAM perceptions (z=9.42, p=0.000)
- Load higher on the experimental factor (z=1.9, p=0.057)
- Load higher on the productive factor (z=1.9, p=0.057)

Grass Covers (GC): The probability of having a positive intention to use grass covers is increased almost 2.4 times by being a member of a discussion group or part of the DEP scheme. The TAM factor is positive and a significant influence as perception increases the probability of intention to use grass covers increases by a factor of 2.29.

Summary farmers with a positive intention to use grass covers are likely to have:

- Be a member of discussion group (z=1.73,p=0.083)

- Have a positive TAM perception (z=9.138, p=0.000)

Rotational Grazing (RG): the stepwise regression has three significantly influential variables TAM perceptions is again significant. Those with higher TAM perceptions are 2.32 times more likely to have a positive intention to use rotational grazing. Farmers are 2.8 times more likely to have a positive intention to use rotational grazing if they are or have been in the DEP or are a member of a discussion group. For each additional increase in the farms total livestock units per hectare the farmer is 2.2 times more likely to have a positive intention to use rotational grazing. The probability of having a positive intention to rotational graze and have a third level agricultural education is positive and approaching significance (z=1.39, p=0.163).

Summary farmers with a positive intention to use rotational grazing are likely to have:

- Have positive TAM perception (z=6.84, p=0.000)
- Operate a farm with higher livestock units per hectare (z=1.72, p=0.086)
- Be a member of a discussion group (z=1.83, p=0.068)

Reseeding (R): Farmers with higher TAM perception are 1.4 times more likely to have a positive intention to use reseeding. Similarly, farmers who are exposed to specific management advice through discussion groups are 2.2 times more likely to have a positive intention to reseed. Farmer who loaded on the productive factor is more probable to reseed by a factor of 1.48. Also farmers who load on the experimental factor are 1.3 times more likely to have a positive intention to reseed. Having a positive intention to use reseeding in you are also more likely to have a positive intention to stay in dairying for the foreseeable future and intend to expand post 2015. Although this is not statistically significant it is positive and approaching significance (z=1.45, p=0.146).

Summary farmers with a positive intention to reseed are more likely to have:

- Higher TAM perception (z=7.47, p=0.000)
- Membership of a discussion group (z=2.30, p=0.021)
- Load higher on the experimentation factor (z=1.81, p=0.07)
- Load higher on the productive factor (z=2.12, p=0.034)

Table 2.12 Stepwise Logit (nine independent variables)

Technology	**GB**	**OR**	**GC**	**OR**	**R**	**OR**	**RG**	**OR**	**GW**	**OR**	**SRP**	**OR**
Variables												
TAM	+ ***	1.9	+ ***	2.3	+ ***	1.4	+ ***	2.3	+ ***	2.3	+***	1.9
Total lu/ha							+*	2.2				
Age												
Agri Edu.									+ **	8.9		
D.G/DEP			+ *	2.4	+ **	2.2	+ *	2.8	+ *	4		
Future exp.												
Experimental	+ *	1.6			+*	1.3			- *	0.6		
Conservative												
Productive	+ *	1.5			+ **	1.5					+*	1.4
Log-L	93.74		60.36		115.1		48.93		62.01		88.85	
Pseudo R2	0.649		0.776		0.414		0.695		0.765		0.663	
Hosmer-L	8.24		3.25		16.47		1.48		18.66		67.01	
Prob > chi2	0.41		0.917		0.033		0.993		0.016		0.00	
N 389												

***<0.001 **<0.05 *<0.1

Grass Wedge (GW): Having a third level agricultural education means a farmer is over eight times (8.87) more likely to do a grass wedge. Being a member of a discussion group or DEP means the farmer is 4 times more likely to have a positive intention to use a grass wedge that non-members. Farmers are 2.3 times more likely to have a positive intention to use a wedge the higher their TAM perceptions are. Farmers exhibiting high loading on the experimental factor are less likely to have a positive intention to use a grass wedge by a factor of 0.6.

Summary farmers with a positive intention to use grass wedge are likely to have:

- Have higher positive TAM perception (z=8.87, p=0.000)
- Have a third level qualification (z=2.94, p=0.0003)
- Likely to be in a discussion group (z=2.7, p=0.006)
- Load lower on the experimental factor (z=-1.73, p=(0.084)

Spring Rotational Planner (SRP): Two variables have an impact on the probability to use spring rotational planning, the TAM perceptions factor and the productive factor. Farmers who load higher on the productive factor are 1.4 times more likely to have a positive intention to use spring rotational planning. With each additional increase in the TAM perception factor, farmers are 1.9 times more likely to have a positive intention to use the planning tool.

Summary farmers with a positive intention to use spring planner are likely to have:

- Higher TAM perception (z=9.46, p=0.000)
- Load high on the productive factor (z=1.63, p=0.104)

Based on these finding TAM perception variable dominated the predictive probability of all other variables in the model. When trials were carried out removal of the TAM perception resulted in many changes. It was decided to investigate this further through running two separate models. Using the same set of variables, two models were run, but splitting variables used into socio-economic and perception variables. The significant differences in the variables are discussed in the next section. Models are run separately and then their predictive probabilities compared against the outcome which is the intention variable.

Model Set 2: Socio Economic

The second set of models uses the traditional economic factors listed in Table 2.13. The significance of variables increased as the TAM factors and objective factors were not controlled for in the model.

Grass Budgeting (GB): The diagnostic Hosmer-Lemeshow goodness of fit indicates this is a good model fit. The grass budgeting model shows all variables are positive and significant except age. Age however, is moderately negatively correlated (-.35) with intention to expand. Excluding this expansion variable age became significant which indicated a negative relation as expected. However, age was retained in the model due to its neutral impact on the significance of other variables in the model. For each unit increase in level of intensity (measured by livestock units per hectare), a farmer is 1.5 times more likely to have a positive intention to using grass budgeting. A farmers with a third level agricultural qualification is 2.1 times more likely to have a positive intention to use grass budgeting. Similarly, the odds ratio of intention to adopt is 1.9 times greater for farmers who intend on staying in dairy farming for the foreseeable future and expand post 2015. The strongest predictor of intention to adopt grass budgeting is membership of a discussion group or being part of the DEP at a factor of 3.3.

Summary: Farmers more likely to have a positive intention to use grass budgeting are:

- Members of discussion groups or part of the DEP z=5.18 (p=0.000)
- Operate more intensive systems z=2.34 (p=0.019)
- Intend to remain in dairying and intend to expand post 2015 z=2.69 (p=0.007)
- Have a third level agricultural qualification z=2.059 (0.040)

Table 2.13 Traditional Socio Economic & Demographic Variables

Technology	**GB**	**OR**	**GC**	**OR**	**R**	**OR**	**RG**	**OR**	**GW**	**OR**	**SRP**	**OR**
Variables												
Total lu/ha	**	1.5	*	1.4	**	1.9	*	1.7	*	1.3		
Age			- **	0.9	- **	0.9	- **	0.9	- **	0.9	- **	0.9
Agri Edu.	**	2.1	**	2.2					**	2.5		
D.G/DEP	***	3.3	***	4.1	**	2.4			***	3.4	***	2.5
Future exp.	**	1.9			***	2.9						
Log-L	228.0		221.8		167.4		143.3		223.9		210.7	
Pseudo R2	0.147		0.175		0.147		0.106		0.152		0.082	
Hosmer-L	4.47		3.03		29.88		11.95		7		2.20	
Prob > chi2	(0.81)		(0.93)		(0.00)		(0.15)		(0.54)		(0.9)	
N 389												

Reseeding (R): Farmers who intend to remain in dairying for the foreseeable future and intend to expand output after 2015 are almost 3 times more likely to have a positive intention to reseeding (2.97). Discussion group or DEP members are more than twice (2.4) as likely to have a positive intention to use as non-members. The probability of having a positive intention to use reseeding increases with stocking rate by a factor of 1.98. The older the farmer is the less likely they are to reseed by a factor of 0.9. The goodness of fit measure however, indicates this is not a good model fit.

Summary: Those who have a positive intention to use reseeding are:

- Younger z= - 2.06 (p=0.039)
- Have more intense systems z=2.78 p=0.005
- Be members of discussion groups or the DEP z=2.98 (p=0.003)
- Have a positive intention to stay in dairying and expand z=3.36 (p=0.001)

Rotational Grazing (RG): The results for the most widely used practice rotational grazing indicate the intensity variable and age are the two strongest predictors of a positive intention to rotational graze by a factor of 1.7 and 0.9 respectively. The Hosmer-Lemeshow goodness of fit measure however, indicates this is a good model fit.

Summary: Farmers who are more likely to have a positive intention to use rotational grazing are:

- More intensive systems z=1.97 (p=0.048)
- Younger z=-3.21 (p=0.001)

Grass Covers (GC): The exposure to advice on grassland practices through membership of discussion groups again is a highly significant predictor of positive intention to use grass covers with an odds ratio of 4. Farmers are 2.2 times more likely to have a positive intention to use grass cover if they have a third level agricultural qualification as someone who does not. For grass covers, age was significant predictor: older farmer were less likely to have a positive intention to use a grass cover by a factor of 0.9. Intensity was significant and positively associated with an intention to use grass covers by a factor of 1.4.

Summary: Farmers with a positive intention to use grass covers are

- Younger z=- 2.75 (p= 0.006)
- Have third level agricultural qualification z=2.15 (p=0.031)
- In a discussion group or member of the DEP z=6.28 (p=0.000)
- Have more intense systems z=1.76 (p=0.078)

Grass Wedge (GW): Those using the grass wedge those with more intense systems were 1.3 times more likely to have a positive probability to use the practice. Older individuals were less likely to use grass wedge by a factor of 0.97. Those with a third level agricultural qualification were 2.55 times more likely to have a positive intention to use a grass wedge than those who do not have a qualification. Member of discussion groups and the DEP are 3.4 times more likely to have a positive intention to use compared to non-members.

Summary: Those with positive intention to use grass wedge are more likely to be

- More intensive z=1.658 (p=0.097)
- Younger z= - 2.38 (p=0.017)
- Have third level agricultural qualification z=2.83 (p=0.005)
- Be a member of discussion group or the DEP z=5.165 (p=0.000)

Spring Rotational Planner (SRP): Those who are older were less likely to have a positive intention to use by a factor of 0.9. Members of discussion groups are 2.5 times more likely to have a positive intention to use the practice.

Summary: Those having a positive intention to use a spring rotational planner were

- Younger z= - 2.357 (p=0.018)
- Members of discussion groups z=4.07 (p=0.000)

Overall the models fit well. The only exception is the reseeding model as indicated by the Hosmer-Lemeshow statistic.

Model Set 3: TAM and Objectives

The final set of models used four variables based on individual perceptions towards a practice and their wider farming objectives. The TAM factor is significant across all models. The conservative objectives factor had no significant effect of having a positive probability to use for any practice.

Grass Budgeting (GB): The probability of having a positive intention to use is influenced by three of the four variables. Farmers with higher TAM perceptions are

1.89 times more likely to have a positive intention to use grass budgeting. Also if a farmer loads highly on either the experimental or productive factors, they are 1.49 times more likely to have a positive intention towards using grass budgeting in the next twelve months.

Summary farmers who intent to use grass budgeting are more likely to be:

- Farmer with higher TAM perceptions (z=9.815, p=0.000)
- Exhibited high loading: experimental factor (z=1.733, p=0.085)
- Exhibited high loading: productive factor (z=1.70, p=0.088)

Grass Covers (GC): In predicting the intention to use grass covers the TAM perception influences. Farmers exhibiting high loadings on experimental factors are more likely to have a positive intention to use grass covers.

Summary: Farmers with a positive intention to use grass covers are more likely to

- Higher TAM perceptions (z=9.575, p=0.000)
- Exhibited high loading: Experimental factor (z=1.71, p=0.086)

Rotational Grazing (RG): Farmers are 2.2 times more likely to have a positive intention to using rotational grazing the higher their TAM perceptions (z=7.038 p=0.000). None of the three objective variables are significant experimentation (z=1.05, p= 0.294), conservative (z=-0.65, p=0.518) or productive (z=1.18, p=0.239) factors.

Reseeding (R): Farmers intending to reseed are 1.43 times more likely to have higher TAM perception rating. They are also 1.48 times more likely to load highly on the experimental factor and 1.65 times on the production factor again the conservative factor is not statistically significant (z= - 0.608, p=0.543).

Summary farmers who have a positive intention to use reseeding in the next twelve months are more likely to:

- Higher TAM perceptions (z=7.875, p=0.000)
- Exhibited high loading: experimental factor (z=2.470, p=0.014)
- Exhibited high loading: productive factor (z= 2.839, p=0.005)

Grass Wedge (GW): Intention to use the grass wedge is influenced by the TAM perception variable. It is a statistically significant predictor of probability of intention to use (z=9.779, p=0.000). The higher the farmer's perception of the grass wedge they are 2.2 times more likely they are to have a positive intention to use the practice.

Table 2.14 TAM and Objectives Variables

Technology	**GB**	**OR**	**GC**	**OR**	**R**	**OR**	**RG**	**OR**	**GW**	**OR**	**SRP**	**OR**
Variables												
TAM	***	1.9	***	2.3	***	1.4	***	2.2	***	2.2	***	1.9
Experimental	*	1.5	*	1.6	**	1.5					*	1.5
Conservative												
Productive	*	1.5			**	1.7					**	1.5
Log-L	95.69		63.61		118.9		52.02		69.24		91.05	
Pseudo R2	0.642		0.763		0.394		0.676		0.738		0.654	
Hosmer-L	5.48		3.72		14.69		5.54		23.18		67.55	
Prob > chi2	(0.70)		(0.88)		(0.06)		(0.69)		(0.00)		(0.00)	
N 389												

Spring Rotational Plan (SRP): The use of the spring rotational planner again suggests having a positive TAM perception will result in a farmer being 1.9 times more likely to use the spring planner. Farmer's loading high on the experimental factor are 1.51 times more likely and on the productive factor are 1.47 times more likely to have a positive intention to use spring rotational planning.

Summary: farmer with a positive intention to use spring rotational planning are more likely:

- Higher TAM perceptions (z=9.845, p=0.000)
- Exhibited high loading: Experimental factor (z=2.04, p=0.041)
- Exhibited high loading: Productive oriented factor (z=2.039, p=0.041)

This section indicates the relative importance of the latent factor variables in modelling intention to use six grassland management practices. The findings suggest farmer perceptions are more appropriate in identifying intention to use practice. This is given by the relative strength of the model fit and specifications in model set one and model set two. However there are limitations with the use of such indicators. To expand on these findings further, in examining sets of variables, the next section discusses the formal comparisons, visually using predictive power and more specific classification model analysis.

Stage 2 (a) Comparative analysis

This section first visually and then statistically compares the predicted probabilities of each model specified. Two models are specified for each practice. These models are compared in terms of their predictive power to accurately identify the positive intention outcome. The goodness of fit using the Hosmer and Lemeshow test is one post estimation test. As indicated previously this may not always be the best estimate as it is based on the number of covariate patterns in the data. When using continuous variables this is can be problematic as the chi-squared[67] approximation is dependent on the number of clustered covariate values comparing observed and fitted frequencies.

Due to the unreliability of the tests when using continuous variables a comparison using predicted probabilities and outcomes was first visually inspected and compared (Figures 2.1-2.6). Then the comparisons were formally tested. This is necessary as the visual graphics only give an indication they do not show if the strength of prediction matches outcome. The formal correct classification tests are displayed in Table 2.15. Results suggest the graphics are good indicators of strength of pr

ediction. For all six models the TAM perception factor and objective factors outperform the socio-economic and demographic variables in terms of their prediction of individuals' intention to use practice. This is consistent across all six practices.

[67] Chi squared is a non-parametric statistic used for goodness of fit or as a test for independence.

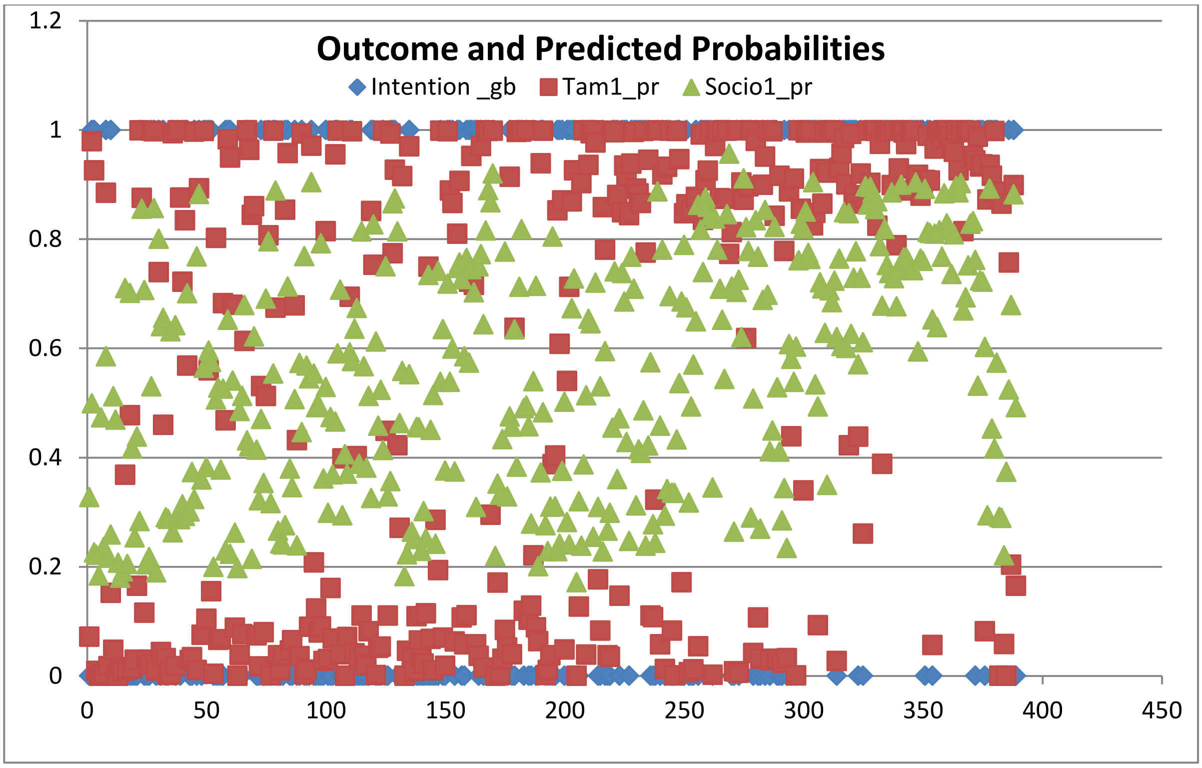

Figure 2.1 Predicted probabilities: Grass Budgeting

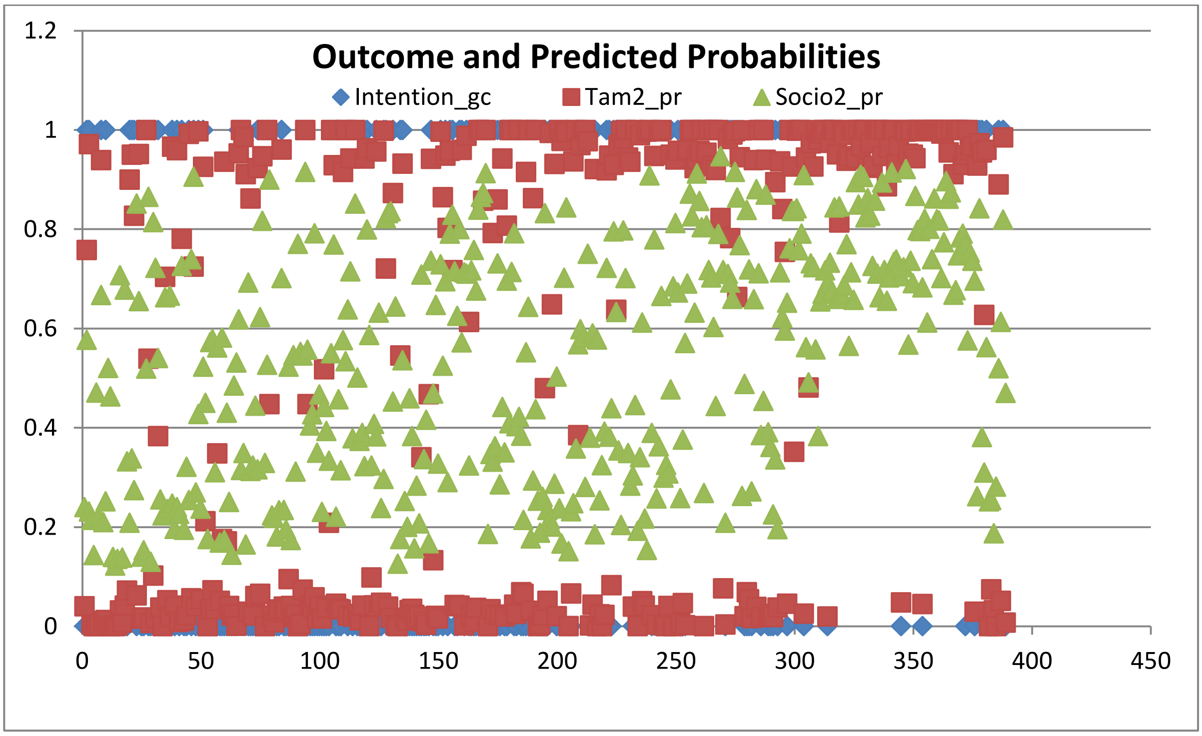

Figure 2.2 Predicted probabilities: Grass Covers

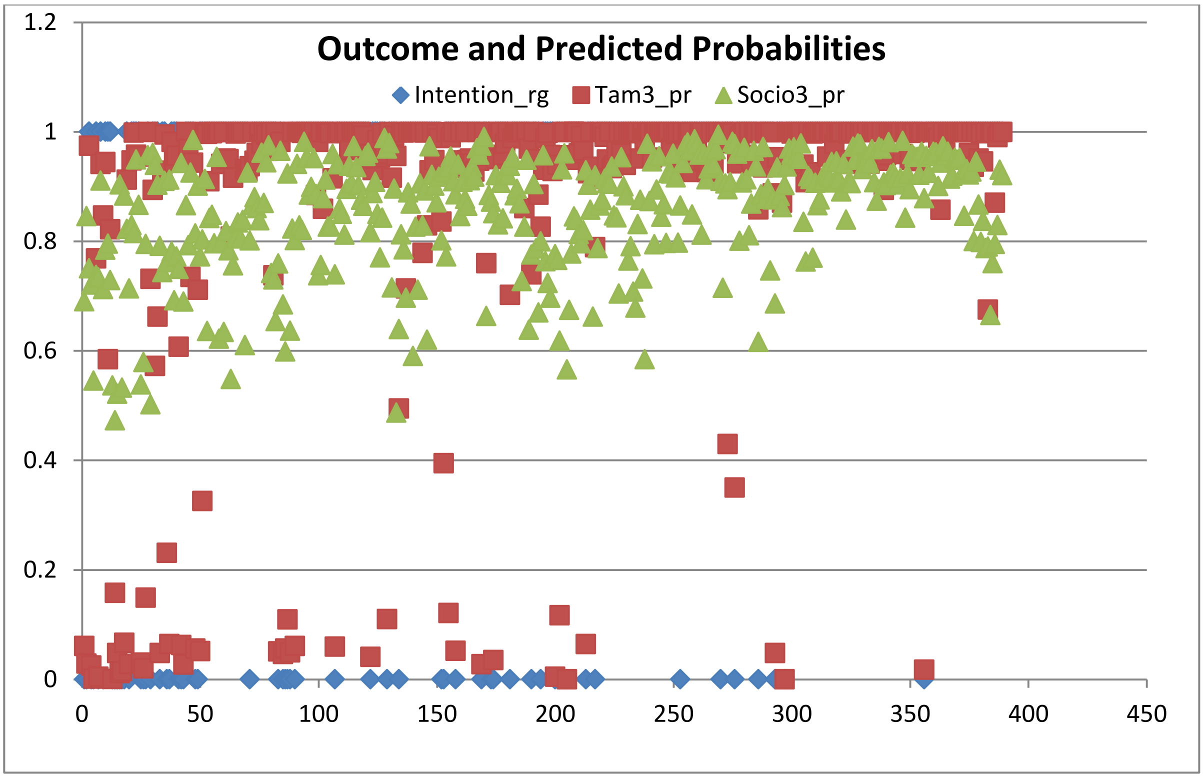

Figure 2.3 Predicted probabilities: Rotational Grazing

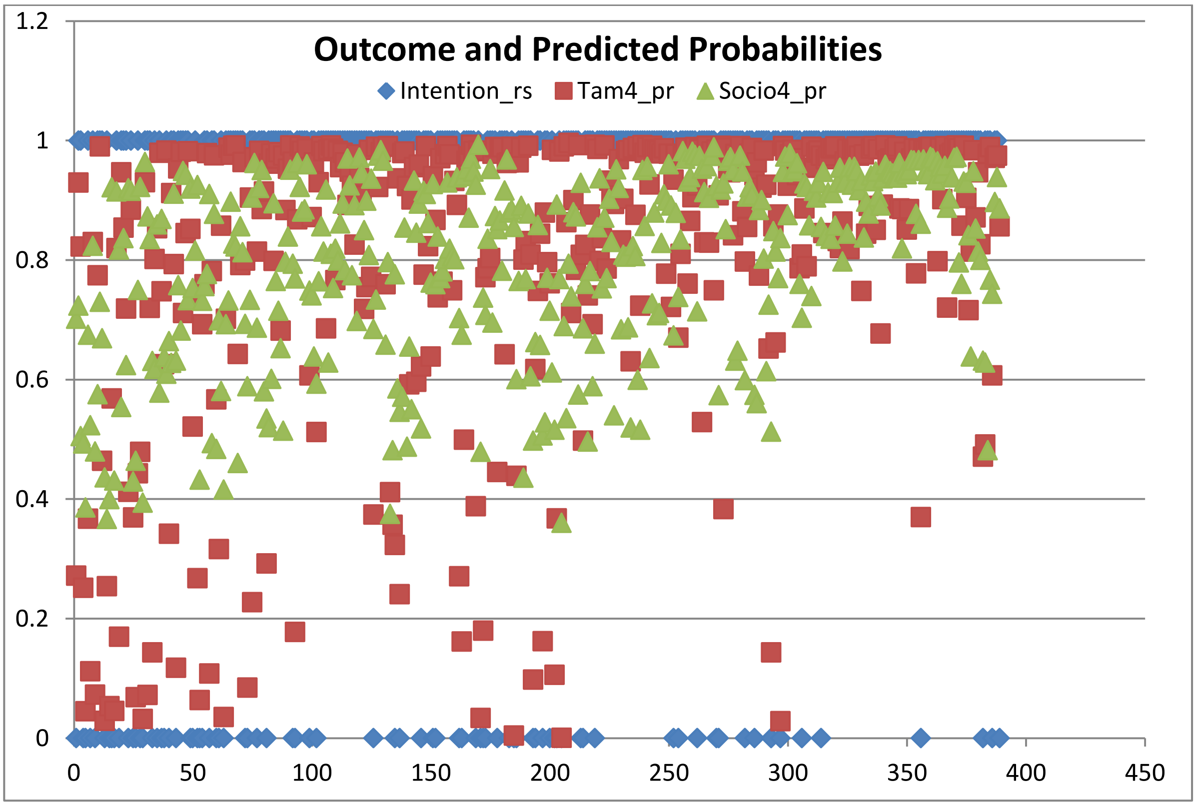

Figure 2.4 Predicted probabilities: Reseeding

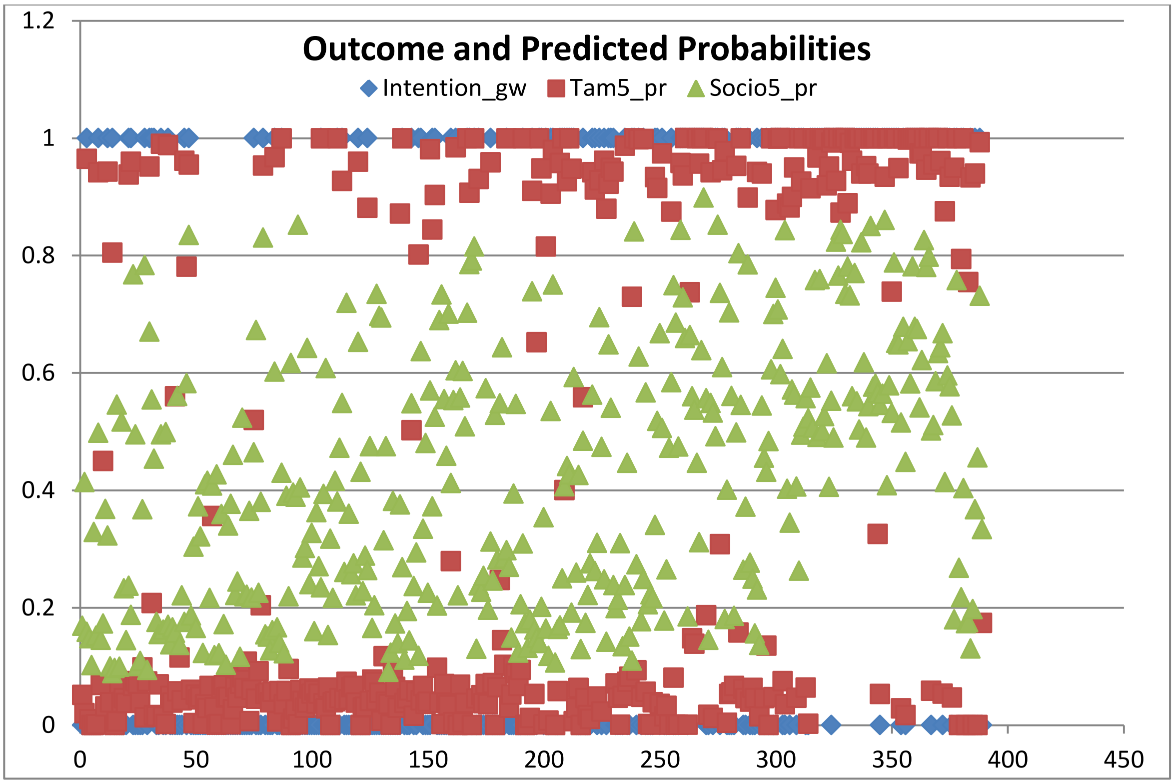

Figure 2.5 Predicted probabilities: Grass Wedge

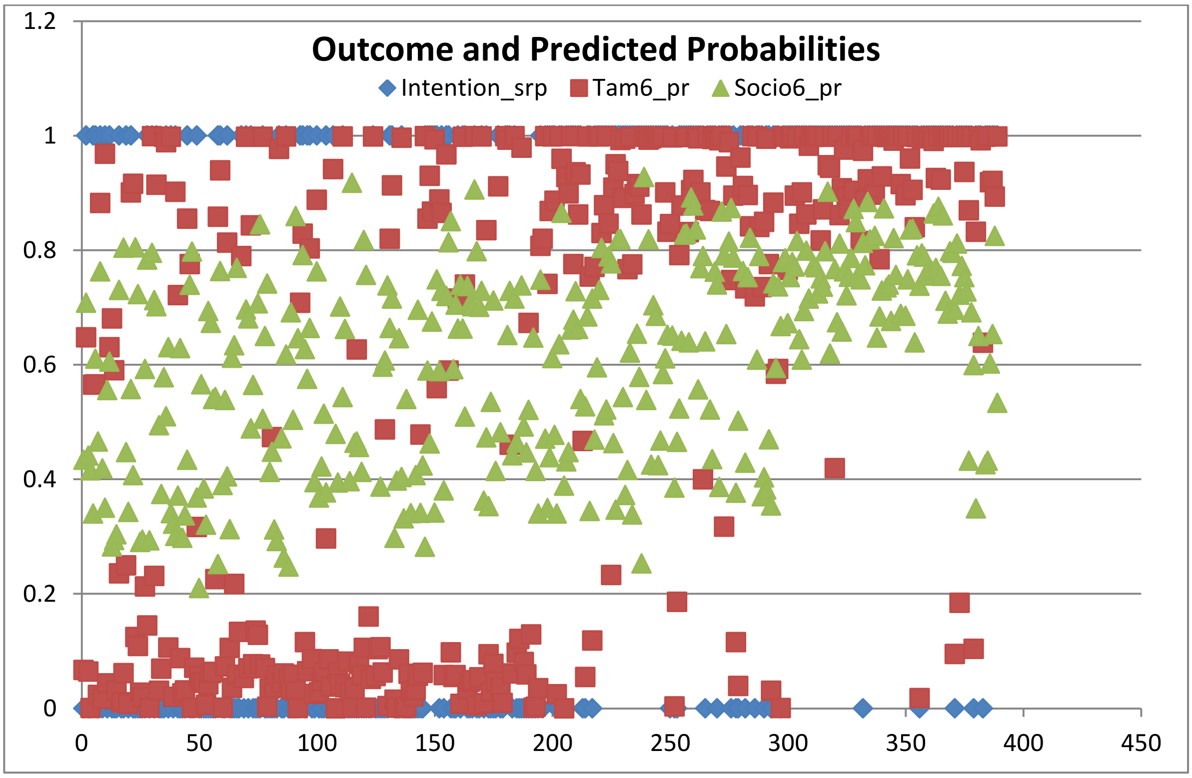

Figure 2.6 Predicted probabilities: Spring Rotational Planning

The classification of predicted probabilities and outcome is based on first defining individual probabilities into a binary variable. As stated a predicted positive outcome is based on the probability is 0.5 or more. This is then compared to the outcome intention variable. Table 2.15 displays the percentage of correctly classified predictions for each model specified in bold.

Table 2.15 Comparative Model Analysis

Classification Table	**Grass Budget**	**Grass Cover**	**Reseeding**	**Rotational Grazing**	**Grass Wedge**	**Spring Planner**
TAM & Objective	**92**	**94**	**89**	**95**	**95**	**92**
Sensitivity	94	95	96	99	93	95
Specificity	90	92	58	75	96	88
Socio & Demographic	**68**	**71**	**81**	**86**	**72**	**65**
Sensitivity	74	75	97	99.7	62	77
Specificity	61	67	19	2	78	48
N389						

The classification Table 2.15 indicate the models using the TAM and farming objective factors more accurately predict intention outcome than the models using socio-economic and demographic models in this survey. On average they correctly predict 19% more correctly classified cases over the six comparative models. The correctly classified cases are given by the figures in bold. The sensitivity results identify the percentage of farmers who have a positive intention to use. The specificity figures indicate the prediction of non-use among non-users.

The specificity statistics for the more established practices, rotational grazing and reseeding are low for both model sets. This indicates the relative difficulty the model has in identifying non-users within the population. This is also reflected in Figures 2.3 and 2.4 which identify the predicted probabilities. The rate of adoption is high, 81% and 85% respectively.

Stage 3: Kelman Social Influence

Kelman Effect: Compliance, Identification and Internalisation.

The relative importance of the farmers' perceptions and objectives has been highlight by the study. Technology adoption studies suggest the importance of social factors in the decision making process. From social-psychology literature this influence is a prominent feature of much of the most widely used models such as the Theory of Reasoned Action and the Theory of Planned Behaviour. The TAM has in more recent models incorporated a measure of social influence using Kelman's (1958) theory. This social influence is separated into two latent factors s*ubjective norm* using Kelman's compliance and internalization and *image* based on items relating to identification. In this study social influence was not measured as latent factors as it was not the purpose to identify the impact of social influence on intention to use practice this is accepted in the agricultural literature, but rather Kelman was measured as a categorical variable. The rationale for this is based on the identification of social groupings which influence decision to use practice.

Table 2.16 Social Influence and Mean Perception

Kelman	**Grass Budget %**	**Grass Cover %**	**Reseeding %**	**Rotational Grazing %**	**Grass Wedge %**	**Spring Planner %**
Compliance	29	34	34	39	38	40
Identification	11	10	8	5	9	9
Internalisation	60	56	58	56	53	51
Chi sq	0.149	0.011	0.019	0.624	0.033	0.629
N	**171**	**156**	**310**	**328**	**134**	**193**

For all practices between 5% and 11% of current users did not intend to use it in the next year. The category has less than 30 observations in all six cases. For those reasons Kelman effects could not be modelled. However, the Kelman categorical variable was used to identify the social groups who influenced adoption of practice in the next section.

The chi squared statistic reports the difference of TAM perception across three groups (Table 2.16). There is no difference in user perceptions of grass budgets and rotational grazing across the three groups. For users of grass covers there is a statistically significant difference (0.01) the mean rank of perception across the groups indicate the highest ranking group were those who believe in and wanted to do grass covers while those who felt they should do it had the lowest mean perception. This was also the case for reseeding (0.019) and grass wedge (0.033) although the actual difference in mean ranking between the lowest (internalization) and the middle rank (compliance) was very small. The identification group had the lowest mean rank for all six practices.

Kelman: Influential Social Groupings

The next step in the analysis used the three Kelman groups to identify the associated influential social groups. Farmers, using the practices, were asked first to identify their rationale for using based on the predefined Kelman influences. Then they were asked to choose a social group most influential in the choosing of the Kelman effect (Compliance, Identification and Internalisation). Farmers were given four choices (Family, Neighbours, Discussion Groups and Other). The other category identified an additional four influential groups (Table 2.17).

The most influential social groupings were the family and discussion groups. Personal decisions regarding management also were important influencer which highlights the significance of the farmer's individual perceptions. These groups were most influential in terms of Kelman effects compliance 57%.

Table 2.17 Influential Social Groups

Kelman	**G.B. %**	**G. C. %**	**RS %**	**R.G. %**	**G. W. %**	**SRP %**
Family	35	37	45	47	31	45
Discussion Groups	47	50	28	29	52	42
Personal Management	8	5	13	10	5	5
Teagasc	4	4	3	3	7	3
Neighbours	4	4	8	9	5	5
Financial/IFJ	2	1	2	1	<1	<1
College/Advisor/Co-op	-----	-----	<1	1	-----	-----
N	**171**	**156**	**310**	**328**	**134**	**193**

In using (Venkatesh and Davis 2000) compliance and internalization are combined and measured as one latent factor: subjective norm. Theoretically, this has the greatest impact on intention. Identification, termed: image has a weaker indirect effect on intention. Numerically the qualitative distinction made by dairy farmers in terms of their social influence reflects this.

Image or identification is not a strong rationale for using practice while subjective norm including compliance and internalization is. The most important social groups in influencing subjective norm and image are the family and membership of discussion group for all three Kelman influences. There is no distinction between the influential social groups identified and the type of social influence on farmers.

Table 2.18 Social Influence and Groupings

Kelman	**G.B. %**	**G. C. %**	**RS %**	**R.G. %**	**G. W. %**	**SRP %**
Compliance	(N50)	(N53)	(N104)	(N126)	(N51)	(N76)
Family	56	55	53	56	49	61
Discussion groups	26	30	19	23	33	26
Identification	(N19)	(N16)	(N24)	(N18)	(N12)	(N18)
Family	37	44	42	61	25	39
Discussion groups	53	50	38	33	50	50
Internalization	(N102)	(N87)	(N181)	(N183)	(N71)	(N98)
Family	24	24	41	40	20	34
Discussion groups	57	62	31	32	66	53
N	**171**	**156**	**310**	**328**	**134**	**193**

2.6 Discussion

In the case of this research the adoption of a technology such as grassland management at some level exists for almost all Irish farmers as the operate mainly a grass based system. The land management strategy employed however, may not be codified as is recorded by this survey, but rather it may be part the a process based on experience or tacit knowledge. The adoption rate of innovations also may be attributed to regional characteristics and variations in socio-economic conditions as well as localised application of technology-specific information (D'Emden, Lelwellyn and Burton 2006). However, this research suggests the comparative strength in using attitudinal variables to predict adoption. More specifically this research suggests the Technology Acceptance Model as one that exhibits potential for further use for future agricultural adoption studies.

Agricultural studies support this, farmers revealed their own knowledge and expertise, supplemented by the vet's advice is preferred to view of an institution with a mandate to advise and inform (Garforth et al. 2006 p.166). It is highly dependent on the individual, demographics of the individual have also been seen to influence attitude. Women farmers placed more emphasis on the labour saving element of the technology while smaller farmers tended to look at the ability of the technology to be used all year round (*ibid*). The characteristics of the technology are important, relative to what the technology is useful for on their farms.

The decision making of farmers is viewed as being dynamic and specific to farm (Vanclay 2004). The issue is often not to merely predict and understand attitudes as Ajzen and Fishbein intended with the TRA but also to realise the problem may not always be farmers having the wrong attitude, but rather a possible conflict of views, relating to what constitutes "good farm management" (*ibid*). Vanclay expands on "good farm management" as not a singular absolute, but rather a process of evaluation which has many different beginnings.

The use of longitudinal studies is advocated to incorporate decision-making across time (Venkatesh and Davis 2000) and situation through the use of structural equation modelling (SEM) (Flett et al. 2004). Suggested methodologies have allowed the possibility of viewing technology adoption as it changes over time while simultaneously examining effect of variables. When looking at the adoption of technology by farmers it must be realised that they operate within a dynamic environment where situational variables are likely to have considerable influence on their decision making process (*ibid*).

2.7 Conclusion

These findings suggest the importance of farmer perceptions and farm objectives on practice uptake. Particularly the strength of the TAM perception variable on the intention to use grassland practices. This supports the substantial body of literature which exists using TAM in the prediction of intention. The findings of this study are not directly comparable to findings from other TAM applications as the hypothesized factors of PU and PEOU were not found. However, the study strongly supports the relevant importance of TAM perceptions in predicting intention. Furthermore through using two groups of variables a comparative analysis confirms this in the Irish context. Based on the broader social-psychology literature that suggests intention to adopt is closely linked to behaviour and given the findings of this study the relative importance of individual goals and objectives in decision making are reemphasized by the findings from this research. The decision to use new practice or to have a positive intention to use a practice is largely based on perceptions on individuals rather than socio-economic or demographic variables.

Further in terms of social influence "image" has little or no impact on the farmer's perception of grassland management practices. This supports Flett et al. (2004) which identified the rating of *"gaining recognition from other farmers"* as an objective of New Zealand farmers as second last in a list of fifteen objectives. There is little evidence for the existence of image as a social influence in the dairy sector.

This study has looked beyond the use of socio-economic and demographic variables. Through exploring the use of latent factor variables, it has found perceptions of farmers to have much greater influence on to use practice than the more traditional variables used in the wider literature. This highlights the importance of farmers' beliefs about a practice. This places the emphasis on the farmer. The third and final study engages with the farmer. It identifies how practices are implemented on dairy farms. It focuses on the farmers' experience with using nutrient management practice.

3. Study three: Organisational Routines in Nutrient Management Decision Making

3.1 Introduction

This study examines the influence of existing routines and knowledge on the adoption of a new practice. Technology adoption is an act of innovating and is generally considered to be the engagement with a new way of carrying out an activity. While, the complexity of terminology relating to “innovation” and “adoption” has resulted in inconsistency in how adoption is studied (Kremer et al. 2001), adoption can be considered in two ways: firstly, as described by Rogers (1962), it can be a binary decision to adopt; and secondly, it can be studied at the implementation stage, where fundamentally, the innovation may occur.

While definitions of innovation vary, most definitions of innovation are variations of the original contribution of Joseph Schumpeter (1934). Schumpeter defined innovation as the creative combination of new or existing resources at the firm level. It is the word *resource* in Schumpeter’s definition that is often redefined in subsequent definitions. For example, recent definitions suggest a list of possible resources internal and external to the firm that can be creatively combined through interaction between actors to bring about successful change: innovation (Smits 2002; Ekboir 2012[68]). The innovation literature also now recognises that a firm does not innovate in isolation but rather depends on extensive interaction with its environment (Fagerberg 2006). Innovation is generally now thought of as an interactive process.

The activities of firms can be described as routines. Schumpeterian (1935) growth is defined as *continuous changes in economic data (inputs and outputs) absorbed by the system without perceptible disturbance.* This reflects routines building and evolving,

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[68] Innovation is defined not as an isolated concept but as part of the wider system, interaction between actors in the system and also interaction with the wider socioeconomic environment. This places increasing emphasis at the micro level on individuals {skills, specialist knowledge and learning} and at a macro level collective behaviour and an enabling environment.

as a function of the status quo of resources within the firm. The importance of resources in growth is highlighted by the work of the resource based theories, which Penrose (1959) developed in her theory of growth. According to Penrose's (1959) theory *services* rendered by resources are of greater importance than the resources themselves. This then points to a higher level, the *capability* of the firm, which comprises of existing bundles of interacting routines, knowledge, experience and skills of the firm (Richardson 1972). Routines, knowledge, experience and skills are all resources of the firm. The capability of the firm is a function of these resources. Capabilities are bundles of routines, which fill the gap between intention and outcome, the outcome is a reflection of what is intended (Dosi, Nelson and Winter 2000). Resources alone are not enough for successful change (innovation) to occur the firm must utilize these resources, in achieving organisational goals.

Traditionally routines were viewed as recurrent patterns (Nelson and Winter 1982) however, more recently routines are identified as vehicles for change (Feldman and Pentland 2003; Pentland and Feldman 2005). Nelson and Winter (1982) note change is not always predictable, having adopted a new technology the change in routine "*will not be closely predictable until a reasonable amount of actual operating experience with it has been accumulated*" (1982: 129). Nelson and Winter (1982) view innovation to be a change in routine "*a new combination of existing routines*" may emerge from a "*problem-solving effort*", the effort to solve (change of routine) acts as a target for innovation. Such innovation includes new patterns of information and material flows, redesigned through incorporating existing organisational routines and heuristics[69]. Nelson and Winter (1982) identify the results of innovation activity as "routine" in this sense, are not predictable, results may be radical. Therefore, contrary to the common understanding, which might suggests that routines and innovations are unrelated concepts, recent routines research suggests that the two theoretical concepts are closely related (Feldman and Pentland 2003: Pentland and Feldman 2005).

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[69] Newell, Shaw and Simon (1962:85) defined heuristic as "any principle or device that contributes to the reduction in the average search to solution" (Nelson and Winter 1982:132).

This study uses the organisational routines literature to explore technology adoption at the implementation stage of adoption, rather than focussing on the binary decision to adopt. In this study, two aspects of routines, ostensive and performative[70] elements, are used to analyse the activities of farmers. Though routines are multifarious in nature and pose challenges to research, they can capture firm activities at a meaningful level and can act as a driver of endogenous change (Becker et al. 2005). By using Pentland and Feldman (2003: 2005) concepts of ostensive and performative aspect of routines, this study seeks to *unpack* the nutrient management organisational routines of farmers. The organisational routines literature has not been applied in the context of agricultural adoption, with only one empirical application in the agricultural sector (Lazaric and Denis 2005[71]) to date.

Examining rates of adoption can at best give us limited information about adoption. Empirical evidence from study one shows that nationally almost 70% of farmers test their soil. This is a high rate of adoption (of soil testing), however, there is an increasing trend in numbers of soil test results reporting low fertility, based on soil samples taken by Teagasc between 2006 and 2011. This finding of increased low levels of soil fertility, despite increased soil testing, is consistent across regions in Ireland (Donnellan, Hanrahan and Lalor 2012). These figures suggest that soil tests results are being conducted, but results are not being incorporated at farm level to improve the soil fertility levels. The benefits of the technology (innovation) are not being realised.

In terms of technology adoption encouraging a singular action (adoption) may do little to increase capabilities of the firm. The questioning of the depth of commitment has been highlighted in the environmental literature (Morris and Potter 1995) and more recently with a call to equip managers with increased "know-why" as opposed to "know-how" (Ingram 2008). It is important to understand that adoption is a single

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[70] Other dimensions identified include technological and social, motivation and cognitive (Becker et al. 2005).

[71] Use cognitive and motivational dimensions of routines, Lazaric and Denis (2005) concluded while useful in describing the empirical findings, could be better depicted as a change in organisational as opposed to procedural memory using ostensive and performative dimensions.

step, how it is incorporated into the firm given existing routines is of much greater importance, which is a continuum rather than a binary decision.

The act of adopting a new practice or technology is one element in the overall process. Adoption must be coupled with a change in behaviour which is much larger than a dichotomous adoption decision. It must aim to change the routine of the firm and enhance capabilities through experience and learning. This involves a systematic change in the ways of doing and ways of determining what to do, a direct engagement with current routine. A firm must be actively engaging and implementing practices to encourage innovation and achieve change. Behaviour is adapted and so experience in doing things in a different way is gained and new knowledge is created. This is not tapped into when a rewards based system is based on single action processes (Miron-Spektor, Gino and Argote 2011). A single action may not encourage further action and so the experience gained and knowledge created is limited, consequently the organisational learning is limited, measuring how a change occurs and acquires experience, is how learning is established in the organisation (*ibid*).

3.2 Theoretical Framework: Organisational Routines

What is an Organisational routine?

While routines are part of an existing literature that examines the co-ordination of resources at a firm level, the development and application of the routines concept by researchers more generally has been described as frustratingly slow (Cohen 2007). The routines concept is the foundation of evolutionary economics (Nelson and Winter 1982) and is prevalent in organisational and management literatures. The work of behaviourist theorists Cyert and March (1963), and organisational theorist Simon (1947), provide the underpinnings of organisational routines (cited in Parmigiani and Howard-Grenville 2011). Prior to a focus on routines, “rule guided” behaviour focused on the individual, with Dewey (1922) emphasising habit and emotion, and Cohen (2007) emphasising cognitive process (cited in Cohen 2007). Routines are identified as resources employed in the co-ordination of activities. Routines are collective phenomena repetitious in nature and are the building blocks of firm capabilities (Dosi Nelson and Winter 2000).

Nelson and Winter (1982) describe routines as being decision rules best associated with production techniques and what is *regular and predictable* in a firm. Nelson and Winter (1982) formed the basis for evolutionary economic theory, while sympathising with behavioural theorists the work did not seek to propose an explicit theory of individual firm behaviour, but rather *behaviour of collections of firms* (Nelson and Winter 1982: 36). This reverts back to Richardson's (1972) idea that similar activities take place in similar firms.

The functionality of a routine is dependent on common goals of the firm (Witt 2011). Coordination and coherence can be difficult in a firm with uncoordinated goals; a routine may fail to benefit the organisation if it serves interests beyond predefined organisational goals (Witt 2011). When a technology is adopted in an involuntary manner then it becomes questionable if this serves the predefined interests of the organisation therefore it may or may not enhance the capabilities of the organisation. If the routine is not serving the organisational goals, then the changed activities (routine) may not be successful (innovative). According to Nonaka (1991) innovation and creating knowledge is as much about ideals as ideas.

Routines enable researchers to capture change, identify driving forces and "zoom in" to make a change, at a micro level in organisations (Becker et al. 2005). It is for this reason the organisation's routines, and the related concepts of adoption and capabilities, form the basis of this study. Specifically, these concepts are defined as follows:

- Adoption, as stated earlier, is the uptake of an innovation by individuals (Leeuwis 2004).
- Routines are activities within the firm that are "ways of doing and ways of determining what to do" (Nelson and Winter 1982).
- An organisational capability is essentially an expertise which compromise of bundles of routines co-ordinated by collective individual skills of the firm (Richardson 1972: Nelson and Winter 1982: Dosi, Nelson and Winter 2000).

Routines and Capabilities

The capabilities of a firm are viewed as a large scale unit of analysis with specific purpose expressed in terms of a particular outcome (Dosi Nelson and Winter 2000). Routines may require a contextual requisite which support the capability (*ibid*). Capabilities also depend directly on individual skills (Nelson and Winter 1982). Tacit knowledge can be an individual skill which is essentially a resource accumulated in the form of human capital in a firm. Penrose (1959) examined resources as a function of growth of the firm. It was Penrose who illuminated the essence of resources not as factors of production, but rather as differentiated resources in terms of the *services rendered* from them. Richardson (1972) continued in this vein when equating capabilities of the firm with *activities* of the firm.

Organisations have a wide range of activities including discovery, projections, execution and co-ordination of processes; these activities are carried out with appropriate capabilities, organisations with similar capabilities carry out similar activities (Richardson 1972). Using this definition of capabilities, organisations specialise in *activities* where their capabilities offer some comparative advantage. Capabilities determine activities, through co-ordinating skills (Dosi, Nelson and Winter 2000). Richardson (1972) refers to Penrose's (1959) theory of growth of the firm, which stipulates that a firm is a collection of productive resources. The firms' activities are distinguished by *their use* of productive resources for the purposes of production and selling of goods and services (Penrose 1959). Resources can be both tangible and human resources. Although these human resources are not owned by the firm, the loss of an employee at the height of their ability is the equivalent to a capital loss, this is important in terms of capabilities in a firm. In this distinction activities and services are determined by capabilities and resources. The salient nature of *services rendered* from resources stems from Penrose (1959).

Routines of Owner/Manager: Individualistic Perspective

The major debate in the literature surrounds the definition and composition of a routine (Becker et al. 2005: Dosi, Nelson and Winter 2000). There is general agreement that routines are repetitive, recognisable, interdependent actions with the fundamental feature of pattern carried out by multiple actors (Feldman and Pentland

2003). However, beyond that there is much disagreement. In differentiating between a routine at a firm level and at an individual level, the focus is on distinguishing between routines, skills and habits. As a collective phenomenon, only multi-agents are capable of having a routine, while individual agents have skills and habits, but not routines (Vromen 2011).

However, the collective coordinated actions within a firm depend on cognitive and motivational attitudes of members which bring the idea of routines to an individualistic perspective (Witt 2011). The importance of the entrepreneur is recognised in the form of an authority who directs resources (Coase 1937). Coase (1937) defined the firm as a "*system of relationships which comes into existence when the direction of resources is dependent on an entrepreneur*". Nelson and Winter (1982) also alluded to this when they referred to routines at an individual level, linking action and performance of a routine to individual activity in relation to "*knowing one's job*". Nelson and Winter (1982) connect the individual "*repertoire*", from which the organisation member draws upon, to choose performance of an appropriate routine. They state (1982:100):

> *"knowing what routines to perform and when to perform them. For the individual member, this entails the ability to receive and interpret a stream of incoming messages from other members and from the environment. Having received and interpreted a message, the member uses the information contained therein in the selection and performance of an appropriate routine from his own repertoire".*

Within the literature there have been attempts to bring clarity to the distinction between "skills" and "routines". Generally it is thought best to attribute the *skills* characteristic to the individual and the *routines* characteristic to the firm (Dosi, Nelson and Winter 2000). These authors see the organisational routines as one of the building blocks of organisational capabilities; skills are among the building blocks of routines, they hold the major function or co-ordinating skills. Although these authors make a clear distinction[72] they argue that skills and routines are inextricably linked.

The context of a single person operational organisation is not addressed in the routines literature[73]. The distinctions becomes blurred when an owner-manager holds the "*repertoire*" of skills, but also co-ordinates these skills at the higher level of choosing appropriate organisational routines for the firm. Given this scenario it is appropriate to revert to the original Nelson and Winter (1982) discussion on organisational memory which closely relates individual skill to firm routine. It is appropriate to make the distinction between skills and routines. This is based on Nelson and Winter (1982) a routine is evident "the way of doing" is clear through direct observation of the outcome, but the skill required to carry out this "way of doing" is embodied in the individual; they are qualities of that individual hold in that firm.

This individually brings the agency of actors to the fore in routines research more recently[74]. It is also fitting to define routines in terms of the individual in cases where the individual is the sole decision maker in the firm, and so the co-ordination of skills within the firm. The firm routine falls with that individual. For the purpose of this study routines are analysed at firm level from the perspective of one individual.

How have Routines been studied in the literature?

Routines for Nelson and Winter (1982) cut across the traditional notions of capabilities[75] and choice[76] and they treat these as similar within the firm, not as a given set of abstract possibilities. To establish an existing routine and the adapted

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[72] Similarly distinguishing between routines and capabilities, "we think of 'capability' as a fairly large scale unit of analysis one that has a recognizable purpose expressed in terms of the significant outcomes it is supposed to enable, and that is significantly shaped by its conscious decision both in its development and deployment" continuing to state "subject to qualification some organizational routines might be equally called capabilities" (Dosi, Nelson and Winter 2000)

[73] This is important for agriculture as 72% of those estimated to work in agriculture forestry and fishing are self-employed (CSO 2012).

[74] Special Edition December 2012 Journal of Management Studies

[75] The techniques a firm uses

[76] The maximisation aspect of traditional theory of the firm

routine it is necessary to look at firms at an individual level analysing their activities and corresponding capabilities. Holding the routine of the firm as the core unit of analysis or as a target for solving firm problems leads to innovation (successful change) in the firm (Nelson and Winter 1982). This is a reflection of Schumpeterian ideology building on current routines and existing capabilities. Routines have been described as consistent, given their repetitive nature, and characterised by their interdependence in a firm. These features ensure both stability and flexibility in any routine, but also engage with the dynamic nature of routines. Routines were traditionally viewed as static typically in the literature as akin to habits and genes of the organisation (Nelson and Winter 1982). The emphasis was on this stability and structure until more recent contributors expanded this understanding.

Feldman and Pentland (2003) conceptualized the dynamic elements of routines. They used two distinct elements of routine: *ostensive* and *performative*. These distinct elements allowed theory to maintain the “static” nature of a routine, as a repetitive action according to the original theory, but provided theoretical underpinning for the dynamic nature of routine. Pentland and Feldman (2005) identify routines as containing two aspects: abstract understanding and specific performance. These aspects are supported by physical artefacts. They distinguish between these three aspects as follows:

- Ostensive: the abstract or generalized pattern of the routine (narrative or script)
- Performative: specific actions reflecting their engagement with the routine (improvised)
- Artefact: are physical manifestations of routines which support decision-making (standards/rules embedded)

The difference between the ostensive and the artefact aspect of routine is: the artefact (standard operating procedure) is an indicator of the ostensive aspect (script). The artefact is an attempt to codify the ostensive aspect of the routine (Pentland and Feldman 2005). Ostensive aspects of a routine may become artefacts over time. The ostensive element embodies the *structure* of a routine while the performative element embodies specific *action* by specific people. These ostensive and performative elements give a new ontological view of routines which allow routines literature to evolve. An applied example of ostensive and performative aspects of a chemical routine can be seen in Figure 3.6 (P185).

The work of Feldman and Pentland does not undermine the original definition of routines as repetitive recognisable patterns of action which are interdependent in a firm with multiple actors, but rather compliments it by arguing routines cannot be viewed as static and unchanging. The performative element gives the routines concept an individualistic perspective and strengthens its theoretical foundations. It allows for the study of a changing routine, which has not come from exogenous factors, but rather from within the firm, from engagement with the current routine (Feldman and Pentland 2003). The context dependent nature of routines has been widely accepted in the literature (Cohen et al. 1996). The dynamic nature of routines has not received much attention however, until recently.

Two approaches have been identified for studying routines. The most commonly used "black box" approach and the more recently explored partial examination of a routine (Pentland and Feldman 2005). The former approach is simple and general though less accurate, as it overlooks internal structure (*ibid*). If the aim of a study is to influence change in routine the internal structures of the routine must be understood and therefore the routine itself must be studied. The exploration of agency and individualism associated with the routines concept is increasing (Dionysiou and Tsoukas 2013: Felin, et al. 2012: Turner and Fern 2012). The evolution of the routine is viewed through the activities in the firm. Through understanding these aspects of routines the decision-making process is clear. So influencing change in ways of doing and ways of determining what to do is possible. The debate has moved from arguments on defining routines to engagement with the routine itself through insights of empirical studies (Parmigiani and Howard-Grenville 2011)[77].

[77] Using a systematic approach based on certain restrictions (Papers were eliminated on the basis that routines were not the focal construct or did not fit into the capabilities or practice perspectives. See notes 4 and 5 in their paper.) a total of 51 papers on the subject of routines with 18 empirical studies.

The emphasis in this study is on the routines and the interactions within the firm. This endogenous approach places a focus on the interactions of the firm (who hold the routine). The literature has been characterised by a movement towards a more holistic approach to studying routines, looking at patterns and dynamics of actions, in a dissected manner. Routines are more than rigid, mundane mindlessly codified activities (Cohen 2007). The ideology of routines and its research agenda should be enhanced with empirical evidence to aid its progression (Parmigiano and Howard-Grenville 2011) looking at multilevel process phenomenon, participant engagement, grounded in situated activities (Dionysiou and Tsoukas 2013). This study extends current research on farmers' decision making in identifying nutrient management activities as organisational routines.

3.3 Research Question

Routines allow the process of change to be examined as they illustrate and frame decision making within firms. To understand and influence change, it is important to understand the process, how change occurs. In terms of technology adoption this study uses the routines literature to explore the process of adoption.

The traditional routines literature lacks the detail to describe routines, using Feldman and Pentlands work (2003: 2005) the identification of ostensive and performative aspects of routines aids in unpacking the traditional black box approach to routines. Felin, et al. (2012) provides a platform from which routines at a micro-level can be analysed. However, to understand the micro-foundations of routines it is essential to identify the routine in terms of its attributes. The ostensive aspect of the routine, gives stability or structure and the performative aspect, the actions carried out by specific people (Feldman and Pentland 2003).

Individuals engage with routines in different ways by exercising the capability to enact the routine. When enacting a routine, individuals can maintain or deviate from the ostensive element, the central importance of Feldman and Pentland's (2003) contribution is the importance of subjectivity, agency and power, in flexibility and change in organisational routines. The range of possible changes in routines is a function of the resources and structures the organisations are subject to. Routines are mediated by the interdependence of actions in an organisation therefore change of a routine need not be exogenous, but can occur through engagement with the routines (Feldman and Pentland 2003).

Study one of this thesis identifies an adoption-innovation gap. This gap relates to the adoption of nutrient management practices and is influenced by policy. This study builds on that work. It explores this adoption-innovation gap through examining how adoption of nutrient management occurs at farm level. Having knowledge of adoption activities enables those responsible for improving practices at farm level to identify new ways of supporting adoption and innovation. There are many potential avenues which are open when examining on-farm activities. The wider agricultural research community could benefit from such work.

Question

This study uses the routines literature to examine the implementation of technology at firm level, exploring the nutrient management activities of Irish dairy farmers, it asks of farmers using and not using nutrient management practices:

- What are the commonalities and differences in existing nutrient management routines at farm level?
    - How are nutrient management practices implemented at farm level?

3.4 Research Methodology

The purpose of this study is to examine the impact of existing routines on technology adoption. This study uses the routines literature to examine the nutrient management activities, based on 20 interviews with dairy farmers. A qualitative approach to data collection and analysis was appropriate to answer the research question and provide rich context specific evidence.

The empirical setting for this work is the Agricultural Catchments Programme (ACP), funded by the DAFM and implemented by Teagasc. The ACP is operated by a team of researchers, advisers and technicians working closely with farmers. Their main objective is to monitor water quality at the spatial scale of river catchments. Farmers were chosen from this programme for interview.

Unit of Analysis: Nutrient Management Practices as Routines on farms

Historically on-farm nutrient management is important with writings that mention the fertility of land dating back to 2500 B.C. These early records show variation in barley yields in Mesopotamia[78] region up to 300 fold in some areas, though how, and when fertilization began is not known (Tisdale and Nelson 1966).

Salient nutrient management routines were chosen from an ACP nutrient management survey carried out on catchment farmers. Theses routines (Table 3.1) were identified and agreed upon through informal discussions with agriculture experts and the lead researcher who designed the survey[79]. These routines were also used to stratify and select participants for interview. They have not been weighted in terms of importance although there is consensus around the importance of soil testing as the key decision making tool. For the purpose of this study the analysis focuses on three routines: lime, slurry and chemical application.

The routines concept applies most naturally to large complex organisations that produce the same goods and services over extended periods (Nelson and Winter 1982). All farms fulfil these elements, in the production of agricultural commodity milk, multiple actors fulfil routines, contracting staff external to the firm and on-farm labour, including family, with the managing director who is the farmer. Organisational routines are identified in the nutrient management activities of the farm. Prior to interview knowledge suggested aspects from the routines literature (listed below) would be found in the empirical setting given, which was confirmed by the data. Routines have widely accepted distinguishing features. Organisational Routines are: (1) Collective Recurrent Interaction Patterns: (2) Interdependent: and (3) Path and Context Dependent.

[78] This area located between two of the main rivers (Tigris and Euphrates) in the Middle East spans across a number of countries including Iran, Syria, Turkey and Iraq.

[79] Dr. Cathal Buckley, Economist, Agricultural Catchment Programme, Teagasc Mellows Campus, Athenry, Co. Galway, Ireland.

Collective:

Routines are sub elements of the overall capability of the firm and are carried out by multiple individuals. These routines are often carried out by the farmer himself, but other actors are also involved in terms of purchasing of inputs and also performance of routines which are often contracted. The current farming system has an impact on the requirement and availability of nutrients and so its management. It is the management of these resources which is done in a collective manner through co-ordination of multiple actors.

Table 3.1 Nutrient Management Routines

Routines
1. Soil testing
2. Using Soil Test results
3. Nutrient management planning
4. Following nutrient management plan
5. Applying lime
6. Application of slurry in spring
7. Recording slurry application at field level
8. Calibrating equipment used in slurry application
9. Laboratory testing/estimating slurry content
10. Application of chemical
11. Recording chemical application at field level
12. Calibrating equipment used in chemical application

Recurrent:

Annually the farm applies nutrients to grassland to encourage grass growth. Organic nutrients are a readily available resource on almost all dairy farms. This is a valuable farm by-product which is used to replenish nutrients taken by grazing or crops. The nature of farming is such that activity is seasonal and so certain activities occur at the same time. From the empirical study the sequence of activities associated with these routines tended to remain static. An example of this is the application of nutrients generally applied after cutting crops first crop cut in May/June and an application thereafter. In 2012 the timing of crop cutting varied due to weather conditions[80]. The recurrent post-harvesting routine, the application of nutrients, remains the same regardless of the timing. These routines (harvesting and nutrient application) are directly linked irrespective of time (calendar date) of the first routine, displaying their recurrent nature.

Interdependent:

Internally routines are a function of each other. Externally firm routines are a function of exogenous effects such as weather and global prices for chemical nutrients also. They are a function of resources and structures, the building blocks of the nutrient management capability. The availability of organic manure is a function of storage capacity and also livestock units held on the farm. The number of livestock units is in turn a function of size of the farm and so the nutrient management activities. This interdependence is apparent within all routines identified.

Path and Context Dependent:

These are elements of a routine which are based on the past experience of the farmer. As farms are often family run business routines are evident and follow from one generation to the next. The ways of doing and ways of determining what to do are tied to the past. This is based on local knowledge and tacit knowledge, which is a function of incumbent resources, particularly for nutrient management relating to land characteristics. Context dependence is fundamental as the routine may be successful in some contexts, but not in others (Cohen et al. 1996).

Research Method: Interviews

Data were collected through interviews with farmers. The interviews could be described as a purposeful conversation to understand activities on the farm. The focus of each interview was to uncover nutrient management activities. When using qualitative interviewing there is a triple ask of participants in that they are relied upon to: recollect, reflect and communicate (Polkinghorne 2005). During the interviews,

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[80]Most Irish weather stations reporting June 2012 as being the wettest June on record, changing climate conditions dictated activities. http://www.met.ie/climate/MonthlyWeather/clim-2012-ann.pdf accessed April 2013

both general questions about adoption of technologies and more specific questions about *how* they implemented technologies were asked. The interviews were guided by a theme sheet (see Appendix C). The questions on the theme sheet acted as a check, to ensure all aspects of the routine and its associated activities were spoken about. These were theoretically informed lines of inquiry which were fitted into conversation on a specific topic.

Semi-structured interviews were carried out to examine the on-farm adoption decisions of 20 Irish farmers. As a method, semi-structured interviews allowed for the routines story to be told with examples provided from practical application. This is of interest as 70% of the population carry out tests, but fertility levels are falling (study one). If farmers are not optimising their input/output through using soil test results efficiently what are they using for decision making. The qualitative interviews explore their long term commitment to using the practice, a compliance effect based on fulfilment of requirements (Kelman 2006). Soil testing is a site-specific routine with rationality for non-adoption given factors such as soil quality (Khanna 2001). How and why the technology is adopted is of importance.

Qualitative interviews allow for the demonstration of diversity among routines at firm level. Singular routines are not stand alone concepts, but are operating in parallel with other routines, which protect from change: change is costly, risky and disruptive (Narduzzo, Rocco and Warglien 2000). Because of the interdependent nature of routines at a firm level minor change in singular routine has further reaching consequences. The interviews are based on a conversation around how these routines are articulated at the micro level. These routines represent best practice in the field. Conclusions are based on farm level data using an inductive approach to interview using the routines literature as a guide.

Within the routines literature a range of methods are encouraged as a means of uncovering routines, experiments, ethnographic field studies, longitudinal studies and statistical/econometric approaches (Cohen et al. 1996). Of the eighteen empirical studies carried out on routines, according to (Parmigiani and Howard-Greenville 2011), eleven took qualitative approaches including case studies, longitudinal approaches using a range of qualitative tools including interviews, observation and document analysis.

Interviewing is a widely used tool in qualitative research. The methodology of qualitative interviewing in mainstream economics is, however, less well developed. Macgregor and Warren (2006) used a general inductive method looking at farm practices in environmentally sensitive areas that are interview based. Broadly speaking a qualitative approach is more widely used in environmental economics with authors using a more participatory approach to research. Such studies sometimes also quantify the data using modelling techniques and analytical tools such as Q Methodology (Buckley 2012).

It is difficult to get the balance right in presenting data as contextual detail is often lost in aggregate representations of qualitative information. The differences that exist between responses are often also of interest. It was for this reason computer software was not employed in the analysis of the qualitative data for this study. The outlier response, or contradicting response, highlights the complexity of the social situation to which we are not indifferent (Schumpeter 1949). These contextual factors often impact decision making. The concept of routines within a firm is part of a wider complex social phenomenon which requires some “unbundling” (Narduzzo, Rocco and Warglien 2000).

3.6 Data: Selection of Interviewees

Agricultural Catchment Programme (ACP) selected designated catchments areas for geographical reasons (within river catchments). A national spatial database, Geographical Information System (GIS) and a multi criteria decision analysis framework were used to select representative catchments. Farmer were then within those bounds were classified as catchment farms. This was also based on localised characteristics, land use and potential for nitrogen and/or phosphorus transfer risk to waterways (Fealy, et al. 2010). The ACP conducted a detailed nutrient management survey with a total of 403 ACP farmers completing, 201 part of the programme and 202 part of a control group. It is from the ACP survey (201 group), participants for interview in this study are chosen. This is principally due to accessibility but also based on the availability of data relating to nutrient management practice use. It allowed for the choice of farmers with low, medium and high numbers of nutrient management routines.

This study used an existing ACP survey[81]. From the ACP population (201) two selection variables[82] were used to get a sample population of 45 active dairy farmers. This was the pool of farmers from which the author selected interview participants. A further two participants were excluded from the final choice because of recent bereavement leaving a sample population of 43 participants.

In the ACP survey each participant was asked a binary adoption question to assess rates of adoption for each routine. Farmers were categorised into numbers of routines employed (Table 3.1) as per survey responses. Candidates were chosen based on a stratified random sample. The sample was stratified, firstly based on location[83] (catchment based) and then on numbers of routines employed and randomly selected.

The participants represent three groups, low, medium and high, that relate to the number of routines implemented on their farm according to the survey responses. Location was chosen as a selection variable to ensure regional variation and numbers of routines employed as an indication of rate of adoption.

The rates of adoption determined three categories: low routine category (6 or less adopted), medium routine category (7-9 adopted) and a high routine category (10-11 adopted). This was to ensure no selection bias from the sample and the farmers represented a cross section of dairy farms. In addition to this the profiling of the farmers in the next section a comparison of technology adoption rates of the interviewed cohort and the ACP population is also outlined.

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[81] The ACP carried out a survey on a total of 403 farms 201 participants in the programme and 202 a control group from outside the programme. A total of 99 participants were dairy farms with 45 participating in the programme. It was from this cohort, interviewees were chosen.

[82] A binary filter variable (Do you have a milk quota? Y/N) and a continuous variable (On average how many dairy cows did you have in 2009?).

[83] North East, South East, South West and West.

Profiling Interviewees

As part of the ACP, all farm holdings were soil tested and a detailed nutrient management survey was carried out in 2009. This survey was used to profile farmers (Table 3.5 Appendix C). Two farmers interviewed were not surveyed at that time, so the profiling in this section is based on eighteen responses from those interviewed. The following categories (Table 3.3) were used to profile farmers.

Table 3.3: Categories used to Profile from ACP survey

Total Population	**No.**	**Dairy Population**	**No.**
Total Farmers (ACP & Control)	403	Total Dairy farmers (ACP & Control)	99
Pop EI (exc. interview)	385	Dairy TEI (Total exc. interviews 99-18)	81
Total ACP Farmers	201	Dairy ACP T (Total ACP)	45
Interviews			**18**

Farm Characteristics

The average farm size of the population is 134 hectares, the cohort interviewed have a larger average at 175 hectares. Farms in the population range in size from 2-445 hectares. Dairy TEI farms range in size from 13-243 hectares, with those interviewed ranging from 27-214 hectares. Using t tests, descriptive statistics suggest there is no significant difference ($t=-0.04$, $p=0.97$) between average heard size held of Dairy TEI and those interviewed, this ranged from 9-275 and 15-200 for the respective groups.

In terms of age, farmers interviewed have a slightly younger profile although the majority of farmers are 36+ as expected, with between 74%-79% of the three groupings over 36 years old. Consequently their years of farming experience was also lower than the Dairy TEI (on average five years). Rates of adoption for the two groups; interviewed and the Dairy TEI, for each nutrient management practice, is displayed in Table 3.4 Appendix C. For further details on rates of adoption for the population see Figure 3.3 and Figure 3.4, Appendix C.

The descriptive profiling of dairy farmers interviewed compared to farmers from all systems shows little variation (Table 3.4 Appendix C). However, an analysis within the dairy cohort is a more accurate reflection of how the participants compare to their dairy counterparts. From Figure 3.1 it can be seen that the interviewed individuals have a higher rate of adoption (>10%) for one nutrient management routines. But have similar responses in the adoption of remaining routines: (1) Following the NMP closely.

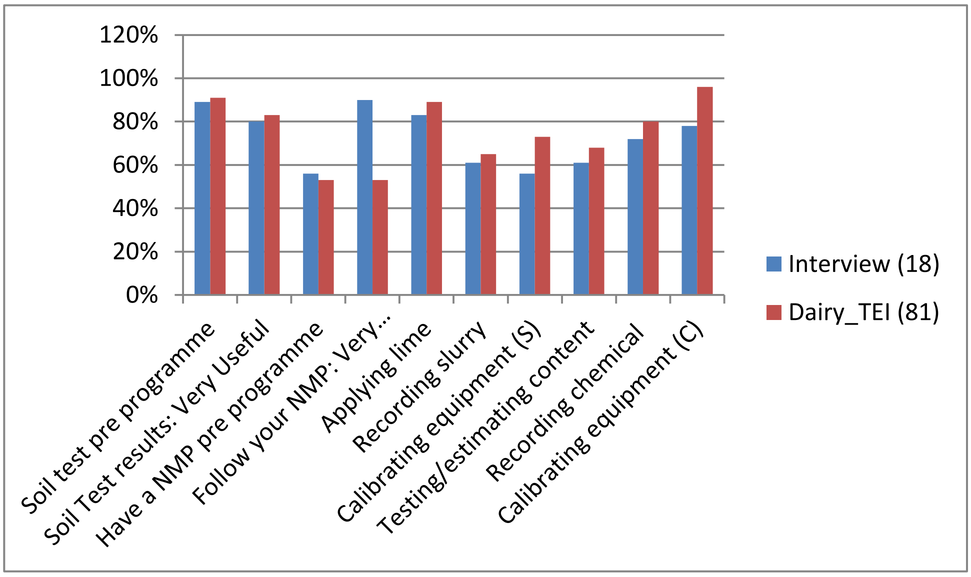

Figure 3.1 Rate of Adoption Dairy only

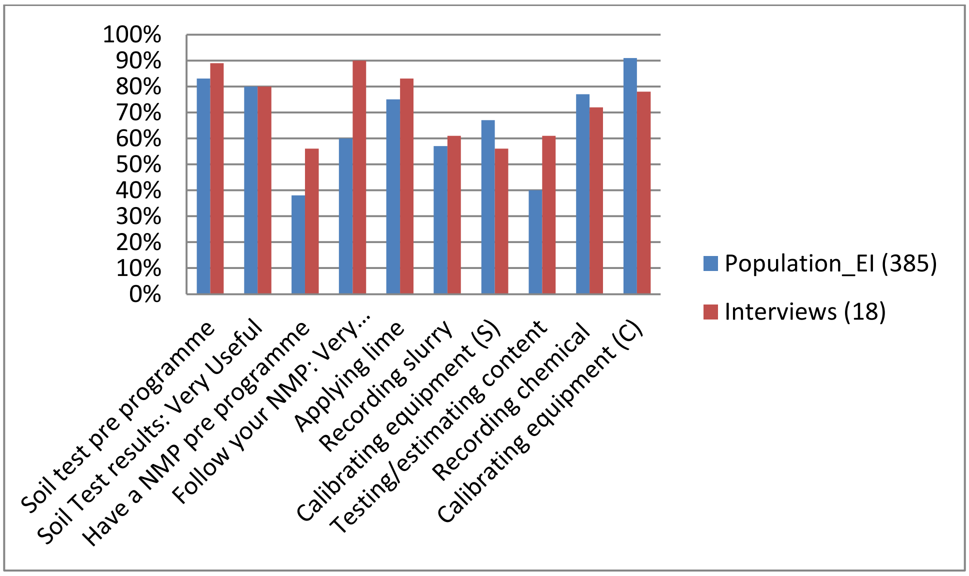

Figure 3.2 Rates of Adoption All Systems

It is clear from Figure 3.2 that again rates of adoption are similar across the population, and for the selection of farmers interviewed the trend is comparable for most routines. With the exception of one routine following NMP where up to 18% more of cohort interviewed have a NMP, prior to the programme. This is likely to be a function of the intensity of output in the dairy sector dairy. Regulation requires having a NMP for derogation application.

Data: Collecting, Recording and coding

The following steps were taken:

1. An interview schedule was drawn up, based on the chosen nutrient management routines (Appendix C). This was used as a guide during the interviews and it ensured all aspects of routines were discussed during the conversation. These were not posed as a list of scheduled questions, but rather asked of the farmers during our conversation.

2. Each interview was recorded using a hand held recorder. The audios were transcribed before being prepared and organised for analysis. The transcription involved a process of listening to the audio creating the transcript re-listening and correcting, highlight all relevant dialogue.

3. The twelve pre-defined nutrient management routines were identified in each transcript and colour coded separately (Table 3.2. Appendix C). These manifest themes were all direct references to nutrient management routines, latent themes were also identified which included conversation and associated issues implicitly referring to these routines (Figure 3.7, P212).

4. These transcripts were summarised individually so a contextual story emerged for each farmer relating to nutrient management activities in his farm. This aided in condensing the data and empirical evidence for each farmer.

5. Using both the extracted summaries and the raw data the next step condensed the data further. In a spreadsheet each farmers' response was summarised in

relation to each nutrient management routine. The movement between data and theory then became much clearer.

The primary routines are soil testing and the use of results and nutrient management plan and use of the plan. It is these primary routines which theoretically inform all other nutrient management routines. The twelve original routines (Table 3.1) were collapsed to five (Table 3.2) during the analysis stages. As indicated two primary routines soil testing and nutrient management planning. These primary routines inform the three application routines (chemical, lime and slurry) which are the focus of the analysis. Theoretically the primary routines greatly influence application routines. The crucial element in these routines is the implementation for innovation to occur at farm level.

Each routine was examined individually in relation to the primary routines: soil testing and nutrient management planning. It was found that no nutrient management decisions were based on soil test results or a plan alone. The decision to adopt a new practice is more than a binary ‘yes’ or ‘no’ choice, with varying degrees of adoption among those who chose to adopt. There exists a broad spectrum of adoption which is at a descriptive level is a continuum. Through examining activities it is possible to understand how farmers adopt nutrient management practices. This is based on their experience with using or not using these technologies, soil test results and other conditional factors (Figure 3.7, P212).

The findings are divided into three sections. The first section (Section 3.7 Findings: Primary Routines) addresses the farmers’ use of soil testing and nutrient management planning. Theoretically they inform all nutrient management decisions on the farm. This is followed by Section 3.8 Findings: Application Routines – Lime – Slurry and Chemical each examines the application routines of lime, organic and chemical. Each application routine is discussed for each farmer and summarised in Tables 3.6 to Table 3.8. In Section 3.9 Findings: Overview, an overview of the findings from each interview is presented (Figure 3.7, P212).

3. 7 Findings: Primary Routines

Soil Testing

The testing of soil is a core tool provided by scientific evaluation of available plant nutrients (See study one for more details). Soil analysis is carried out in a laboratory and recommendations for nutrient application are made to the farmer. Soil results allow for optimum allocation of inputs, it tests the nutrient status of the soil and indicates deficient areas. Based on soil test results, it is generally an external advisor who provides on-farm recommendations for application of nutrients. Results inform wider nutrient management routines and plans. It is a key decision making tool.

From the interviews the frequency of soil testing varied. It was annual routine on some farms where samples were taken on a rolling basis, while others ‘blanket tested’ the whole farm at interval periods. A whole farm test is recommended every 3-5 years. All, but one farmer had conducted a soil analysis on their holding. However, the way in which they used the soil test results varied. There was no strict application of the results at a field by field basis, but rather their current baseline application would be altered as per the recommendations. Generally farmers had a baseline quantity of annual nutrient application. This baseline was then tweaked mindful of the recommendations provided by the soil test results and numerous other conditions (Figure 3.7, P212). These conditions often included those outside the control of the farmer. The overall application of nutrients showed elements of continuity however, firms also have distinctive ways of doing things and generally are heterogeneous in the way they perform functionally similar tasks (Dosi, Nelson and Winter 2000). This was clear from the interviews; inputs would generally remain the same “*it’s just to get a picture again*” (F_17), “*no harm to see how things are going*” (F_14).

Use of Results

The implementation of the soil tests results is where the technological benefits accrue. Adoption of the technology does not mean its strict implementation. Empirical evidence from the interviews suggest soil test results are used post-adoption for the first year or two, often for lime application. However, soil test results were used in a much more blended fashion than the scientific procedural approach suggests. This reflects the performative aspect of the routine.

The soil test results were broadly taken into account, but it was dependent "*on how it was working out* (variable conditions)*…..more so than to the letter of the law*" (F_4). If there was an indication a field was low a farmer may put out a bit extra, this bit extra may be surplus organic fertilizer available on the farm or a half a bag of chemical per hectare. This choice would depend on a range of conditions, including the availability of organic on the holding or the cost of chemical input. Soil test results indicate level of nutrient available in a particular field. Three levels are used: low, optimum (adequate) or high. Science would recommend no chemical fertilizer to be applied to 'high' results. However, farmers would advocate application of "a little bit". This was viewed as maintenance for the ground.

One farmer expanded on this stating "*we found if you didn't give them* [fields] *any they weren't performing at all ….especially if you were mowing it you wouldn't get half the quality or the quantity*" (F_1). Another farmer stated "*we weren't spreading any artificial phosphate after year three definitely by four you could see a reduction in grass output...there was no question about that.....you know regardless of figures you need to spread maintenance artificially and then top it up with organic*" (F_7). Most farmers would use the crop (grass/other) also as an indicator of the required application.

The targeting of fields, step 3 in the prescribed five step plan for soil fertility, is a key step in implementation. However, this was dependent on available resources rather than scientific requirement. When asked if fields are targeted, responses included "*sure if they want a couple of bags….if a field was low in P&K you'd give it, if you had it, a heap of farmyard manure*" (F_6). No farmer wanted to waste resources through over-application. This again was dependent on how high mineral levels were and on crops past and planned, but "*generally as little as you think you can get away with….last couple of rounds only got half a bag to the acre…seemed to respond fairly well*" (F_4).

The visual response from fertilizer was important "*you wouldn't overdose… I might give them a little bit once like you know, like the chemical will always probably work with the organic fertiliser like you know you just can't depend on organic fertiliser all* *the time it doesn't suit the soil either you need to put in the P's and K's like just one application and you will probably see a good response*" (F_17).

There was a clear existing routine on each farm with a trade-off between the baseline applications and applying a little bit more or a little bit less, given the prevailing conditions, mainly weather and growth. This indicates the existence of the theorised ostensive and performative aspects of the routine (Feldman and Pentland 2003).

Nutrient Management Plan (NMP)

The NMP is a planning tool which is required of those who apply for derogation to the nitrates directive allowing for the increase in the application of organic nitrogen. As part of this plan a soil test is required and an overall plan for the farm is developed. The use of this plan formed part of the discussion with each participant in relation to its overall use for planning nutrient application on the farm.

Not all farmers had a NMP. In holdings with a plan, it was not used as a strict planning tool "*The soil results are…more important... we…follow them more than the NMP*" (F_1). Another response was "*it's not really practical in so far as em, it depends on what you are doing with the field*" (F_4).

Some viewed it as part requirement for derogation and to keep within requirements of the directive "*we have to stay within the limits of the plan and…basically the plan…it helps us stay within the perimeters of the… directive itself*" (F_7). Some were unaware they had a nutrient management plan, when asked F_16 responded "*Nutrient management plan*?" even though this farmer as part of his derogation application is required to have a plan for his farm. Retrospective planning with the advisor was also evident "*we work out this nutrient management plan or em to cover our activity for the year… well it would be based on actual tonnage that's bought in… basically it would be to satisfy…an inspection"* (F_12). In this case inputs were purchased as per farm requirement and the plan was based on these purchases.

The primary function of NMPs at the farm level was to cover activity and to stay within legal requirements of directive in the event of inspection. The remaining farmers would not have used it and the soil test results were viewed as more important in terms of decision making. Plans were used to "*keep within the guidelines...as best you can...well it can vary...we can just tweak it a bit*" (F_10). Plans are useful as a guide for legal requirements.

3.8 Findings: Application Routines

Lime Application

Table 3.6 (page 177) highlights a (paraphrased) summary of each participant response to how soil test results were used in the application of lime. Lime application varied in holdings. Some farms have a natural liming requirement while other participants disagree and question the need for lime in other areas. Such conclusions were based on a mix of information prior to soil test results and also experience farming the land and its historical performance and activity. A general lime requirement is known and understood by the farmer with his land. It is accepted that farmers use an array of source of information in decision making. Tisdale and Nelson (1966) identified a mix of salient information sources when determining lime application which are still relevant today: 1. Requirement of crop, 2. Texture, organic matter and pH, 3. Time and frequency of liming, 4. Nature and cost of liming material.

The liming decision of the remaining farmers were also based on land requirement either historically as a regular activity (land requirement: F_1, F_2, F_7) or through testing and targeting fields (F_3-6, F8-20). Lime requirement, as per soil test results, were given particular attention by (F1, F3-F20) farmers. The exception was the non-tester (F_2) who had not applied lime since 1984, who believed there was a lesser land requirement for lime.

Differences across farmers

Eighteen out of the twenty farmers spoke about using soil test results as a resource for guiding lime application; twelve were classified as basing requirement on path dependency[84], nine on tacit knowledge[85] and three on experimental and experiential

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[84] Path dependence defined as sequence of economic changes, where the outcome is influenced by remote events either "chance" or "systematic" happenings, the dynamic process of change "*takes on an*

learning[86]. However, these are not mutually exclusive categories. Farmers F_2, F_14 did not use soil tests results as a resource for lime application, but rather there use was for different reasons.

Both farmers relied on tacit knowledge F_2 based on his understanding of the farm through historical experience and F_14 retested based on the questioning of initial recommendations received. F_2 did not use soil tests as he knew historically that his holding does not require lime, this represents the ostensive aspect of the liming routine on his farm "*lime would stay in the land do ya know...it'd go down as far as the marl maybe like and that'd be it, it'd stop there…in light shally ground it washes*

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essentially historical character" (Daivd 1985 p.332). It generally refers to the notion that "history matters" (Durlauf 2008). Martin and Sunley (2006) identify three approaches taken to path dependency in economics "lock-in" (Paul David) "dynamic increasing returns" (Brian Aurthor) and more recently (Douglas North and Mark Setterfield) "institutional hysteresis". The nutrient management activities of farmers follow closely the view of path dependence described as "institutional hysteresis". Setterfield (1993). This is not a new phenomenon, it reflects ideas of Carl Menger's "institutional emergence" and Thorstein Veblen's "cumulative causation" (Martin and Sunley 2006).

[85] Tacit knowledge is defined as per Michael Polanyi quote "we know more than we can tell" (Nonaka 1991). Nonaka (1991) identified characteristics of tacit knowledge as being rooted in action and individual commitment to a context, highly personal, it consists of skills captured in "know-how", often difficult to articulate principles recognising the importance of the cognitive dimension ingrained beliefs. To do and be unable to explain how it is done is more than logically possible it is common situation (Nelson and Winter 1982).

[86] Experiential learning is defined as per Kolb "*Learning is the process whereby knowledge is created through the transformation of experience*" (1984 p.38). Kolb (1984) describes the learning from an experiential perspective as having three characteristics. It emphasis process of learning and adaption rather than content and outcome, a transformational process ever changing, opposed to acquisition and transmission being created and recreated not an independent entity. He describes learning as process that transforms experience emphasising the importance of understanding the nature of knowledge, further the nature of knowledge must understand the process of learning. Leeuwis (2004) identified aspects of the learning process, becoming aware, becoming interested, becoming involved in active experiential (social) learning and establishing adapted practices and routines. This may involve learning on a variety of topics and issues, such as organisational and technical solutions, stakeholder perspectives (experiential) and feedback on effectiveness of change (adapted routine) (Leeuwis 2004).

down into the bounds of the earth". This was confirmed by a soil scientist; heavier (wet land) soil has a lesser lime requirement as it retains the mineral. Upon reseeding fields F_2 did apply lime (performative), based on a recommendation from the local merchant.

F_14 received recommendations for lime from soil tests, but carried out his own experiments with fast acting lime and "*invariable there was no difference*". He suspected there was no need to spread lime and through conducting an experiment he was satisfied there was no need. Further to this F_14 got advice from an agronomist who confirmed through another set of tests lime was not required. The ostensive activity of soil testing had been conducted in the past and was planned again in the future; the test results were questioned prior to being exercised in the performative aspect of the routine again placing value on personal knowledge and experience.

Similar to F_2, land requirement for lime was low for F_15, however, his performative aspect differed to F_2 as a more frequent application was given "*Not much no doesn't take much lime heavier land doesn't take much lime…every three or four year we'd spread a little bit..all the soil samples were showing up okay them there two year ago"* (F_5).

Similar to F_14, F_8 questioned the recommendations received by test, although he used the soil test results as a resource to identify fields that were low. The artefact (results) suggested a application rate for each field, (ostensive), however, the farmer chose to apply a uniform application (performative) which was "*spur of the moment thought*" (tacit) (F_8). From the conversation it was clear this was based on his past activities. His surprise at recommendations was based on recommended lime applications on recently reseeded fields "*showing more…so low in lime now than ever*" but also based on an experiment carried out (F_8). The questioning of recommendation was also based on current output, the recommended soil test results (artefact) suggested application on fields which surprised F_16 as there was plenty of grass "*still showed low in lime*" a less than recommended amount was used (performative). F_16 maintained he may return with more lime in the future depending on field "*you kind of say how could that be so low… It was a good field of grass… You'd say that you might put out extra fertilizer that's driving on the grass or* *what*" (F_16). Although he used the results as a guide for liming, the performative aspect of the routine was influenced by his own experience described as a cautious approach to change (Table 3.6).

The value of this personal information was evident in liming activities of farmers; even though tests are carried out they may not always be followed strictly in relation to lime. Two cases indicate this "*I just tried the bag lime that year and ah grass was totally different on the fields cows were eating it off clear seemed to be sweeter they were happy on it and I was happy*" (F_3). Even though it is recommended to test before reseeding it is not always carried out "*sometimes I don't* (test) *to be honest…All I do is I throw out about 2 or 3 tonne of lime just to keep it going*" (F_13). This again is based on a tacit knowledge of knowing what is required based on experience. F_3 and F_13 were quite different, one was a firm believer in lime "*if ya don't put lime out I think it's nearly a waste putting out fertilizer*" (F_3). The other farmer used a different approach; the ostensive routine was based on time, crop itself and his father's advice. For crop fields "*I might give it a run of lime maybe after three or four years give it a touch up with lime*" for grassland "*my father was saying…if you throw out too much lime it's no good to it either so you just, small, d'you know between 2 and 3 tonne d'you know*" (F_13).

Scientific evidence presented was often not followed stringently; farmer experiments were also carried out (F_3, F_8, F_14). Recommendations for lime were questioned by these farmers and used with caution. F_1 used soil tests results as a primary resource for lime application targeting fields. Liming was an important activity and historically an annual activity for as long as he could remember on the holding as an annual activity. On another holding it was described as a "*constant battle"* F_7, for this farmer the soil test was described as a principle guide in decision making on acidic soil. Both farmers relied heavily on results based on historical land requirement. This is discussed later in factors effecting which include soil type. Farmers with wet land where soils were described as heavy were found to retain lime better than dryer land/soil (F_2). This dryer soil was "*hungry*" (F_3) than wet soil which retained the lime longer, this was based on his experience working on other farms.

F_3 through working for contractors in spreading lime identified differences in fields in the locality "*across the main road up here…you could put out lime every year you could put out 2 tonnes of lime to the acre every year and... your land could still be just border line on lime (okay) down here ya could get away with spreading lime if your lime is up in the land if it's okay, you'd get away with maybe every three four years (okay) and maybe more like it's just difference hungry land different types of land up there that you could spread definitely you could spread a tonne two tonne to the acre and it'll still, still if you tested it next year or the year after it'll still be always wanting (want lime) am down here its different your only talking half a country mile across here as the crow flies (ya ya) it's just different land your up more higher country more drier different rock like round here maybe holds minerals*" (F_3). This was also the case other farmers (F_20). These farmers stated that on their farm there is a lesser requirement for lime, this is based on land, and on experience farming that land.

F_10 applied very little lime in the past except when reseeding fields "*rarely now we would have put lime on grass prior to this*" the REPS plan made liming recommendations and from that liming on grassland commenced. This shows the positive impact of REPS "*most of the farm done actually there's only a small amount to be limed now then back testing what you started with you know*" (F_10). It also shows the intention to test again. Another REPS farmer F_15 also expressed a more recent use of soil test results through targeting fields that are low and now uses results as a guide for liming. Starting in 2008, prompted by REPS visually he knew fields were low in lime, prior to REPS largely would have only looked at crops fields "*once it was rotated all the time and you felt it was okay then*" this tacit feeling was based on activity and visual indicators (F_15).

An inexperienced lime user, who applied lime as per recommendations had an over-supply of grass, as historically liming was not conducted on his farm he lacked the experience in using it (F_9). The farm was very low in lime and needed a large application as per the soil test results. F_9 acted on the advisors suggestion to begin with lime, lime is a starting point for improved soil fertility. Contrary to this there was a sense from F_12 that a satisfactory level of lime had been achieved "*grassland now* *has all been done over the term and it's pretty well okay… we'd always have had that pretty well okay*" (F_12) with an existing non-requirement for lime "*lime would be okayish*" (F_17). Comparatively, prior to F_15 taking over the farm his father and uncle ran two separate farms which he now operates as one, this existing routine was not in place. During their management lime was not a priority and when F_15 began testing the whole farm was low "*so it was a major thing to get the whole thing completed…basically limes are okay at this stage like we have done a pile of work on that*" (F_15). Also as part of the "*catchments we were given like an A4 map of the farm all its numbers, they gave each field a number and the corresponding results were on the back then for your nitrogen Ps and Ks and your limes*".

Lime was identified as an initial action that could be carried out straight away (F_15, F_11) as this is in relation to timing of test and application of lime, conducting a test in the autumn allows time to address an lime issues immediately and over the winter period to address any other nutrient requirements. Ostensive liming routines were also related to ownership (F_4, F_11, F_12) as rented land generally was not limed.

Performative aspects changed based on weather conditions, soil test results and on plans for that field (age of pasture). When reseeding lime is applied generally "*I knew that one was low cause it hadn't got lime in for years and it was old pasture*" (F_3), "*like that field now if I was reseeding I'd put out a few tonne of lime on that anyway… it wouldn't have gotten lime for a number of years*" (F_19) using soil results, but also using historical information about previous farm liming activities. When reseeding land, all farmers spread lime and used soil test results for recommendations and changed their performative routine in some form based on existing conditions. This was generally based on the three main factors soil type, results and future intentions discussed in the next section. Farmers generally used the soil results as a guide for lime applying; the ostensive routine was clear from (artefact) results, performative aspects varied depending on changing conditions. Soil test results give you a "*picture*" (F_16, F_17), but you'd go with what results recommend for lime generally (F_17).

Factors influencing liming activities

The farmers developed an understanding as to the land requirements for lime. The lime requirement was a function of three main factors: (a) Soil type, (b) Test results and (c) Past application/Future intentions.

The relative importance of these sources, seems to be in the order above (a,b,c), is of interest as they establish the importance of the liming programme for that farm. Soil type is a major function of lime requirement and is the most important element in liming applications. Participants frequently spoke about the "*land requirement*" referring to the natural "*lie of the land*". This type of information has developed from experience in farming their land. The differences in soils were a prominent issue, within the same location soil type would be completely alien in terms of management. One farmer described farms in a neighbouring area as being "*different country altogether….you'd have to be used to it*" (F_1), which comes with experience in performing nutrient management activities. This farmer gave the example of well drilling where professionals would have to reach a depth of up to 90 foot before hitting rock compared to his holding (less than ten minute drive away) where you would hit rock at a depth of 10 foot. In limestone areas also, the requirement for lime is diminished and so the associated management practices "*not much need for lime*" (F_20). The converse of this, is in more acidic areas where they would "*have to spread lime*" as it is a "*constant battle to keep the pH level up*" (F_7). The given examples highlight the variance in relative importance which exists with liming routines based on soil type alone at the farm level. The relative importance of the routine is a function of farm activities and resources.

Liming is one of the more widely adopted practices compared to other conservation practices (Pannell et al. 2006). This was obvious from most interviews "*lime that would be your immediate one that you would target that straight away*" (F_15*). "well first is you'd look at the lime right and then you'd say if any of them need a top up of lime or that so you'd be doing that fairly straight away"* (F_11). The quantity of lime was at times questioned. The soil test results for F_8 showed land low in lime *"which I am surprised at like, maybe it's just with a right bit of usage of nitrogen that is pushing the lime out of the ground you know, em even fields that got lime maybe was* *reseeded in the last couple of years and got lime at that time and they are still showing low in lime*" (P_8). When asked if he thought the recommendation were too high he responded *" to tell you the truth I did yes, yes, like I know they recommend lime, but I don't have great or that good faith in lime really like*" (P_8). Given a 'high' recommendation farmers did split the quantities to be applied (P_8 intended to revisit with lime) "*if they needed a lot…you wouldn't be putting it all out in the one go"* (F_11).

In terms of targeting these lower fields F_8 gave instruction to the contractor to apply a blanket cover "*they showed all low in lime, but some of them were lower than others, but I just put a flat rate on them all*" (P_8). Uniform application is not uncommon with chemical as another farmers stated when asked if he targeted each field individually he said "*more or less…you'd try get an even read across the two or three fields and put them in as one sample because the chances are…when you go back to it it's going to be treated as a single block anyway…plus the fact that you'd know where the problem areas were*" (F_12).

Four main conceptual themes emerged from interview data, these themes represent decision rules used by farmer for lime application activities:

1. Path dependency
2. Scientific evidence (soil test result)
3. Tacit knowledge
4. Experiential learning

These four concepts are used as categories in explaining the similarities and differences which exist between farmers liming activities. Liming activities are summarised in Table 3.6 descriptively in column two and conceptually in the discussion section. Four themes are identified to categorise the activities, these are not mutually exclusive categories, but rather aids in framing the routine in terms of its ostensive and performative aspects. The description of the corresponding activities varied in many cases under the same theme. These similarities and variations were important in identifying how decisions were made and why.

The ostensive element of each activity was identified through the information used from on-farm artefacts. Artefacts as defined are physical manifestations of routines which support decision making, in this case could be seen as the soil test results. The results were not the sole source of information. Three factors were salient for liming application of farmers interviewed, soil results, soil type and past/future intentions for the land. These factors are all based at a very micro level on the specific field. This field based approach allowed farmers to evaluate local conditions and requirements for lime beyond the scientific recommendations.

The farmers who soil test are given a set of results and recommendations for lime application. These results were relied upon by eighteen interviewed and used as a resource for activity. All eighteen rely on results in the application of lime; this is a reflection of the ostensive aspect of the liming routine. The use of soil test results represents the abstract of generalized pattern of the liming routine. Use is influenced in part by the artefact soil test results given by scientific standards. The level of reliance on that information varied. This represents the performative aspect of the liming routine as highlighted in the activities of each farm. The ostensive and performative aspects of the liming routine were further informed by soil type and past and future land use decisions.

Soil type varied. This variation resulted in the different management strategies of farmers. Soil was identified as a resource by the farmers in two ways: as a productive asset and as source of information itself. It is a physical resource which has potential to produce an output. The ostensive activity associated with the field varied based on soil type. Land requirement was important and an inherent need for lime understood through the four conceptual themes identified. Potential problems were identified either visually, physically or through testing which informed both the ostensive and performative aspects of the liming activity. In this way the liming activities of farmers was based on soil type and the information used in decision making could be classified under any or all of the four themes identified above. The soil type was a self-classification relative to their farm and informed by the four themes as per Table 3.6.

Similarly past and future decisions informed the performative aspect of the liming routine. Knowledge of the land and an intimate understanding of the potential performance and liming needs of land was evident from the four themes in Table 3.6. The current liming activities were closely related to past activity and future intentions. In particular, it was related to timing of reseeding; a grassland management practice. The age of pasture and liming requirements were closely connected to the current performative liming routine. Activities were improvised based on this historic and planned information.

In relating the coded data to the themes there is no a single linear relationship, but rather a complex matrix of relationships. This is a reflection of research carried out specifically looking at decision making (Öhlmér, Olson and Brehmer 1998) but also in relation to information sources (Ingram 2008, Ingram, Fry and Mathieu 2010, Raymond, et al. 2010) as supported in this study. Table 3.6 (a) provides a summary of these relationships in reality it is not as clear as the tabulated figure indicates. For example, the code 'historic' is by definition associated with, path dependency however, this historical activity is influenced also by tacit knowledge. Where farmers rely on stories from the past that influence current activities this could also be classified as learned or a tacit understanding which impacts current liming activity. Historic was also influential where farmers, while conscious of path dependent activities, also used new knowledge using soil test results as a resource to influence the performative aspect of the liming routine. This historic activity may be influential under all four headings, however, is most closely associated with, path dependency.

In a similar way rule guided approach to using soil test results was influences by path dependent activities and tacit knowledge which was also mediated by learning. It is impossible for this study to evaluate the extent to which these themes directly impacted activities however, during the conversations it was evident a set of complex dynamic relationships exist. This is based on the resources held by the farm. The knowledge of land was largely tacit in nature. However, it was also a function of soil test results and path dependency. This study extends current research on farmers' decision making in identifying these nutrient management activities as organisational routines.

Table 3.6 Application Routine: Lime

Farmer	*Farm Activity: Lime Application*	*Category Codes*
1	Always applied, reasons cost & land requirement.	Annual Historically
	If needed, would use results to indicate low areas	Target Field
2	Prior to 2012, spread no lime since 1984, no land requirement	Land retain minerals
3	Results indicate need, were so low put out less than recommended and planned on reseeding	ST Guide Historic
	Previous activity, believes in lime it's long term	Experience working
	The requirement is dependent on land "hungry for it"	Knowing your own land
4	Would spread lime but not in rented fields	ST Guide
5	No major land requirement but is important, would rotate on the farm	Historic
	Would also use results	Test confirms
6	Would spread 2-2 ½ tonne regularly, use results	ST Guide (rule of thumb)
	Not much land requirement	Historic
7	Regular lime requirement acidic soil, constant battle	Historic
	Use results, lime requires time	ST Principle guide
	Seen results retesting shown soil to neutralize	Experiment /Experience
8	Does not believe in lime. Surprised to find land low in lime, put out flat rate, split amount recommended	Experience/Experiment ST Guide (rule of thumb)
	Feels overuse of Nitrogen pushes out lime	
9	Only apply lime to reseeds in the past	Historic
	Was very low in lime, applied small amount	ST Guide
	Result was a surplus of grass, forced to bale short later	Lack of experience
	Plans to build up lime slowly	Future plan
10	Wouldn't have limed grassland in the past (rare)	Historically
	Test revealed lime requirement and it was applied	ST Guide
11	Would begin recommendations immediately little by little	ST Guide
	Not on rented ground even though it needed it	Future unsure
12	Use the results	ST Guide
	Always had it pretty okay on owned land	Historic
13	Use results to identify areas in need	ST Guide
	Would generally spread 2-3 tonne every 3-4 years touch up, fathers rule also when reseeding	Historic
14	Believes in lime if needed test stating lime needed agronomist said no lime. Experiment (fast acting lime)	Questioned advice Site Experiment confirmed
15	Wouldn't have put out much lime	Historic (previously)
	More recently have worked on it and now is up	ST Guide (now)
16	Would use it	ST Guide
	Surprised at results, tailored use didn't put out as recommended, (plenty of grass)	Experience Cautious
17	Give indication of pH. Lime okay	ST Guide
18	Would use results	ST Guide
	Also when reseeding	Historical
19	Would use result indicate low areas	ST Guide
	Also when reseeding	Historic
20	Not big land requirement	Experience
	Would use result not big response when applied	ST Guide

ST denotes soil test.

Table 3.6 (a) Lime Application

	Themes	Category Codes
On- Farm	Path Dependency	Historical, Annual, future plan.
Resources:	Soil Test Result: Resource	Target.
Physical		Guide: Rule of thumb, principle guide.
Human		Test confirms.
Social		Experimentation/Experience.
	Tacit Knowledge	Know your own land: Retains minerals.
	Learning	Work experience.

The routines literature recognises decision making as having two distinct characteristics ostensive and performative activities (Feldman and Pentland 2003, Pentland and Feldman 2005). It supports previous research in recognising the complex web of relations which inform decision making and develops an awareness of the importance of routines in identifying a broader capability within the farm. This literature gives structure to the decision making activities of farmers.

Slurry Application

The performative application of slurry again varied. The nutrient content of slurry varied on each farm and at different times in the year. Generally each farmer gauged the quantity as typically between 1,000-1,500 gallons per acre after grazing and 2,000-5,000 gallons per acre after crops were taken off (silage). This varied as it was also dependent on the type and quality of slurry. These generally were uniform at farm level and represented the ostensive aspect of the routine. Tacit decisions were made in understanding the quality of slurry which was difficult to explain other than the visual appearance "*I know what's hot and what's not*" (F_14). This farmer paid for an expensive test to identify the level of available nutrients in the slurry however, he did not make any changes based on the test at field level "*you'd just know… again you'd know your fields*" (F_14).

The use of soil test results are seen in the targeting fields that are low in fertility, using soil results as a resource. Fields were targeted to increase soil fertility. Historical activities were also salient in the performative aspect of the routine. To some extent the ostensive aspect was stable as crop fields were treated in the same way most years a particular quantity was applied to particular fields, as this is a function of their storage capacity, generally a slatted house. They must apply this amount annually unless the farmer had additional storage capacity or he may export off-farm.

Farmers described slurry as (a) ‘Soiled water’/’Dairy washings’ (2) ‘Watery good colour’ and (3) ‘Thick “Real” slurry’. Slurry was often intentionally watered down or unintentionally through water entering tanks from rooftops. Decisions concerning application were subjectively based. There were a number of fixed factors which influenced the routine including the field and weather conditions.

The performative aspect of routines was altered based on the resource slurry, itself and the land conditions explained by (F_15) *“I suppose I don’t know 3,000 gallons to the acre very watery stuff I find it em, you are not doing the earth worms any good, you could find them coming to the top, they would almost drown in the ground or something like. If it was thicker stuff maybe you’d go 3,000 gallons alright that it wouldn’t wash it into the ground, but for watery stuff 2,000 gallons is enough”*.

There were two overarching influencing factors which impact all farm slurry application: (1) the field and (2) weather condition.

(1) Field

The field itself influences slurry application in two ways first in terms of location: the accessibility in terms of roadways and entrances and the distance away from home farmyard (where slurry is stored). The greater the distance between the field and the storage facility the less likely the field was to have slurry applied to it. This formed part of the ostensive aspect of the routine. In the absence of a network of roads throughout the farm fields would often be difficult to get to. “*If you had to go across two fields to get there……it wouldn’t be done….when you get your path around the farm the roadways it really means that every field is fairly close to the yard*”(F_11). Chemical may be used as alternative in fields with no road access or a greater distance away from source as the volume of nutrient required is much smaller with chemical so transportation is less of a burden.

Secondly the field capacity, land type, wet land is less well able to "*take*" slurry. Particularly in 2012 as it was a year of heavy rainfall. Field capacity also relates to size, F_4 when speaking about nutrient application of two similar fields slurry was used on one and dung on the other, when asked why this variation he deemed it was down to field size and the quantity of available organic remaining "*Well there wasn't an awful lot of slurry left and the smaller one just finished it up like you know"*.

(2) Weather

The performative aspect of the slurry application routine was a function of other on-farm resources. The surface conditions also determined whether or not slurry was applied, if it was "*fit to travel*" (F_2) on then the farmer deemed slurry could be spread. Most farmers used this rule of thumb as a guide within time periods allowed.

Weather conditions were the second most important factor. In a year with lower levels of rainfall slurry can be utilized more efficiently, chemical is relied upon less as there are savings to be made. However, all farmers had spread both chemical and organic fertilizer. Variable weather patterns make organic nutrient application difficult without appropriate equipment. Science suggests most value is gained from spring application of organic nutrients. "*spreading all your slurry in the spring is another…disaster…that should be spread out over the whole year like ya know… in a dairy farm every second day I'd say*" F_14 farmer felt "*your miles better off to have a little a lot that a lot a little*" (F_14). This is also a function of the fact that F_14 is restricted in terms of P and K application under nitrates regulation. As a result he has a system in place where he follows the cows after grazing with slurry application. One farmer purchased a pipe system which allowed for slurry application on steep hills in wet weather (F_8), a contractor and viewed this as an investment (€20,000) for the future.

Timing

Timing is a subroutine of slurry application and influenced by both the field and the weather. The ostensive timing of application was dependent on growth of the grass and avoiding application when grazing is possible. This was generally uniform for all holdings. Also the number of times slurry can be applied in one year is limited as it "*sours*" grass and becomes "*unpalatable*" (F_7) for the "*selective herbivore*" (F_15), they "*turn around in the field…it might look nice…but they don't like it*" (F_9).

The following timings are not exclusive for farmers who spread early in spring and again later on in the year. Spring application occurred after first grazing a light coat not to damage grass. Twelve farmers spread slurry in spring which is recommended practice while four spread all year round. Some of the spring applicators also spread some in summer which was generally before and after harvesting crops, ten apply slurry biannually.

The application of slurry during closed periods was a cause of concern for farmers and a number of farmers discussed at length the concerns about the regulation this issue is expanded upon in the discussions section. Four themes were identified and are summarised in Table 3.7 (a). The slurry application activities of each farmer are detail in Table 3.7 (page 183). The slurry application routine is described using four category codes, historical, experience, maximise usage and targeted. These represent how the farmers decide slurry application of slurry for their farm.

The timing of application as affected by the weather conditions and the land conditions. This also was influenced by farmers experience with his system of farming and understanding quality of slurry. This was a function of feed given to animals and recognised visually by farmers. Farmers adjusting their slurry routine did so slowly through trial and experimenting with changing weather conditions. Three farmers in particular were focused on getting the most out of their slurry through maximising their usage and a further five were also aware of the value of slurry for increased productivity using their experience as an indicator of the value of the nutrients. These data summarise the slurry application of twenty specialise dairy farmers interviewed (Table 3.7). The variation in slurry application was based on their resources. Such resources were as identified fixed assets such as land, storage of the physical organic compound itself. Human resources were also of importance this included drawing on their own experience as farmers in making decisions to apply slurry. Often, a judgement call was made, the decision to spread or not was important in terms of its potential to cause environmental problems.

In summary, the relationship between the category codes and themes from literature (Table 3.7a) again were not exclusive between theme and code with much overlap. Soil test results were used as a resource however, tacit knowledge about the field itself and past activities were valuable for decision making. Slurry application was associated with efficiency and productivity, but also with past activities and tacit indicators and historical decisions. Soil test results were also used to identify fields that are low, dynamic conditions in particular weather influenced the performative aspect of the slurry application routine. Slurry has potential to pollute water courses, but also harm the soil conditions itself (the earthworms, 'sour' grass). The performative aspect of the routines is heavily dependent on the weather conditions as it is an environmental issue.

Table 3. 7 Application Routine: Slurry

Farmer	*Activity: Slurry Application (timing quantity)*	*Category Codes*
1	Low fields targeted with slurry, usually in the spring April after	Targeted (low/high)
	sheep graze it first on home farm only, wherever it was needed	Historical (Timing)
2	After crop taken(silage), water it down, not heavy application so	Experience
	not to sour grass,	
3	Usually March depending on weather, quantity usually the same	Historical (Timing)
	early application and after crop cutting, hay/silage hard on land	
	so might get bit extra, targeted fields low. Additional organic if	Targeted
	necessary depending on growth	
4	Recently changed to Spring application for silage/crop. Would	Experience (trial)
	look at results lowish/highish, not to letter of law	Target
	First fertilizer application usually slurry.	Historical (weather)
	Amount depends on slurry itself	Visual Guide
5	All farm would generally get slurry, mostly crops(maize)	Historically (crop req)
6	Low fields get slurry and dung	Targeted
	Slurry for silage before and after,	Historical
	Calibrate with eyes, stay close to what you want (guide)	Visual & Experience
7	Spreading throughout the year, weekly basis max usage	Historical
	Believes its not enough artificial needed	Experience
8	Mainly spring and after crop cut, whole farm if possible	Historical
	Not too heavy 2-2.5 ,wouldn't record but fair idea	Experience
	Feels big difference with value of slurry	
9	Try get our early not during grazing pending land condition	Historical (wet land)
	Suspect fields (colour) would get "lick" slurry first	Experience
	Need to get timing right rain after application (sour)	
10	Spring application on silage ground same most years and empty	Historical
	tanks in October tillage land also, adequate storage	
	Wouldn't record have fair idea	Experience
11	Prior to nitrates when it was fit now	Historical
	Light spring application before/after silage, (have storage)	Regulation
	Roadways allow for access to low fields with additional	Maximise usage
	ST& generally know low fields after a number of cuttings	Experience
12	Anywhere that needed gets it early on P&K attribute it to test	Historical
	but also field history, future plans	Targeted
	Dry year more slurry cut back on chemical	Maximiser usage
13	Slurry applied after first grazing watery enough (Feb 2012)	Historical
	no set pattern, no record would have fair idea	Experience
14	Would and he wouldn't would generally know what is required.	Historical
	Valued specialised knowledge. Get a system going after cows.	Experience
	Spread all year little a lot better than a lot a little	Maximise usage
15	More use recently applied targeted approach, gives picture	Target
	Would spread all year better use,	Maximise usage
	Fair idea of what you would put our generally	Experience
16	Skin of slurry early thicken grass, crop fields silage	Historical
	Changing things around watery slurry bring on grass	Experimenting
	Save on fertilizer in dry year	
17	Watery stuff for grassland and for silage ground know what you	Historical
	have always done, get last grazing out of slurry	Maximise usage
18	Would mostly go on silage and in summer watery washing may	Historical
	go after cows	
	Generally know, when you're out every day	Experience
19	After the first and then after silage again, not summer	Historical
	Consider tests use slurry if possible weather/land, generally tank	Experience
	acre	
20	On silage ground mainly bit less in spring would have a fair idea	Historical

Table 3.7 (a) Summary Slurry

	Theme	Category Codes
On-Farm	Path Dependency	Historic: Timing, weather, crop, land.
Resources:	Tacit Knowledge	Experience, visuals, learning, historical.
Physical,	Productivity/Efficiency	Maximise usage, growth, experience.
Human, Social	Soil test result as resource	Targeted.

Chemical Application

Recommendations for application chemical and lime are received by soil testers from advisors based on laboratory results. Generally farmers placed greater weight on the liming recommendations, which is a not an annual activity, than on the chemical application. The annual activity of chemical application is an established practice. Each farm tended to have a range/baseline application. This range is the ostensive aspect of the chemical application routine. This ostensive aspect was altered according to a number of indicators, including, soil test results, plans for crops, availability of current crops, cost of resources and growth conditions, culminating in the performative aspect of the chemical routine.

The ostensive baseline application had emerged in all cases historically, through understanding land and farm requirements. The farmers understand these requirements through experience with farming their holding. F_2 relies solely on this experience using crop output as an indicator. In all other cases the soil test results were also considered as a guide, but to a lesser extent. The recommendations given are mediated through the eyes of experience with working their land. It must be noted recommendations were not ignored, but they were not applied in a strict sense F_4 "*not to the letter of the law*" but rather in a blended sense. This approach allowed for alternative pieces of information, deemed important for decision making, to be used by the farmer, in particular the availability of grass and crop outputs.

Past, present and future activities were important. The ostensive baseline figure was altered in terms of the performative aspect of the routine coded in Table 3.8 (page 192). The activities described in column one is coded as follows: regulation, crop output, soil test results and prices. Crop output is the most influential factor in the chemical application routine. The growing conditions for grass influenced performative application as output is directly affected. All twenty farmers spoke about the crop growth and output.

These codes are used to group similar activity again mutually exclusive groupings do not exist as farmers make decisions based on changing conditions. Figure 3.6 is an example of how these four codes impact both ostensive and performative aspects of the chemical application routine in the long and short run respectively. A change in any one of these immediately impacts the performative application and over time the ostensive aspect.

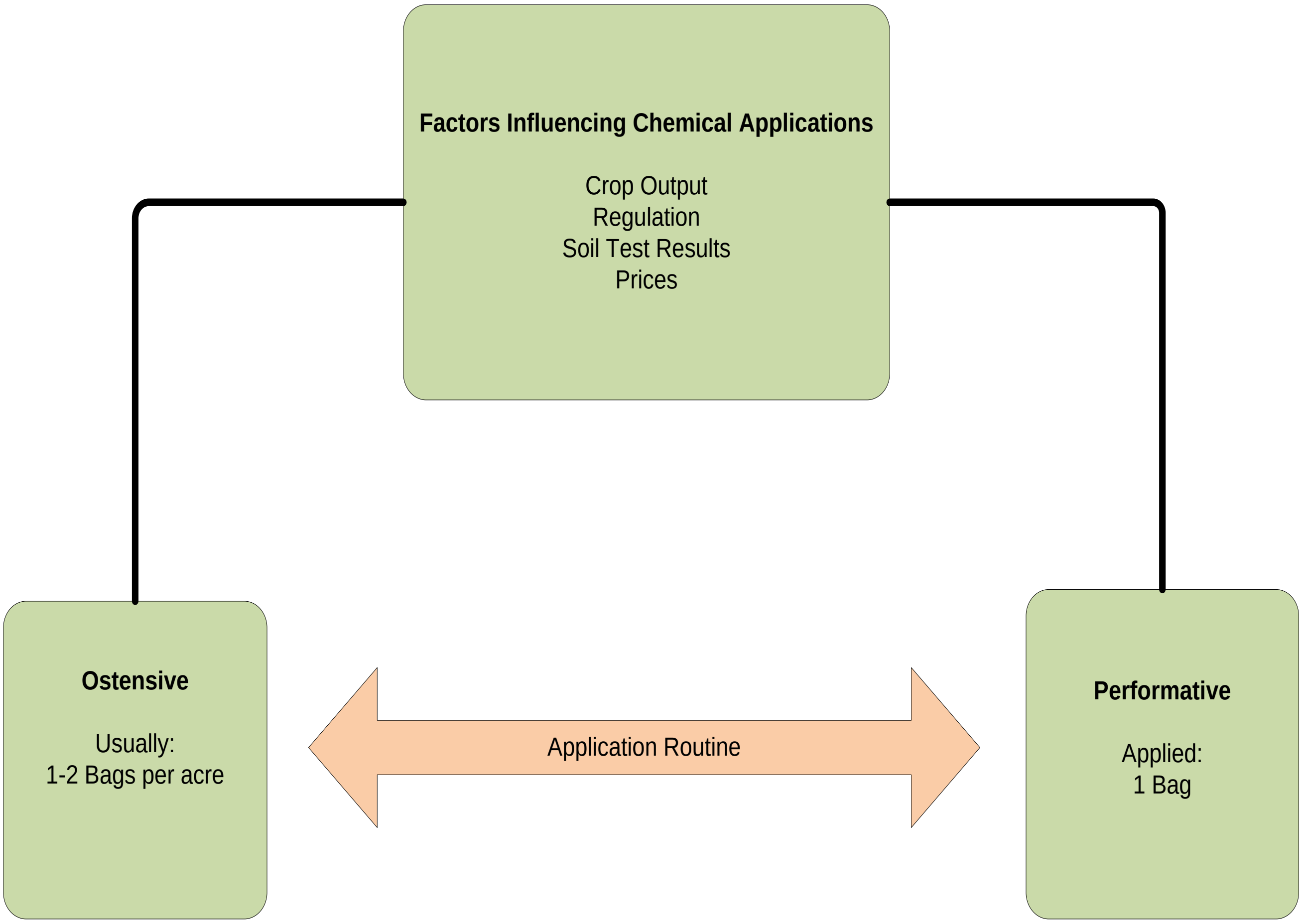

Figure 3.6 Ostensive and Performative Chemical Routine

The ostensive routine

The ostensive application is based on historic activities; what has been done in the past. Mainly this has been set by two main parameters, the land type and the system of farming. These parameters set out the output potential for the farm. To realise this output certain activities were carried out, that set this ostensive application it is path dependent in nature.

The range which the farmer applied generally is described by farmers in terms of quantity. According to one farmer one bag to the acre may be too light and two was too heavy so roughly 1 ½ bags to the acre was what was used as a guide (F_16) depending on the listed factors (Table 3.8). Another farmer (F_4) described the quantity as being as little as he could get away with depending on "*what's in front of you*" (F_8).

This quantity wouldn't change a "*big pile",* the application was dependent on grass available "*a wee skite of nitrogen*" may be applied *"a bag to a bag and a half of nitrogen to the acre…not every time…if you could see that it didn't need it…if you were scarce you'd be doing it every time…depends on growth and numbers*" (F_8). Further to that these decisions were dependent on a range of other conditions mainly growth and weather. The grass itself is a visual indicator without ever looking at test results (F_14) "*it's pretty much obvious if we're if you're missing anything…if your anyway low in P or K it'll show up straight cause the place will just go yellow (The grass?) ya you won't see the lush in it*". The performative aspect of the routine in Table 3.8 identifies four codes for classification of activities regulation, crop output, soil test results and prices.

The performative routine

The four codes used to classify activity are part of an inter-functioning relationship seen below. The following function represents the dynamic elements which influence change in the performative aspect of the routine. The function of change in chemical application routine: $Q = f\,(growth + weather + regulation + price + soil\ test\ results).$ The quantity (Q) of chemical applied is a function of each or all of these variables. The relative importance of these varied depending on the farm. Growth and weather in combination was attributed to crop output. The ostensive routine was based on path dependency and experience of the farmer. This may also be changed due to regulation (nitrates directive) which restricted chemical application.

Nitrogen, potassium and phosphorous sales have been decreasing over the period 2000-2009, with the decrease in nitrogen close to 25%, the sales in potassium (57% decrease) and phosphorous (59% decrease) were at a 50 year low in 2009 (Donnellan, Hanrahan and Lalor 2012). Agri-environmental measures (REPS and Nitrates Regulation), prices of fertilizer relative to feed and improved management practices are factors influencing this change (*ibid)*. The soil test results of this study complement those of Donnellan, Hanrahan and Lalor (2012). Specifically, the findings from this study suggest two factors, environmental measures (regulation) and crop performance impact usage. The nitrates regulation strictly impacted two of the farmers interviewed as they were not permitted to apply phosphorous legally. There are no restrictions on the use of potassium however, farmers spoke about these two nutrients in tandem. F_15 used a specialise compound which had no phosphorous this was based on soil tests results which indicated the need and the availability of the compound in the co-op which was a supply factor. Donnellan, Hanrahan and Lalor (2012) note the falling trend in potassium even with no restrictions on that nutrient.

Interview data suggest crop output availability of resources to be the most influential factor in fertilizer usage. Figure 3.6 shows the factors influencing the ostensive and performative aspect of the chemical application routine. The listed factors, crop output, regulation, soil test results and prices are now discussed.

Crop Output/Growth and Weather: The level of growth is a function of weather conditions including land conditions, soil temperature, rainfall etc. the performative aspect of the chemical routine application was altered depending on these conditions, which were seen as critical. The greatest concern for the farmer is the availability of crops for feeding animals and keeping within regulatory requirements. The weather conditions can hinder application and uptake of chemical as in heavy rain periods, there is a danger fertilizer is not being utilized by the soil and so the benefits in this scenario are limited in term of crop output. Further applications may be required as

F_2 made a decision to go early with fertilizer as the land recently reseeded was "*hungry*" for it and as the weather didn't come the fertilizer was described as being "*dead in the ground". "I went out too early this year, I had ta go early as I said the reseed was hungry for it like ya know its wasn't doing and then the manure is gone dead before the real growth comes"*(F_2). The timing of fertilizer was weather dependent also "*Whenever it got good an(d) growy…depends on the year*" (F_4). The amount of fertilizer then was "*as little as you think you can get away with…see how it's going the last couple of rounds only got half a bag an acre…that seemed to respond fairly well"* when asked how he gauged the response he replied "*just by how much grass I don't do a filed wedge now* (quantified measure) *just by how much grass looks to be ahead"* (p_4).

When asked how would you make a decision between the application of one bag of chemical versus two bags to the acre F_17 suggested: "*Well I suppose the ground you know the soil samples and that then and the nature of the fields that you know need it like, may be they need two applications*" (F_17). Attributes this to experience "*If they were cut like you, a field some particular fields might (need) two applications after grazing…you'd know from yourself like, you know the response you'd get and the soil sample what it has shown before…you will know it from experience anyway sure what soils need and what the ground needs*" (F_17).

The activities are a function of weather conditions and management given the limited availability of grass. During the short periods of growth it is often difficult to manage output. This gives rise to an over or under supply of resources, an example in relation to the liming routine, having spread lime, the "*grass jumped out of the ground*" (F_9). Farmers referred to this as a difficult in controlling and planning resource output during this growth period. It made it difficult to plan even having a plan meant very little if growth doesn't come "*You could be tight on grass we were tight on grass and all of a sudden in one week we were just outta hand…you'd have to take out paddocks and bale then maybe all of a sudden you've done to much your tight it's just a big job at certain times of the year"* (P_5). Such strategies were also taken by others farmers, fields removed from production and "*make early bales*" (F_9). Bales were stored for use later. However, this caused a problem of F_9 as given the weather conditions and the poor growth later in the year F_9 "*got tight for grass*" as it was one of his better fields.

This is a direct example of reactive strategies farmers capabilities could be enhanced to deal appropriately with such scenarios. Plans may be in place however, it does not always work accordingly "*you're dealing with nature*" (F_12). Other farmers reported being tight for feed also and fed animals during the summer. These activities in the summer of 2012 were necessary due to adverse weather conditions and the consequences were born out in early 2013 with their Irish "fodder crisis". Feeding animals during the 2012 summer was essential to maintain the cows and keep them "happy". There are standards required of milk and farmers are paid on quality. Farmers must give quality feed to the animals and this is reflected in milk quality. In relation to individual fields also milk may be up or down in certain fields (F_5). The importance of visual indicators was prominent in many conversations and crop performance in deciding whether or not to apply more or less than usual. Grass availability was the main indicator of the performative chemical application routine.

Regulation: The impact of environmental regulation restricts the quantity of chemical fertilizer use which is permitted on any holding. If farms are high in restricted nutrients then they are not permitted to spread any chemical (F_7, F_14). This changes as farm falls back to within the limitations stipulated by the directive when which they may be permitted to spread again. Chemical can be reintroduced if fertility levels are falling.

Teagasc research shows, that nationally their clients have a falling trend in soil fertility specifically in relation to P and K. Partially influenced by agri-environmental measures (Donnellan, Hanrahan and Lalor 2012). For farmers interviewed there is a notable change in output due restricted activities under legislation "*the biggest disadvantage of the nitrates directive was the limitations of artificial phosphate… It definitely, definitely reduced grass growth substantially…we're allowed to spread a small bit of artificial phosphate…this year for the first and there was a significant improvement in output*" (F_7). Such change activities are required as per the nitrates directive impacting the performative aspect of the chemical application routine. F_14 similarly was restricted "*we use the slurry for our P and K, we don't buy any chemicals and we put out…if we can usually UREA cause it's the cheapest form of nitrogen or if we hadn't that CAN and we use ah sweet grass through it sulpha CAN cause when you use a lot of slurry*" (F_14).

Soil test results: Results are generally used as guide, it was difficult to identify exactly how they were used however, one farmer stated what he did with the soil test results which summated the activities of all others he stated "*I'd sorta remember them anyway like if there was extremes anywhere…(*if*) soil samples showing it needs a lot of P & K well then you'd do more soil samples to see if the rest of the land was the same*" (F_19). Other farmers stated "*it's just to get a picture again… you could probably tell what they are going to be before you take them, to a certain degree*" (F_17). The difficulty was in the subjectivity of usage, what are 'extremes' and to what 'degree' they were relied upon.

All testers used the results of soil tests as a guide: F_5, F_13 and F_14 to a lesser extent. When F_14 was asked if he would use the soil test results stated "*I would and I wouldn't*" but he would test again "*yeah I would ya it's no harm to see how things are going any how ya know I suppose*" (F_14). Even though he didn't use them as a guide per say he looked at the colour of the grass as an indicator of a need for P and K "*I'll tell ya it's pretty much obvious if we're if you're missing anything…if your anyway low in P or K it'll show up straight cause the place will just go yellow like…you won't see the lush in it like*" (F_14). It is difficult to identify a singular way soil test results are used as they are used in a multiplicity of ways based on dynamic farming conditions. When F_14 was asked if he kept records or a diary for planning purposes he said yes for crops silage and then he stated "*I think what your getting at is do we analyses well field number two well according to the soil test it needs…..that no I wouldn't do it anyway*" (F_14).

Price: They were cautious in the application of chemical for a number of reasons it was not done without due consideration "*you'd be looking at the grass and looking at your pocket as well*" (F_2). The requirement of the resources available was a key factor in deciding application of chemical. It is an expensive input as highlighted in the empirical study one, where fertilizer represented 18% of farmers costs (NFS 2009). The efficient use of chemical is apparent from the interviews. It is necessary to utilize available organic nutrient on the farm, but also farmers were of the opinion that some level of chemical is necessary to maintain the ground. Also given the condition farmers are faced with the application of organic is not always possible as there is greater potential to leach from topsoil also some farmers believe there is a limit to the amount of organic applied as there is a point reached where the grass is no longer palatable for the cows.

In summary each farmer had an established baseline application of chemical application. This then was adjusted on the basis of the environmental conditions (growth, weather), legal requirements (nitrates directive), cost (fertilizer) and the availability of crop (grass). The final environmental condition is the most important factor. If they don’t have resources (grass) they won’t have quality product for market (milk). This is a key point for farmers with grass based systems (all in this study). Grass is the basic input requirement for the farm. Chemical application based on experience working on that farm was associated with two themes one was path dependency and the second tacit knowledge. This emerges from the activity itself experience knowing the land was based on path dependent activities relative from year to year a change was seen as gauged against activities of the past. This understanding the field requirements was tacit in nature.

As stated with the liming and slurry application routines the chemical application similarly indicated an array of ways farmers’ base decisions upon. There was not an exclusive relationship between the codes and themes. The weightings given to categories varied and were mediated by resources. The ostensive aspect of the chemical application routine was well established on all farms this was based on a close understanding of the land requirements and experience with farming as well as the soil test results however, there was no isomorphic relationship.

Table 3.8 Chemical Application

Farmer	*Activity: Chemical Application (timing quantity)*	*Category Codes*
1	Chemical topped up after slurry, depending on how low it was, everywhere got a small bit keep things ticking over using resources available	Experience Historical/Guide Crop output/efficiency
2	Depending on happenings, timing of application using what is available, baseline climate conditions	Crop output Experience
3	Depending on available organic likes to choose a chemical that "feeds" the ground, the baseline varied accordingly	Crop output/efficiency Experience/Guide
4	Generally do something similar annually, depend on grass, when weather conditions improved for growth	Crop output/efficiency Experience/Guide
5	Generally used a range 1 bag at beginning and half end cautious to have pH correct otherwise it's a waste	Experience Crop output/efficiency
6	Generally would put out the same annually, if they wanted a couple of bags in the fall would put it out depending on the weather. Result as indicators of fields low, if it wanted it.	Historical Crop output Guide
7	Heavily restricted by regulation need for maintenance and increased flexibility, exporting organic very little chemical. Soil results verified. Grass growth reduced substantially. Avoids unnecessary application	Principle guide Visual Output/efficiency
8	Depends on what's in front of you, growth numbers Not be a huge amount of change in application	Crop output/efficiency Historical/Guide
9	Use a mix of chemicals, less if he got out with organic a bag or two at the beginning of the year not much nitrogen, If not happy with response test, colour of grass not "right"	Historical Guide Crop/output
10	Generally do the same thing nitrogen using test results also depends on what is planned	Guide Crops/efficiency
11	Depending on what was planned the chemical would be applied use organic	Crops/efficiency Guide
12	Got with organic top up with chemical depending on climate conditions, wait and see response	Crops/Efficiency Guide
13	Used similar type and quantity of chemical noting strict Used indicators weather conditions, grass	Historical Crop
14	Exporting organic doesn't buy chemical P&K only nitrogen Crop response very important	Restricted Crops/ outputs
15	Would generally look back at last year similar pattern alternating chemical and organic throughout grazing used specialised compound for field not suitable for organic	Guiding principle Crops output/efficiency Historic
16	Usually follow something similar depending on weather grass and plans for field	Guide Crop/output
17	Generally would use similar applications depending on response, know the ground using results	Historic Crop/output Guide
18	Similar pattern in chemical depend on grass using results and crop growth	Historic/crop output Guide
19	Same fertilizer applied generally, would remember results, extremes If they were normal or reasonable put out a bit if it needs it	Guide Experience/crop
20	Normally chemical is similar every year depending on resources (available feed)	Guide Experience/crop/output

Table 3.8 (a) Summary Chemical Application

	Themes	Category Codes
On-Farm	Path Dependency	Experience, historical, guide, crop output
Resources:	Tactic Knowledge	Experience, crop output, efficiency
Physical	Productivity/ Regulation	Principle guide, crop output
Human Social	Soil Test as Resource	Learning, guide, principle guide, historical

3.9 Findings: Overview

Nutrient management decisions are based on past, present and future activities. The decisions are also based on information sources accumulated by the firm. Figure 3.7 (P212) depicts a range of influences on nutrient management practices it represents highlighted issues for the analysis. During the course of the interviews many topics were discussed, but one major focus area was the role of information, learning and advice in decision making.

Farm soil fertility is informed by various past and present information sources and influenced by factors outside the control of the firm together with future plans. Kolb (1984) examined learning as a process which requires opposing abilities. This requires moving from specific involvement (act) to general analytical detachment (reflect) (Kolb 1984). The activities of the past may still be having effect in the soil today, and so it is important to consider these issues when investigating current routines. This acting and reflecting was evident in nutrient management decision making of the 20 farmers interviewed. The art of nutrient application was not exact in terms of rules of applications and timing: "*in and about*" (F_6). Nutrient management decisions were not rule based as referred to in neo-classic economics on maximisation and optimisation rules, but rather a continuous learning process based an accumulated resources.

This section will discuss Figure 3.7 (P212). The figure gives an overview of the finding in this section focusing on the farms salient knowledge sources in nutrient management planning. The findings are divided into two sections by Figure 3.7. This figure summarises the information and knowledge sources used by farmers in nutrient management decision making. The first section discusses the information and knowledge sources in Box 1 Figure 3.7 (Personal, Scientific and Industrial). The second section discusses Box 2 Figure 3.7 information and knowledge sources which are out of the control of the farmers (Weather, Prices and Resources).

Knowledge and Information Sources

Box 1 Figure 3.7: Individual resources

- Personal knowledge comes from past experience
- Scientific knowledge from testing of the soil and wider industrial information.
- Industrial information could potentially come from experts in the field, advisors, media and press etc. which are sources drawn upon by the firm (public or private).

Personal Experience: Accumulated knowledge through learning.

While personal experience is a broad term, each farmer spoke about personal experience with detailed examples of how their experience acted as a resource for decision making. It took many forms and was both positive and negative. Experience was gained from activities within the firm, but also through interactions outside the firm. It emerged from specific individuals and groups and was from formal and informal sources.

Through changing activities changes in output was noted, using alternative ways didn't work in some cases "*we found the other way just with straight nitrogen just wasn't working at all especially if you were mowing you wouldn't get near the quality or the quantity*" (F_1). Despite the scientific evidence presented by the soil test results, personal experience and knowledge gained through on-farm experimentation often had greater influence on the farmer's decision making. The scientific knowledge was not ignored, but rather it was used as a guide, with personal experience held in greater esteem (F_1). Soil test results were relied upon and viewed as an important source of information and as an indicator of what activity is required. Prior to F_1 taking over the farm no soil tests existed, "*We'd always start off every year start off with three bags of 18-6-12 I'm talking do'ya know 20 years ago religiously* *everywhere would get it*" (F_1). A number of years prior to interview soil results stated no requirement for chemical and so none was applied however, "*we learned the hard way that if ya didn't keep putting out a little bit like I was saying we found they were fading quick….. So we keep putting out a little bit every year*". He found giving "*a little bit every year…just kept everything ticking over*" (F_1). This changed the ostensive application of chemical with lesser amount of P and K being applied which maintained output levels.

There was a general pattern in most farms regarding ostensive application of chemical. Nitrogen was functionally described by farmers for grass growth and potassium and phosphorus which feed the grass. The choice of chemical was straight nitrogen or a compound mix of the three main nutrients this was generally an established mix of uses. One farmer described this general pattern as follows "*suppose every couple of years I'll give the silage ground em cut sward d'you know I wouldn't give it nitrogen every year...but it'd get the same amount of slurry and em and eh and the grazing ground would always get pasture sward*" (F_9). This description was generally a fixed routine. Cut sward and pasture sward was the most popular compound mixes used.

Farmers found better soil test results "*if you're putting a little bit of feed back into the ground*" (F_3) using pasture sward or cut sward which contain nitrogen in largest ratio with smaller amounts of P and K provide the ground with "*feed... leafyness*" (F_14) "*some fellas I know might go a bit heavier I know some fella's go lighter, but I just I just follow what I think roughly is a bag to the acre after the cows ah just throw out a bag…maybe pasture sward and a bit of CAN…then I might top up with em slurry, but at the moment now I find the ould slurry…great tack any bit of ould slurry kind of greens up the ground great*" (F_13).

Historical decisions influences current decision making and the tacit knowledge associated with the land: "*no results like, the ould field wouldn't be giving great results…kind of grass*" (F_13) and "*then again if you could get out slurry like…I like to put out a skin of slurry on a lot of ground if I could… It thickens up the grass… You spare your fertilizer then on it*" (F_16). The liming routine was also influenced by personal experience farming their holding historically it was important again associated with the land type and experience farming "*were always at it for as long as I can remember we'd always be spreading a load or two every year*" (F_1). Father experience was identified as influential and useful "*you wouldn't be that experienced*" (F_13). Another experienced farmer attributed his knowledge to his predecessors "*I was well tutored like when I was younger like there was always a good standard here like so – we weren't that big like in farming like in that like we weren't massive… things were always done fairly well and that kind of thing, we were always good yielding cows and that was where we were like and still are at the same place really*" (F_17).

Personal experience also influenced slurry application regarding quantity and timing "*we put a spread sprinkle of slurry on it when it was fit to travel*" (F_2). This is a subjective decision based on experience with farming the land. Further to this one farmer specifically disagreed with expert opinion conducting his own trials on slurry application "*think meself that what these experts say is in slurry is nothing… maybe I'm wrong*" (F_6). Having tested the slurry and the soil test results showing no need to spread chemical fertilizer he saw its value for grass growth, but "*far as I can see it only grows docs* (weeds)" (F_6). This was based on his own experimentation "*I seen fields here that I sowed them down and after sprayed them and they'd be dead clean until you put slurry on them…I tried a couple of fields here that I didn't put on the slurry for 3 or 4 years…they were perfect no weeds…but the year I come on and put slurry in them there were docs in them the end of that year*" (F_6). F_6 accepted it helps grow the grass, but he believed it also encouraged undesirable growth of weeds. The advisor who he respected and described as a "*good man…he knows what he talks about…brought up on a farm, he knows d'you know*" (F_6) disagreed with this opinion. They had good relations and the farmer held the advisor in high esteem as a "*big asset in our area*" (F_6) despite this his personal opinion was not changed.

Visual Indicators

The importance of visual indicators again represents an assessment stage, before and after application (F_11). The benefits of organic nutrients were understood to "*thickens the grass…any bit of ould slurry kind of greens up the ground*" (P_13).

"The pasture sward gives you nice grass… It seems to be more, sweeter looking" (F_13). "I put out a run of pasture sward now on the paddocks right and you'll skip a turn then you go maybe can then for a turn or two and you go pasture sward again…pasture sward is fair dear… it's sweeter or something than the CAN…it comes better like thicker… the CAN I think the grass kind of goes stem-y" (F_16) and F_6 "grows up in the grass".

F_2 did not use soil tests and did not have a nutrient management plan "*No plan tell ya the truth, we're on our own plans*" (F_2). When asked how decisions were made F_2 said "*we're probably not doing it right at all as regards fertilizer… sure you'd have an idea of it like"* making decisions based on *"the look of the field and the growth*" (F_2). Visual aids were relied upon and historical information about nutrient management activities in each specific field.

Visual aids were salient "*keeping an eye on everything myself like with the stock and see how the fields perform…if one field weren't as good a crop as the other field they be get bit more dung or slurry…see how the stock performs there's some fields the stock will prefer the grass*" (F_3) was held in high regard. The importance of value and worth of the produce itself was given greater regard that profits, taking pride in the outputs.

Recording

Learning and personal experience was also important for farmers interviewed. Formal recording of on farm activities also occurred in diary format (F_3) "*I'd be flicking back on and off during the winter see what I gave fields what they got to refresh my memory before the spring*" (F_3). Notes on application of nutrients are "*all scribbled down…Surprising though you forget…three weeks later, did I do it or not…I find that useful now…Your only a second jotting it down*" (F_4). "*We'd look back on it for silage ground more than anything or say if we were going say fertilizer put out on the first of April…how much did we say 100 units roughly 2 units a day it's okay 50 days later you can cut your silage*" as a timeline these records were used for crop fields (F_14). But "*do we analyses well field number two, well according to the soil test it needs….that no I wouldn't do it anyway*" (F_14).

Also as part of the ACP this farmer kept records for his advisor regarding quantity and application of nutrient however, when asked if he used those notes to plan for himself he replied *"You give him the book once a year and you give him a book and he'll give you another back…I writes it in for him and t'is like I gives it to him I know my own knowledge"* (F_16). Records were kept for different reasons resulting in different outcomes in terms of use.

Records were kept for lime and slurry application as well as chemical application on silage fields "*when you're putting out a good bit d'you know when you put it out and how much you put out… come to next year you'd be able to look back to see when did you spread the silage manure say last year or the year before… I mean I'd just scribble it in the diary like at least you'd know*" (F_6).

Other farmers would record for tillage, but not for grassland "the *grassland then I'd have a reasonably good idea of what I'd put out*" (F_10) "*I have a rough idea I throw the bag*" (F_13). "*em I seem to be happy enough with the I'd find the mix of the slurry and pasture sward seems to be good enough like do'ya know*" (F_13). "*ah I'd remember it anyway to a certain extent do you know. I nearly know what I'd be kind of putting out like from field to field do you know, what you been doing last year*" for slurry application the recording mostly happened for the cows AI and pedigree recording (F_17).

Reminders of unsuccessful activities are also recorded "*I've a diary and everything any mistakes we make are written into it… So we won't we won't repeat them*" (F_7). "*we'd be constantly trying to improve the overall performance of the farm and if something works for us we'll write it down and try and implement it again if something doesn't work if a mistake is made d'you know try and learn from it not to make the same one twice*" (F_7).

There was a sense of constantly learning from activities "*Amazingly we're still learning…I thought that if I got one or two years over me I'd sort of free wheel along…But it didn't work that way*" (F_7). Mistakes were recorded "*if we make a* *mistake I generally I have a day to day diary, but I also have a black book that I write down everything…what not to do next year*" (F_14), for others it was a mental note. This was a personal recording or noting of mistakes made in the past. Others rehashed stories from their father's experience (F_9, F_13). Learning was on-going; a good farmer was described as one with "*Ah bit of taste and a bit of common sense anyway, what else obviously stockmanship…Eyes and ears are the most important thing I am always telling the lads here keep your eyes and ears open like that will do a lot for ya like ya know. Small bit of planning ahead bit of foresight like ya know… fellas will say meanness*" (F_14).

Trials

Experiments and trials were common (F_3, F_6, F_8, F_14) finding a change in outputs "*number of bales*" (F_3) for better or worse. Also through their own professional experience as contractors returns to practices were identified through the daily use of chemical (lime and fertilizer type brands) and also land management practices (spiking) (F_3).

In terms of lime application recommendations were questioned "*maybe periodically during the year I'd spread grani cal which is a fast acting…am lime right and I'd say I rem I do a strip up through that field and I'd do a bit up through this field and a strip I'd just look see if there's any difference after…and invariably there's no difference like, but yet maybe we're told to spread maybe two or three tonne of lime*" (F_14). This personal experience was supported by a visiting agronomist who called selling a product, "*he genuinely knows what he's talking about like and he's not commercially driven by any means...he was here to back up this guys story (sales) but he wasn't backing it up like ya know he wasn't selling, he was only, like he was telling his own story like*" (F_14).

Experiments were conducted on their own farms "*I've done experiments here on me own field with me own grassland aerator just for compaction I'd go around the headlands of the field and work me way in and leave about an acre in the middle of the field just to see would there be any difference and people would ring me up and ask me about it and I'd say go to such and such a field and take a look at it you tell* *me if there any difference*" (F_3). These experiments were conducted as a selling point for contracted services this point was supported by advisor who equated this practice with a bag of nitrogen to the acre for compacted land, prior to purchasing the equipment he inquired about the benefits. There was also an awareness of what other farmers do "*some fellas start with urea…I don't bother because, I could I... try urea then afterwards, but I just don't find that I get no results early in the year from urea*" (F_13).

Personal experience was an influential factor in on-farm decision making regarding the management of land and application of nutrients. The act of changing ways of doing brought about learning through building on an accumulated stock of knowledge. Learning from others in particular predecessors who farmed the same land in the past was also important as their experience is valued. It also occurred through keeping records of successful and unsuccessful events. Furthermore, farmers performed experiment and trials of their land based on their tacit knowledge and often against the recommendations of science.

The Influence of Scientific Information

As stated earlier personal experience outweighed scientific advice, in relation to chemical application (F_1). Another example of this relates to lime application. It is recommended to apply lime every 3-5 years as a general rule, and there exists a time lag, in opposition F_3 disagreed: "*they say put out lime this year it takes nearly a year to work, but on experience for years working with contractors for years before I went out on me own...seen fields bare, put out lime on them knowing fields hasn't got any fertilizer what so ever…maybe got run out of lime on it and in a few weeks time you'd see the difference within three weeks to a month we just went up and down did a run just went up and down on small bit of it*" (F_3).

The science was viewed as important, but personal experience and knowledge of your own situated farm was also important "*there is some of it you kinda have to go between what your told and what ya think yourself…ya should know your own land better than your advisor, but…ya may need ta be told what new things*" (F_3). There was a sense of respect for science, but also for their situated knowledge. In another farm the advisor was regarded as *"a very smart man"* (F_9) but his advice was not followed a simple solution to the problem was found based on a suggestion from a fellow farmer, previously unknown at an event. This farmer echoed F_3 "*there's a mixture of, there's a happy medium between everything, like you know and I suppose once you find that you're not too bad*" (F_9).

The influence of science on the application of chemicals was also of interest. Farmers tended to use the information received from the results and adjust them accordingly. One farmer when asked if he would stick by what the soil test results and recommendation "*You would more so the first year or two…More or less…depending on how it was working out, silage wise and everything else now, more so than to the letter of the law… if there was one particularly low in P or K you'd put extra on it*" (F_4). Factors beyond the objective scientific results were also taken into consideration when making nutrient management decisions. The scientific results indicate if a field is "*highish in something or lowish in something… It gives you an idea, but again it's not really practical in so far as em, it depends on what you are doing with the field*" (F_4).

The goals and capacity of the farm are not considered when soil test recommendations are made. Recommendations from scientific tests are based on optimum output however, if you are not operating your farm at the optimum this recommendation may not be the best approach to take. Results recommended for F_9 suggested the whole farm needed improving, significant application of lime. The farmer was taken aback by the results "*jez they were bad*" (F_9) in terms of lime. He conducted a trial run on a number of fields and the grass grew out of control "*the grass got too strong on me and it jumped out the ground and then I ended up cutting it*" (F_9).

Tests are viewed as cost savings in cases where historically fields received sufficient levels of organic nutrients. For F_8 silage fields in particular they "*always get a right bit of slurry…it would have always got plenty of slurry or farmyard manure, before slurry started it would have got a lot of farmyard manure*" so when the tests came back high on those fields it was understandable "*when we weren't doing soil tests we would have been putting cutsward on it and probably didn't need it really*" (F_8).

On some farms soil test results are strictly followed based on legal requirement "*we would base fertilizer planning on…the outcome of those tests we use them to formulate a plan for applying phosphate and lime*" as main farm requirements "*Intensive grassland farming is…demanding of lime*" (F_7). "*Using the soil tests to to try and get the pH to the optimum level and obviously lift the, it is a question of trying to lift the phosphate index at this stage*" (F_7). However, give the science presented it was often thought not to be correct "*know regardless of the figures you do need to spread maintenance…artificially and then top it up with with organic*" in this farm "*the phosphate levels dropped so low that we were given a bit of leeway to spread to spread to I suppose work at it it wasn't an enormous quantity about 10 units per acre and it definitely did lift output you know we could see it happening, but the soil tests more or less verified it*" (F_7). F_14 stated "*you need nitrogen to grow crops or grass and whatever like ya know, but you need an awful lot of P & K too*" (F_14). The restriction in place are calculated based on a number of variables on the farm i.e. concentrates fed to animals and livestock units per hectare. However, it is believed "*in theory we produce enough phosphate to to maximise grass growth on the farm, but in reality it's not happening*" (F_7) based on output (grass) at farm level. Legislation also impacted application routines in terms of timing closed periods operate where it is illegal to apply nutrients.

In the year interviews were conducted weather conditions did not permit farmers to apply nutrients "*this year, you wouldn't know when you'd spread it…before this whole nitrates came in you'd been out nearly the whole time whenever the ground was dry enough to travel on*" (F_11). An extension of the closed period dates was granted in 2012. The extension was welcomed however, it was not without criticism "*it's some system that we can get a derogation to spread when it's not fit to spread, but if it was fit to spread we wouldn't be allowed. I could go in today and get a derogation to spread slurry on account of the wet year and you shouldn't be out, but if it was bone dry season they wouldn't let you out with it*" (F_12).
There was also a questioning of the approach used "*I mean why don't they...do a bit more interaction like why this closed season*" (F_12) "*we had massive dry periods…we could do nothing…with a result right the whole place is going out the*

same…week spreading slurry" (F_14). There was a logical argument for an open period as opposed to a closed period. "*put fertilizer into your soil you haven't done any harm to the soil structure by going out when it was dry…You haven't brought muck out on the roads you haven't em polluted any water courses…By the time the rain would arrive most of that will have made its way into the soil*" (F_12). This was proposed on the basis of the nature of the game "*when you're dealing with nature and you're dealing with rain and you're dealing with weather patterns…the system has to be flexible rigidity doesn't work*" (F_12). He suggested the use of weather data and information farmers do not have access to aid farmers "*instead of coming out biting the head of us you know like if they want a result they're going to have to if they're going to impose penalties and they're going to impose restrictions…they're going to have to provide a bit more assistance and solutions*" (F_12). Another suggestion was the use of a localised system "*It should be local guys…there is no common sense…somebody should be able to go out and say right…look the next three weeks of November are looking dry, lads be belting away there at slurry now…your stopping on the 20th and I mean the…20th any fella caught after that immediate €1000 fine, we're all happy…we'll take our…queue from that right your being fair with us*" (F_14).

Legal requirements also mean more efficient use of available organic nutrients "*that's one focus we have is to maximise the use of it you know*" even though a basic level of artificial phosphate is still required "*at least 10 units per acre*" (F_7). Further there is a practical and an environmental limit to the quantity of organic nutrients land can retain "*there's only so much slurry that the land can take…if you go anymore than three times a year em it it can cause drainage problems… And basically leaves the grass less palatable*" (F_7). Specialist advice is relied upon to support farmers experienced positioned "*I'd be talking to specialised tillage operators and tillage advisors and…they always maintain that you'll never grow a crop to its optimum on organic product alone*" (F_7).

There was a sense of the legislator versus the farmer "*All we see out there is people to fine you to penalise you"* (F_12), when a preferred option for the farmer was improved solutions and working closer with authority. Considering the level of communications available currently each farmer is contactable through mobile phone.

This was also the case with a feeling of disconnect between farmer and legislator “the Gestapo” in terms of inspections “*what invariably happens it if you’re going to have an inspection is that, I get a letter I’m having an inspection…I must get on to who I got what off and have I got prescriptions to match get the list of tag number and put any tags in and that’s what really happens…(those) policing that…aren’t doing what they should be doing, helping Irish*” (F_14).

This farmer compared our country with New Zealand informed by two workers of that nationality who were working on his farm. This farmer from conversations with the workers, one in particular who was a professional farmer with an environmental science background felt that in New Zealand “*the entire country is behind him…the government, and everybody, everybody is behind the dairy farmers in NZ…it’s good will and constantly helping on the dairy industry in Ireland??...its total opposite and it’s from the minister of agriculture down like there’s just zero common and the department especially and all that sure they are a right they are like the…Gestapo because they have such power*” (F_14).

The complexity of the legislation is such that a convicted cattle smuggler known to F_14 could not be touched described by the farmer as “*the dregs of agricultural society*” (F_14). F_14 knew there was slurry being released from their yard and directly going into a river “*yet nobody could touch them, yet if Ms officious or Mr officious from the department wants to come down here…gets out their laptop and see are all my tags in order they can shut me down, nobody can touch them there*” (F_14). This was viewed as unfair and working against the farmer who is law abiding and relatively speaking he recognised the pollution as much greater offense. The lack of tackling this particular farmer was attributed to the bureaucracy within the department. “*They couldn’t touch him like because the veterinary office says oh we’re doing our best we’re investigating (okay) and sure can’t ye get onto the pollution outfit there... well ya know now that(s) their department…and of course there was a bit of we don’t want to mess with them*” (F_14) there is a lack of common sense in the system (F_14).

Specific calibration of equipment for slurry and chemical application was done formally using specific setting on machines (F_1-5) but also informally. For chemical application F_6 suggested an alternative to calibration: "*that there will tell you,...see them two eyes…I mean Jaysus...if you've (gone) out to put 200 weight on a field like you don't put 3 on it…you write down the settings of the machine and the gear you drive in the speed you drive in… the revs and the settings on the spreader sure I mean you can't be wrong*" (F_6). Informal guides were also used for organic application depending on the quality "*usually first high in the tortoise in the tractor is 1,500 gallons an acre, the third medium is 2,000 gallons an acre*" (F_4). Also through knowing capacity of equipment and counting loads (F_6, F_7, F_8, F_16). These were alternatives to using specific ruled based calibration.

The questioning of recommendation was also the case with lime application F_8 was surprised at the quantity of lime recommended as newly reseeded pastures which had received lime showed low. He split the recommended application did not use a field by field assessment, but rather contractor was told to apply a flat rate on the identified fields. This was also the case where there was no issue with abundance of resources however, scientific results showed it was lacking. "*some of the fields it surprised me they were low…they'd be loads of grass there…they still showed up low on lime…put a small a smaller em run of lime*" (F_16) planned further application of lime, but would see how it goes first and also await soil test results.

In summary, conflicting views exist between farmers, experts and the scientific results of soil tests. This could be a function of farms objectives and farm goals. Science informs regulation on nutrient management and farmers believe it does not reflect the reality they are faced with. Particularly in relation to weather conditions and the legislation surrounding "closed periods". The inflexibility of regulation is an issue for farming and farmers made suggestions as how to overcome this through more joined up thinking.

The Influence of Industry

The local merchant would often offer advice matching fertilizer to what was require as per test "*he's good not he'd match everything up for ya*" (F_1). F_1 was based in the area and frequented regularly. F_1 also stated that the REPS advisor would also give this same advice, but he would be likely to use the merchant as he would be visiting there *"when you'd be going down there anyway he'd do it for ya in a minute...and on ya go like*" (F_1). The co-op was relied upon also as they are recognised as valuable based on their experience and they are current "*listening to other people coming in and talking*" (F_3). There was no need for farmers to keep results in "*he'd have them on his phone…The merchant…he'd be advise me what ta spread*" (F_5).

There was a realisation they merchants are also in the business of selling "*they'd give you advice about putting money in their pocket*" however, their advice was accepted because they were trusted "*X & X would be good like…I mean they try and sell ya what's going to, they'd sell you what you want d'you know. They don't try push other stuff d'you know…they're there sure and like they give you a bit of credit*" (F_6). The availability of credit was viewed as an important factor by comparison to mobile seller's cold calling top farms, primarily sales representatives from companies. In terms of lime application the merchant is again relied upon for advice on how much lime to apply (F_2). Tests were also conducted by merchants on silage again there was mixed opinion on the results some would not choose that path "*That's just dodgy I think...you'd hardly trust them...maybe that's just me*" (F_9). The merchants selling the tillage chemical were relied upon for advice "*chemicals for the crops off X we use their advice a good bit*" (F_10). Other advisors used them for fertilizer and crop planning (F_10). There was mixed opinion on advice received from merchants and likely the rationale for this use was based on their requirements.

Group settings were another source of information that proved to be very informative. Many farmers referred to discussion groups which are the core extension tool used by Teagasc to access farmers in group settings. Many of these groups are focused on grass growth and were referred to as the grass groups however, they take many forms and are provided by private consultants also. F_1 "*we have learned a good bit from it…especially with the grass the grass has improved a good bit…ya wouldn't see that until you'd start talking to other lads…they'd be very honest there'd be no messing* *they'd tell ya straight out, if they do'ya know of made a bags of it they'd tell ya…you'd see other fellas mistakes ya know, you wouldn't do it yourself then*" (F_1).

The wider benefits of group meetings was realised through interaction with other members "*lads would be trying things and they'd tell ya straight out, if it's waste of time*" (F_1). The advice was trusted and taken from direct users "*you go around to see all the other fellas farms and you see what they are doing and what they are thinking, lads would give suggestions what they are doing right or wrong and you know why they are doing different, you see different ideas*" (F_11). In addition to the sector providing this informational resource there was also a publicly funded monetary incentive "*it was €900 there now for the year*" (F_1). This fund was part of the Dairy Efficiency Programme (DEP).

Links reached beyond the groups also, through informal established links between members and non-members of groups "*I keep in touch with…the discussion group members…I'd get a feel for what they're thinking and I'd run ideas past them*" (F_7). Taking advice from trusted sources was also important "*one of the discussion group members told me stretch it by a week cause the…biggest percentage of the grass growth occurs in the last week…I did that it made a huge difference*" (F_7). This farmer recognised the benefits of group learning, but was not a member for two reasons, one was the time commitment and secondly he felt he did not work well in group situations.

Another farmer thought it would widen his existing links beyond his existing ones and hoped to see something new, but found it did not, "*Sure I can ring them any night or any day...it's like being beside me in the discussion group, you might not draw it up, ya know at the discussion group meeting, but you can be talking to a fella next*" (F_17). "*I probably knew all the lads before and I was in a lot of their yards before like, a lot of it isn't much new…we kinda didn't go anywhere we never went anywhere on day out or anything like…there is a lot of farmers within X County like that are like doing different systems and a lot of them aren't that far away like and they are very good like operators even from an intensive systems their high yielding to low yielding to whatever intensive or extensive and like we never went anywhere or saw* *anything like that's why I joined it I thought we would be going on a day out during the summer to see a few farms and I would have an evening out*" (F_17).

In contrast F_14 was part of a group for 10 years, it was in operation for 25 years. The experience was quite different to F_17's experience, they had gone on many trips visiting a few farms around the country, but also abroad trips to Holland and England. In terms of learning F_14 invested in a machine for drying grass "*after that trip to Holland and I bought it…I saw them…over there ya know*". When asked if there were any negative with a discussion group he simply answered "*I wouldn't say there's any negatives…a few personalities that might prefer wouldn't be there…but ah no*" (F_14).
A group also is a means through which a number of large farmers buy inputs such as diesel and fertilizer in bulk and gain from lower cost. The group was large "*We buy the fertilizer and there's about I'd say there's about 7,000 acres in that group…would push for the best price and it would be on the basis that we would pay them…On the day*" (F_12) the decision of who to purchase from was a group decisions, based mainly on price however, "*you would try and spread it out…if there's only a few bob in the difference…keep the other guys right too*" (F_12).

Attending walks and open days is seen as a beneficial "*you'll always learn something every day you go out…maybe even the smallest thing…sounds like a bit of an old cliché now right, but a day you don't learn something even at home you'll always learn something just keep your eyes open and file it*" (F_14). The information returning to the holding from open days, walks or visits was in relation to structures on the farm buildings (F_13) and field layout (F_19). "W*hat fellas are doing in the yard and stuff like that…whatever grass seeds he's picking I dunno it's hard to say*" the farmer felt he had no interest in visiting he also was not a member of a group as e felt he wasn't ready "*No not yet anyway…maybe when I have the place a bit more better looking I might*" (F_13). This displayed a lack of proximity reflected in his lack of interest in joining the group. From attending an open day of farm walks or visiting other farms the most useful information points was around "*farm buildings and things like that no you would ya*" (F_16). Also from working with contractors "*Down through the years you'll see...other ideas other farmers has like*" (F_16).

The difference between public and private consultants was highlighted in a comment by one farmer who stated "*X has his own agenda…He'll have the message to get across…and he keeps us informed as to what's going on*" (F_12). "*I wouldn't want to be doing everything they say…a couple of years ago there was some meeting up in the thing and they were saying oh go Jersey go Jersey go Jersey…they don't mind they'd only give out advice but you have to...pay for it if anything goes wrong…there isn't a grunt now about Jerseys*" (F_13).

Popular media weekly newspapers were read by all farmers. An innovation bias was identified by farmers towards the use of certain brands and means of operating. However, the media is useful for structural ideas including calving pins, gates and crushes, or any structures for handling animals, which aid farmers.

Individual relations also between industrial advisors and farmers was a function of where farmers got their information on nutrient management "*I used to be in with a fella…dunno if he's still there…now if he was advising people out on farms what to do everyone is better retire sooo I gave up I used to have him out here (ha ha) ah jez and he was I thought he was a disaster…but it depends on the advisor some of the advisors are very good*" (F_3). This was often a deterrent to engaging with an advisor in a local area.

Specialist advice was also used by a number of farmers from specialise suppliers seeds and sprays "*that's all he does grass seed spray & liquid nitrogen*" (F_2), seed mixes and ration (F_8), nutritionists "*a bit on the nutritional side from companies I would deal with...X they've a very good nutritionist there*" (F_7), livestock advice "*vets would be very good on...animal husbandry*" financial "*then you know the accountant*" (F_7) AI technician (F_13), agronomists (F_14). Services required were chosen from specific individuals for specific problems. In terms of tillage a specialised job was often required "*he does crop walking, spraying, soil analysis he does soil analysis himself*" with another advisor doing the grassland "*that's the way that works*" (F_12). Soil test results were not fully followed when contradicting evidence suggested by other expertise, one farmer who uses an agronomist "*by the* *way he talks…our soil samples are all wrong like ya know…and like...he'll take you down the field and he'll dig a sod like and he'll say this is the set up here like ya know this is what's wrong and this is what's right*" (F_14).

Industry: A broad range of sources are drawn upon by farmers including merchants, co-op's, discussion groups, open days and walks, media, public and private consultants. All represent sources of information and knowledge provided by the wider industry that farmers use to inform nutrient management activities.

This section captures sources of knowledge and information used by farmers interviewed in making nutrient management decisions. These are largely resources farmers can choose or seek to get information and gain knowledge. The next section identifies sources of information and knowledge which is out of the control of the farmer however, is vital for decision making. The following section addresses Box 2 Figure 3.7 (P212): Weather, Resources and Prices.

Box 2 Figure 3.7: Factors outside the control of the firm

- Weather
- Resources
- Prices

The importance of human capital resources is evident from these interviews, both in terms of the farmer himself and to those he is connected with. Experience and experimentation is important however, the resources available to the farmer are the most important influencing factor in nutrient management decision making. These are both endogenous and exogenous to the farm, but largely speaking within the control of the farmer. The influential factors beyond the control of the farm are now described.

The right hand side variables, weather, prices and resources (Box 2 in Figure 3.7) are beyond the control of the firm, yet are influential in terms of nutrient management decisions. The weather impacts activities in two ways: (1) Environmental - Potential to pollute; and (2) Economic - Misuse of resources (financial & on-farm). Prices are based on the wider global markets and reflect availability of inputs, including: nutrients chemicals and fuel. Information and knowledge of resources specifically relates to on-farm resources: (1) Organic nutrients soil quality: (2) Availability of grass- growth (weather).

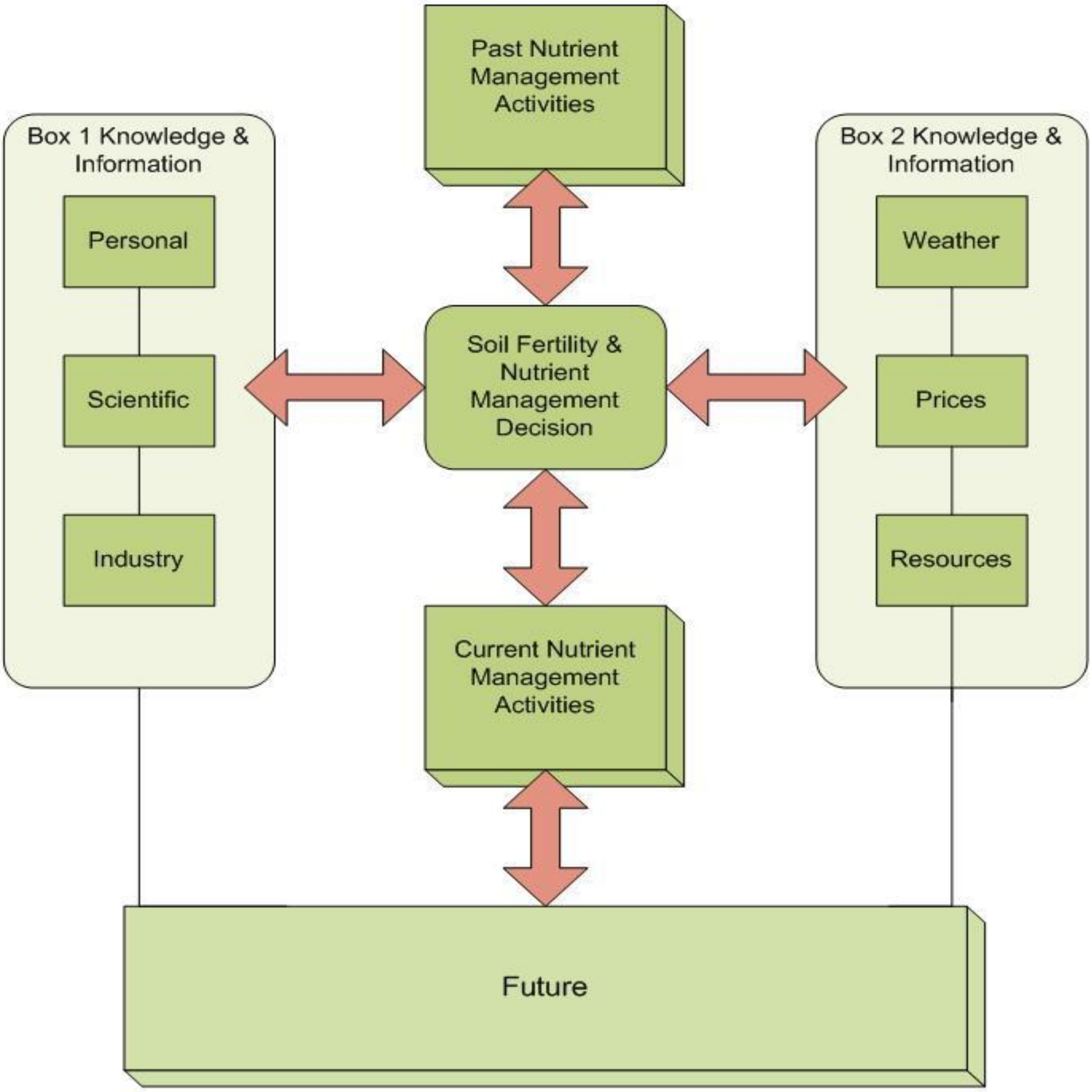

Figure 3.7 Activity and Potential Influences

The Influence of Weather Conditions

For the timing of application of fertilizer there were again a number of factors, but the weather was a key factor. When F_1 spoke about timing of fertilizer "*you'd have to be watching amm soil temperature, especially the weather…with the rain it's impossible there at the minute*". He went on to describe the unpredictability of the weather giving an example of how close the rain was coming "*it's just so a stroke of luck like*". If it was possible an early application was preferable for F_6 although it depended on weather "*if I could get out early with the 10-10-20 on the silage ground I'd go with it*" (F_6).

In terms of application and fertilizer the weather again impact dramatically if a rain event occurs after application there is a danger of run-off from nutrients. In the event of this happening "*We'd see how it'd go and if it wasn't performing then you'd have to go again…see what ya thought like but oh we have got caught from time to time…come out the blue like…but if you could get a day or two even two or even three days it generally do be alright especially if the ground is damp it dissolves*" (F_1) "*weather's the key of the whole thing like*" (F_16).

On another farm F_2 described his land as wet. When wet conditions persist cows walk grass and manure into the ground where it's "*gone for the year*" (F_2). In the event of this happening he stated he would "*have to go with a sprinkle of nitrogen I suppose…it's hard to keep the job right when you have wet land*" (F_2) again this is a function of type of land (resource). "*You'd, could be tight on grass we were tight on grass and all of a sudden in one week grass…just outta hand… Then…all of a sudden you've done too much your tight (F_5).* When asked if planning would help *"Well we would…but depends on the…growth ya get, the weather*" (F_5).

The application of nutrient depended on the fields condition "*if I did get slurry out on the fields which... doesn't always happen here like you know"* (F_9). The weather and ground conditions were also factored into grazing patterns "*if it is wet weather or softish ground, what you do is, you just give them half a day's one eating then you'd move them do ya know what I mean, but if the ground conditions is good you'd be eating it bare*" (F_11). The variability of activity is weather dependent.

Conditions were difficult in the summer when the interviews were conducted "*just it was a bad year for grass now we found this year you know with the wet and the poaching and everything it was very hard to keep it* right...*the land the other side there the road would be very heavy ground*" (F_10). Weather conditions impact growth so timing is crucial for either organic or chemical application "*Whenever it got good a growy…it depends on the year…we would have spread very little last year now it was such a good growy year there would have been more spread this year*" (F_4).

This is also the case in relation to slurry application "*all depends on growth*" (F_2) as slurry is usually applied after the harvesting of silage crop the interdependence between harvest and slurry application is a function of weather and growing conditions (weather). "*Nothing much changes around here only the weather*" (F_2). The slurry application is also weather dependent and also resource dependent (land conditions), subjective decisions are made based on experience with the land "*we draw the slurry up there depends on the year, in spring, its wet enough up there so if you could get out in March early April we'd go*" (F_2). The application of slurry is particularly dependent on weather. In dry weather slurry "*sticks to the grass and the cattle don't like it*" (F_3). Slurry and ground conditions are closely linked "*if the weather was dry if the ground conditions let me I get slurry out*" (F_9) having an understanding of what is possible with given resources was important. The capacity of the field given weather conditions influenced activities "*this farm here now would be heavy enough clay, like it'd be clay it's not gravely ground, rocky it's just clay ground, when it starts raining it gets wet quick enough*" (F_11).

The strategy employed depends on the weather, when using a compound and straight nitrogen "*you usually you'd try and go every... second grazing if you could, if there's good growth there…maybe two bags of cut of pasture sward now and you might get a grazing an extra grazing before you put out stuff again*". (F_16).

With organic application timing was closely connected to the ground conditions and weather "*we had it ready to go and every time you cut the next day was spilling rain and I think we only put one small bit*" (F_11). This highlight that even thought it was permitted under the regulation common sense prevailed. Conditions were not suitable and it was a waste of resources and potentially harmful to waterways.

Weather conditions often insist on a change in activities. A change in weather conditions could results in an unexpected abundance or scarcity of resources. One such event resulted in a farmer cutting a crop in March. In a normal course of events slurry application occurred early in the year prior to grazing to boost grass however, "*you couldn't put slurry on it there was too much grass…I had a notion sure I cut it and baled it… It was good quality silage yes it was 84 DMD*[87] *…different people told me oh it will not keep and it'll rot and there'll be no sugar in it and I said sure ah I'll try it…March 26th*" (F_8).

Plans for application of organic was often hampered by the weather "*plan was to spread it* (organic) *on three of those and the year that was in it we got one of them spread and the other were just too wet*" so alternative plans are made to utilize the resources "j*ust went to dryer fields with the dung*" (F_4).

The change in growth hinders pattern for grass growth and so the corresponding plans "*They were very slow to come back this year*" and equally so for slurry application "*we didn't get out there normally we'd try and empty the tank in October just before the close off*" (F_10). Usually fields that get organic early in the year was not possible "*This past spring now there's a lot of grass outside in the springtime to get grazed before I do spread slurry, but like it's too bad weathers too bad in January… last days of January before I spread slurry*" (F_16).

In summary each application routines (Lime, chemical and slurry) are dictated by weather conditions. The liming routine is less affected as it is not required to grow grass with immediate effect. It is applied during the autumn periods of low growth. So it's application can be delayed without immediate impact on output. For chemical and slurry application information on weather was an extremely important to plan activities however, weather is difficult to predict.

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[87] Dry Matter Density

Land as a Resource

References to land featured in all discussions concerning nutrient management practices. Areas in close geographical proximity have been described in terms of land as "*different country altogether like it'd be terrible we… You'd have to be used to it, but of a wet year now it'd have to be tough*" (F_1). Under weather conditions wet land can be difficult to manage (F_2), the land farmers have is a resource and the single biggest asset of the holding. The resource (land type) requires specific management capabilities as there is huge variability in land where farms maybe be split and subject to different conditions (F_3) this requires different management skills. This is also the case within farms "*This would all be very wet land and you could nearly draw a line across there, the couple up here are reasonably dry and everything below then is wet*" and within fields "*the top half of the field is dry and the bottom half is wet*" (F_4). "*Grass didn't grow well enough with a heavier soil…you could draw a line across the dry part in the field you could see where the grass is yellow and the other is lovely and green*" (F_5).

The soil itself was important "*have a few fields now that are fairly low in K like even though they have been getting a good bit like, but that's the nature of the soil like they are just... they'd be different structure soils, around the house here now would be very fertile… but that's always the case… I suppose all the mineral was there around the yard with the pipe and shovel and that kind of thing so that's why*" (F_17).

Having an understanding of one's fields was perceived as giving one a greater appreciation of its potential to produce "*some of that land up there is very rough....you wouldn't even dream of ploughing them like it's all rock land up there*" (F_9). This understanding was passed down from generation to generation "*was some never ploughed in me father's time*" (F_9). Gaining this understanding and familiarity with land type comes with experience as it takes getting used to (F_1).

Personal experience is closely linked with understanding the resource in relation to the liming application "*it's just difference hungry land different types of land up there that you could spread definitely you could spread a tonne two tonne to the acre and it'll still…if you tested it next year or the year after it'll still be always wanting* (lime) *am down here it's different your only talking half a country mile across here as the crow flies…it's just different land you're up more higher country more drier different rock like round here maybe holds minerals*" (F_3).

Based on this assessment of the land F_3 noted that other farmers in the area had taken alternative strategies to reseeding because of the land type. He saw a movement away from reseeding to using alternative machines to "*tear up the top of the land, your land is harder then when it comes out to graze or cut silage…more firm base and…you're not ploughing down all your…minerals and lime you've spent money on for years*" (F_3). Other land did not have a high liming requirement "*lime would be done per requirement by the... soil testing…*have I'd be confident enough of holding onto it if you know what I mean…*the grassland now has all been done over the term and it's pretty well ok… Wouldn't be too bad*" (F_12).

Understanding the land is reflected in terms of output of milk and grass "*they would milk different in fields*" (F_5). Certain fields yield better quality (proteins and fats) and quantities of milk that F_5 attributed to the soil itself. It is for this reason a personal understanding of the resource is essential for land management decisions. There is an understanding of the land they are farming, science gives an objective opinion that either confirms or contradicts personal experience "*heavier land doesn't take much lime…every three or four year we'd spread a little bit ya…All the soil samples were showing up okay them there two year ago*" (F_5).

In terms of chemical application, an essential quantity was applied to maintain a satisfactory level of growth F_1 "*ticking over*" (see personal experience Box 1). In relation to application of nutrients, having this knowledge is vital for nutrient activity "*you just know by your fields like I know like this field here now right…always a bit yellowy like that that needs it and two here on top right if they don't (ref to map) these will show up these will show up ah these will show up yellowy like whether you put out watery slurry or P & K like ya know…and just go green again and this place here there there's about three feet of topsoil on that it if I could have that field everywhere that is an unbelievable field to grow grass…even X…they did the soil cores and they said there was unbelievable amount of top soil there…for some reason I dunno*"

(F_14). "*when I was a young fella that used be unreal to grow grass…we'd graze that now every 16-18 days*" (F_14). These historical details are situated in the farmer and link to his farm and its ability to produce an output.

Past Activities

Having knowledge of the land itself in terms of past activities was also important *"that land hadn't been turned up for a good many year too and that wasn't great what was turned down cause it was after been rented for years and years…we got that off the land commission…lads would have it drained out*" (F_2). Knowing and understanding the history of the soil was important in making future nutrient management decisions this particular piece of conversation was in relation to a field reseeded in that year and he spoke about how nutrient application varied based on this.

Visual Indicators

Knowing land required certain nutrients without the tests was also evident from farmers "*well I knew that one was low cause it hadn't got lime in for years and it was old pasture like so that's why we didn't want to put much lime on it cause we were gonna plough it and do it up like so, when was freshening up the field then I spread the lime on it*" (F_3). This statement also highlights the relationship between future plans and current nutrient practice. The output from any resource was also an indicator of a potential need for change you may suspect a field if it is not performing "*you'd often see a field there the colour of the grass mightn't be right or that d'you know…I'd probably give it a lick of slurry first and see how she'd go after*" (F_9) before soil testing again.

Visual indicators are the primary trigger "*go to ones you thought was the worst grass like, which was producing the worst grass"…*secondary is the objective indicator "*you put the cows out to a field a field right and they always dropping the milk on it and stuff like that like if they don't produce as much milk on them fields… You'd notice it so you they'd be the ones you'd be lining up for reseeding*" (F_11). The soil testing routine was also influenced by such indicators where testing was not regularly conducted "*we would a bit ya* (soil test) *but I'll tell ya it's pretty much obvious if* *we're if you're missing anything like ya know I mean if your if your anyway low in P or K it'll show up straight cause the place will just go yellow like (7.38) ya know which we are a bit low in P & K (The grass) ya you won't see the lush in it*" (F_14).

Available Nutrients

The availability of resources was also an issue for nutrient management. There was a trade-off between the availability of organic nutrients and the requirement for chemical: "*could get two…two and a half 3 bags of that now it depends on if I hadn't got any ahh slurry or anything like that it'd probably get three bags to the acre (ya ya) usually I'd try go out with a bit if slurry earlier in March or sometime if possible*" (F_3).

The quantity of nutrient available was also an influencing factor on application decision. In terms of chemical "*I was looking for 0's last fall where I reseeded… there was nothing to be got only nitrogen so it got nothing then, that didn't get anything then until the spring we put a spread sprinkle of slurry*" (F_1). Also in relation to organic application F_4 spoke about two different strategies used for two fields, the smaller field was in index 2 and the larger field was index 3, based on availability of resources the decision was made "*there wasn't an awful lot of slurry left and the smaller one just finished it up…the smaller one got the slurry*" (F_4). The targeting of fields with lower (indexes) levels of major nutrients as per soil test results was also dependent on availability of the resource "*if a field was low in P & K…you'd give it if you had a heap of farmyard manure…you'd put that in it anyway*" (F_6).

Grass

Also the abundance of grass is an issue in relation to application of nutrients "*but the odd time during the summer if it was real dry or that and I was maybe getting short in grass or something just for a quick boost I would go with a bag or a bag and an quarter of straight Nitrogen like, but usually a bag in the summer is plenty and 27- 2 ½ - 5 usually and works out*" (F_3).

The quantity of nutrient application was based on abundance of resources generally similar types of nutrients are applied, but the quantity may vary "*it's generally as little* *as you think you can get away with…see how it's going…just by how much grass I don't do a field wedge* (formal measure) *or anything now, just by how much grass looks to be ahead and all like*" (F_4). In the absence of formal measuring there were a number of informal decision making rules were used to decide when to move animal on or take out paddocks. Based on the grass itself was an indicator "*It depends on the if the grass was too strong then you'd have to leave it one side but...you just usually go by the look of it like you know once the cows is happy with it*" (F_9). Other ways based on a 24 hour system, but largely it's the animal who decides "*cows decide when they'll* move…they won't go back into it second time round they'll tell you…if they do go back in they go in under protest and there's no milk that evening" (F_12). "*It depends on the weather…they weren't happy inside in it*" (F_16). The quality of grass also is reflected in the milk and in the animal "*you'll see it in them you'll just know by the cows if their if their if they don't have fresh grass* (How?) *Milk,...as soon as you walk into the parlour like you know, if you travel down to the fields to them you'd know, I went down to them now last night I just had to close the wire that was left open but am (ya) the cows weren't happy like by right I should have moved them… they all got up to me as soon as I went down*" (F_14).

The quantity of chemical applied also is a function of grass availability "*depends on what you have in front of you type of thing, how much grass is a head usually a bag maybe to a bag and a half of nitrogen to the acre maybe each time most times, not every time you know, if you could see that didn't need it the next round you wouldn't put any out maybe for a while and then if you were scarce you'd be doing it every time type thing, every field be getting it every time*" (F_8).

The resource itself (nutrients) the output resource (grass) was important to the application of organic and chemical in terms of timing and quantity. This was dependent on both the future resource (grass) and the current resource (nutrient availability). The future plan was important "*I wouldn't go that thick like really cause ah I'd usually be trying to graze the ground then again afterwards*" (F_3). This was the same with grazing plan on other farms, organic nutrients sours the grass as spoken about in relation to the weather conditions and slurry application. "*Depending on what you are doing with the field you put less on the grazing paddocks the way it wouldn't* *be souring for the cows as much… put more on the silage ground*" (F_4) this again reflect future plans for the field.

Generally something similar was applied most years "*you'd tell him how much em farmyard manure or slurry went on it and he'd tell you then if if any compound if any compound was needed and then after that it would just be nitrogen…we planned to get all the the Ps and Ks out anything that's needed gets it early on…once you get the P and K on all you need then is the the nitrogen…it'd be in the slurry and it could be in in in farmyard manure or compost…it could be down to field history it could be a lot of things you know… fields that would be destined for maize would get an awful plastering with slurry and that which would build them up for a couple of years…sort of piggy back on that for a while*" (F_12). There were multiple reasons for change. But generally things wouldn't change that much "*some years it's dry, some years you'd get a lot of slurry and compost out and you can cut back on those years…on the chemicals you apply and then some years you get a better response out of nitrogen than than you do, like I've seen us putting out nitrogen and three weeks later you'll realise the crops just it's the cold weather or something it didn't pick up*" (F_12).

The quality of the resource was a factor in deciding quantity in particular for slurry application. The quantity of slurry applied was a function of the quality of the slurry "*soiled water I'd always put that on a lot every year*" (F_4) other descriptions of slurry included, "*our slurry would be watery enough*" (F_13), "*I separate the slurry…it's all water we have like it's the watery fraction we have which is what I want… cause it won't stick…and it's reasonable handle you've no solids*" (F_14).

For one farmer his experience working in contracting was important in evaluating resources: "*I feel myself there is a big difference in in the value of the slurry… cows getting no meal and you put it out and you it doesn't show very well and you go to somebody else then that is fattening cattle… maybe a right bit of meal stronger slurry I would think shows far better going out like you know*" (F_8). "*We feed a right lot of meal…a lot of me own slurry it would show better than a lot of the slurry that I would be putting around the country em, no I'd say there is a big difference in the strength of slurry*" (F_8).

The availability of grass often meant a change in strategy a lack of grass meant reserves were often used, in early summer one farmer found himself short and had to take action "*grass is gone no grass there…open the pit of maize I said I'll use it now in the middle of summer if grass gets scarce I used it in May. The cows are absolutely charmed with it*" he was also feeding bales "*buffer feeding*" (F_16). One benefit of it is "*Oh it brings up the solid big time…the cows are a lot happier as well and you won't haven't to boost on so much ration*" (F_16).

Ownership of the land was also an issue in relation to management of the resource. There was a general consensus that rented land on short term lease (annual) was not treated as land owned by the farmer. F_1 "*now that's leased so we would be treating that now like our own really cause we have it on the long term like but the conacre now we wouldn't…we wouldn't bother cause that goes for public auction every year*", F_2 "*I'd be looking after the land a bit more here cause it's my own land…the other two places are just places I have rented*" ; F_3 "*you do be inclined not to go as much dung or slurry*"; F_12 "*rented land is never in great shape…nobody would want to build that up…it's different in your own*". A strategic approach to nutrient application was taken when renting land. "*I's say, we'll get it on our own ones first, we will get all our own ones up*" (F_11). Renting in marginal land not of value for production was also used as a strategy to offset nitrates (F_1 & F_11).

Impact of Prices

Farmers are price takers for their output milk as it is dependent on global trends and commodity prices. They are subject to this uncertainty and this is risky as not all producers are in contracts, and this variability is ever present given the perishable nature of the goods. The price of fertilizer is viewed as a major expenditure (F_1-2, F_4) and is often discussed in informal groups "*we'd often be talking among us about fertiliser prices*" (F_4). Farmers usually stick with one supplier known over a number of years based on location or to get the best price on fertilizer (F_7). As it is an expensive input a farmer might be expected to soil test for this reason. Again these decisions were based on path dependent activity *I would give it a couple of shakes of nitrogen through the year, but no I wouldn't I wouldn't go at nitrogen all the time just* *try save a few pound*" (F_9). The price of fertilizer and the variation that exists between brands of fertilizer was recognised by farmers (F_1, F_3, F_14).

Farmers generally did not mention profits. The farmers were more focused on the output of their animals and crops as opposed to a lower cost base. An example of this was in an diversified farm enterprise making cheese, where the farmer stated that it was not the profit alone that was the driver "*there's money in it ya but it it's a great interest to have too…you meet a lot of people and you get out and about more and em you know like just milking and the dairies taking away every day like you never really get any feedback…it just goes off in a belly of a lorry*" (F_12).

The relative cost of reseeding was compared with sowing a crop "*the way that we were looking at it was in this farm, is if you went in a spend say 5 to 10,000 on a field draining it and reseeding it and getting it into top condition and kept moving around the farm and got them all reseeded and all that you'd actually get more production out of them – when you get around them all you definitely get more production than you would out of the maize*" (F_11).

"*That's the most important thing really – sure whatever about soil, grass or yields or whatever like it is the bottom line is what your, that is the most important thing I suppose like you know, no good to be so much grass per acre and all that if you haven't got profit after it…– there is no one farming for fun or farming for their health or anything… Money is the name of the game*" (F_17).

3.10 Discussion

This study uses the organisational routines literature to provide insight into the adoption decisions of 20 Irish dairy farmers. The focus of the analysis was on nutrient management practices of which soil testing is core decision making tool. Soil test results are a physical resource. The use of this resource, the implementation of the information is the service rendered from it. This formed the rationale for this study in focusing on the organisational routine specifically the performative aspect of the routine. Three application routines were focused on liming, slurry and chemical.

Themes common to all three routines were path dependency, tacit knowledge and soil testing as a resource.

The findings of this study are as follows. First, the evidence suggests there is a hierarchy of factors that influence farmer's decision making. In general soil testing was relied upon for liming decisions. For the application of slurry, weather conditions were most important. Chemical application is based on availability of crop and compound.

Second, the interviews identified four main themes from the data that explain the adoption process. These are path dependency, tacit knowledge, experiential learning, and resources. Resources formed the basis of Penrose's (1959) theory of growth of the firm. Penrose (1959) defined productive resources of the firm as tangible resources and human resources. This broad definition includes physical fixed assets, but also skills of individuals within the firm. What is key to this definition of resources is not the resources themselves, but rather the services rendered from the resources.

The importance of resources availability was evident from the empirical analysis. Services rendered from these resources remain central to the continuum of adoption. These services are dependent on individual agency and existing routines. What is salient are the similarities in the routines and activities of firms, firms who perform similar activities draw on similar capabilities (Richardson 1972). More typically studies tend to focus on the similarities of individuals characteristics. This study however, does not define typologies of farms, but looks for the similarities and the differences that exist between firms. It does this through focusing on the performative element of the routine. No two farm routines are exactly the same in terms of how the routines are carried out. The adoption decision is not reflected, as is universally understood, as a binary decision, as indicated from the results of this study. Rather the findings support the existence of two elements of the routine: ostensive and performative. The ostensive aspect is static or procedural, in this case adoption. The performative aspect of the routine is dynamic, adapted to fit with incumbent resources on the firm. The decision to adopt practice is dependent on current routines and resources.

Third, this study adds to understanding how regulation and mandatory activities influence adoption of technologies. Mandated use of practice purely focuses on the ostensive aspect of the routines while ignoring the crucial performative aspect of the routine. The routines literature highlights that regulation and mandates to adopt technology do not support the performative element of the adoption routine. Findings suggest that adoption of practice is not binary in the sense there are varying extents to which an individual carries out an activity. One cannot assume equivalent benefits from a singular activity of testing for example across a population. Mandates to adopt practice result in a singular static activity, the adoption of the tool; it does little to support the performance of the activity. The procedures like approach to nutrient management and improvement of soil fertility does not account for other prominent influences, as per Figure 3.7. The farmers in this context are established managers. Their styles of management are varied at a micro-level. However, there are clear routines that emerge in the data. This is not to say there is a clear homogeneity between firm routines, but there are distinct similarities between the nutrient management practices.

Fourth, this study provides an explanation for why farmers may not adopt practices that scientific evidence and rational behaviour would suggest should be used. In considering the soil activities of farmers, the literature suggests there are multiple sources of information used in addressing soil management. Soil tests are viewed as the main starting point by advisors and policy makers. This undoubtedly, reflects the scientific evidence relating to the effectiveness and benefits of soil testing. Many farmers however also rely heavily on personal experience with farming the land and dynamic conditions such as the prevailing weather. There is little formal support given to sources of information which are tacit or anecdotal, even though it is accepted that testing the soil nutrient content alone only accounts for 46-61% of soil quality (Fernandes et al. 2011). The remaining factors are associated with natural characteristics of the soils such as water retention capacity or capacity for root development. These may form part of the farmers experiential knowledge of farming the soil.

Farms with similar resources have developed capabilities over time to get optimum results from soil. These optimum results are a function of organisational goals. The link between existing resources and activities is well-established (Penrose 1959), with a firm’s (nutrient management) *activities* carried out using appropriate *capabilities* (skills knowledge and experience) (Richardson 1972). While the relationship between firm activities/routines and firm goals are clear, the relationship between incumbent firm routines and imposed external routines is not.

Imposed activities may not serve the incumbent goals of the firms. The firm develops a comparative advantage through activities to achieve firm goals. The opposite of this may also be true if imposed activities are not aligned with incumbent goals. In the context of this study, test results can be identified as the rigid (resource) element of the routine and the performative element of the routine is a function of other sources of information. This is in line with two broad associated literatures, the environment literature, in terms of sources of information in decision making, and the routines literature in relation to the distinctive ostensive and performative elements of a routine.

Fifth, in terms of the advice used by a farmer the analysis suggests that farmers are subject to multiple sources of information and opinions. The farmer must decipher this information in order to identify what is the most appropriate advice for their situation. There is a key difference made between giving advice based on information received and advice based on similar information, but also the experience with operating. In one interview the preference for specific crop advice was based on experience, F_17 explained this: “*he wouldn’t know anything about sprays, he could get it off the computer and that - he wouldn’t have been applying them or anything*” (F_17). The farmer recognises the value of user based knowledge. It is well established in the literature that environmental managers-farmers, use a multiplicity of knowledge to make changes (Cerf et al. 2011). Much of the literature focuses on knowledge integration and exchange (Ingram 2008). However, the integration of knowledge at the farm-level has not been examined in terms of the existing routine of the firm. Influenced by findings from early thesis findings this study focuses on the process of adoption.

Contributions

Importantly there are a number of contributions that arise from this study outlined as follows. First, it contributes to an understanding of the adoption of practice by farmers focussing on how on-farm nutrient management decisions are made. Specifically, by using a routines perspective, the study identifies how path dependency, tacit knowledge, experiential learning and existing resources, influence how farmers approach nutrient management.

Second, this study highlights the limitations of the binary decision aspect of the Roger's Innovation Diffusion Theory (IDT) model. While the IDT examines the stages of adoption, research does not sufficiently consider the adoption process (Kremer et al. 2001). This study suggests that the factors that influence the decision to reject or accept a new technology is not uniform across all firms. The data highlights how the acceptance/rejection distinction becomes blurred in the context of the actions of individual farmers. It appears from the data there is a continuum of acceptance and rejection that is partially influenced by, the motivation to adopt coupled with a range of endogenous factors. This continuum is also influenced by wider exogenous factors out of the control of the firm.

Third, this study extends the study of routines into a new domain – the adoption of land management practices by farmers. This study is, to the knowledge of the authors, the first application of the organisational routines literature in context of farm level agricultural adoption.

3.11 Conclusion

There are two important implications of this research for policy makers and practitioners involved in advising farmers. These are as follows:

Firstly, to influence change, in this case the performative aspect of nutrient management routines and, the type of influences used must be considered. Specifically, this research suggests that the focus should be on supporting existing ways of doing and ways of determining what to do rather than prescribing to a singular way of doing as per the 'procedure' like approach, that assumes all else is equal. That is, this research suggests that a user informed model that explicitly includes the alternative influences other than ‘economic rationality’ should inform practices and interventions that seek to increase adoption, of new practices by farmers.

Secondly, information is vital for innovation at all stages in the adoption and post adoption process (Läpple 2012). The findings of this study suggest that local knowledge in particular is important to the adoption process. There is evidence that the more simplistic Rogers framework of “transfer of technology” and “diffusion of innovations” has been partly replaced by an approach that seeks an understanding of the system and on what knowledge, information and advice, food producers require. This suggests that a change in approach is required if increased adoption and innovation in the agricultural sector is to be adequately achieved.

Garforth (2011) identified five areas as follows:

1. Understanding the systems that sustain food production
    - Using current science in combination with local knowledge
2. Information on current and new technologies in real farm settings
    - Using economic performance from the perspective of the farm and household
3. Business management advice
    - Focus on farming as a business
4. Information markets
    - Linking producers to markets looking at market requirements
5. Environmental regulation
    - Advancing thinking on the role food production has on sustainable rural development.

While the role of extension services is important in advancing this change, how services are delivered to farmers has begun to change. This movement in Ireland is seen by the national body of education and extension, Teagasc, actively changing their approach to extension. This is currently being achieved through programmes such as the Better Farms Programme and through Discussion Groups now the main extension tool used by Teagasc to access farmers. However, it is evident more work is needed in the development of a broader range of tools to support farmer's in their decision making. A range of sources of advice and information are used by farmers and the extension services must aim to support these sources to ensure farmers have access to the most appropriate information for decision making. Farmers interviewed mentioned access to weather data, localised response to regulation, greater flexibility and more 'joined up thinking' around nutrient management issues.

Section III

Conclusions

This final section outlines the main findings, contributions and implications for policy of the three studies presented in this thesis.

The Technology Adoption Problem

Technology adoption is a complex social phenomenon. Within extant literature, research has yet to adequately address these complexities. The complexities relate to how technology adoption is viewed by policy and research, and how technology adoption is viewed by the end user. Technologies, supported by evidence based research, are not always adopted by farmers. Current research in the agricultural field largely views adoption as a binary decision. This is reflected in agricultural policy and legislation, which mandate adoption of technology. While such mandates and policy instruments may increase rates of adoption, adoption is not necessarily associated with change in practice on the farm.

Research on agricultural innovations does not typically account for real life farming conditions, through which these innovations are adopted. If adoption is considered to be a dynamic social decision, described as a continuum rather than, as a binary decision, social sciences researchers need to consider the adoption decision and issues surrounding implementation. Much of the current input from research in the social sciences to agricultural policy focuses on measurable economics. Such approaches typically consider adoption of agricultural technologies as a binary decision. The modelling of binary decision outcomes, are limited to the range of measurable parameters that exist between firms. Broadly speaking there are two types of variables used to study adoption of technology: the specific traditional socio-economic and demographic variables and the self-reported latent factor variables, which are less amenable to direct measurement. Such approaches do not consider the endogenous 'non-measurable' factors within the firm, yet, this is where technology adoption, and potentially innovation, occurs.

Technological change is often communicated to end users in a top-down manner. The fundamental issue that exists with this linear model is a 'pro-innovation bias'. This assumes unidirectional movement towards an identified, optimum adoption strategy. In this 'science model', field based experimentation emphases the compelling evidence in support of the laboratory experimentation, but provides no social infrastructure to enhance and sustain successful change (adoption) for innovation to occur.

There are issues that are typically ignored by the 'science model', that are necessary and influential for change and decision making in the adoption of new technology in agriculture. The 'science model', for example, typically ignores the ease of use of a particular technology and whether the technology achieves farmers' goals and objectives. These are important influencers of successful adoption. If a new technology does not fit with the current ways of doing or does not support current farming goals or objectives, then it is possible the implementation of a practice may not be successful.

The research in this thesis addresses these issues by studying technology adoption by exploring the role of perceptions and existing practices in technology adoption. In three studies it explores the adoption of two suites of technology, grassland management and nutrient management, in the Irish dairy sector. The approach itself is novel as three separate literatures are used to study technology adoption. Furthermore, three methodologies are used, to study the issue of technology adoption. Collectively the findings of the three studies identify the farmer as salient in the successful adoption of technology. Study one identifies the adoption-innovation gap. It is at the level of the farm where adoption and ultimately successful change (innovation) occurs. Study two identifies the relative importance of farmer perceptions, compared to socio-economic or demographic variables, in the prediction of adoption. Study three explores the importance of the farmer in a specific context, at a specific time, in the implementation of practice at the farm level.

The empirical context for this study, the adoption of grassland and nutrient management practices by Irish dairy farmers, is important for a number of reasons.

Firstly, both suites of practices are ‘green technologies’ as they promote sustainable resource efficiency and reduce potential negative externalities at farm level.

Secondly, these technologies are both inexpensive and management intensive practices, which exhibit low levels of adoption by Irish dairy farmers. Thirdly, benefits of using these practices results in increased utilisation of available natural resources. As this occurs dairy farmers become more resilient to global prices of inputs. They gain greater command over management of available natural inputs. Fourthly, a wider benefit associated with these practices is, the rebuilding of natural resources and the soil ecology. As such farms become more sustainable through restoration and enhancement of the holdings natural capital.

Research Questions

This thesis is divided into three separate studies: the associated characteristics of users (Study one), the intention to use (Study two), and the implementation of practice (Study three).

In study one adoption was studied as a binary decision. Weighted regression analysis using National Farm Survey (NFS) data identifies cohorts of farms and farmers who are likely to adopt practice. The specific research question studied is:

- What are the farm and farmer characteristics of Irish dairy farmers who soil test? (Study one)
- What are the farm and farmer characteristics of those who regularly soil test on a voluntary basis?

Study two uses latent factors based on the social psychology model TAM to explore the probabilities of farmers having a positive intention to use practice and social influence. More specifically, study two explores farmer perceptions and identifies influential social groups relating to six grassland management practices. Using regression analysis study two examines the performance of socio-economic and demographic variables in the prediction of intention to use with perceptions and goals of individuals. The specific research questions studied are:

- Are latent factor social variables more appropriate in predicting intentions to use practice than more traditional measurable variables? (Study two)

- What type of social influence impacts adoption of practice and who are the most influential social groups? (Study two)

Study three explores how the adoption of practices occurs at farm level. Using semi-structured qualitative interviews, study three explores the nutrient management practices of 20 Irish dairy farmers. The specific research question studied is:

- What are the commonalities and differences in existing nutrient management routines at farm level?
    - How are nutrient management practices implemented at farm level?

Research Contributions

This thesis makes a number of contributions to the study of technology adoption in agriculture. These are as follows.

First, the research suggests that technology adoption is more than a binary decision. Adoption of technology involves the incorporation of a new or altered way of doing, with the current way of doing being adapted from past and current activities, routines and resources. In viewing adoption as a binary decision the current way of doing is not considered, and the new way of doing is either adopted or not adopted: that is, it is a binary decision. However, this thesis suggests adoption of a new practice involves the incorporation of the new way into the farm and is a function of current resources of the farm. These physical resources include: the land conditions, the outputs, and weather, while non-physical resources include: personal experience, past activities and future plans. Based on a combination of these resources, a technology may be adopted. The level of adoption varies and is more accurately described as a continuum.

Second, as technology adoption is a social decision, or at least is influenced by non-physical factors, there is a need to consider measuring and predicting adoption activities using latent factor variables. These latent factors are more appropriate for predicting probabilities of practice use, rather than, socio-economic and demographic variables. Many of these latent factors are social factors such as the beliefs and objectives of farmers.

Third, this research suggests that successful technological change and innovation are fundamentally different to practice adoption. By studying the process, researchers can get insights into how a practice is adopted and the extent to which a practice is adopted. As the studies in this thesis have shown, the factors that influence the adoption process are varied and are beyond the basic descriptors of the farm and of farmer characteristics. If research and policy seek to improve innovation through practice adoption it must incorporate this wider perspective on adoption.

Fourth, in an Irish context, this research is the first to apply social factors, and specifically the TAM model, to the technology adoption question. Through focusing on the continuous process of adoption, farmers' activities are understood. It is the process of adoption, which, over time results in economic or social changes. If the focus remains to be on the binary adoption decision the innovation will fail. It is only when successful "change" occurs that innovation has occurred as a result of technology adoption.

Fifth, the research highlights the range of factors that influence the nutrient management practices on farms. These include six sources of information and knowledge. Three of these are controllable factors: personal, scientific and industrial knowledge information; while three are sources of information that are outside of the control of the farmer: weather, resources and prices. This suggests that greater attention needs to be focussed on the context in which the adoption occurs. History and context matter in understanding adoption activities and practices of farms and farmers.

Sixth, given the external environmental concerns and pressures on farming, Rajalahti (2012) has called for an increased focus and increased knowledge on sustainable 'green' growth and the capacity to develop such knowledge. By focussing on the adoption of technologies that can have a positive environmental impact, this research makes an initial contribution to such knowledge. The adoption of grassland management practices is one example of a green practice that is influential in achieving improved use of resources. Equally the adoption of nutrient management practices lessens the potential to pollute. This has wider positive externalities including the quality of water in rivers, underground waterways and lakes.

Limitations

There are a number of limitations presented in this thesis. These are as follows. First, this thesis focuses on one type of farmer. It addresses technology adoption in the dairy sector only. Relative to other farming sectors such as beef and sheep, dairy farmers are generally characterised by higher rates of adoption. The factors influencing adoption of land management in these sectors may differ, as they operate different farming systems.

Second, in both the first and the second study logit analysis is used to predict the decision and the intention of technology adoption. While such binary outcome models have dominated the technology adoption literature, there are limitations to this approach. Specifically, the analysis is limited by the variables that can be included. More specifically, in study one farm and farmer characteristics are used to model the adoption decision of soil testing. The use of such survey variables is limiting in two ways: (1) the variables are observed at a point in time, and (2) the variables are measured after the adoption decision is made. This does not capture information about the process of adoption and the changes that occurred over a period of time. While this can be addressed through the use of panel data, this was not possible as the soil question was only included in one year of the National Farm Survey.

In study two the variables are also observed at a point in time. A further limitation in study two is that the latent factor perceptions were captured using self-report measures. The use of cross sectional data is an issue with all survey instruments, as is the use of self-report variables. Latent factors were used to measure farming objectives and perceptions. Objectives measured using cross sectional self-report data may change as external conditions, such as regulation, affect farming objectives.

There is evidence that farmer responses display positive post-adoption evaluation (Bagozzi 1991, as cited in Flett et al. 2004). It is possible that farmers were less likely to rate grassland management practices as negative given its proven benefits. Further due to space limitations in the survey it was not possible to measure social influence as an ordinal variable.

Third, in study two the TAM items did not factor as two factors as theorised. This is limiting in that it is not possible to compare the results of this study with past TAM research. Consequently TAM was used as a single perception variable in the analysis.

Fourth, the use of binary outcome models limits the policy implications that can be drawn. Geroski (2000) has identified two limitations for policy from the use of binary outcome models as: (1) such models limit actions policy makers can take, and (2) such models place the firm (farm in this context) as the source of the problem. These limitations are applicable to study one and study two.

Fifth, in framing famer's decision making processes, many literatures could be used. Given time and space limitations it was not possible to explore all such literatures in this thesis. Researchers and policy makers interested in adoption could potentially benefit from focusing on a wider range of literature and specifically on the environment in which transactions take place (Metha 2013).

Implications for Policy

Existing approaches to the study of technology adoption in agriculture focus on identifying similar attitudes or typologies of farms and farmers who are likely to use practice. From a policy perspective this offers limited options. However, these limitations are overlooked as such approaches may be the most effective means of targeting groups to increase adoption of practice. This is based on a top-down approach to extension. Swanson and Rajalahti (2010) describe this approach to extension as a teaching institution. Such extension services identify groups in the population to target and provide information to these groups. While this is effective in terms of the transfer of information, it has been argued that extension should be considered as a learning institution as "*every farm is different and farmers know more* *about their respective farms than any extension field worker can ever know*” (Swanson and Rajalahti 2010). The examination of factors identified by the users as critical to technology acceptance is essential to understanding why a technology might be successful (Yi et al., 2006). This thesis suggests extension has an important role to play in the adoption process, not only in the transfer of information but also, through adapting and change approaches currently used, facilitating learning from end users.

This research identifies an adoption-innovation gap and suggests mandatory adoption policies do little to reduce this gap. This thesis explores the low levels of adoption of practices which have proven scientific benefits, (Creighton et al. 2011; Donnellan, Hanrahan and Lalor 2012; NFS 2009; Tunney et al. 2010). In Ireland, the interventions taken by government have been incentivised schemes. For example, the Rural Environmental Protection Scheme mandated the use of soil testing; and the Dairy Efficiency Programme required attendance at six group meetings (the meetings focused on promoting the land management practices). These interventions are essentially subsidies given to farmers in the promotion of technical change, and supports innovation through practice adoption. There is a need for policy makers to be innovative in identifying ways to address the innovation-adoption gap.

One approach adopted by policy makers is the provision of information about the benefits of a technology. The provision of information is not the only point where policy can intervene. While science and economics will remain salient in term of agricultural technology development, specifically in relation to design and value for money, the evidence presented in this thesis suggests that the adoption of technology is a decision making process best described as a networked social activity that takes place at the individual firm level. This thesis suggests these major elements could be further enhanced through considering social issues effecting adoption of technology.

A further implication for policy makers is that they may be able to influence adoption by focussing on knowledge flows at various stages of the technology development process. However, the type of information required by farmers and the type information provided by experts may be mismatched if there is no consideration of what is required by farmer as end user of a technology/practice. Experts can offer specialised up to date information on their area of expertise. However, as they do not generally operate at the frontline, the information provided may not include any consideration of local conditions, culture, circumstances and needs (Parker et al. 2009). The combination of expert and local, on the ground, information may improve the current centralised, scientific approach. A more decentralised approach might enable those at the ‘frontline’ free to work on the details of new technology in context of local needs (Parker et al. 2009).

Directions for Future Research

Building on the studies in the current thesis there is a need to restructure how researchers view technology adoption. The following perspectives could provide potentially interesting avenues for further research in the area of technology adoption.

First, the study of adoption could focus on farm level networks. This would add to, and complement the focus this research had on routines. By identifying the knowledge flows and sources of information that exist at farm level, a much greater insight could be gained in terms of understanding the implementation process of practice adoption. It is at the level of decision making that change might be best understood. Recent models of innovation and change embrace participatory aspects of decision making. Co-decision and co-creation of innovations is an area where end users can be influential. Technology must be informed by scientific evidence but also informed by end users.

Second, while the ultimate adoption decision lies with the individual, there may be a role for the communications (extension) agent. Communication is essentially an intervention (Leeuwis 2004) which involves the exchange of meaning through information signals, the nature of which can be instrumental (top-down) or interactive approaches (participatory) (*ibid*). The agent has the potential to support decision making at a number of stages of the process. Future research could explore the role of such agents. There are a number of stages in the adoption process where the agent may be important; (1) research and design, (2) communication, and (3) end user implementation.

Third, the transfer or exchange of information could benefit from an extended loop of interaction and learning between the farmer (end user) and the (technology/practice) research groups and those responsible for policy. Double loop learning is an extension of single loop learning (Morgan 1986), in that, it takes a double look, by questioning the relevance of operating norms in organisations by encouraging on-going debate and innovation. In order to attain this level of learning each of the members of the chain must be in close proximity, what Boschma (2005 p.63) terms organisational proximity. This closeness of relations is of upmost importance in the adoption process. If a process of continuous learning is to exist in the agricultural sector, a feedback mechanism must be appropriately infiltrated into the current linear system. Bottom-up approaches however, are also subject to power differentials in rural areas (Shorthall 2004). Organisations often control information flows, shaping knowledge available to others, in accordance with a view of the world that favours their interests deemed 'gatekeepers', so as to influence people's perceptions of situations and therefore the way they act in relation to that situation (Morgan 1986). Such restriction on knowledge inhibits opportunities and activities (Levinthal and March 1993). Gatekeepers monitor and translate external conflicting information to internal members of the organisation in a form that is understandable. This is an idea adopted from Tushman (1977) who identifies gatekeeper as acting in a boundary role.

Appendix A

Trends in national fertiliser use, CSO figures show approximately a €40 million increase in expenditure on fertilizer from 2010 figures however, this is a reflection of prices increases as consumption has fallen by approximately 13%.

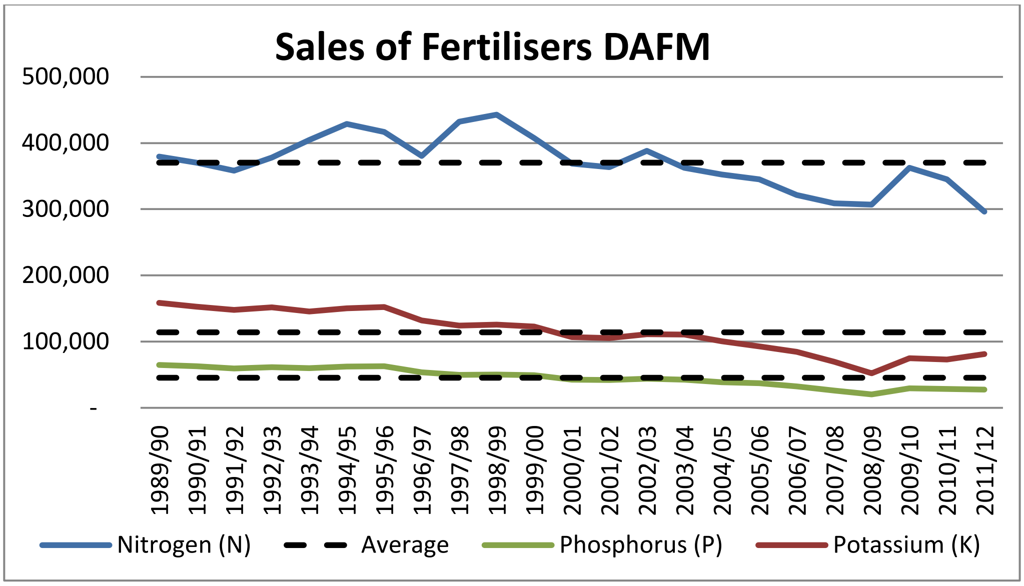

Figure 1.1 Department of Agriculture Food and Marine

Appendix B

TAMS Survey

amárach
research

Teagasc
Dairy Farmers Acceptance and use of Technologies 2012/13

August 2013

ASK ALL
QA **Confirm that respondent is the owner/operator of the farm**.

Yes	1
No	2

<u>If no, seek the owner/operator. If not available, go to another farm.</u>

RECORD
QB **Record gender of respondent.**

Male	1
Female	2

ASK ALL
QC **Confirm that farmer is dairy farmer.**
(Interviewer note: if no livestock, mark as 0)

	LIVESTOCK (Present on the farm)	**NUMBER**
A	Dairy cows	
B	Other cows	
C	In calf heifers	
D	Cattle <1 year old	
E	Cattle 1-2 year old	
F	Cattle >2 years old	
G	Stock bull	
H	Ewes	
I	Other sheep	
J	Horse/ponies	
K	Other (specify, record all___________________) ______________________________	

DECISION RULE

If number dairy cows is <u>greater than 50%</u> of all other animals, proceed with interview.
If number of dairy cows is <u>less than 50%</u> of all animals, select another farm.

QD **Region.**

Louth, Leitrim, Sligo, Donegal, Monaghan	1
Dublin, excluding from NFS analysis due to small sample forms	2
Kildare, Meath, Wicklow	3
Laois, Longford, Offaly, Westmeath	4
Clare, Limerick, Tipperary N.R.	5
Carlow, Kilkenny, Wexford, Tipperary S.R., Waterford	6
Cork, Kerry	7
Galway, Mayo, Roscommon	8

DAIRY FARMERS ACCEPTANCE OF TECHNOLOGY

FARMER AND HOUSEHOLD CHARACTERISTICS

ASK ALL
Q1a **How many persons live in your household?**
Q1b **How many children (under 18 years) live in your household?**

Number of persons in household	
Number of persons under 18	

ASK ALL
Q2 **What is your highest education level?**

Primary school	1
Some secondary school ~(e.g. inter cert or junior cert)	2
Completed secondary school (e.g. leaving cert)	3
Bachelor’s degree	4

Master’s degree	5
PhD	6
Other	7

ASK ALL

Q3a **Do you have any specialised agricultural education?**

Yes	1
No	2

ASK ALL WHO ANSWERED YES @ Q.3a

Q3b **What is the specialist agricultural education?**

Certificate in farming	1
Third level degree in agriculture	2
Masters degree in agriculture	3
Farm apprenticeship scheme/trainee farmer scheme	4
1 year at an agricultural college	5
Course < 60 hrs	6
Course > 60 hrs	7
Other (please specify: ______________________________)	8

ASK ALL

Q4 **What year were you born?**

ASK ALL

Q5 **In what year did you start farming as the main farm holder**?

ASK ALL

Q6 **Do you currently have an off-farm job?**

Yes	1
No	2

ASK ALL WHO ANSWERED YES TO Q. 6, OTHERWISE GO TO Q.7.

Q6a **Please record occupation** (eg, accountant/machine driver)

ASK ALL WHO ANSWERED YES TO Q.6A

Q6b **Is the off-farm job?**

Full Time	1
Part Time	2

ASK ALL

Q7 **Are you?**

Single	1
In a relationship (married/partner)	2
Other (e.g. widowed/separated)	3

ASK ALL WHO ANSWERED CODE 2 TO Q.7 OTHERWISE GO TO Q.9.

Q8 **If married/with a partner does your wife/partner currently have an off-farm job?**

Yes	1
No	2

ASK ALL WHO ANSWERED YES TO Q.8

Q8a **Please record occupation (e.g. nurse/teache**r)

ASK ALL WHO ANSWERED YES TO Q.8

Q8b **Is your wife/partners off-farm job?**

Full time	1
Part time	2

ASK ALL

Q9 **Have you identified a successor to take over from you here on the farm?**

Yes	1
No	2
Not decided	3
Don't know/not sure (please specify: ______________________)	4

FARM PROFILE

ASK ALL

Q10 **What is the <u>main (principal) dairy</u> enterprise on this farm?**

Creamery milk	1
Liquid milk	2
Other (Please specify: ______________________________)	3

ASK ALL

Q11 **What is the <u>secondary farming</u> enterprise on this farm?**

Not relevant (100% dairying)	1
Dry stock	2
Sheep	3
Tillage	4
Dry stock and tillage	5
Other (Please specify: ______________________________)	6

ASK ALL

Q12 **Farm holding:**

(Note for interviewers: Make sure 12a is the sum of answers of c,d,e)

		HA	ACRES
A	What is the total agricultural area of your farm in hectares or acres*?		
B	How many hectares or acres is utilizable agricultural area?		
C	How many hectares or acres do you own?		
D	How many hectares or acres are rented-in?		
E	How many hectares or acres are let-out?		

**1 hectare=2.471 acres*

ASK ALL

Q13 **How many separate parcels of land make up the total farmed area?**

ASK ALL

Q14 **What size is the milking platform in hectares or acres?**

HA	ACRES

ASK ALL

Q15 **Are you presently in a REPS scheme or the AEOS scheme?**

Yes	1
No	2

ASK ALL

Q16 **Did you receive derogation to farm at above 170kg/ha of organic nitrogen under the Nitrates Directive in any year from 2006 to 2013?**

Yes	1
No	2

ASK ALL

Q17 **Which of the following best describes your farm trading status?**

Sole trader	1
Partnership	2
Limited company	3
Other (Please specify: ________________________________)	4

ASK ALL

Q18 **Are you a member of a discussion group?**

Yes	1
No	2

ASK ALL WHO ANSWERED YES AT Q.18

Q18a **How many years have you been a member?**

ASK ALL WHO ANSWERED YES AT Q.18A

Q19 **How many meetings of the discussion group, on average, do you attend each year?**

ASK ALL

Q20 **Are you a Teagasc client?**

Yes	1
No	2

ASK ALL

Q21 **Are you/were you in the 'dairy efficiency programme'?**

Yes	1
No	2

ASK ALL

Q22 **Are you a 'new entrant to dairying'?**

Yes	1
No	2

ASK ALL

Q23 **Have you heard of animal health Irelands 'Cellcheck' programme?**

Yes	1
No	2

ASK ALL

Q24 **Do you have a copy of the 'Cellcheck' guidelines on mastitis control?**

Yes	1
No	2

ASK ALL

Q25 **What are your future farming intentions?**

Remain in dairying for the foreseeable future	1
Remain in dairying for the next 3 years but not sure thereafter	2
Will exist dairying in the next 3 years	3
Undecided	4

ASK ALL

Q26 **Are you aware of the targets under 'Food Harvest 2020' to increase dairy output by 50% by the year 2020?**

Yes	1
No	2

ASK ALL

Q27 **Do you intend to increase your milk output after 2015 when quotas are removed?**

Yes	1	**GO TO Q. 29**
No	2	**GO TO Q.28**

ASK ALL WHO ANSWERED NO TO Q.27, ALL OTHERS SKIP TO Q.29

Q28 **Why not?**

Not enough land	1
Increased labour requirement needed to increase output	2
Restricted capacity of current facilities	3
Satisfied with current output level	4
Other (Please specify: ________________________________)	5

ASK ALL WHO ANSWERED YES TO Q.27

Q29 **By how much do you think you will be able to expand your output?**

0-10%	1
10-20%	2
21-30%	3
31-40%	4
41-50%	5
Greater than 50%	6

ASK ALL

Q30 **What price per litre of milk would you need to receive to get you to increase production by that amount?**

26 cents per litre	1
27 cents per litre	2
28 cents per litre	3
29 cents per litre	4
30 cents per litre	5
31 cents per litre	6
32 cents per litre	7
33 cents per litre	8
34 cents per litre	9
35 cents per litre	10
36 cents per litre	11
Other (Please specify: ________________________________)	12

ASK ALL

Q31 **On average how many hours a week <u>do you</u> spend working on the farm?**

Less than 10 hours a week	1
10-20 hours a week	2

21-30 hours a week	3
31-40 hours a week	4
41-50 hours a week	5
51-60 hours a week	6
61-70 hours a week	7
70 hours or more a week	8

ASK ALL

Q32 **Looking at this table, could you please tell me what best describes your annual farm income <u>BEFORE TAXES</u> and <u>NOT INCLUDING</u> the single farm payment?**

€0-€3,999 per annum	1
€4,000-€9,999 per annum (€80-€195 per week)	2
€10,000-€19,999 per annum (€195-385 per week)	3
€20,000-€29,999 per annum (€385-€580 per week)	4
€30,000-€39,999 per annum (€580-€770 per week)	5
€40,000-€49,999 per annum (€770-€960 per week)	6
€50,000-€59,999 per annum (960-€1150 per week)	7
€60,000-€69,999 per annum (€1150-€1350 per week)	8
€70,000-€79,000 per annum (€1350-€1535 per week)	9
€80,000-€89,999 per annum (€1535-€1730 per week)	10
€90,000-€99,999 per annum (€1730-€1900 per week)	11
€100,000+ per annum (€1900+ per week)	12

ASK ALL

Q33a **In addition to your main farming business, does this farm have an alternative <u>on-farm</u> enterprise?**

Yes	1
No	2

ASK ALL WHO ANSWERED YES TO Q. 33a, OTHERWISE GO TO Q. 33b

Q33a-1 **Specify what it is:**

Q33a-2 **What year was it established?**

ASK ALL WHO ANSWERED NO TO Q. 33a.

Q33b **In addition to your main farming business, does this farm have an alternative <u>off-farm</u> enterprise?**

Yes	1
No	2

ASK ALL WHO ANSWERED YES TO Q.33b, OTHERWISE GO TO Q. 34

Q33b-1 **Specify what it is:**

Q33b-2 **What year was it established?**

Dairy Farmers Acceptance of Technology

ASK ALL

Q34 **Which of the following technologies are you currently using and how many years have you been consistently using them**?

		Currently Using		How many years have you been consistently using this technology?
		Yes	No	
	Grassland Management			
1	Grass budgeting **(if yes, go to Q34 a & b)**	1	2	
2	Grass cover **(if yes, go to Q34 c & d)**	1	2	
3	Rotational grazing **(if yes, go to Q34 e &f)**	1	2	
4	Reseeding **(if yes, go to Q34 g & h)**	1	2	
5	Grass wedge **(if yes, go to Q34 i & j)**	1	2	
6	Spring rotation planner **(if yes, go to Q34 k & l)**	1	2	
7	Soil sampling	1	2	
8	Topping paddocks	1	2	
9	Using diet feeder	1	2	
	Animal Health			
10	Dry cow therapy	1	2	
11	Teat disinfection	1	2	
12	BVD vaccination	1	2	
	Breeding Management			
13	Herd plus & EBI reports	1	2	
14	Active bull list	1	2	
15	Heat detection aids	1	2	
16	Milk recording	1	2	
17	Artificial insemination (AI)	1	2	
18	Use of genomic bulls	1	2	
	Financial Management			
19	Creating annual farm accounts	1	2	
20	Creative 5 year written plans	1	2	
21	Financial budgeting	1	2	
22	Teagasc e-profit monitor	1	2	
23	Teagasc e-cost control programme	1	2	
24	Measuring cash flow	1	2	

ASK ALL WHO ANSWERED YES TO Q. 34 (1), OTHERWISE MOVE TO 34c

GRASS BUDGETS

Q34a **Are you doing grass budgeting because (choose one only)?**

You feel you have to do grass budgets	1
You feel that you should do grass budgets	2
You believe in and want to do grass budgets	3

Q34b **What is the biggest influence on the reason you just outlined (choose one only)?**

Family	1
Neighbours	2
Discussion group	3
Other (Please specify: ________________________________)	4

ASK ALL WHO ANSWERED YES TO Q. 34 (2), OTHERWISE MOVE TO 34e

GRASS COVERS

Q34c **Are you doing grass covers because (choose one only)**

You feel you have to do grass covers	1
You feel that you should do grass covers	2
You believe in and want to do grass covers	3

Q34d **What is the biggest influence on the reason you just outlined (choose one only)?**

Family	1
Neighbours	2
Discussion group	3
Other (Please specify: ________________________________)	4

ASK ALL WHO ANSWERED YES TO Q. 34 (3), OTHERWISE MOVE TO Q. 34g

ROTATIONAL GRAZING

Q34e **Are you doing rotational grazing because: (choose one only)**

You feel you have to do rotational grazing	1
You feel that you should do rotational grazing	2
You believe in and want to do rotational grazing	3

Q34f **What is the biggest influence on the reason you just outlined? (choose one only)**

Family	1
Neighbours	2
Discussion group	3
Other (Please specify: ________________________________)	4

ASK ALL WHO ANSWERED YES TO Q. 34 (4), OTHERWISE GO TO Q. 34i

RESEEDING

Q34g **Are you reseeding because: (choose one only)**

You feel you have to do reseeding	1
You feel that you should do reseeding	2
You believe in and want to do reseeding	3

Q34h **What is the biggest influence on the reason you just outlined? (choose one only)**

Family	1
Neighbours	2
Discussion group	3
Other (Please specify: ________________________________)	4

ASK ALL WHO ANSWERED YES TO Q. 34 (5), OTHERWISE GO TO Q. 34k

GRASS WEDGE

Q34i **Are you using grass wedge because: (choose one only)**

You feel you have to do a grass wedge	1
You feel that you should do a grass wedge	2
You believe in and want to do a grass wedge	3

Q34j **What is the biggest influence on the reason you just outlined? (choose one only)**

Family	1
Neighbours	2
Discussion group	3
Other (Please specify: ______________________________)	4

ASK ALL WHO ANSWERED YES TO Q. 34 (6), OTHERWISE GO TO Q.35

SPRING ROTATIONAL PLANNER

Q34k **Are you using the Spring Rotational Planner because: (choose one only)**

You feel you have to use a spring rotational planner	1
You feel that you should use a spring rotational planner	2
You believe in and want to use a spring rotational planner	3

Q34l **What is the biggest influence on the reason you just outlined? (choose one only)**

Family	1
Neighbours	2
Discussion group	3
Other (Please specify: ______________________________)	4

PERCEIVED USEFULNESS AND EASE OF USE OF SPECIFIC TECHNOLOGIES

For all the following technologies, please complete ALL the scales. The scale goes from number 1 which means **STRONGLY DISAGREE** to number 5 which means **STRONGLY AGREE**. Even if you **DO NOT** use these technologies please answer how you think they would affect your farming?

GRASSLAND MANAGEMENT PRACTICE

ASK ALL

Q35 **Grass Budgeting**

		Strongly Disagree 1	**Disagree 2**	**Neutral 3**	**Agree 4**	**Strongly Agree 5**
A	Grass budgeting is important to your farming needs	1	2	3	4	5
B	Grass budgeting is able to increase production for you	1	2	3	4	5
C	Grass budgeting is better than what it replaces	1	2	3	4	5
D	Grass budgeting increases your profits	1	2	3	4	5
E	Grass budgeting saves you time	1	2	3	4	5
F	Grass budgeting is easy for you to understand	1	2	3	4	5
G	Grass budgeting is easy for you to use	1	2	3	4	5
H	I plan to use grass budgeting in the next 12 months	1	2	3	4	5

ASK ALL

Q36 **Grass Covers**

		Strongly Disagree 1	**Disagree 2**	**Neutral 3**	**Agree 4**	**Strongly Agree 5**
A	Grass covers are important to your farming needs	1	2	3	4	5
B	Grass covers are able to increase production for you	1	2	3	4	5
C	Grass covers are able to increase	1	2	3	4	5

	your profits					
D	Grass covers are better than what they replace	1	2	3	4	5
E	Grass covers save you time	1	2	3	4	5
F	Grass covers are easy for you to understand	1	2	3	4	5
G	Grass covers are easy for you to use	1	2	3	4	5
H	I plan to use grass covers in the next 12 months	1	2	3	4	5

ASK ALL
Q37 **Reseeding**

		Strongly Disagree 1	**Disagree 2**	**Neutral 3**	**Agree 4**	**Strongly Agree 5**
A	Reseeding is important to your farming needs	1	2	3	4	5
B	Reseeding is able to increase your profits	1	2	3	4	5
C	Reseeding is better than what it replaces	1	2	3	4	5
D	Reseeding is able to increase production for you	1	2	3	4	5
E	Reseeding saves you time	1	2	3	4	5
F	Reseeding is easy for you to understand	1	2	3	4	5
G	Reseeding is easy for you to use	1	2	3	4	5
H	I plan to reseed in the next 12 months	1	2	3	4	5

ASK ALL
Q38 **Rotational Grazing**

		Strongly Disagree 1	**Disagree 2**	**Neutral 3**	**Agree 4**	**Strongly Agree 5**
A	Rotational grazing is important to your farming needs	1	2	3	4	5
B	Rotational grazing is able to increase your profits	1	2	3	4	5

C	Rotational grazing is better than what it replaces	1	2	3	4	5
D	Rotational grazing is able to increase production for you	1	2	3	4	5
E	Rotational grazing saves you time	1	2	3	4	5
F	Rotational grazing is easy for you to understand	1	2	3	4	5
G	Rotational grazing is easy for you to use	1	2	3	4	5
H	I plan to use rotational grazing in the next 12 months	1	2	3	4	5

ASK ALL

Q39 **Grass Wedge**

		Strongly Disagree 1	**Disagree 2**	**Neutral 3**	**Agree 4**	**Strongly Agree 5**
A	Grass wedge is important to your farming needs	1	2	3	4	5
B	Grass wedge is able to increase your profits	1	2	3	4	5
C	Grass wedge is better than what it replaces	1	2	3	4	5
D	Grass wedge is able to increase production for you	1	2	3	4	5
E	Grass wedge saves you time	1	2	3	4	5
F	Grass wedge is easy for you to understand	1	2	3	4	5
G	Grass wedge is easy for you to use	1	2	3	4	5
H	I plan to use Grass wedge in the next 12 months	1	2	3	4	5

ASK ALL

Q40 **Spring Rotation Planner**

		Strongly Disagree 1	**Disagree 2**	**Neutral 3**	**Agree 4**	**Strongly Agree 5**
A	Spring Rotation Planner is important to your farming needs	1	2	3	4	5
B	Spring Rotation Planner is able to increase your profits	1	2	3	4	5

C	Spring Rotation Planner is better than what it replaces	1	2	3	4	5
D	Spring Rotation Planner is able to increase production for you	1	2	3	4	5
E	Spring Rotation Planner saves you time	1	2	3	4	5
F	Spring Rotation Planner is easy for you to understand	1	2	3	4	5
G	Spring Rotation Planner is easy for you to use	1	2	3	4	5
H	I plan to use Spring Rotation Planner in the next 12 months	1	2	3	4	5

ASK ALL

Q41 **Teagasc eProfit Monitor**

		Strongly Disagree 1	**Disagree 2**	**Neutral 3**	**Agree 4**	**Strongly Agree 5**
A	Teagasc eProfit monitor is important to your farming needs	1	2	3	4	5
B	Teagasc eProfit monitor is able to increase your profits	1	2	3	4	5
C	Teagasc eProfit monitor is better than what it replaces	1	2	3	4	5
D	Teagasc eProfit monitor is able to increase production for you	1	2	3	4	5
E	Teagasc eProfit monitor saves you time	1	2	3	4	5
F	Teagasc eProfit monitor is easy for you to understand	1	2	3	4	5
G	Teagasc eProfit monitor is easy for you to use	1	2	3	4	5
H	I plan to use Teagasc eProfit monitor in the next 12 months	1	2	3	4	5

EXTERNAL SOURCES OF ADVICE

ASK ALL

Q42 **Can you tell me who has provided you with the most important advice over the past 5 years about the grassland management technologies/practices we have just discussed? Rank top 5 in order of importance 1, 2, 3, 4, 5), where 1 is most important and 5 is least important.**

		RANK TOP 5
A	Teagasc advisor	
B	Teagasc specialist	
C	Teagasc researcher	
D	Private agricultural consultant	
E	REP’s planner	
F	Bank personnel	
G	Equipment/feed supplier	
H	IFA	
I	Macra na Feirme	
J	ICMSA	
K	Local cooperative	
L	Milking machine technician	
M	Vet	
N	Neighbour	
O	Family member	
P	Other relative	
Q	Other (please specify: _______________-____________)	

FARMING OBJECTIVES

ASK ALL

Q43 **Ask the farmer how important to him/her personally are the following?**

		Not very important to me 1	**Somewhat important to me 2**	**Neutral 3**	**Very important to me 4**	**Extremely important to me 5**
A	Utilising your resources fully	1	2	3	4	5
B	Being organically certified	1	2	3	4	5
C	Having the best livestock/pastures	1	2	3	4	5
D	Having time for other activities	1	2	3	4	5
E	Maximising profit	1	2	3	4	5
F	Producing high quality products	1	2	3	4	5
G	Keeping buildings/fences/dikes in good repair	1	2	3	4	5
H	Off-farm work is necessary to stay in farming	1	2	3	4	5
I	Keeping debt as low as possible	1	2	3	4	5
J	Being environmentally friendly	1	2	3	4	5
K	Increasing the size of the farm	1	2	3	4	5
L	Spending time with the family	1	2	3	4	5
M	Minimising risk in farming	1	2	3	4	5
N	Providing a satisfying lifestyle	1	2	3	4	5
O	Having up-to-date equipment and machinery is important	1	2	3	4	5
P	Saving money/accumulating assets for retirement	1	2	3	4	5

Q	Trying new varieties of livestock/crops	1	2	3	4	5
R	Staying in farming whatever happens	1	2	3	4	5
S	Reinvesting in the farm	1	2	3	4	5
T	Having the respect of other farmers in the community	1	2	3	4	5
U	Using chemicals sparingly	1	2	3	4	5
V	Improving living standards of family life	1	2	3	4	5
W	Leaving the land in as good a condition as you received it	1	2	3	4	5
X	Having other interests outside farming	1	2	3	4	5
Y	Preventing pollution	1	2	3	4	5
Z	Being innovative by using new technologies/practices	1	2	3	4	5
Aa	Getting all that you are due from current schemes	1	2	3	4	5
Bb	Developing a family business	1	2	3	4	5
Cc	Having a successfully diversified farm	1	2	3	4	5
Dd	Meeting challenges	1	2	3	4	5
Ee	Having investments	1	2	3	4	5
Ff	Maximising production	1	2	3	4	5
Gg	Having other skills outside farming	1	2	3	4	5
Hh	Entering and winning competitions/shows	1	2	3	4	5
Ii	Expanding the business	1	2	3	4	5

FEEDBACK TO SURVEY PARTICIPANTS

Copies of the summary and final results of this survey will be made available to all participants. If you want a copy of these reports please provide your name and address below.

Name: ____

Address: ____

____

____

____

In order to maintain confidentiality do not attach this form to the completed survey!

Table 2.8 TAM Items: Frequencies

Practice	Grass Budget			Grass Cover			Rotational Grazing			Reseeding			Grass Wedge			Spring Rotational Planner		
Adoption Rate	**44**			**40**			**84**			**80**			**34**			**50**		
Likert / Items	DA	N	A	DA	N	A	DA	N	A	DA	N	A	DA	N	A	DA	N	A
Farming needs	11.6	27.8	60.7	11.1	34.2	54.7	2.1	9	88.9	4.6	8.2	87.1	12.1	46	41.9	6.4	28.3	65.3
Production	6.7	30.3	63	8.7	34.4	56.9	2.8	9.5	87.7	3.1	9.5	87.4	11.1	46.5	42.4	6.4	30.6	63
What it replaces	6.2	36.2	57.6	7.2	39.3	53.5	1.8	12.6	85.6	2.6	11	86.4	9	50.6	40.4	4.9	34.2	60.9
Profits	7.5	29.8	62.7	8	37	55	1.5	9.8	88.7	4.6	7	88.4	10.5	46.8	42.7	4.6	31.9	63.5
Time	12.3	37.3	50.4	12.9	38	49.1	5.1	14.9	80	9	20.6	70.4	12.1	49.6	38.3	8.7	30.8	60.4
Understand	10.3	33.4	56.3	9.3	36	54.8	1.3	10.5	88.2	2.6	8.5	88.9	7.5	49.4	43.2	4.9	32.4	62.7
Use	8.7	33.2	58.1	9.5	35.5	55	2.6	11.3	86.1	4.9	9.8	85.3	10.5	48.8	40.6	6.2	31.9	62
Intention	14.9	29.6	55.5	15.7	31.1	53.2	4.9	9.5	85.6	7.5	12.9	79.7	19	39.3	41.6	13.6	27.5	58.9
N 389																		

DA: Disagree or Strongly Disagree

N: Neutral

A: Agree or Strongly agree

Appendix C

<u>Nutrient Management :</u>*What happens on your farm?*

<u>Soil Testing</u>

Do you soil test…..and how is it carried out on your farm?

How important is soil testing on your farm? (in the greater scheme of things)

Do you use the results?

At what level field or farm?

How do you use results (decision making)? pH....... P K levels.......

Will you do them again or when do you plan to do them?

<u>Fertilizer Application: Organic and Chemical (including lime)</u>

Do you have/use either?

When do you spread?

Time of year & application timing

How do you decide how much to spread? (if very general ask specific)

This year how did you decide how much to spread?

Would it change from year to year?

Would you record how much per field in terms of spreading but also in terms of production outputs grass/milk/weight gained etc.

Do you test organic slurry

Would you spread lime? (ask associated timing and application questions)

<u>Nutrient Management Plan</u>

Do you have/use a NMP on your farm?

Do you use it at field level?

Do you keep notes throughout the year in order to adjust your plan for the following year

In the greater scheme of thing how important is the NMP?

<u>Education & Learning</u>

Who gives you most advice on the farm regarding soil testing

Where do you get your information from if your deciding what sort of slurry to spread

Do you plan ahead using past information/experience (planning retrospectively?)

Discussion Groups: What are they useful for? Why? Is there any negatives?

Do you attend any farm walks or demonstrations what sort of information would you get?

Do you ever put it into use when you return home to your own farm?

Probing questions

Could you tell me a bit more about?

Would anyone do it differently?

Does anyone have a similar experience? Or use this in the same way?

Routines used in analysis

Table 3.2 Colour Coding of Routines in Transcript

Routines		
Primary Routines	1	1. Soil Testing (ST) 2. Use of Soil Test Results (UST)
	2	3. Nutrient Management Planning (NMP) 4. Following Nutrient Management Plan (UNMP)
Application Routines	3	5. Application of Lime (L)
	4	6. Application of slurry (AS) 7. Recording slurry (RS) 8. Calibrating slurry equipment (CS) 9. Testing/Estimating slurry (TS)
	5	10. Application chemical (AC) 11. Recording chemical (RC) 12. Calibrating chemical (CC)

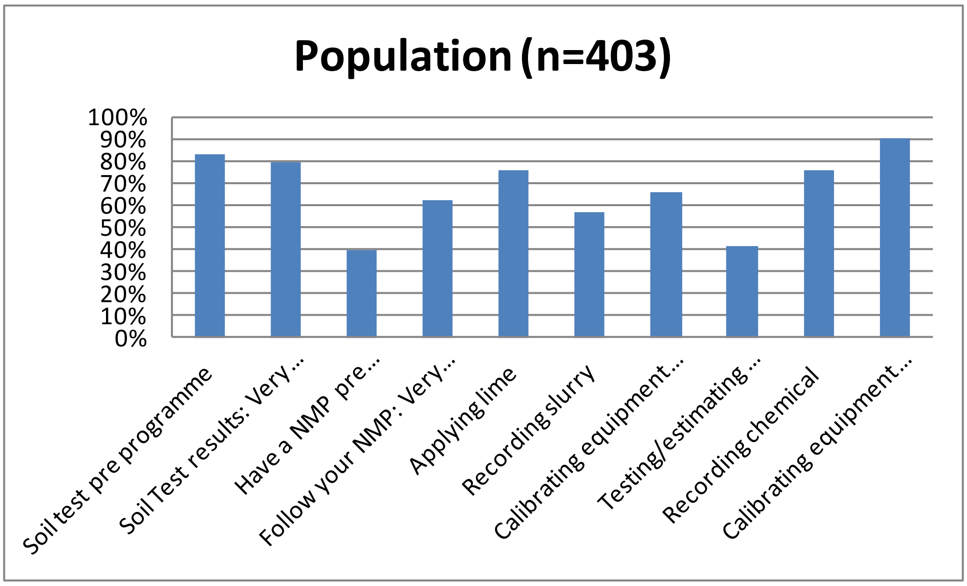

Figure 3.3 Rate of Adoption Population

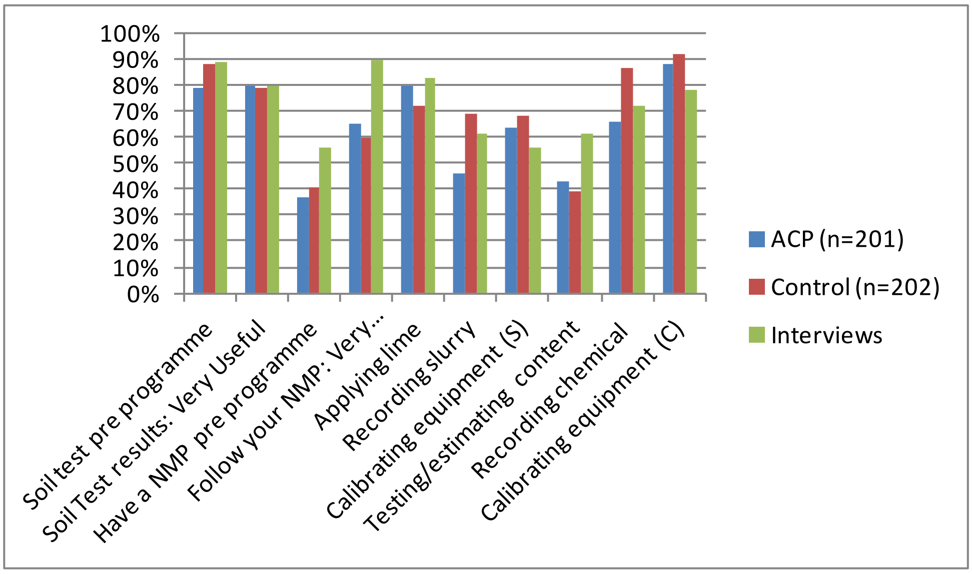

Figure 3.4 Rates of Adoption Population: Categories

Table 3.4: Rates of Adoption

Routines	Y/N	Pop. N403	Pop. EI N385	ACP N201	Dairy TEI N81	Interviews N18
ST: Did you soil test	Yes	83%	83%	79%	91%	89%
(pre)programme (N385)	No	17%	17%	21%	9%	11%
Using Soil Test results						
Very Useful		79%	80%	80%	83%	80%
Somewhat useful		19%	18%	18%	17%	20%
Not very useful		1%	1%	1%	-	-
Not at all useful		1%	1%	1%	-	-
NMP: Did you have a	Yes	39%	38%	37%	53%	56%
NMP (pre) programme (N385)	No	61%	62%	63%	47%	44%
Following NMP						
Very closely		62%	60%	65%	53%	90%
Somewhat closely		31%	32%	30%	35%	10%
Not very closely		4%	4%	2.5%	7%	-
Not at all		3%	4%	2.5%	5%	-
Unsure		-	-	-	-	-
Applying lime (N385)	Yes	76%	75%	80%	89%	83%
Y/N	No	24%	25%	20%	11%	17%
Application of slurry in spring		(Continuous variable)				
Recording slurry application at	Yes	57%	57%	46%	65%	61%
field level (N295)	No	43%	43%	54%	35%	39%
Calibrating equipment used in	Yes	66%	67%	64%	73%	56%
slurry application (N296)	No	34%	33%	36%	27%	44%
Laboratory testing/estimating	Yes	41%	40%	43%	68%	61%
slurry content (N385)	No	59%	60%	57%	32%	39%
Recording chemical at	Yes	76%	77%	66%	80%	72%
field level (N335)	No	24%	23%	34%	19%	28%
Calibrating equipment used	Yes	90%	91%	88%	96%	78%
in (chem.) application (N335)	No	10%	9%	12%	4%	22%

Table 3.5 Farm Profile

Variable	Total EI	Dairy EI	Interviewed
Farm size (mean ha)	134	142	175
Years Experience	34	31	26
Num of cows (avg.)	16*	72	56
Income			
Refused	8%	2%	17%
Less than €10,000	23%	9%	-
€10,001-€20,000	26%	12%	22%
€20,001-€30,000	17%	19%	17%
€30,001-€40,000	8%	7%	17%
€40,001-€50,000	6%	11%	6%
€50,001-€60,000	2%	5%	11%
€60,001-€70,000	2%	5%	-
€70,001-€80,000	1%	5%	-
Greater than €80,000	7%	25%	11%

*Not exclusively dairy all systems

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