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Factors underlying farmers' intentions to adopt best practices: The case of paddock based grazing systems

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Abstract

The Irish beef sector is expected to increase output as part of the most recent national agriculture strategy. General improvements in pasture production efficiency can be achieved by increasing grass utilisation. However, Irish beef production is primarily based on extensive pastoral grazing with low uptake of best management practices among farmers. An important step in facilitating innovation in the sector is to gain improved under- standing of the innovative behaviour of farmers. Hence, this study uses psychological constructs to analyse factors that affect the adoption of paddock based grazing systems by Irish beef farmers (n = 382). Farmers were surveyed from different regions within Ireland and Principal Component Analysis used to empirically confirm the hypothesised Theory of Planned Behaviour (TPB) constructs. Cluster analysis was thereafter employed as classification criteria to cluster respondents into types. The TPB was subsequently applied to explain intention to implement the grazing practice. Three clusters of farmers were elicited based on their beliefs of paddock based grazing systems and labelled The Engaged, The Restricted, and The Partially Engaged. The Restricted cluster was particularly unlikely to uptake the grazing practice as they perceived they lacked the required resources to implement the innovation. This was of particular relevance as the practice can be implemented with relatively few resources and therefore signals a knowledge gap. The findings are relevant to policy as they provide insights on the factors influencing the process of targeting knowledge transfer through appropriate channels which can help build potential drivers for behavioural change.

1. Introduction

Agricultural production is forecast to expand significantly over the coming decades as the global population continues to rise. One of the major challenges facing the food system is the rapidly increasing demand for red meat and its associated environmental externalities (Godfray et al., 2010). The environmental impact of beef production is often determined by production efficiencies (Hyland et al., 2016). Hence, action is required throughout the sector to increase food provision while concurrently lowering environmental impacts. For this reason it is vitally important that farmers adopt best practices that in- crease productivity which can in turn reduce environmental damage. Therefore, management practices which allow farmers to sustainably intensify are particularly significant; i.e. increasing agricultural output without adverse environmental impacts and without the cultivation of more land (Garnett and Godfray, 2012; Smith, 2012). Effective grassland management is an innovation shown to increase productivity and income while reducing environment impacts (Borges et al., 2014).

Taube et al. (2014) and Baumont et al. (2014) have suggested that general improvements in pasture production efficiency can be achieved by increasing pasture utilisation; placing less importance on inputs.

In many regions of Northern and Western Europe grass is the primary dietary constituent for beef production systems due to favourable temperate climatic conditions. Ireland presents characteristics that are applicable to many European beef farmers of similar climatic conditions. The topography of the country varies considerably, encapsulating an array of challenges and environments faced internationally by many in the sector. Irish beef cattle are fed predominantly on grazed grass with grass silage complimented with some concentrate fed during winter; sometimes high levels of concentrates are used in the finishing period (O'Mara, 2012). Ireland has a competitive advantage over many EU countries as it has the potential to grow grass forage over a long growing season. Consequently, 54% of the lifetime weight gain of beef cattle is typically derived from grazed grass and 24% from grass silage (O'Donovan et al., 2011).

The beef industry is an important component of the Irish agri-food sector and accounts for 30% of gross annual agricultural output. The vast majority of this output is destined for the export market (McGee and Crosson, 2016). Nevertheless, the industry faces numerous challenges such as the increasing cost of production, fluctuation of beef prices and an unstable international economic environment (Teagasc, 2016, 2017). The sector is characterised by a high dependency on subsidies, an ageing farmer profile, and small farms with low average farm incomes (Hennessy et al., 2013). Advancements in the productivity of the beef industry are therefore required in order to offset such pressures and to maintain profitably. Furthermore, industry output is expected to grow as part of the most recent national agriculture and food strategy Food Wise 2025 (DAFM, 2016). Increasing grass utilisation by 2 t/ha is one of the approaches which could assist the Irish beef industry improve productivity (DAFM, 2016). However, in order to improve grassland utilisation there is a need to adopt efficient grass management practices such as paddock systems.

Farmer's individual approaches to grazing may vary spatially and temporally (Bohnet et al., 2011). Nevertheless, there are likely to be consistent characteristics and patterns of value systems, motivations and social and economic factors which influence their respective grazing practices (Bohnet et al., 2011). On-farm grass utilisation among Irish farmers is low, with significant potential for expansion and in- creased efficiency (Creighton et al., 2011). Thus, paddock based grazing has been promoted as a best management practice with environmental benefits and associated higher revenue but its adoption rate remains low (Creighton et al., 2011). This poses a major challenge to policy makers and agricultural extension program designers who aspire for the maximum uptake of best management practices. Potential reasons for the non-adoption of best practices for cattle farmers include unfamiliarity, non-applicability, high cost, still considering adoption, and preference not to adopt (Gillespie et al., 2007).

The underlying psychological constructs which affect farmers' behaviour are often overlooked when evaluating the adoption of management practices (Blackstock et al., 2010). Farmers may be uncertain about technology adoption if faced with an innovation that involves conflicts between monetary, management, and social factors (Kim et al., 2008). Paddock grazing is a well-established technology with an expectation of diffusion given the identified benefits. Despite this, implementation of paddock based grazing has been poor on Irish beef farms despite extensive promotion (McGee and Crosson, 2016).

Research concerning farmer adoption of new and novel agricultural technologies has attained considerable attention; however, less focus has been directed towards the low adoption of well-established technologies. The use of landholder typologies has been recommended to improve the effectiveness of agricultural policies and extension pro- grams (Emtage et al., 2007). The purpose of this study is to establish a typology of Irish beef farmers based on their perceptions of paddock based grazing systems and thereafter to use the Theory of Planned Behaviour to evaluate what factors determine their intention to implement the practice. This paper aims to use psychological constructs to analyse factors that affect the adoption of paddock systems by commercial beef farmers in Ireland. The findings may be extrapolated to aid policy-makers in other temperate regions to encourage farmers in adopting measures that aim to increase grass utilisation.

1.1. *Paddock based grazing systems*

The profitability of Irish beef farming is underpinned by the level of grass utilisation (O'Donovan et al., 2011). However, on-farm grass utilisation among Irish farmers is low, with significant potential for expansion and increased efficiency through adoption of grassland management technologies (Creighton et al., 2011). Paddock based grazing systems (also referred to as rotational grazing) are defined as where a paddock is grazed and rested regularly, either on a set calendar schedule or intermittently as needed. In contrast, continuous grazing is defined as where a paddock is stocked continuously at a generally consistent stocking density whether or not it is with the same animals (Sanderman et al., 2015). Paddock grazing allows an area to be grazed by a group of animals in a fast and planned manner, allowing the sward to rest and rejuvenate quickly post grazing (Creighton et al., 2011). The paddock system is a systematic rotational grazing system which is used on beef and sheep farms. It involves roughly equal-sized paddocks and dividing the herd into separate grazing groups to plan the spring grazing rotation. Some of the key benefits of such a system include: control of over grazing, higher grass production, improves grass quality and better access during wet weather (Teagasc, 2011; Undersander et al., 2014).

Paddock based grazing is an intensive management system and can be expensive as it requires capital investment in fencing, water and access routes (Clarke, 2016). However, this need not be the case and it can often be carried out inexpensively through temporary fencing and a radial plot design from existing water sources (Butterfield et al., 2006). The herd graze one paddock at a time, the farmer doesn't allow animals to bare the paddock completely, permitting faster grass recovery time (Allen et al., 2011). It is recommended that paddocks should be equal in size with water supplied to each grazing division (Clarke, 2016). There are many advantages to paddock based grazing systems as they promote higher grass production, improve grass quality, and ensure greater grass utilisation (Dorrough et al., 2004). Furthermore, rotational grazing can be effective in controlling pasture-borne parasites (Larsson et al., 2006). Animal performance is therefore increased when pasture is rotationally rather than continuously grazed (Marley et al., 2007).

1.2. *Theoretical background: the theory of planned behaviour*

The study attempts to explain the low rates of paddock based grazing adoption using the Theory of Planner Behaviour (TPB) as its conceptual framework (Ajzen, 1991). The main construct of the theory is that human behaviour can be explained through intention to behave in a particular way. Intention is the outcome of individual attitudes and beliefs, which are divided into three global categories: personal, normative and control. The three global beliefs are determined by numerous differential components; for instance attitude can be determined by indirect beliefs such as behavioural belief strength and evaluation of outcomes (Fig. 1). Personal beliefs relate to an individual's perception of the outcomes of a specific behaviour, normative belief are related to the perceived social pressure to perform a behaviour and control beliefs are associated with the individuals perception of how easy or difficult it is to perform the behaviour (Fig. 1). Therefore, adoption of a grassland management tool is directly related to a farmer's intention to adopt it, which in turn, is based on the farmers' beliefs about the grassland management tool.

The TPB has been used in agricultural research to explain the pro- cesses of farmers' decision making (de Lauwere et al., 2012; Mattison and Norris, 2007). The three central global constructs used in this study are Attitude (farmers' perceptions of paddock grazing), Subjective Norm (perceived social pressure upon farmers to implement paddock grazing), and Perceived Behavioural Control (farmers' perceptions about their capacity implement paddock grazing). The TPB is based on aggregating Attitude (A), Subjective Norms (SN), and Perceived Behavioural Control (PBC) beliefs and can be depicted in a model to explain behavioural intention (BI) in Eq. (1). In the TPB model, β represents the empirically determined weights that estimate each aggregated belief and ε is defined as an error term:

$$BI = \beta_1 \text{ A} + \beta_2 \text{ SN} + \beta_3 \text{ PBC.....} + \varepsilon \qquad (1)$$

2. Methods

2.1. *Questionnaire design and distribution*

Teagasc is a national body providing integrated research, advisory and training services to the agriculture and food industry and rural communities in Ireland. The study used the Teagasc Client Information Management System (CIMS) database to identify respondents. The database contains information regarding client farm details. In total 13,925 beef farmer records from the CIMS were initially elicited. Beef farmers from the sample were then categorised in terms of their income; thereby providing guidance of representation. Income was decided as being the optimal indicator from the database to ascertain the relative “commerciality” of farmers. Clients were subsequently contacted and invited to complete a paddock grazing questionnaire. In total 382 respondents, based upon the income categories attained from the original CIMS sample, answered the survey. While not nationally representative of beef farming in Ireland, the research does give an indication of this system of farming in particular regions and the use of certain grassland management practices - in this case the use of a paddock system.

A structured survey was designed using the TPB and included other socio-demographic variables. The survey was conducted over the telephone from May to August by one primary researcher. Telephone surveys have been

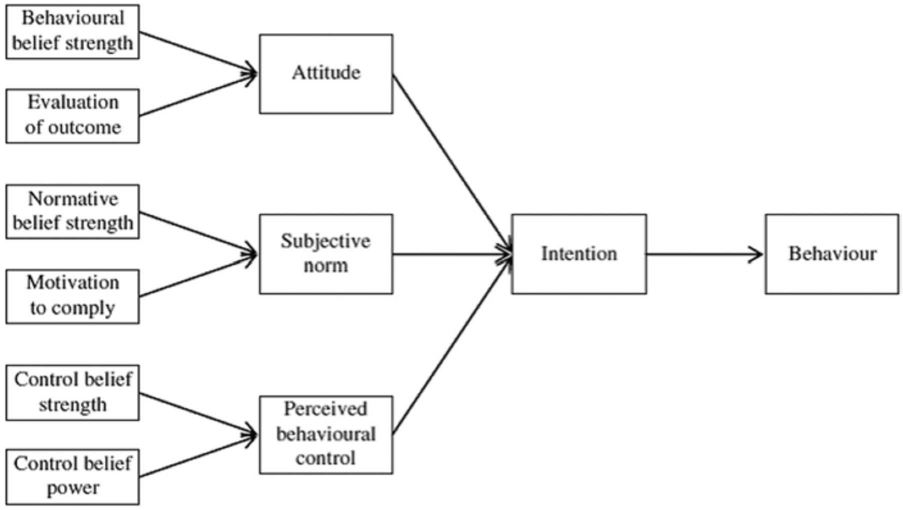

Fig. 1. Conceptual framework of the theory of planned behaviour.

shown to allow a large sample to be interviewed and positive response rates to be achieved and to provide reliable and accurate results (Denscombe, 2010). The questions were selected to obtain a general description of farm and farmer characteristics followed by specific questioning on the relevant grassland management practice.

2.2. *Statistical analyses*

2.2.1. *Principal component analysis*

The questionnaire used homogeneous ordinal categorical variables that expressed different TPB constructs. Principal Component Analysis (PCA) identifies common factors to account for most of the variation in data and was performed by examining the pattern of correlations among independent variables (i.e. questionnaire statements) (Field, 2009). The PCA was carried out on standardized variables. PCA allows us to empirically confirm the hypothesised TPB beliefs. For Instance:

$$PC_1 = \alpha_{11}\chi_1 + \alpha_{12}\chi_2 + \cdots + \alpha_{1I}\chi_I = \sum_{i=1}^{I} \alpha_{1i}\chi_i,$$

$$\vdots$$

$$PC_J = \alpha_{J1}\chi_1 + \alpha_{J2}\chi_2 + \cdots + \alpha_{JI}\chi_I = \sum_{i=1}^{I} \alpha_{Ji}\chi_i, \qquad (2)$$

α_{ji} represents the weight calculated for each belief χ_i across the $j = 1\ldots J$ potential principal component (PC) (Eq. (2)). PCA determines the eigenvector α that maximises the variance λ given the constraint that $\sum_{i=1}^{I} \alpha_{ji}^2 = 1$. Thereafter, it attains a second linear function PC_2 that is uncorrelated with PC_1. The process is continued so that at the mth stage, with $m \leq J$, a linear function of PC_m is found that has a maximum variance and is uncorrelated with other linear combinations. The attained variables are the principal components.

A PCA with varimax rotation was carried out to reduce the number of psychological variables to their underlying dimensions (Field, 2009). The 'grouped' variables or factors obtained from PCA were interpreted within the TPB. The Kaiser-Meyer-Olkin measure of sampling adequacy was found to be > 0.6 (0.808), thereby verifying that the dataset was appropriate for PCA. Subsequently, the Bartlett's test of sphericity was seen to be significant ($p < 0.05$), thus indicating that PCA could proceed (Pallant, 2010). Replacing the initial beliefs (A, SN, PBC) with the empirically identified principal components Eq. (1) becomes:

$$BI = \beta_1 PC_1 + \beta_2 PC_2 + \beta_3 PC_3 \ldots \beta_m PC_m. + \varepsilon \qquad (3)$$

2.2.2. *Cluster analysis*

Cluster analysis helps to account for heterogeneity within the sample. The components extracted from the PCA were subsequently used as classification criteria to cluster respondents into types (Bidogeza et al., 2009; Voss et al., 2009; Barnes and Toma 2012; Morgan-Davies et al., 2012; Nainggolan et al., 2012). These groupings are internally homogenous, while being externally heterogeneous from one another (Janssens et al., 2008). Hierarchical cluster analysis was used to identify the optimal number of clusters based on Ward's method, which optimizes minimum variance within clusters (Mooi and Sarstedt, 2011). This method works by merging groups or cases resulting in the minimum increase in the within-group sum of squares. An elbow test verified the ideal number of clusters for the successive k- means clustering method (Mooi and Sarstedt, 2011).

The K-means method minimizes the distances within each cluster to the center of that cluster and was carried out following hierarchical cluster analysis. K-means methods are superior to the hierarchical methods when the choice is made for an initial configuration based on the results of hierarchical clustering (Janssens et al., 2008). Subsequently, respondents were grouped into their respective clusters. The types were labelled according to evident differences in their respective construct scores.

2.2.3. *Examining the heterogeneity of TBP beliefs across clusters*

PCA regression was used to identify the effects of the TPB components on framers' intention to use a paddock based grazing system. PCA regression involves using the principal components attained through PCA as independent variables instead of adopting the original variables (Aguilera et al., 2006). Intention was measured using a five-point Likert scale. Hence, ordinal logistic regression was applied with BI as the dependent variable and the identified principal components as in- dependent variables. From this, estimate coefficients (β) were obtained. The integrated logistic-PCA regression model was applied to each cluster obtained from the previous cluster analysis. The central limit theorem, a tendency for asymmetric distribution of psychometric measures, and the robustness of multivariate regression to non-normality minimized any concerns about non-normality with sample sizes of $n \geq 30$ (Tipton, 2014).

PCA was initially employed to empirically confirm the TPB constructs and to avoid collinearity in regression analysis (Aguilera et al., 2006). PCA is limited in that important variables may reside in low Eigen value components or may have opposite signed influences which cancel over components. However, information attained from PCA and the ordinal logistic regressions can be used to identify the different effects of beliefs on intention. This method provides more detailed in- formation than obtained from regression analysis (Läpple and Kelley, 2013; van Rensburg et al., 2015). Therefore, two importance measures were constructed; namely, net importance (I) and absolute importance (Ĩ) of each respective PCA component. To obtain information about the importance of underlying predictor variables, we combine the regression parameters β with the factor loadings α (Läpple and Kelley, 2013; van Rensburg et al., 2015). This allows the calculation of the effect of heterogeneous beliefs on intention by inserting the linear combination of the principal components into Eq. (3):

$$BI = \beta_1 \sum_{i=1}^{I} \alpha_{1i} \chi_i{}^* + \beta_2 \sum_{i=1}^{I} \alpha_{2i} \chi_i{}^* + \beta_3 \sum_{i=1}^{I} \alpha_{3i} \chi_i{}^* , \beta_m \; ... \sum_{i=1}^{I} \alpha_{mi} \chi_1{}^* , + \varepsilon \tag{4}$$

The technique combines the estimated parameters β and component weights α and then sums the product of these parameters for each underlying predictor in χ, and across the components observed to be statistically significant. The relative/net importance of a belief χ_i^* can be calculated using the following equation which is based on the linear combination of the J principal components and the calculated weights for each χ_i^*:

$$\Upsilon_1 = \beta_1 . [\alpha_{11}] + \beta_2 . [\alpha_{21}] + \beta_3 . [\alpha_{31}] + ... + \beta_m . [\alpha_{m1}]$$
$$\Upsilon_I = \beta_1 . [\alpha_{1I}] + \beta_2 . [\alpha_{2I}] + \beta_3 . [\alpha_{3I}] + ... + \beta_m . [\alpha_{mI}] \tag{5}$$

It should be noted that only significant estimated regression estimates are used for calculation. The vector Υ_i represents the effect the effect of χ_i^*. The regression estimate coefficients are depicted by β, where α signifies the individual PCA weights (eigenvectors). The absolute importance is calculated using the following equation:

$$|\bar{\Upsilon}_1| = |\beta_1| . [|\alpha_{11}|] + |\beta_2| . [|\alpha_{21}|] + |\beta_3| . [|\alpha_{31}|] + ... + |\beta_m| . [|\alpha_{m1}|]$$
$$|\bar{\Upsilon}_I| = |\beta_1| . [|\alpha_{1I}|] + |\beta_2| . [|\alpha_{2I}|] + |\beta_3| . [|\alpha_{3I}|] + ... + |\beta_m| . [|\alpha_{mI}|] \tag{6}$$

In order to determine the robustness of results the relative and absolute importance of each belief was assessed. Differences between the relative and absolute importance of a belief indicated that predictor effects may cancel out when summing across components. Thereby, indicating that the relative measure in Eq. (5) may underestimate the importance of a predictor. Ordered regression models are commonly used models for ordinal outcomes, such as intention in this case, in the social sciences. However, ordinal models assume proportional odds (i.e. the coefficients describing the relationship between each pair of out- come groups are the same) (Field, 2009). The ordered variable ‘intention’ may be dichotomised (agree and other) and a binominal logistic regression models fitted if the proportional-odds assumption for an ordinal regression is violated.

2.2.4. *Descriptive statistical analysis*

Statistical analyses were undertaken on each cluster to characterise each identified cluster using means and standard deviations (continuous variables) or frequencies (categorical variables) for variables of central concern from the entire survey. Cluster comparison and validation was carried out by a one-way-analysis-of-variance and Bonferroni multiple comparison tests; the tests verified significant differences present between groups with regard to their perception of the four PCA components. Furthermore, Pearson's Chi-Squared test (X^2) was used to determine whether groupings differed significantly in the frequency in which they answered questions not included in PCA analysis ($p < 0.05$). A significant result between categorical variables was further examined by converting the adjusted residuals (Z-scores) to Chi-square values and testing those against a Chi-square distribution (Bonferroni corrected p-value) (MacDonald and Gardner, 2000; Sharpe, 2015).

3. **Results:**

3.1. *Principal component analysis and cluster analysis*

The Kaiser-Meyer-Olkin measure of sampling accuracy was 0.729, indicating that PCA was appropriate **(**> 0.500). Moreover, Bartlett's test of sphericity was significant ($p \leq 0.001$) and, therefore it could be concluded that the strength of the relationship among the variables was high. Interpretation of the scree plot revealed inflexions that justified retaining four components (Pallant, 2010). The acquired factor loadings observed in Table 1 from PCA are the correlations among all individuals' answers to each of the questionnaire statements with the derived component score. A statement was retained if the loading factor was at least 0.35 (Janssens et al., 2008), and the difference between cross loadings > 0.30 (Wang and Ahmed, 2009). The content of a component was best interpreted by examining items with factor loadings of 0.4 or above, such factors are considered to be ‘fair’ (Costello and Osborne, 2011).

Four belief components were identified from the analysis and named: Attitude Resource Constraint, Knowledge/Understanding, and Subjective Norm. Both Knowledge/Understanding and Resource Constraint can be described as differential components of Perceived Behavioural Control and reflect farmers' perceptions of factors that constrain their ability to put paddock grazing into effect. It is normally suggested that such differential components are subsumed to the global component as they can be highly correlated (Ajzen, 1991).

The PCA scores were used for the Ward's hierarchical clustering (Mooi and Sarstedt, 2011). The selection of a final cluster solution re- quires substantial researcher judgement (Hair et al., 1998). The application of the hierarchical cluster analysis suggested the presence of three clusters from interpretation of the dendrogram (Köbrich et al., 2003).

3.2. *Cluster characteristics*

The final cluster centres were computed as the mean for each PC variable within each final cluster derived from the k-means cluster analysis. All the clustering variables' means differ significantly across all the clusters. Hence, the final cluster centres interpret what is typical for a particular cluster. Therefore, the means of all clustering variables were used to interpret and name the segment. Multiple comparisons of cluster means are presented in the supplementary material (Table S1).

The final cluster centres reflect the characteristics of the typical case for each cluster and are illustrated in Fig. 2 (based on Table S2 in the Supplementary material); the clusters themselves will be discussed in more detail in the sections that follows. Tables 2 and 3 illustrate the frequencies, means and standard deviations for categorical

Table 1
Eigenvector weights for each of the 13 original variables according to the principal components (PC).

TPB component	Questionnaire statement	PC1	PC2	PC3	PC4
Attitude	A paddock system can help increase production	0.800			
	A paddock system can help increase overall profits	0.793			
	A paddock system can help ensure enough grass for the season	0.681			
	Would your advisor recommend using a paddock based system	0.573			
	Conditions on-farm (would) allow for the implementation of a paddock system	0.441			
Perceived behavioural control	A paddock system requires additional labour		0.850		
	A paddock system can be time consuming		0.794		
	A paddock system imposes extra costs		0.750		
	I have all the information I need to set up a paddock system			0.868	
	I have a good understanding of how to use a paddock system properly			0.850	
Subjective norm	Would a member of your family recommend using a paddock system				0.757
	Would other farmers recommend using a paddock based system				0.751
	Would your discussion group recommend using a paddock system				

and continuous questionnaire variables, as well as the statistical differences among clusters. All clusters shared some common characteristics.

3.2.1. *Cluster 1: the restricted (n = 75, 19.6%)*

Farmers in The Restricted cluster were characterised by their high sense of resource constraint despite an appreciation that they were knowledgeable on how to implement a paddock based system. This may also explain their low score for the TPB component, Attitude. The cluster had a significantly lower herd size than the other two clusters. There was a significant association between farmers in the cluster and the sub-division of fields, with a low percentage of its members taking part in the management practice. Furthermore, there was a significant association between cluster membership and implementing a paddock based system, with a higher percentage (25.3%) of farmers in the group not having any paddocks. A significantly lower proportion of farmers in this cluster stated that they intended to use paddock based grazing next year.

3.2.2. *Cluster 2: the engaged (n = 213, 55.8%)*

The cluster was characterised by their positive attitude towards a paddock based grazing system. They perceived less resource constraints than the other clusters and scored high in their knowledge of the system. Unlike the other clusters they scored higher in the TPB component Subjective Norm; therefore, they strongly agreed that their peers and family would recommend implementing a paddock system. There was a significant relationship between the cluster and off-farm income, with a lower proportion of its members attaining income from off-farm employment. Herd size was significantly higher than The Restricted, but did not differ significantly from The Partially Engaged. However, the cluster had a significantly lower number of fields com- pared to The Partially Engaged. Members of this group had the highest number of paddocks, significantly higher than observed in The Restricted. There was a significant association between farmers in the cluster and the sub-division of fields, with a high percentage of its members taking part in the management practice. A significant relationship was also observed between recording grass growth and cluster membership; although it was higher than the other clusters it was still low at 6.6%. Moreover, there was a significant association between cluster membership and implementing a paddock based system, with a lower percentage (7.5%) of farmers in the group not having any paddocks. A significantly higher proportion of farmers in this cluster stated their intention to use paddock based grazing next year.

3.2.3. *Cluster 3: the partially engaged (n = 88, 23.0%)*

Members of this cluster did not perceive a lack of resources to be problematic in implementing a paddock based grazing system. However, the cluster was characterised by their low perceived sense of possessing knowledge and understanding of paddock grazing systems. They differed significantly in their attitude to a paddock based grazing system when compared to the other clusters, with members scoring lower in their attitude towards the management regime than The Engaged, but higher than The Restricted. There was no significant relationship

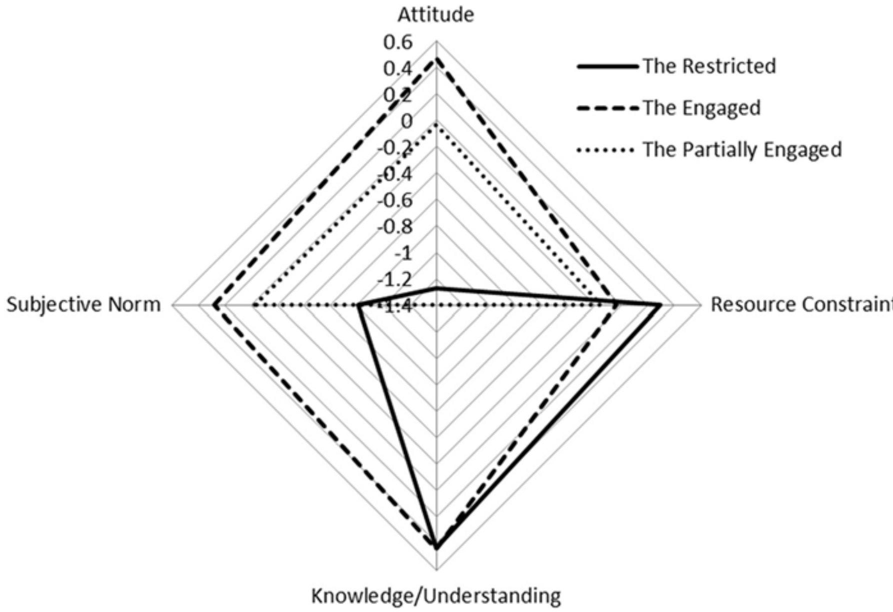

Fig. 2. Final cluster centres of the four principal components (PC), as derived from the k-means cluster analysis for the classification of the 382 beef farmers. Figure based on Table S2 in Supplementary material.

Table 2
Socio-demographic, land, grazing management, and knowledge acquisition profiles of the three farmer clusters.

Characteristics	The restricted	The engaged	The partially engaged
Gender (%)			
Male	89.3	93.4	92.0
Female	10.7	6.6	8.0
Age			
<40	9.3	11.7	10.2
40–54	29.3	31.5	36.4
55–69	41.3	46.8	37.5
70+	20.0	16.0	15.9
Education (%)			
Primary	22.7	19.2	17.0
Secondary	53.3	59.2	53.4
Third level	24.0	21.6	29.5
Agricultural degree	37.3	39.9	42.0
Income (%)			
Off-farm income	86.7	77.0*	90.9
<20 units	42.7	35.7	34.1
20–40 units	33.3	30.5	34.1
40–60 units	22.7	12.7	14.8
60–80 units	0.0	8.5	9.1
>80 units	1.3	12.7	8.0
Land (%)			
Poorly drained	21.3	11.7	12.5
Land fragmentation	61.3	62.9	58.0
Grazing management (%)			
No paddocks	25.3*	7.5*	12.5
Fields sub-divided	36.0*	73.2*	58.0
Fields equal sized	49.3	60.1	47.7
Perfect paddock system			
Grazing groups			
Days grazing paddock (2–5 days)	14.5	24.9	22.7
Recovery weeks (2–3 weeks)	39.6	57.7	46.8
Record grass growth	1.3	6.6*	0.0
Knowledge acquisition (%)			
Discussion groups	10.7	23.0	12.5
Private advisor	5.3	6.6	12.5
Intention (%)			
Intention to use paddock grazing	34.7	85.9	70.5

*Significant ($p < 0.05$) between each cluster variables and clusters after Bonferroni correction.

Table 3
Mean farm characteristics across each of the farmer clusters.

	The restricted		The engaged		The partially engaged	
	Mean	SD	Mean	SD	Mean	SD
Size of farm (ha)	26.0	22.3	27.9	20.9	30.0	18.7
Size of herd (total)	28.0[a]	27.7	45.2[b]	42.6	40.0[ab]	38.4
Number of blocks	2.4	1.7	2.5	1.9	2.8	2.8
Number of fields	10.2[ab]	6.6	10.6[a]	6.2	12.7[b]	7.9
Number of individual Paddocks	6.6[a]	6.6	9.4[b]	7.6	8.0[ab]	5.6
Number of grazing groups	2.0	1.3	2.4	1.5	2.2	1.5
Intention to use paddock grazing (%)	34.7[a]	0.9	85.9[b]	0.6	70.5[c]	0.8

[abc] indicates significant differences ($p < 0.05$) between each cluster after appropriate post-hoc tests.
SD represents standard deviation.

Table 4
Results of ordered logistic models for the PCA beliefs for each cluster.

	The restricted		The engaged		The partially Engaged	
	β	P value	β	P value	β	P value
Attitude	0.592	0.061	1.006	0.022	1.077	0.005
Resource Constraints	−0.621	0.023	−0.63	0.008	−1.171	0.001
Knowledge/ Understanding	−0.054	0.877	0.936	0.029	1.359	0.004
Subjective norm	0.393	0.118	−0.487	0.193	−0.987	0.141
Nagelkerke R^2	0.152		0.174		0.432	

between the cluster and any of the socioeconomic, land type, grazing management, or knowledge acquisition variables assessed in this study. Farmers in the cluster have significantly more fields in comparison to The Engaged, but did not differ significantly from other clusters in regard to the number of individual paddocks they incorporated.

3.3. *Effects of individual beliefs on intention*

Information from PCA and regression estimates was used to identify the different effects of beliefs on intention. As both Knowledge/ Understanding and Resource Constraint formed different components in the PCA it was deemed applicable to access them separately in the TPB model. The influence of the four principal components on intention to adopt a paddock based grazing system was subsequently assessed separately for each of the three clusters. The proportion odds assumption was violated for each respective clusters regression model so a binominal regression was subsequently fitted. For a binominal logistic regression a linear relationship is required between any continuous independent variables and the logit transformation of the dependent variable. The Box-Tidwell method was used to test the assumption of linearity in the logit which involved adding a term of the form (X)ln(X) to the equation. If the coefficient for these variables were statistically significant, there was evidence of nonlinearity in the relationship be- tween logit(Y) and X. Nonlinearity was subsequently observed between 'Subjective Norm' and the logit transformation of intention for cluster 3. Therefore, for The Partially Engaged a categorical variable for Subjective Norm was used based on its median. Table 4 shows the results of the binominal logistic regression analyses.

It was observed that for The Restricted both Attitude and Resource Constraints were significantly related to intention. Conversely, there was no significant association between the principal components knowledge and understanding and Subjective Norm with intention. With the exception of Subjective Norm there was a significant relationship between all other principal components and intention for The Engaged. It was observed that with the exception of Subjective Norm all other principal components had a significant relationship with intention for The Partially Engaged.

While the estimate coefficients of the binominal logistic regression model provide information about the aggregated effect of beliefs, they do not provide insights into the underlying beliefs on intention. The relative and absolute importance of the underlying beliefs was calculated using Eqs. (5) and (6). The effects of the individual beliefs are presented in Table 5. Absolute intention should exceed or equal relative importance for a predictor. If the relative score is smaller, this indicates that a variable's influence is having positive and negative impacts across multiple principal components that cancel when summing to recover its score. Thereby, indicating that the relative score is under- estimating the true importance of a variable. When both relative and absolute scores are equal it denotes the variable has the same signed influence across all principal components (van Rensburg et al., 2015).

The PCA results from Table 5 are able to provide more detailed insights into the impact of underlying beliefs. By focusing on the relative and absolute values of the three clusters it was possible to observe each individual beliefs effect on intention. Performing a robustness check by comparing the relative and absolute importance within each cluster provided insight to the extent to which underlying beliefs may cancel each other during summation across multiple principal components.

The Restricted was marginally influenced by attitudinal beliefs a such as 'Conditions on-farm (would) allow for the implementation of a paddock system' and 'A paddock system can help ensure enough grass for the season' in which each had an absolute value of 0.17 and 0.07 respectively. However, the beliefs that make up Resource Constraints emerged as limiting factors for The Restricted as they had high negative values (i.e. a relative value of −0.53 for the statement 'A paddock system requires additional labour'). The robustness check suggested that the product of the PCA weight and regression parameter for all Resource Constraints beliefs were underestimated for The Restricted. Hence, such beliefs transpired as being of most importance to The Restricted. The Subjective Norm belief that other farmers would re- commend paddock based grazing and the beliefs that they had all the information required to carry on the practice were lowest in terms of their absolute importance.

Table 5
The relative and absolute importance (robust check) of individual beliefs on intention for each cluster.

	Robust checks					
	The restricted		The engaged		The partially engaged	
	Relative	Absolute	Relative	Absolute	Relative	Absolute
Attitude						
A paddock system can help increase production	−0.01	0.01	0.83	0.84	0.89	0.92
A paddock system can help increase overall profits	0.06	0.06	0.83	0.90	0.93	1.02
A paddock system can help ensure enough grass for the season	0.07	0.07	0.92	0.92	1.11	1.11
Would your advisor recommend using a paddock system	0.01	0.01	0.66	0.66	0.75	0.75
Conditions on-farm (would) allow for the implementation of a paddock system	0.17	0.17	0.85	0.85	1.14	1.14
Resource constraints						
A paddock system requires additional labour	−0.53	0.53	−0.57	0.58	−1.03	1.04
A paddock system requires can be time consuming	−0.49	0.49	−0.59	0.69	−1.01	1.16
A paddock system imposes extra costs	−0.47	0.47	−0.71	0.71	−1.18	1.18
Knowledge/understanding						
I have all the information I need to set up a paddock system	0.00	0.00	0.93	0.93	1.30	1.31
I have a good understanding of how to use a paddock system properly	0.04	0.04	0.97	0.97	1.37	1.37
Subjective norm						
Would a member of your family recommend using a paddock system	0.02	0.02	0.21	0.21	0.28	0.28
Would other farmers recommend using a paddock system	0.00	0.00	0.19	0.33	0.18	0.39

The knowledge related beliefs good understanding and information emerged as most important for The Engaged farmers in in regard to both relative and absolute importance (i.e. an absolute value of 0.97 for the statement 'I have a good understanding of how to use a paddock system properly'). Attitude beliefs such as paddock based grazing would provide enough grass, increase profit and increase production followed thereafter. Resource Constraints were deemed to be of least relative importance (i.e.an absolute value of 0.58 for the statement 'A paddock system requires additional labour'). However, the robust check suggests that the importance of these beliefs may be slightly underestimated and that Subjective Norm beliefs were of lower standing.

For The Partially Engaged, intention was found to be affected most strongly by a good understanding of the concept along with attitudinal beliefs. Most belief values of high influence were quite similar with regards to relative and absolute importance. However, the negative effect of the beliefs that made up resource constrains observed for relative importance was underestimated. Indeed, The Partially Engaged denoted costs and time as influential factors in the adoption of paddock based grazing (i.e. absolute values of 1.18 and 1.16 respectively). Much like the other clusters, Subjective Norm beliefs were elicited as being of lowest importance in term of intention with other farmers and family recommendations least influential.

4. Discussion

The study was innovative as it involved using psychological constructs to evaluate why beef farmers in Ireland poorly implement paddock based grazing. While many social studies in developed countries tend to concentrate on farmer update of newer technologies, it is not as prevalent to concentrate on the uptake of well-established technologies – in this case paddock grazing. The methods used in this study are interesting as the research combines the TPB with both PCA and cluster analysis to categorise farmers into different groups based on belief constructs. Furthermore, regression analysis and robust tests were used to reveal how such beliefs relate to farmers' intention to adopt a paddock based grazing system.

Three clusters of farmers were elicited from the analyses based on Irish beef farmers' beliefs of paddock based grazing systems: The Restricted, The Engaged, and The Partially Engaged. The three groups did not differ in most of their socio-economic characteristics. The Restricted was characterised by their high sense of resource constraint despite a conviction they were knowledgeable on how to implementing a paddock based grazing system. The Engaged was the largest cluster and defined by their positive attitude towards paddock based grazing. The cluster deemed resource constraints to be less of an issue than the other clusters and scored high in their knowledge of the grazing practice. This is of particular relevance as paddock grazing can be set up initially with very little resources and represents a knowledge gap. Members of The Partially Engaged did not perceive a lack of resources to be problematic; however, the cluster was characterised by their low level of knowledge of paddock grazing.

Variance in adoption rates of a technology may be explained by its relative advantage (e.g. economy and status), its compatibility (e.g. values, norms and practices), and its complexity (difficulty in under- standing and usage) (Rogers, 1995). This study disaggregated the broad categories of the TPB measures by combining information from PCA and ordered logistic regression analysis. By accounting for individual belief heterogeneity it was possible to access the importance of all beliefs in terms of their influence on intention to adopt a paddock based grazing system. The R^2 obtained for The Restricted and The Engaged regression models were 0.152 and 0.174 respectively which could be classified as relatively low. However, relatively low R^2 values are typical in logistic regression models (Ash and Shwartz, 1999), and they should not be compared to the R^2 values of linear regression (Hosmer and Lemeshow, 2000). The results reveal that attitude beliefs are among those with the highest impact with regard to adoption of paddock based grazing, which is consistent with the regression results. Other beliefs show a lower effect on intention, which implies that farmer perceptions of Resource Constraints, Knowledge/Understanding, and Subjective Norms are less influential.

Creighton et al. (2011) demonstrated that best grassland management practices do not appeal to some Irish farmers due to the requirement for new skills development, attention to detail and long-term commitment. The beef sector is particularly impervious to technological innovation when compared to other sectors of Irish agriculture as a result of lower farm incomes (Läpple et al., 2015). Weber (1997) proposed a 'finite pool of worry', which implies that individuals have a limited capacity as to how many issues they deem relevant at any one time. Farmers therefore may feel compelled to align management decisions towards actions that may be implemented with ease. Indeed, this limited capacity to prioritise relevant issues could be a limiting factor for adoption in The Restricted. While those in the cluster felt knowledgeable on how to implement the management practice they deemed themselves to be constrained by numerous resources. Läpple et al. (2015) found that off-farm income hinders innovation for Irish farmers which may also contribute towards the low adoption rates of paddock based grazing for The Restricted. The low levels of knowledge depicted by those in The Partially Engaged may explain their low attitudinal score. Tversky & Kahneman (1973) describe 'availability heuristic' as when a decision maker relies upon knowledge that is readily available rather than examine other alternatives or procedures. Readjusting focus towards paddock based grazing management practices may be therefore condemned as superfluous by farmers in The Partially Engaged.

An established method of conceptualising change at farm level is Roger's diffusion of innovations approach. Rogers (1995) designated a set of five stages by which innovations are adopted: knowledge, persuasion, decision, implementation, and confirmation. An individual is exposed to the innovation during the initial stage of adoption, but is not motivated to learn more about it; thereafter, the individual becomes interested and actively seeks out information; in the third stage an adoption decision is made; in the fourth stage the innovation is implemented (to varying degrees) and finally the decision is made to fully implement the innovation. However, Wilson (2008) argues that transition at farm level is a complex non-linear process that is consequently somewhat unpredictable. Wilson outlines the importance of resource capacities and priorities held by farmers, and the varying levels of constraint positioned on farmers with regards to their ability to adopt new innovations. This may in some way explain the differences observed in this study in terms of intention to adopt, and adoption, of paddock based grazing; most notably in The Restricted cluster.

Adopters of best management practices generally have been exposed to greater information and have greater resources to devote to the operation (Gillespie et al., 2007). Of particular relevance is the importance of attitudinal beliefs on intention across all three clusters. Garforth et al. (2004) observed that attitude towards a technology had a strong influence on farmers' intention to adopt. Similarly to the findings of this study, both Martínez-García et al. (2013) and Borges et al. (2014) established that attitude had a significant influence on the intention of farmers to use improved grassland. Prokopy et al. (2008) found the determinants of farmer's adoption of best management practices to include utilisation of social networks and access to in- formation.

Difficulties in engagement with farmers can be overcome by adopting a pragmatic approach to research-oriented towards practical problem-solving activities (Le Gal et al., 2011). The careful design of extension efforts addressing paddock based grazing could consequently assist in overcoming some of the barriers identified for adoption. McDonald et al. (2016) suggests that increased education and training can contribute to an increase in the rate of grassland management technology adoption on Irish farms while O'Donoghue and Heanue (2016) confirm that Irish farmers with formal agricultural education have higher rates of adoption of grassland management practices. Various epistemologies influence the mobilization and transformation of knowledge. The traditional knowledge-transfer approach however has been criticised as it fails to adequately address heterogeneity within the farming community (Klerkx et al., 2012), and may explain the variance in awareness and risk perception among the types in this study.

The limitations of the traditional paradigm led to the formation of non-didactic 'human development' approaches, which are based on participation and empowerment (Black, 2000; Fleming and Vanclay, 2010). Innovation creation involves the input of various actors (Knickel et al., 2009); this may include farmers, farm advisors, etc. (Klerkx et al., 2012). Lankester (2013) demonstrated how organised collective group learning is an effective method of fostering behaviour among Australian beef farmers. Participatory methods of knowledge creation are particularly important in this context as they can empower actors to find relevant solutions to challenges they face. Farmers consequently gain ownership of a problem and are therefore more likely to adopt solutions.

Social learning bases its philosophy on participation and integrating knowledge from different perspectives and involves critical thinking, interactions, dialogue, and questioning assumptions that underline individual concepts (Leeuwis et al., 2002). Such an approach could allow individual farmers to discuss their perceptions of grassland management with each other and experts. Participatory methods would therefore provide a platform to increase awareness and to deliberate the adoption of a best management technique. Participatory methods are particularly beneficial as they can accelerate the innovation process (Chevalier and Buckles, 2013). The method would have to involve many actors who share information and subsequently drive success and innovation in the knowledge transfer process (Chevalier and Buckles, 2013). Therefore, knowledge transfer processes are enhanced by farmers' practical knowledge of key problems and ideas of how to solve them.

The Partially Engaged was lacking in their knowledge of paddock grazing; therefore, it is reasonable to assume that effective participatory approaches could encourage adoption. Social learning can also ease unfounded risk perceptions that farmers such as The Restricted may hold (Langford, 2002; Maiteny, 2002). However, Läpple et al. (2015) also suggests the creation of centres of excellence which focus on particular aspects of farming and provision of professional development courses which could strengthen the links between research, education, extension and farmers. There is still therefore a need for access to re- liable scientific information, just as there is a need to promote communication within a social system (Black, 2000). Furthermore, information sources that are trusted by farmers should be used, irrespective of the model used (Reed et al., 2014).

5. Conclusions

The importance of measuring and assessing agricultural best management practices is increasingly recognized in light of recent reports which focus on fostering productively within the Irish beef sector (e.g. Food Harvest 2020, and Food Wise 2050). Increased grass utilisation in Irish beef farming has been outlined as one method of increasing productivity within the sector. The results suggest that there are three cohorts of cattle farmers with regards to implementation of a paddock based grazing system; with one group particularly unlikely to uptake the grazing practice. The findings are relevant to policy as they provide insights of the factors influencing farmer decision making. This in- formation can subsequently be used for better knowledge-transfer through appropriate channels which can help build potential drivers for behavioural change. Although the human development model is seen as an improvement on the knowledge-transfer approach, no single model is likely to be sufficient by itself for effective knowledge exchange and/ or knowledge transfer. Therefore, both linear and social approaches to knowledge transfer should be encouraged. The fact that no one paradigm suits all further illustrates the importance of recognising the heterogeneity within the farming sector. Hence, carefully planned communication, targeted at the different farmer types, can help encourage a positive change in farm management practices that promote paddock based grazing.

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Conflict of interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https:// doi.org/10.1016/j.agsy.2018.01.023.

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