

# Farmers' perceptions of climate change: identifying types

John J. Hyland<sup>1</sup> · Davey L. Jones<sup>1</sup> · Karen A. Parkhill<sup>2</sup> · Andrew P. Barnes<sup>3</sup> ·  
A. Prysor Williams<sup>1</sup>

Accepted: 30 March 2015 / Published online: 13 May 2015  
© Springer Science+Business Media Dordrecht 2015

**Abstract** Ambitious targets to reduce greenhouse gas (GHG) emissions from agriculture have been set by both national governments and their respective livestock sectors. We hypothesize that farmer self-identity influences their assessment of climate change and their willingness to implement measures which address the issue. Perceptions of climate change were determined from 286 beef/sheep farmers and evaluated using principal component analysis (PCA). The analysis elicits two components which evaluate identity (productivism and environmental responsibility), and two components which evaluate behavioral capacity to adopt mitigation and adaptation measures (awareness and risk perception). Subsequent Cluster Analyses reveal four farmer types based on the PCA scores. 'The Productivist'

and 'The Countryside Steward' portray low levels of awareness of climate change, but differ in their motivation to adopt pro-environmental behavior. Conversely, both 'The Environmentalist' and 'The Dejected' score higher in their awareness of the issue. In addition, 'The Dejected' holds a high sense of perceived risk; however, their awareness is not conflated with an explicit understanding of agricultural GHG sources. With the exception of 'The Environmentalist', there is an evident disconnect between perceptions of agricultural emission sources and their contribution towards GHG emissions amongst all types. If such linkages are not conceptualized, it is unlikely that behavioral capacities will be realized. Effective communication channels which encourage action should target farmers based on the groupings depicted. Therefore, understanding farmer types through the constructs used in this study can facilitate effective and tailored policy development and implementation.

**Electronic supplementary material** The online version of this article (doi:10.1007/s10460-015-9608-9) contains supplementary material, which is available to authorized users.

✉ A. Prysor Williams  
prysor.williams@bangor.ac.uk

John J. Hyland  
johnhyland85@gmail.com

Davey L. Jones  
d.jones@bangor.ac.uk

Karen A. Parkhill  
karen.parkhill@york.ac.uk

Andrew P. Barnes  
andrew.barnes@sruc.ac.uk

**Keywords** Environmental impact · Farmer engagement · Livestock · Red meat · Sustainable intensification

## Abbreviations

A	Awareness
ER	Environmental responsibility
GHG	Greenhouse gas
P	Productivism
PCA	Principal component analysis
PR	Perceived risk

## Introduction

Approximately 14.5 % of anthropogenic global greenhouse gas (GHG) emissions can be attributed to livestock production (Gerber et al. 2013). Per kg of produce, red meat

<sup>1</sup> School of Environment, Natural Resources and Geography, Bangor University, Gwynedd LL57 2UW, UK

<sup>2</sup> Department of Environment, University of York, Heslington, York YO10 5DD, UK

<sup>3</sup> Land Economy Research Group, SRUC, Edinburgh EH9 3JG, UK

such as beef and lamb, has a higher carbon footprint in comparison to cultivated crops and alternative protein foodstuffs (Lesschen et al. 2011). For industry to reduce emissions, it is important to understand how farmers perceive climate change and their willingness to alter current management regimes. The aim of this study is to establish the different types of beef/sheep farmers, based on their sense of self-identity and their perceptions of climate change. Such information can serve to improve future policy by enabling the targeted transfer of climate change information.

In a pioneering study, Gasson (1973) suggested that farmer behavior is driven by profit maximization. Subsequent research proposes that basing farmer behavioral types on the assumption of a simple profit-maximizing behavior is inappropriate (Vanclay 2004; Pannell et al. 2006). Other reevaluations of behavior have unveiled that farmers do not act in ways that are strictly governed by economic principles. Therefore, participation in environmental initiatives is determined by more than just financial incentives (Vanclay and Lawrence 1994; Lockie et al. 1995; Edwards-Jones 2006). It is therefore necessary to better understand what underpins farmer's participation in environmental initiatives when developing effective policies and extension programs (Vanclay et al. 2006; Pannell et al. 2006).

Farmers often ascribe different levels of importance to environmental and production aspects of farm management (Vanclay and Lawrence 1994; Vanclay et al. 1998). However, extension strategies and practices have traditionally ignored farmer diversity, presuming that adoption programs are universally applicable, and thus universally adopted (Vanclay and Lawrence 1994). Different epistemologies influence the mobilization and transformation of knowledge. The limitations of the traditional paradigm of knowledge transfer led to the formation of non-didactic 'human development' approaches, which are based on social learning, participation, and empowerment (Black 2000; Fleming and Vanclay 2010). Categorizing farmers into groups has been proposed as a means of effectively capturing this diversity (Valbuena et al. 2008). Whilst perception-based farmer types are regarded by some to have limited salience—a criticism being farmers do not identify themselves within pre-defined groups (Vanclay et al. 2006)—they have gained prominence as a basis to effectively capture heterogeneity, and to effectively target farmers for the voluntary uptake of environmental initiatives (Bidogeza et al. 2009; Voss et al. 2009; Barnes and Toma 2012; Morgan-Davies et al. 2011; Nainggolan et al. 2012).

Few studies use typologies to characterize the perceptions of climate change from livestock farmers of temperate regions. Eggers et al. (2014) found that North German

grassland farmers could be grouped into four types based on their perceptions of the issue. The research, which focuses on adaptation measures on ley and permanent grassland, postulates that farmers consider adaptation on economic factors or emotional reasoning. Elsewhere, Barnes and Toma (2012) depict six distinct types of Scottish dairy farmers from perceptions of climate change and planning goals. Half of the farmer types in the study believed that climate change would impact them negatively in the future; signaling the likely adoption of technologies to combat such scenarios. Conversely, other groupings did not perceive climate change as a significant enough threat to change their future management planning. Whereas these studies have focused on farmer types in other sectors, or on one aspect of adaptation or mitigation (Eggers et al. 2014; Bruce 2013), there is a specific need to investigate beef and sheep farmers' perceptions of climate change in temperate regions. Such analyses are important in light of the considerable attention bestowed on the red meat sectors' contribution towards climate change; therein, assisting the industry's aspirations in reducing emissions.

Farmers' perceptions of climate change differ—conceptual, practical, and information barriers all act as limitations to pro-environmental behavior (Fleming and Vanclay 2010). As such, understanding farmers' self-identity, their awareness of an environmental issue and perceptions of its risk, are essential in tailoring initiatives aimed at providing improvements in the environmental performance of agriculture (Greiner et al. 2009; Yazdanpanah et al. 2014). These constructs may influence the likelihood of farmers' voluntary uptake of climate change measures, and their participation in programs that focus on reducing the sector's GHG emissions. Research proposes a gap between awareness and pro-environmental behavior. Reasons for such disconnect can vary when considering climate change, and may be caused by the complexity of a problem that is global in character (Kollmuss and Agyeman 2002). However, the level and type of knowledge can lessen the gap between awareness and mitigation behavior (O'Connor et al. 2002). Moreover, the appraisal of risks climate change may bring is a significant factor in influencing adaptive responses (Arbuckle et al. 2015; O'Connor et al. 1999). Story and Forsyth's (2008) awareness-appraisal-responsibility model asserts that individuals become increasingly likely to protect and sustain the environment as awareness and responsibility of an environmental issue heighten, and appraisal of its risk become elevated.

We therefore utilize constructs that assess farmers' self-identity and their behavioral capacity to implement measures that address climate change. Two constructs determine self-identity, and are based on productivism and environmental responsibility. Motivation to adopt

environmental behavior is based on internal perceptions of how farming should be practiced (farmer self-identity). The Dual Interest Theory acknowledges that both economic and environmental motivations are represented in varying strengths when individuals make environmental decisions (Sheeder and Lynne 2011). Furthermore, two additional constructs assess awareness and risk perception, and hence the behavioral capacity to implement adaptation and mitigation measures. Behavioral capacity can be defined as the latent potential of behavioral change to affect improvements in the environment (Beretti et al. 2013).

Considering the limited focus on beef/sheep farmers perceptions of climate change in temperate regions, the aims of this study are to: (1) determine such farmers' perceptions of the issue; (2) create a typology of beef/sheep farmers based on these perceptions; (3) assess if self-identity influences the behavioral capacity of farmers to implement measures which address climate change. We hypothesize that farmers who align themselves with an environmental self-identity are conscious of the intricacies of climate change and the risks that it may bring. The opposite is foreseen for farmers who display productivist tendencies. In the following section, we critically engage with the conceptual literature associated with the aforementioned motivational and behavioral capacity constructs which are used to assess the hypotheses outlined above.

## Awareness, self-identity, and perceptions of risk

### Self-identity

Self-identity refers to the extent to which certain behavior is considered part of one's self (Terry et al. 1999). Ascription of one's beliefs may be filtered through an individual's value system (Sulemana and James 2014). The more salient an identity, the greater the probability of it being activated; hence it is possible to predict desired action using self-identity (Burke and Stets 2009).

Pro-environmental and productivist identities are two of the most commonly examined in an agricultural context (Sulemana and James 2014). Although modern-day agriculture has adapted to serve multiple purposes (i.e. the provision of food and ecosystem services), research postulates that a productivist identity dominates the decision-making process of farmers (Burton 2004; Burton and Wilson 2006). Productivism is often legitimized by government policies which stress that increasing output serves the national interest (Burton and Wilson 2006). Indeed, Rosin (2013) demonstrated that despite increasing environmental concerns over intensification, the 2008 global food price spike has further reinforced productivist idealisms within New Zealand farmers.

Environmental programs may be resisted in cases where a productivist self-identity is threatened (van der Werff et al. 2013). Therefore, understanding farmers' sense of identity is important in assessing their motivation in adopting environmental measures and participation in environmental programs (Sulemana and James 2014). Indeed, Indiana farmers who were motivated by environmental responsibility (rather than profitability) were most likely to adopt conservation practices (Reimer et al. 2012). Moreover, Lokhorst et al. (2011) observed that self-identity is significantly related to farmers' intention to perform non-subsidized environmental practices. Hence, self-identity can significantly affect an individuals' motivation to undertake voluntary measures where financial reimbursements, or awards, are not forthcoming.

### Awareness

Awareness of environmental problems is a perceived estimate of reality that individuals formulate from accumulated knowledge (Dietz et al. 2007); this construct can subsequently influence behavioral decisions (McCown 2005), and willingness to adopt solutions (Prokopy et al. 2008). Awareness in the context of this study refers to the degree in which individuals are aware that climate change is happening, and that agriculture is a contributing factor to anthropogenic-induced GHG emissions.

Research proposes a positive correlation between awareness of climate change and the likelihood of implementing mitigation measures (Lorenzoni et al. 2007). Mitigation can be defined as an anthropogenic intervention to reduce sources or enhance the sinks of GHGs (IPCC 2001). Climate change awareness is therefore a relevant facet in predicting pro-environmental behavior (Bord et al. 2000; O'Connor et al. 2002; Prokopy et al. 2008; Semenza et al. 2008). Arbuckle et al. (2013) postulate that mitigation action requires farmer awareness of climate change, at least tacitly, and that human activity is an underlying cause of the issue.

### Perceived risk

While awareness of climate change is a powerful predictor of behavioral intentions, it is independent from the belief that climate change will have negative impacts. Risk perception corresponds to the belief about adverse consequences for valued objects (Leiserowitz 2006; Dietz et al. 2007; Brody et al. 2012; Arbuckle et al. 2015); it is dependent on values and ecological worldviews (Stern et al. 1999). Perceptions of the risks that climate change may bring can therefore influence engagement and the support of policies that address the issue (O'Connor et al. 1999).

In the context of this study, perceived risk is farmers' appraisal of the negative effects of climate change on agriculture. Individuals are more likely to adopt pro-environmental behavior when they understand the adverse impacts of no action (Masud et al. 2013; O'Connor et al. 1999). Participation in adaptation and mitigation initiatives becomes less appealing when climate change is weighed up against risks such as economic instability (Stuart et al. 2014). Subsequently, farmers who perceive climate change in terms of local consequences which may negatively impact their enterprise are more likely to support and participate in initiatives that aim to address the issue (Haden et al. 2012; Arbuckle et al. 2015).

The extent to which farmers succeed in living in accordance to their identity tends to be moderated by constraints such as risk (Pannell et al. 2006). Indeed, a dystopian perception of the adverse effects of climate change has been found to be among the strongest predictors of support for climate change policies (McCown 2005; Dietz et al. 2007). For instance, it has been observed that climate change risk perceptions influence support of adaptive actions amongst US farmers (Arbuckle et al. 2015; Niles et al. 2013). Adaptation can be defined as adjustments in human or natural systems in response to actual or expected climatic stimuli and their effects or impacts (IPCC 2001). Therefore, perceptions of the risks associated with climate change are a necessary precursor for the adoption of adaptation measures (Arbuckle et al. 2013).

## Methods

### Wales: a case study

Little attention has focused specifically on beef/sheep farmers' perceptions of climate change in developed temperate regions. Moreover, factors which influence farmers' willingness to adopt initiatives aimed at reducing the sector's GHG emissions have been largely unexplored. This is in spite of livestock production accounting for a particularly high proportion of global GHG emissions (Gerber et al. 2013). To reduce livestock emissions, countries have adopted numerous approaches at the farm level, many of which are voluntary (Cooper et al. 2013).

Wales presents characteristics that are applicable to various nations that aim to alleviate emissions from pastoral-based systems; indeed, beef and sheep enterprises represent the overwhelming majority of farm holdings nationally. The topography of the country varies considerably, encapsulating an array of challenges and environments faced globally by beef/sheep farmers of temperate regions. Wales aspires to reduce its total emissions by annual increments of 3 % from 2011 onwards (Welsh Government

2009); the livestock industry has also initiated a strategic plan outlining how the sector plans to meet such targets (HCC 2011). A better understanding of farmer perceptions of climate change will help identify whether these targets are achievable, and the barriers to change. Like many countries, Wales largely relies on farmers' voluntary uptake of adaptation and mitigation measures. Uptake has been incentivized through initiatives such as efficiency grants offered by government (Welsh Government 2014).

### Questionnaire design and distribution

The development of a pilot questionnaire resulted from a review of relevant literature on farmers' perceptions of climate change (Widcorp 2009; Farming Futures 2011; Barnes and Toma 2012; Hall and Wreford 2012). This was then trialed with 30 livestock farmers, and minor amendments (e.g. to the wording of some questions) were implemented thereafter. The final administered ( $n = 286$ ) bilingual survey (English/Welsh) consisted of three sections (see Supplementary material). Section one elicited socio-demographic information, section two consisted of 29 statements where respondents were asked to express their opinion on a 5-point Likert scale, and the final section captured farmers' general views on climate change sources. Farmers were recruited by convenience sampling throughout Wales during 2012 at union meetings, livestock markets, agricultural extension open days, as well as agricultural shows and events.

### Analyses

Survey results were analyzed statistically in a variety of ways including principal component analysis (PCA) and Cluster Analysis. The first part of the results section presents an overview of all respondents' perceptions of climate change along with issues related to the concept; therein setting the scene for subsequent analyses and discussion. Details of procedures used for PCA and cluster analysis used to assess farmers' motivation and behavioral capacity are outlined in the sections that follow.

### Principal component analysis

Participants' responses to statements in section two of the questionnaire were analyzed using PCA to give a more detailed representation of perceptions of climate change. PCA identifies common factors to account for most of the variation in data and is performed by examining the pattern of correlations among independent variables (i.e. questionnaire statements). When these variables are highly correlated, they are effectively 'saying the same thing' and described as components (Field 2009). The subsequently

acquired factor loadings are merely the correlations among all individuals' answers to each of the questionnaire statements with the derived component score. The components extracted from the PCA are 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. 2011; Nainggolan et al. 2012). These groupings are internally homogenous, while being externally heterogeneous from one another (Janssens et al. 2008).

The Kaiser–Meyer–Olkin measure of sampling adequacy was found to be greater than 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). The factors selected (based on the Kaiser criterion with eigen-values  $\geq 1$ ) explained 55.7 % of the variance.

A Varimax rotation was implemented to increase the interpretability of the results (Field 2009). Considering the sample size, a statement was only retained if the loading factor was at least 0.35 (Janssens et al. 2008) and the difference between the loading, and two other cross-loadings,  $> 0.3$  (Wang and Ahmed 2009). Interpretation of the scree plot revealed inflexions that justified retaining four components; this was supported by parallel analysis (Pallant 2010). 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). Subsequently, the four components were named: awareness (A), environmental responsibility (ER), productivism (P), and perceived risk (PR). Both environmental responsibility and productivism components can be described as identity standards; whereas awareness and risk perception components specifically reflect an individual's behavioral capacity to implement mitigation and adaptation measures (Table 1).

Cronbach's alpha was applied to test the reliability and internal consistency of the derived factor loadings (Pallant 2010). Cronbach alpha's  $> 0.5$  are considered acceptable as evidence of a common factor underlying the responses (Nunnally 1967). The reliability of each factor's Cronbach's alpha was examined through the impact on alpha by the removal of each statement. An alpha value higher than the final value suggested the removed statement was unnecessary (Field 2009). Consequently, question 28 ('I find information on climate change easy to understand') was removed from the analysis.

### Cluster analysis

The factor scores from PCA were subjected to both Ward's hierarchical and K-means clustering methods (Burns and

Burns 2008). The PCA scores were used for the Ward's hierarchical clustering technique as the algorithms require continuous, rather than the categorical Likert scale data collected in the survey. Hair et al. (1998) point out that the selection of the final cluster solution requires substantial researcher judgement. The application of the hierarchical cluster analysis suggested the presence of four clusters from interpretation of the dendrogram (Köbrich et al. 2003). An elbow test verified the ideal number of clusters for the successive k-means clustering method to be  $n = 4$ , which was consistent with the interpretation of the dendrogram (Burns and Burns 2008).

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 perceptions of climate change based on the cluster centers of each grouping. Cluster comparison and validation was carried out by a one-way-analysis-of-variance and Bonerroni 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 ( $\chi^2$ ) was used to determine whether groupings differed significantly in the frequency in which they answered questions not included in PCA analysis ( $p < 0.05$ ).

## Results

### Characteristics and perceptions of respondents

In total, 286 completed surveys were obtained, representing ca. 2.2 % of livestock farmers in Wales (Welsh Government 2012). Table 2 summarizes the general characteristics of the respondents, while Fig. 1 illustrates where farmers obtained information on climate change.

Farmers were uncertain as to what opportunities, if any, that climate change may bring. The main opportunity that climate change may bring was thought to be that of a longer growing season. Unpredictable and extreme weather was ascribed as the greatest risk from climate change on their farms (42.3 %) (Table 3). Whilst there was awareness that anthropogenic climate change is a reality, there was some uncertainty of the contribution of livestock to the problem (Fig. 2). It was interesting to observe how respondents were less hesitant in chastising other industries and activities as being contributors to climate change (Fig. 3).



**Table 1** Factor loadings of attitudinal statement (prior to varimax rotation)

Attitudinal statements	A	ER	P	PR
Livestock farming contributes to climate change	.701			
Climate change will affect Welsh farming in the next 10 years	.669			
I accept that man-made climate change is happening	.633			
Livestock farmers should share responsibility towards the industry's impact on climate change	.612			
Climate change is an important global issue	.612			
It is possible to reduce GHG emissions from my farm without lowering production levels	.461			
Environmental regulations are important for the future of farming	.451			
Others in my family think that I should farm as environmentally friendly as possible		.686		
I want to farm as environmentally friendly as possible		.665		
Switching to a more environmentally friendly farming methods would not require much change from my current operation		.592		
As a farmer I have an obligation to maintain or improve the environment for future generations		.553		
I am interested in trying different technologies and/or systems to reduce my farms' GHG emissions		.534		
The way farming colleagues think about my farm is important to me		.449		
The government should encourage food production in the UK to reduce reliance on imports			.722	
The government should financially support farmers in adapting to climate change			.640	
Other industries pollute more than livestock farmers and should therefore be penalized more			.510	
Any climate change reduction strategies must make economic sense to the individual farmer			.475	
Being seem as primarily as a food producer is important to me			.426	
The best climate change mitigation strategies are too costly to adopt				.639
Climate change poses more of a threat to farming in the next 10 years than that of a general recession				.607
Climate change will lead to lower productivity on my farm due to disease and pests				.579
Uncertainty due to variable weather patterns caused by climate change will negatively influence my ability to farm in the future				.381
Beef or lamb produced with low emissions should be sold at a higher price				.351
<i>Cronbach's alpha</i>	.774	.700	.533	.512

Factor loadings are derived from principal component analysis. The content of a component is best interpreted by examining items with factor loadings of .4 or above

A awareness, ER environmental responsibility, P productivism, PR perceived risk

Farmers were also asked to rank the threat to society from climate change relative to various other pertinent environmental issues. Food security was forecast as being the greatest future threat to society, followed by energy security, water quality, climate change, waste management, and air pollution (Fig. 4).

The responses from all participants suggest an awareness that climate change is happening, but there is an evident disconnect in terms of agriculture's perceived contribution towards the problem. We now create a typology of farmers to assess if the awareness and disconnection outlined above is influenced by farmer self-identity. We also investigate if self-identity impedes farmers' behavioral capacity to implement issues that address climate change.

### A typology of farmers

Through PCA and Cluster Analyses, four types of individual farmers were identified (Table 4). Using the cluster

centers from the most appropriate solution from Ward's method (based on the four PCA components), K-means clustering was applied (Table 4). A radar diagram is constructed from these cluster centers to give a visual representation of the differences between each of the types created with respect to the components elicited from PCA (Fig. 5). Two self-identity components evaluate motivation to act in a pro-environmental manner (environmental responsibility and productivism) while two evaluate behavioral capacity to implement mitigation and adaptation measures (awareness and risk perception). Furthermore, responses to non-statement questions in Sect. 3 of the questionnaire, which are not included in PCA analysis, are assessed based on farmer type and used to further define the four groupings (Table 5). These relate to what/where respondents perceived to be GHG sources. Such analysis deciphers farmer explicit knowledge of agricultural emissions. Where different farmer types obtained information on climate change was also determined (Table 5).

**Table 2** Profile of survey participants

Attribute	Category	Percentage of total respondents <sup>a</sup>
Farmer type	Full-time farmer	68.5
	Part-time farmer	31.1
Gender	Male	90.6
	Female	9.4
Age	18–25	18.1
	26–35	12.2
	36–45	13.3
	46–55	19.9
	56–65	19.2
	>66	17.1
Highest level of education	Primary school	8.7
	GCSE/O-Levels	26.2
	A-Levels/NVQ	18.5
	HNC/HND	19.2
	University undergraduate degree or higher	27.3
Farm size (acres)	<100 (<40.47 ha)	35.3
	101–300 (40.5–121.41 ha)	33.9
	301–500 (121.81–202.3 ha)	14.3
	>501 (>202.75 ha)	16.1
Livestock sector?	Beef only	16.8
	Sheep only	18.5
	Mixed (sheep and cattle)	64.7
Farming experience (years)	0–10	15.7
	11–20	16.1
	21–30	23.8
	>31	44.1

<sup>a</sup> In cases where percentages do not add up to 100 for each attribute, the respective question was not answered on all questionnaires or is due to rounding

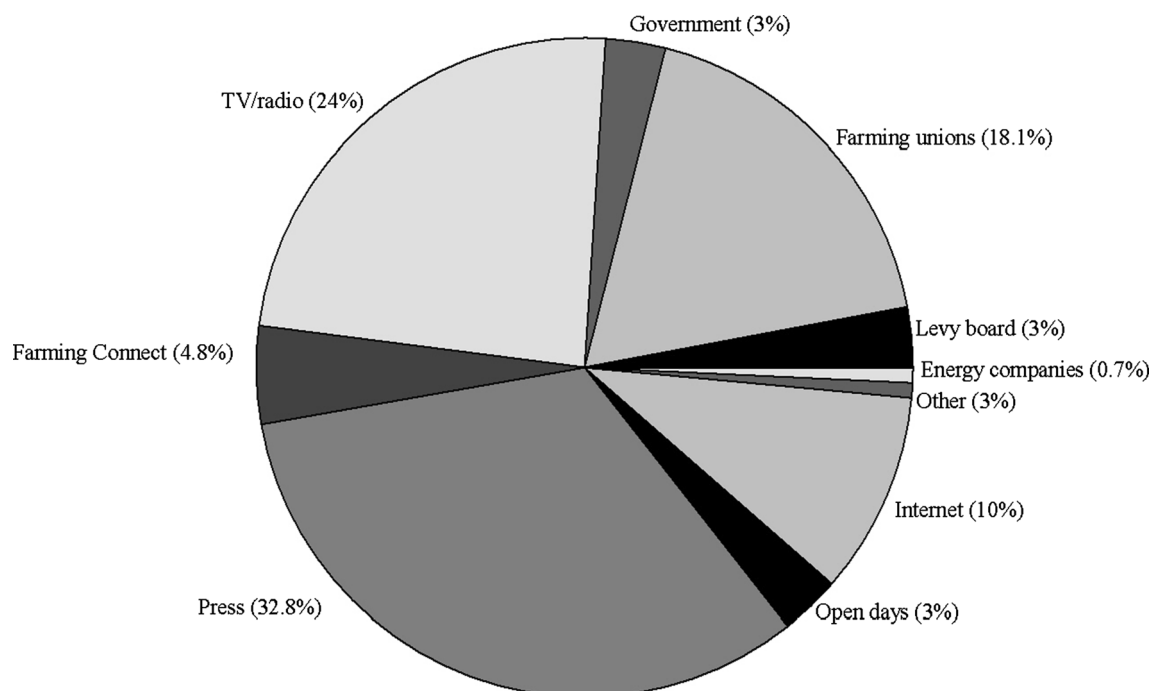
### *The Environmentalist*

The defining feature of The Environmentalist was their high awareness of climate change, while they also encapsulated a high sense of environmental responsibility. Hence, both motivation to act pro-environmentally and behavioral capacity to implement mitigation measures were high. The Environmentalist however had a low perceived sense of the risks which climate change may bring, suggesting a lower likelihood of adopting adaptation measures (Fig. 5). There was a general consensus from farmers in this group that the manufacturing and use of fertilizer, along with methane from ruminants and the management of their manure, contribute towards climate change (Table 5). Compared to the other groupings, a higher percentage of Environmentalists believed methane associated with livestock to be a cause of climate change. Indeed, only 6.7 % ascribed it as not being a contributing factor.

The Environmentalist was the highest educated of the four clusters and 50 % of those sampled had a university degree or higher. A significant characteristic ( $p < 0.01$ ) in defining The Environmentalist from the other groups was the time period they had been involved in farming. Farmers sampled within this type had been farming for between 21 and 30 years, whereas the majority of farmers in the other groups had been farming for over 31 years. Evans et al. (2011) observed that the longer individuals had been farming, the more inclined they were to disagree that science had considered all factors in its estimates of climate change. Essentially, such farmers did not value the findings of scientists and researchers.

### *The Dejected*

Members of this type projected a pessimistic and dejected disposition towards climate change as they expect it to affect them unfavorably. The factor most prevalent in



**Fig. 1** Respondents' main source of information on climate change. Farming Connect is a service financed by the European Agricultural Fund and Welsh Government, offering one-to-one support, knowledge, expertise, training, and advisory services, tailored to farmers' needs

**Table 3** Percent of respondents indicating main opportunities and risks climate change may bring

Main opportunity that climate change may bring	%	Main risk that climate change may bring	%
Don't know	25.6	Unpredictable/extreme weather	42.3
Longer growing season	24.9	Don't know	13.2
No opportunities	10.3	Increased taxes/regulations	9.6
Generating energy	8.9	Increased costs	8.9
Better prices for produce	8.9	Crop failure/reduced yields	6.8
Diversification	6.4	Animal husbandry issues (e.g. heat stress, disease)	5.3
Reduced costs	5.7	No risks	4.6
New markets	4.6	Price/Profit volatility	2.8
Increased biodiversity	1.4	Lower price for products	2.5
Other	1.4	Other	1.4
Carbon capture and storage	1.1	Soil erosion	1.4
Better conditions for livestock	0.7	Nutrient loss through run-off	1.1

characterizing this group is a high sense of perceived risk, indicating an inherent high behavioral capacity to implement adaptation measures. Furthermore, The Dejected scored high in terms of awareness (Fig. 5), which suggests implicit willingness to consider implementing mitigation measures. Indeed, high perceptions of risk, when coupled with awareness of climate change, can be strong indications of adaptation and mitigation (Arbuckle et al. 2013).

Although such farmers were aware that climate change is occurring and that livestock farming contributes towards

the problem, there was an evident lack of understanding concerning how emissions are generated (Table 5). The Dejected was aware to some extent that the management of livestock and their waste led to the emission of GHGs, but only 8 % of those sampled ascribed emissions of methane to livestock as being a major cause of climate change. Indeed, 25.4 % of farmers in this cluster believed that methane associated with livestock farming does not contribute towards climate change (Table 5). This disconnect suggests a conspicuous lack of understanding in linking



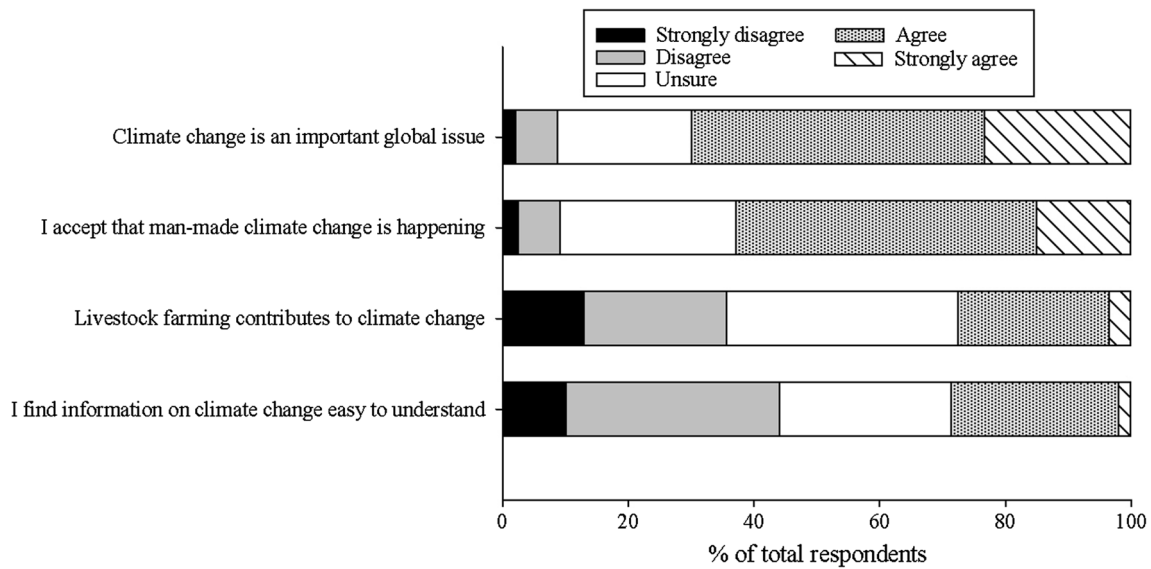


Fig. 2 Respondents' attitude towards climate change statements (%)

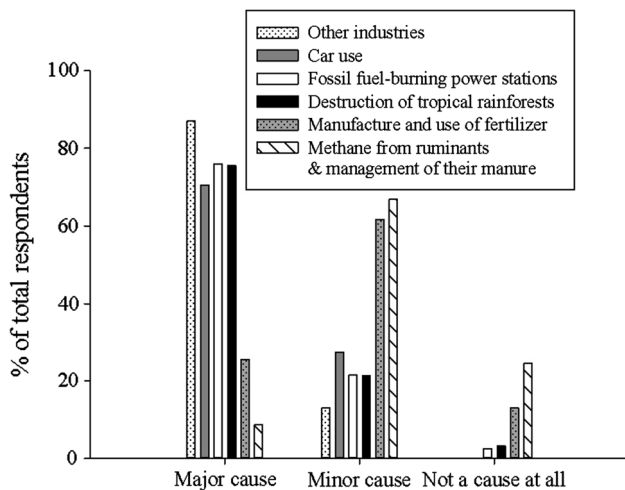


Fig. 3 Respondents' perceived anthropogenic causes of climate change

agricultural emission sources with the concept of climate change.

*The Countryside Steward*

A high sense of environmental responsibility was evident for this particular type of farmer. The Countryside Steward was deeply concerned about the environment and sees themselves as protectors of the countryside. Furthermore, they held a low disposition towards productivism (Fig. 5). The Country Steward's sense of personal attachment to the land is therefore transmuted into the wider environment (Leopold 1949). Consequently, the will to adopt pro-environmental behaviors is evident.

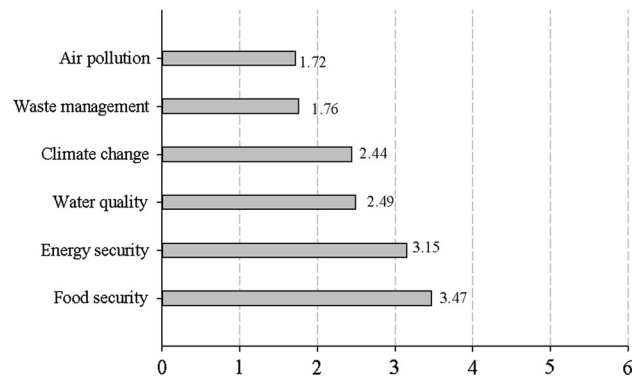


Fig. 4 Respondents' median scores of the risk posed to society by environmental issues. Options ranked 1–6 (1 being the least risk, 6 being the greatest)

Although The Countryside Steward's sense of environmental responsibility was comparable to The Environmentalist, the two groupings differed greatly with regards to awareness of climate change. Indeed, The Countryside Steward scored lowest for this component (Fig. 5). The belief that methane associated with livestock management does not contribute to climate change significantly differentiated them from the other groups ( $p < 0.01$ ). Evidently, 41.8 % of Countryside Stewards perceived such emissions as being unproblematic (Table 5). Furthermore, a higher percentage of this farmer type perceived emissions from other industries as only a minor cause of climate change (Table 5). A low behavioral capacity to implement mitigation or adaptive measures is consequently borne from The Countryside Steward's low senses of awareness and perceived risk. Interestingly, the proportion of

**Table 4** Scores of the final centers of farmer clusters, derived from K-means method

Type	% of respondents	Awareness	Environmental responsibility	Productivism	Perceived risk
The Environmentalist	28	0.742	0.500	0.063	-0.789
The Dejected	26	0.317	0.143	0.333	1.111
The Countryside Steward	23	-0.888	0.284	-0.973	-0.100
The Productivist	23	-0.342	-1.048	0.538	-0.199

Types are labelled according to differences between groupings

university-educated members was significantly lower in this cluster in comparison to the other types ( $p < 0.05$ ).

### *The Productivist*

Farmers within this type were defined by their lower sense of environmental responsibility, while displaying a penchant for productivism (Fig. 5). The disparity observed in motivational constructs suggests that production dictates management decisions. It could be argued that such farmers see their enterprise primarily as a business, where the environment provides the raw materials and resources necessary to produce a profit. Such farmers focus on the quantitative outputs of land management (Lowe et al. 1993; Wilson 2001). Other studies have also revealed farmers with characteristics that predominantly converge on profits and efficiency maximization (Gasson 1973; Guillem et al. 2012; Barnes and Toma 2012).

The Productivist was not as aware of climate change as other farmer types, nor did they perceive it to be a risk to their farming enterprise. Conversely, they denounced emissions from other industries as being a major cause of climate change, while placing little accountability towards the livestock sector (Table 5). Hence, The Productivist may not be as pro-active as other groups since low motivation to act pro-environmentally was coupled with a low behavioral capacity to implement both mitigation and adaptation measures.

## Discussion

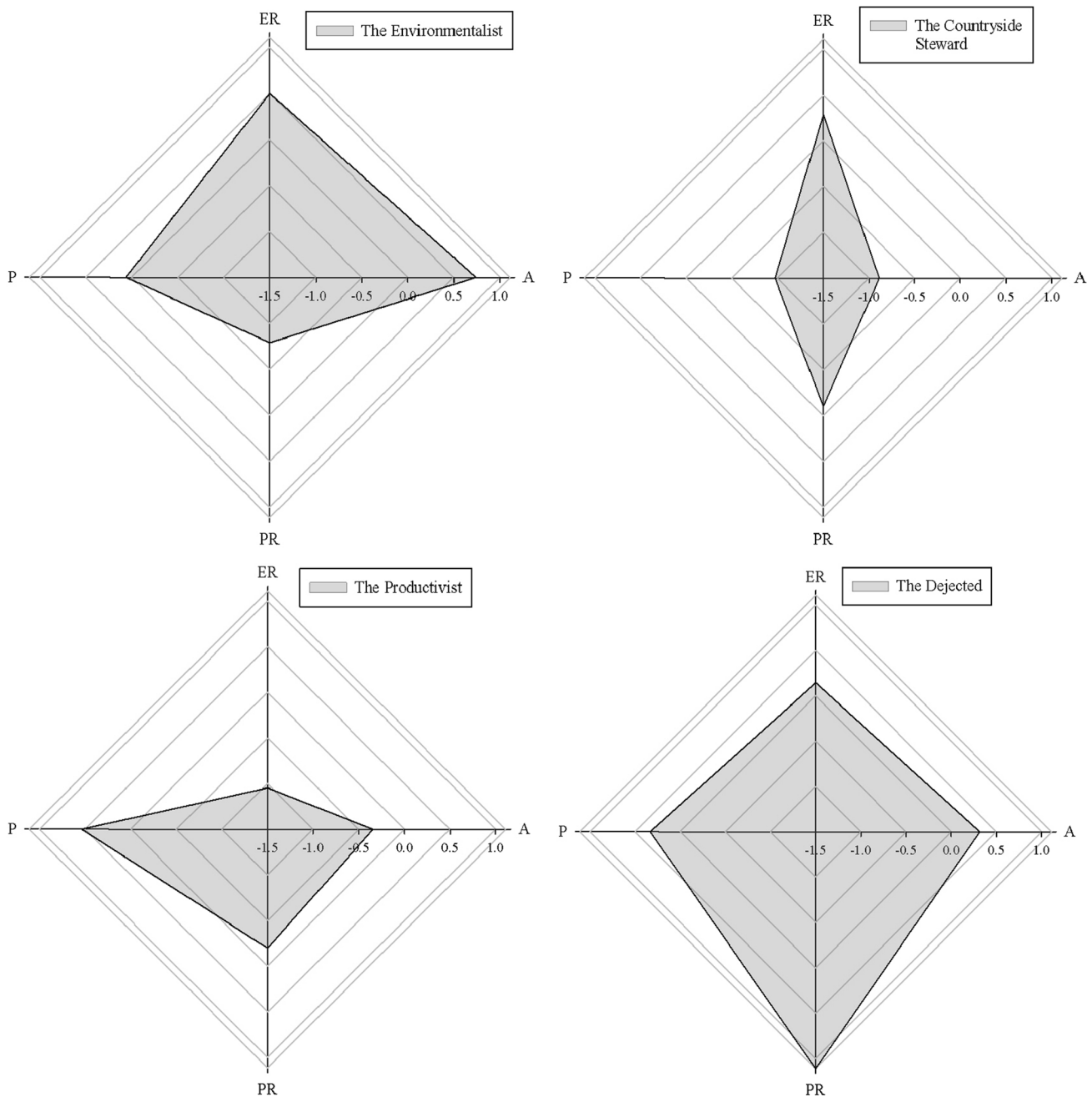
The purpose of this study is to establish a typology of beef/sheep farmers based on farmers self-identity and their perceptions of climate change. The convenience sampling method used has been shown to be representative (Luschei et al. 2009). Although bias is possible (Berk 1983), its potential was considered to be negligible as every possible farmer encountered at the numerous study sites was approached on sampling days. The findings are hence robust for the 286 respondents who gave their views on climate change and provide a sound basis for future investigation.

Pastoral-based livestock systems in temperate regions are ubiquitous the world over. The approach used in this study is particularly relevant to researchers who aspire to determine the perceptions of climate change from farmers who operate in such environs. Moreover, where equivalencies in farmer identity and behavioral capacity are evident, findings may be extrapolated to aid policy-makers in other temperate regions to encourage farmers in adopting measures that address climate change.

Farmers' perceptions of environmental issues are heavily influenced by political agendas (Holloway and Ilbery 1996). Topical issues are likely to be those that are colloquial, where farmers have been forced to recognize issues through legislation or environmental groups. With this in mind, we found that farmers ranked climate change below food security, energy security, and water quality in terms of important issues confronting society in the future. This ranking is consistent with the general public's perception of the issue in recent years (Ratter et al. 2012). Possible explanations are issue fatigue, the impact of the global financial crisis, distrust, and the deepening politicization of the issue (Pidgeon 2012).

Low behavioral capacity is borne from a lack of awareness of climate change and a low sense of the perceived risks that it may bring. This acts as a barrier for both The Productivist and The Countryside Steward in adopting measures that help address climate change. It could be hypothesized that the primary reason that The Productivist would take the climate into consideration is if there are (economic) incentives in place to do so (Defra 2010; Fleming and Vanclay 2010). Messages which focus on low-cost 'win-win' technologies may therefore resonate (Islam et al. 2013). However, the costs of inaction can often be considerably greater than the economic costs of immediate action (OECD 2012). Discourses framed in such a monetary manner may gain recognition with farmers who possess productivist tendencies. Furthermore, the concept of efficiency gains through 'sustainable intensification' could particularly appeal to such farmers as their production tendencies would not be compromised (The Royal Society 2009).

Weber (1997) proposes a 'finite pool of worry', which implies that one's regard for the environment decreases as



**Fig. 5** Radar diagrams showing the scores of the four identified types for the four PCA components. Derived from cluster centers from Table 4 ( $n = 286$ ). *A* awareness, *ER* environmental responsibility, *P* productivism, *PR* perceived risk

other factors gain prominence. The theory suggests that individuals have a limited capacity as to how many issues they deem relevant at any one time. Farmers like The Productivist may feel compelled to assert management decisions towards production as such an alignment may be deemed necessary for survival. Readjusting focus towards the environment may be therefore condemned as superfluous by such farmers. Given The Countryside Steward's

high environmental responsibility, their low awareness of climate change may be an example of 'availability heuristic' (Tversky and Kahneman 1973). It could be hypothesized that they do not consider climate change as being the cause of adverse weather conditions.

It is important to recognize the complexity of climate change along with the intricacy of its causes. Notably, we observe how many farmers depict agriculture as

**Table 5** Percent of respondents with indicated perceptions of emission sources, climate change contributors, and sources of climate change information based on farmer type

	The Productivist	The Countryside Steward	The Environmentalist	The Dejected
Perceptions of emissions associated with the management of livestock and their waste on their respective farms				
Emits	42.1	33.3	56.0	47.1
Neutral	56.3	63.5	42.7	52.9
Stores	1.6	3.2	1.3	0
Perceptions of emissions associated with fertilizer use on their respective farms				
Emits	34.4	22.6	45.3	33.8
Neutral	62.5	66.1	48.0	58.8
Stores	3.1	11.3	6.7	27.9
Perceived contribution of methane from livestock towards climate change				
Major cause	3.1	9.0	13.3	8.5
Minor cause	70.8	49.3	80	66.2
Not a cause	26.2	41.8	6.7	25.4
Perceived contribution of the manufacture and use of fertilizers towards climate change				
Major cause	13.9	23.9	39.5	22.5
Minor cause	67.7	59.7	56.9	63.4
Not a cause	18.5	16.4	6.7	14.1
Perceived contribution of 'other industries' towards climate change				
Major cause	90.8	72.7	92.1	91.6
Minor cause	9.2	27.3	7.9	8.5
Not a cause	0	0	0	0
Information sources on climate change				
Primary source	Press (42.3)	Press (27.0)	Press (30.7)	Press (31.9)
Secondary source	TV/Radio (20.3)	TV/Radio (25.4)	TV/Radio (24)	TV/Radio (26.2)

contributing little towards GHG emissions, whereas emissions from other industries are generally perceived to be a major cause of climate change. Furthermore, none of the farmer types perceive methane from livestock as being a major cause of climate change, further illustrating a reluctance to accept responsibility (Table 5). Such displacement of blame is not unique, and blame avoidance is an important barrier for effective engagement (Kurz et al. 2005; Lorenzoni et al. 2007).

There is evidence that strongly suggests that some farmers who believe in climate change have higher quantitative perceptions of associated future hazards (direct or indirect) (Menapace et al. 2012). This in some way may decipher why farmers like The Dejected feel threatened by the issue. However, there are often uncertainties about aspects of GHG emissions even where individuals accept the overarching scientific consensus that climate change is a reality (Moser 2010). As such, accurate understanding of the causes of climate change is an important determinant of pro-environmental behavior and support of climate change policies (O'Connor et al. 1999). With the exception of The Environmentalist, analyses of the farmer types reveal a

disconnection between agricultural emission sources and their contribution towards climate change. This is particularly evident in The Dejected, who is aware that agriculture contributes towards climate change but is unsure as to how such emissions are generated. The observed disconnect suggests emotional-focused coping to lessen risk perceptions by avoidance, denial, and desensitization (Clayton and Myers 2009). Bruce (2013) demonstrates that beef/sheep farmers conceptualized methane emissions associated with ruminants as a natural occurrence rather than a pollutant. A perception of GHG emissions from ruminants as being environmental benign may allude to why The Productivist and The Countryside Steward are not aware of agriculture's contribution to climate change. Therefore, conceptualizing methane towards the paradigm of being a negative externality requires specific attention, which should be facilitated by knowledge transfer.

The literature recommends increasing attention to the role of advice and information dissemination that leads to voluntary individual and collective action (Hall and Wreford 2012). Understanding farmers' perceptions is therefore imperative in building effective outreach strategies

(Greiner et al. 2009). Both primary and secondary information sources were comparable across the four farmer types (Table 5). Although limited, unilateral information sources can be beneficial if used to support debate and raise awareness so that a common knowledge base is attained (Bizikova et al. 2014). This would be particularly advantageous in addressing the observed disconnect that farmers display between on-farm GHG emission sources and their contribution towards climate change.

Different epistemologies influence the mobilization and transformation of knowledge. The traditional knowledge-transfer approach has been criticized 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 amongst 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). Lankester (2013) demonstrates how organized collective group learning is an effective method of fostering sustainability and pro-environmental behavior among farmers. 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). This approach would allow the four types to discuss views on climate change with each other and experts (Carolan 2006).

Social learning could be propitious in shifting The Productivist's sense of what is involved in being a 'good farmer' away from a purely production standard towards one with more environmental tendencies (McGuire et al. 2013). Group discussion would provide a platform to increase awareness and to deliberate the adoption of measures that are both environmentally and economically beneficial. The Countryside Steward has a particularly high sense of environmental responsibility but is lacking in their awareness of climate change; therefore, it is reasonable to assume that effective participatory approaches could encourage their participation in programs that focus on climate change. Social interaction can also ease unfounded risk perceptions that farmers such as The Dejected may hold (Langford 2002; Maiteny 2002). Communication of risks could also inspire greater action and support of climate change initiatives in other types (Leiserowitz 2006).

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. There is still therefore a need for access to reliable 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 utilized, irrespective of the model used (Reed et al. 2014). The fact that no one paradigm suits all further illustrates the importance of recognizing 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 reduce GHGs for all types (Garforth et al. 2004; Maibach et al. 2009).

## Conclusions

The farmer types elicited in this study can be used as a tool to advance the development and uptake of mitigation and adaptation measures. Farmers are more likely to protect and sustain the environment when they are aware of an environmental problem, consider the environmental threat to be great, and feel responsible for acting (O'Connor et al. 1999; Story and Forsyth 2008). We hypothesize that farmer identity influences assessments of climate change, therein affecting their behavioral capacity to implement measures that address the issue.

Mitigation and adaptation are determined through farmers' awareness of the issue and their perceptions of risks that it may bring. The Environmentalist is therefore most likely to adopt mitigation measures as their awareness is higher than the other types. The Dejected also has a high implicit behavioral capacity to implement mitigation measures. Furthermore, a high inherent capacity to implement adaptation measures is evident through their high perceptions of risk. However, we observe that while The Dejected accepts that livestock contributes towards climate change, there is evidence of avoidance, denial, and desensitization through their lack of understanding of how exactly emissions are generated from livestock farming. Therefore, their capacity to implement climate change measures may be stifled. The Countryside Steward displays a high sense of motivation to act pro-environmentally but is lacking in their awareness of climate change. This implies a low behavioral capacity to implement measures to address the issue.

Globally, environmental considerations are often in competition with other societal outcomes such as food production. Policy-makers should be aware that farmer's adoption of environmental measures depends upon the measures' practicality and cost, amongst other factors (Jones et al. 2013). Such factors may contribute to the concept of a 'finite pool of worry' as individuals have a limited capacity as to how many issues are deemed relevant at any one time. Farmers are also often challenged by changing market conditions whilst also being expected to deliver an expanding range of 'public goods', such as



increasing food production and storing carbon (Stuart and Gillon 2013). Collectively, this means that farmers like The Productivist are less likely to adopt or support environmental measures as motivation to produce overshadows an environmental ethos. Hence, messages framed under the concept of sustainable intensification may particularly appeal to their self-identity characteristics.

The Dejected and The Countryside Steward's lack of knowledge of how exactly livestock contributes to climate change indicates how neither high awareness, nor environmental responsibility, are conflated with an explicit knowledge of the issue. Particular attention should be paid to addressing the evident disconnect in perceptions of agricultural emission sources and their contribution towards climate change. If such linkages are not conceptualized, it is unlikely that the migration or adaptation potentials will be fully realized across the elicited farmer types. The farmer types depicted can enable the effective transfer and exchange of knowledge which can encourage the voluntary adoption of adaptation and mitigation measures. A variety of dissemination methods should be used to facilitate farmer action which addresses climate change based on the types elicited.

**Acknowledgments** We thank Hybu Cig Cymru and the Knowledge Economic Skills Scholarship program for funding this study. Special thanks are reserved for the National Farmers' Union Cymru, the Farmers' Union of Wales and to the managers of the livestock markets attended for facilitating the recruitment of farmers, and all the farmers that took part. We also thank Nuala Quinn for assisting in distributing the questionnaires. We are grateful to Paul Cross for comments on initial drafts, plus the anonymous reviewers and editor for their helpful and constructive comments on the original version of this manuscript.

## References

- Arbuckle, J.G., J.W. Morton, and J. Hobbs. 2013. Farmer beliefs and concerns about climate change and attitudes toward adaptation and mitigation: Evidence from Iowa. *Climatic Change* 18(3–4): 551–563.
- Arbuckle, J.G., L.W. Morton, and J. Hobbs. 2015. Understanding farmer perspectives on climate change adaptation and mitigation: The roles of trust in sources of climate information, climate change beliefs, and perceived risk. *Environment and Behavior* 47(2): 205–234.
- Barnes, A.P., and L. Toma. 2012. A typology of dairy farmer perceptions towards climate change. *Climatic Change* 112(2): 507–522.
- Beretti, A., C. Figuières, and G. Grolleau. 2013. Behavioral innovations: The missing capital in sustainable development? *Ecological Economics* 89: 187–195.
- Berk, R.A. 1983. An introduction to sample selection bias in sociological data. *American Sociological Review* 48: 386–398.
- Bidogeza, J., P.B.M. Berentsen, J. De Graaff, and A.G.J.M. Oude Lansink. 2009. A type of farm households for the Umutara province in Rwanda. *Food Security* 1(3): 321–335.
- Bizikova, L., E. Crawford, M. Nijnik, and R. Swart. 2014. Climate change adaptation planning in agriculture: Processes, experiences and lessons learned from early adapters. *Mitigation and Adaptation Strategies for Global Change* 19(4): 411–430.
- Black, A. 2000. Extension theory and practice: A review. *Animal Production Science* 40(4): 493–502.
- Bord, R.J., R.E. O'Connor, and A. Fisher. 2000. In what sense does the public need to understand global climate change? *Public Understanding of Science* 9(3): 205–218.
- Brody, S., H. Grover, and A. Vedlitz. 2012. Examining the willingness of Americans to alter behavior to mitigate climate change. *Climate Policy* 12(1): 1–22.
- Bruce, A. 2013. The lore of low methane livestock: Co-producing technology and animals for reduced climate change impact. *Life Sciences Society and Policy* 9(10). doi:10.1186/2195-7819-9-10.
- Burke, P.J., and J.E. Stets. 2009. *Identity theory*. Oxford, UK: Oxford University Press.
- Burns, R., and R.P. Burns. 2008. *Business research methods and statistics using SPSS*. London: Sage Publications Limited.
- Burton, R.J. 2004. Seeing through the 'good farmer's' eyes: Towards developing an understanding of the social symbolic value of 'productivist' behavior. *Sociologia Ruralis* 44(2): 195–215.
- Burton, R.J., and G.A. Wilson. 2006. Injecting social psychology theory into conceptualisations of agricultural agency: Towards a post-productivist farmer self-identity? *Journal of Rural Studies* 22(1): 95–115.
- Carolan, M.S. 2006. Sustainable agriculture, science and the co-production of 'expert' knowledge: The value of interactional expertise. *Local Environment* 11(4): 421–431.
- Clayton, S., and O.G. Myers. 2009. *Conservation psychology: Understanding and promoting human care for nature*. Cambridge, UK: Cambridge University Press.
- Cooper, M.H., J. Boston, and J. Bright. 2013. Policy challenges for livestock emissions abatement: Lessons from New Zealand. *Climate Policy* 13(1): 110–133.
- Costello, A., and J. Osborne. 2011. Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research and Evaluation* 10(7). <http://pareonline.net/pdf/v10n7.pdf>. Accessed 13 Dec 2014.
- Defra. 2010. *Low carbon farming: The benefits and opportunities*. London: Department for Environment, Food and Rural Affairs.
- Dietz, T., A. Dan, and R. Shwom. 2007. Support for climate change policy: Social psychological and social structural influences. *Rural Sociology* 72(2): 185–214.
- Edwards-Jones, G. 2006. Modelling farmer decision-making: Concepts, progress and challenges. *Animal Science* 82(6): 783–790.
- Eggers, M., M. Kayser, and J. Isselstein. 2014. Grassland farmers' attitudes toward climate change in the North German plain. *Regional Environmental Change* 14(4): 1–11.
- Evans, C., C. Storer, and A. Wardell-Johnson. 2011. Rural farming community climate change acceptance: Impact of science and government credibility. *International Journal of Sociology of Agriculture and Food* 18(3): 217–235.
- Futures, Farming. 2011. *Climate change survey stage five report*. Cambridge, MA: Farming Futures.
- Fleming, A., and F. Vanclay. 2010. Farmer responses to climate change and sustainable agriculture. *Agriculture for Sustainable Development* 30(1): 11–19.
- Field, A. 2009. *Discovering statistics using SPSS*. London: Sage Publications Limited.
- Garforth, C., T. Rehman, K. McKemey, R. Tranter, R. Cooke, C. Yates, J. Park, and P. Dorward. 2004. Improving the design of knowledge transfer strategies by understanding farmer attitudes and behavior. *Journal of Farm Management* 12(1): 17–32.
- Gasson, R. 1973. Goals and values of farmers. *Journal of Agricultural Economics* 24(3): 521–542.



- Gerber, P.J., H. Steinfeld, B. Henderson, A. Mottet, C. Opio, J. Dijkman, and G. Tempio. 2013. *Tackling climate change through livestock: A global assessment of emissions and mitigation opportunities*. Rome: FAO.
- Greiner, R., L. Patterson, and O. Miller. 2009. Motivations, risk perceptions and adoption of conservation practices by farmers. *Agricultural Systems* 99: 86–104.
- Guillem, E., A. Barnes, M. Rounsevell, and A. Renwick. 2012. Refining perception-based farmer typologies with the analysis of past census data. *Journal of Environmental Management* 110: 226–235.
- Haden, V.R., M.T. Niles, M. Lubell, J. Perlman, and L.E. Jackson. 2012. Global and local concerns: What attitudes and beliefs motivate farmers to mitigate and adapt to climate change? *PLoS One* 7(12): e52882.
- Hair, J.F., R.E. Anderson, R.L. Tatham, and W.C. Black. 1998. *Multivariate data analysis*, 5th ed. Upper Saddle River, NJ: Prentice Hall.
- Hall, C., and A. Wreford. 2012. Adaptation to climate change: The attitudes of stakeholders in the livestock industry. *Mitigation and Adaptation Strategies for Global Change* 17(2): 207–222.
- HCC. 2011. *A sustainable future: The Welsh red meat roadmap*. Aberystwyth: Hybu Cig Cymru.
- Holloway, L., and B. Ilbery. 1996. Farmers' attitudes towards environmental change, particularly global warming, and the adjustment of crop mix and farm management. *Applied Geography* 16(2): 159–171.
- IPCC. 2001. *Climate change 2001: Impacts, adaptation, and vulnerability: Contribution of working group II to the third assessment report of the intergovernmental panel on climate change*. Cambridge, UK: Cambridge University Press.
- Islam, M.M., A. Barnes, and L. Toma. 2013. An investigation into climate change scepticism among farmers. *Journal of Environmental Psychology* 34: 137–150.
- Janssens, W., P. De Pelsmacker, K. Wijnen, and P. Van Kenhove. 2008. *Marketing research with SPSS*. Upper Saddle River, NJ: Prentice Hall.
- Jones, A.K., D. Jones, G. Edwards-Jones, and P. Cross. 2013. Informing decision making in agricultural greenhouse gas mitigation policy: A Best-Worst scaling survey of expert and farmer opinion in the sheep industry. *Environmental Science & Policy* 29: 46–56.
- Klerkx, L., M. Schut, C. Leeuwis, and C. Kilelu. 2012. Advances in knowledge brokering in the agricultural sector: Towards innovation system facilitation. *IDS Bulletin* 43(5): 53–60.
- Köbrich, C., T. Rehman, and M. Khan. 2003. Typification of farming systems for constructing representative farm models: Two illustrations of the application of multi-variate analyses in Chile and Pakistan. *Agricultural Systems* 76(1): 141–157.
- Kollmuss, A., and J. Agyeman. 2002. Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research* 8(3): 239–260.
- Kurz, T., N. Donaghue, M. Rapley, and I. Walker. 2005. The ways that people talk about natural resources: Discursive strategies as barriers to environmentally sustainable practices. *British Journal of Social Psychology* 44(4): 603–620.
- Langford, I.H. 2002. An existential approach to risk perception. *Risk Analysis* 22(1): 101–120.
- Lankester, A.J. 2013. Conceptual and operational understanding of learning for sustainability: A case study of the beef industry in north-eastern Australia. *Journal of Environmental Management* 119: 182–193.
- Leeuwis, C., R. Pyburn, and N. Röling. 2002. *Wheelbarrows full of frogs: Social learning in rural resource management: International research and reflections*. The Netherlands: Koninklijke van Gorcum.
- Leiserowitz, A. 2006. Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change* 77: 45–72.
- Leopold, A. 1949. *A sand county almanac*. New York: Oxford University Press.
- Lesschen, J.P., M. van den Berg, H.J. Westhoek, H.P. Witzke, and O. Oenema. 2011. Greenhouse gas emission profiles of European livestock sectors. *Animal Feed Science and Technology* 166: 16–28.
- Lockie, S., A. Mead, F. Vanclay, and B. Butler. 1995. Factors encouraging the adoption of more sustainable crop rotations in South-East Australia: Profit, sustainability, risk and stability. *Journal of Sustainable Agriculture* 6(1): 61–79.
- Lokhorst, A.M., H. Staats, J. van Dijk, E. van Dijk, and G. de Snoo. 2011. What's in it for me? Motivational differences between farmers' subsidised and non-subsidised conservation practices. *Applied Psychology* 60(3): 337–353.
- Lorenzoni, I., S. Nicholson-Cole, and L. Whitmarsh. 2007. Barriers perceived to engaging with climate change among the UK public and their policy implications. *Global Environmental Change* 17(3–4): 445–459.
- Luschei, E.C., C.M. Hammond, C.M. Boerboom, and P.J. Nowak. 2009. Convenience sample of on-farm research cooperators representative of Wisconsin farmers. *Weed Technology* 23(2): 300–307.
- Lowe, P., J. Murdoch, T. Marsden, R. Munton, and A. Flynn. 1993. Regulating the new rural spaces: The uneven development of land. *Journal of Rural Studies* 9(3): 205–222.
- Maibach, E., C. Roser-Renouf, and A. Leiserowitz. 2009. *Global warming's Six Americas 2009: An audience segmentation analysis*. Yale project on climate change. New Haven, CT: Yale University and George Mason University.
- Maiteny, P.T. 2002. Mind in the gap: Summary of research exploring 'inner' influences on pro-sustainability learning and behavior. *Environmental Education Research* 8(3): 209–306.
- Masud, M.M., R. Akhtar, R. Afroz, A.Q. Al-Amin, and F.B. Kari. 2013. Pro-environmental behavior and public understanding of climate change. *Mitigation and Adaptation Strategies for Global Change* 18(7): 1–10.
- McCown, R.L. 2005. New thinking about farmer decision makers. In *The Farmers' decision: Balancing Economic Successful Agriculture Production with Environmental Quality*, ed. J.L. Hatfield, 11–44. Ankeny, IA: Soil and Water Conservation Society.
- McGuire, J., L.W. Morton, and A.D. Cast. 2013. Reconstructing the good farmer identity: Shifts in farmer identities and farm management practices to improve water quality. *Agriculture and Human Values* 30(1): 57–69.
- Menapace, L., G. Colson, and R. Raffaelli. 2012. Cognitive heuristics and farmers' perceptions of risks related to climate change. *2012 Annual Meeting, August 12–14, 2012, Seattle, Washington*, (124770) 12/08/12.
- Morgan-Davies, C., T. Waterhouse, and R. Wilson. 2011. Characterisation of farmers' responses to policy reforms in Scottish hill farming areas. *Small Ruminant Research* 102(2–3): 96–107.
- Moser, S.C. 2010. Communicating climate change: History, challenges, process and future directions. *Climate Change* 1(1): 31–53.
- Nainggolan, D., M. Termansen, M.S. Reed, E.D. Cebollero, and K. Hubacek. 2012. Farmer typology, future scenarios and the implications for ecosystem service provision: A case study from south-eastern Spain. *Regional Environmental Change* 13(3): 601–614.
- Niles, M.T., M. Lubell, and V.R. Haden. 2013. Perceptions and responses to climate policy risks among California farmers. *Global Environmental Change* 23(6): 1752–1760.
- Nunnally, J. 1967. *Psychometric theory*. New York: McGraw-Hill.

- O'Connor, R.E., R.J. Bord, and A. Fisher. 1999. Risk perceptions, general environmental beliefs, and willingness to address climate change. *Risk Analysis* 19(3): 461–471.
- O'Connor, R.E., R.J. Bord, B. Yarnal, and N. Wiefek. 2002. Who wants to reduce greenhouse gas emissions? *Social Science Quarterly* 83(1): 1–17.
- OECD. 2012. *OECD environmental outlook to 2050: The consequences of inaction*. Paris: Organization for Economic Co-Operation and Development.
- Pallant, J. 2010. *SPSS survival manual: A step by step guide to data analysis using SPSS*. London: Open University Press.
- Pannell, D.J., G.R. Marshall, N. Barr, A. Curtis, F. Vanclay, and R. Wilkinson. 2006. Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture* 46(11): 1407–1424.
- Pidgeon, N. 2012. Public understanding of, and attitudes to, climate change: UK and international perspectives and policy. *Climate Policy* 12(1): 85–106.
- Prokopy, L., K. Floress, D. Klotthor-Weinkauff, and A. Baumgart-Getz. 2008. Determinants of agricultural best management practice adoption: Evidence from the literature. *Journal of Soil and Water Conservation* 63(5): 300–311.
- Ratter, B.M.W., K.H.I. Philipp, and H. von Storch. 2012. Between hype and decline: Recent trends in public perception of climate change. *Environmental Science & Policy* 18: 3–8.
- Reed, M.S., L.C. Stringer, I. Fazey, A.C. Evely, and J.H.J. Kruijssen. 2014. Five principles for the practical knowledge exchange in environmental management. *Journal of Environmental Management* 146: 337–345.
- Reimer, A.P., A.W. Thompson, and L.S. Prokopy. 2012. The multi-dimensional nature of environmental attitudes among farmers in Indiana: Implications for conservation adoption. *Agriculture and Human Values* 29(1): 29–40.
- Rosin, C. 2013. Food security and the justification of productivism in New Zealand. *Journal of Rural Studies* 29: 50–58.
- Semenza, J.C., D.E. Hall, D.J. Wilson, B.D. Bontempo, D.J. Sailor, and L.A. George. 2008. Public perception of climate change: Voluntary mitigation and barriers to behavior change. *American Journal of Preventive Medicine* 35(5): 479–487.
- Sheeder, R.J., and G.D. Lynne. 2011. Empathy-conditioned conservation: “Walking in the shoes of others” as a conservation farmer. *Land Economics* 87(3): 433–452.
- Stern, P.C., T. Dietz, T. Abel, G.A. Guagnano, and L. Kalof. 1999. A value-belief-norm theory of support for social movements: The case of environmentalism. *Human Ecology Review* 6(2): 81–98.
- Story, P.A., and D.R. Forsyth. 2008. Watershed conservation and preservation: Environmental engagement as helping behavior. *Journal of Environmental Psychology* 28(4): 305–317.
- Stuart, D., and S. Gillon. 2013. Scaling up to address new challenges to conservation on US farmland. *Land Use Policy* 31: 223–236.
- Stuart, D., R.L. Schewe, and M. McDermott. 2014. Reducing nitrogen fertilizer application as a climate change mitigation strategy: Understanding farmer decision-making and potential barriers to change in the US. *Land Use Policy* 36: 210–218.
- Sulemana, I., and H.S. James Jr. 2014. Farmer identity, ethical attitudes and environmental practices. *Ecological Economics* 98: 49–61.
- Terry, D.J., M.A. Hogg, and K.M. White. 1999. The theory of planned behavior: Self-identity, social identity and group norms. *British Journal of Social Psychology* 38(3): 225–244.
- The Royal Society. 2009. *Reaping the benefits: Science and the sustainable intensification of global agriculture*. London: The Royal Society.
- Tversky, A., and D. Kahneman. 1973. Availability: A heuristic for judging frequency and probability. *Cognitive Psychology* 5(2): 207–232.
- Valbuena, D., P.F. Verburg, and K.B. Bregt. 2008. A method to define a typology for agent-based analysis in regional land use. *Agriculture, Ecosystems & Environment* 128(1–2): 27–36.
- Vanclay, F. 2004. Social principles for agricultural extension to assist in the promotion of natural resource management. *Animal Production Science* 44(3): 213–222.
- Vanclay, F., P. Howden, L. Mesiti, and S. Glyde. 2006. The social and intellectual construction of farming styles: Testing Dutch ideas in Australian agriculture. *Sociologia Ruralis* 46(1): 61–82.
- Vanclay, F., and G. Lawrence. 1994. Farmer rationality and the adoption of environmentally sound practices; a critique of the assumptions of traditional agricultural extension. *European Journal of Agricultural Education and Extension* 1(1): 59–90.
- Vanclay, F., L. Mesiti, and P. Howden. 1998. Styles of farming and farming subcultures: Appropriate concepts for Australian rural sociology? *Rural Society* 8(2): 85–107.
- van der Werff, E., L. Steg, and K. Keizer. 2013. The value of environmental self-identity: The relationship between biospherical values, environmental self-identity and environmental preferences, intentions and behavior. *Journal of Environmental Psychology* 34(1): 55–63.
- Voss, A.G.J., A. Spiller, and U. Enneking. 2009. Farmer acceptance of genetically modified seeds in Germany: Results of a cluster analysis. *International Food and Agribusiness Management Review* 12(4): 61–80.
- Wang, Y., and P.K. Ahmed. 2009. The moderating effect of the business strategic orientation on eCommerce adoption: Evidence from UK family run SMEs. *The Journal of Strategic Information Systems* 18(1): 16–30.
- Weber, E. U. 1997. Perception and expectation of climate change: Precondition for economic and technological adaptation. In *Environment, Ethics, and Behavior: The Psychology of Environmental Valuation and Degradation*, eds. H.M. Bazerman, D.M. Messick, A.E. Tenbrunsel and K.A. Wade-Benzoni. San Francisco, CA: The New Lexington Press.
- Welsh Government. 2009. *One Wales: One planet*. Cardiff: Welsh Government.
- Welsh Government. 2012. *Farming facts and figures, Wales 2012*. Cardiff: Welsh Government.
- Welsh Government. 2014. *An introduction to Glastir and other UK agri-environment schemes*. Cardiff: Welsh Government.
- Widcorp, 2009. *Understanding farmer knowledge and attitudes to climate change, climate variability, and greenhouse gas emissions*. Melbourne: Water in Dry-lands Collaborative Research Program.
- Wilson, G.A. 2001. From productivism to post-productivism... and back again? Exploring the (un)changed natural and mental landscapes of European agriculture. *Transactions of the Institute of British Geographers* 26(1): 77–102.
- Yazdanpanah, M., D. Hayati, S. Hochrainer-Stigler, and G.H. Zamani. 2014. Understanding farmers' intention and behavior regarding water conservation in the middle-east and North Africa: A case study in Iran. *Journal of Environmental Management* 135: 63–72.

**John J. Hyland** is a Ph.D. student at Bangor University, and his research involves assessing opportunities and barriers to reduce the environmental footprint of food production. This involves interdisciplinary research, including social science, environmental sciences, and economics. Research interests include sustainable intensification, food security, and how farmer's perceptions of environmental issues influence their behavior.

**Davey L. Jones, Ph.D.**, holds a Professorial Chair in Soil and Environmental Science at Bangor University. A major focus of his research is on understanding below-ground processes with specific

focus on nutrients and human pathogen behavior in soil–plant–microbial systems. Current applications of his work includes the use of wastes for land restoration, implementation of strategies for controlling *E. coli* O157 in agricultural systems, enhancing food safety, carbon sequestration in grasslands and ways to improve nutrient use efficiency in cropping systems.

**Karen A. Parkhill, Ph.D.**, has research interests that span energy geographies and geographies of risk. She uses qualitative methods to explore how the public and stakeholders engage with/resists notions of low carbon lifestyles and low carbon transitions, including examining how they themselves consume/perceive energy. She is also interested in risk perception and how the public socially construct and engage with environmental and technocratic risks. Such risks include: energy technologies such as civil nuclear power, renewables or coal with carbon capture and storage; climate change, and; geoengineering. The interaction of place, space and context underpins and flows throughout all of these interests.

**Andrew P. Barnes, Ph.D.**, research interest focuses on capturing the impacts of policy change and farmer behavior at the farm and

catchment level within a modelling framework. He has conducted work on a variety of topics within this area, particularly in terms of understanding attitudes, motivations and perceptions of farmers toward water pollution issues. Some of this work encompasses qualitative methods, such as citizen's juries, although the main thrust has been towards quantitative modelling. This includes traditional linear programming based methods, but also applications using positive mathematical programming and agent-based modelling frameworks. A further research interest lies in measuring and adjusting productivity indicators for non-economic factors, such as animal welfare and environmental impact.

**A. Prysor Williams, Ph.D.**, comes from an agricultural background and much of the applied aspect of my research sits at the interface between academia and industry. He has collaborated with the water, waste and agriculture industries on a number of projects; covering soil science, pathogens, nutrient management, water quality, livestock diseases, sustainable intensification, and animal by-products. As well as the natural sciences, his involvement with many inter-disciplinary projects has given me valuable experiences in socio-economic research.