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Friend or Foe? UK Farmers' Relationships with the Weather

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Key words: Climate change; farmers; extreme weather; local knowledge; risk perception; typology.

Highlights

- The importance of examining weather at the farm scale
- Investigating farmers' local knowledge of weather and climate change based on extreme events
- The identification and analysis of four types of farmer-weather relationship which demonstrate a convergence of local and scientific knowledge
- An exposition of farmers' information-seeking behaviour regarding weather
- The implications of farmer-weather types for the development of weather and climate services through better targeting of information

Abstract

Climate change will exacerbate the future challenges posed to sustaining food security in the UK. More frequent and intense extreme weather events will impact upon the ability of British farm systems to maintain or increase levels of food production. However, in this cultural context, relatively little is known about farmers' relationship with 'the weather', formed from their daily experiences of it. This paper engages at the farm scale to explore farmers' information-seeking behaviour about the weather, which influences their current risk perceptions of extreme weather conditions, through exploration of their assemblages of meteorological and local knowledge. Views are collected using a broad-based quantitative scoping survey combined with in-depth qualitative research with farmers located in the Welsh Marches border region of England and Wales, UK. Findings demonstrate that different types of farmer-weather relationships can be recognised depending upon the way weather and climate information is sought and utilised. We present a typology of farmer-weather relationships, categorising farmers as: analysts; intuitives; fatalists; or disengagers; with regards to the way in which they seek and interpret weather and climate information. This

typology may assist the formation of new weather and climate services through an improved understanding of how lay and scientific knowledges interact in practice.

1. Introduction: Farmers, Weather and Climate Change

Emerging concerns over global food security have, within the current decade, led some authors to begin to reinterpret the geography of agricultural change in the UK context (for examples, see Ilbery and Maye 2010, Evans 2013, Maye and Kirwan 2013). The multitude of challenges faced by the UK farm sector is set to be amplified further by the mounting pressures of climate change (Defra 2012, Griffiths and Evans 2015, IPCC 2014, Kirwan et al. 2017). As rising global temperatures continue to be observed, the impacts of climate change are increasingly realised (IPCC 2018). Against this backdrop of long-term climate change, the impacts upon social-ecological systems, including farming, are made considerably more complex by the emergence of increasing incidence of weather extremes (Tate et al. 2010). Extreme weather events have been observed with greater frequency since the 1950s (Defra 2012, IPCC 2007, 2013), presenting growing challenges to agrarian systems configured both in modern and traditional ways. Predicted impacts on agriculture include the redistribution of water availability, increased soil erosion and decreased crop productivity (Arkbuckle et al. 2015, Howden et al. 2007, McCarl 2010). Without adaptation, such impacts present immediate and localised economic risks to farmers (Arkbuckle et al. 2015).

Notable affects upon UK agricultural production have already been felt by farmers in the UK (Ambler-Edwards et al., 2009, Defra 2012, Griffiths and Evans 2015, Tate et al. 2010). Given highly localised differences in the practice of agriculture, extreme weather events bestow upon farmers continual additions to their stock of local knowledge, serving to build up their perceived understanding of climate change. This further feeds into their ability to respond and adapt to future extremes (system shocks) and, ultimately, their resilience to future climate challenges. Despite the emergence of such issues, how farmers compile their knowledge about weather extremes and changing climate, using the information they receive about it, is yet to receive detailed consideration; especially in relation to ‘Global North’ agriculture and the UK cultural context in particular. Hence, the purpose of this paper is to examine the ways in which farmers acquire, regard and process information – lay and scientific – about the weather in light of their experience of extreme weather events in the UK region known as the Welsh Marches. We explore the interactions of local knowledge and risk perception alongside the use and interpretation of weather and climate information from conventional scientific-based sources. Upon analysis, a typology of farmer-weather relationships becomes apparent, characterised by the different ways in which farmers regard the weather's degree of 'control' over their farming practices. We argue that a typology is useful to assist weather and climate information service-providers, now and in the future, on how their information is received and interpreted in practice, taking into consideration an increasingly complex convergence of scientific and local knowledge. This is in view of a drive to enhance the accessibility of weather and climate information services for the agricultural sector under the Global Framework for Climate Services (WMO 2014).

2. Culture, Risk, Knowledge

2.1 Cultural regard for weather extremes and climate change

Climate is summarised by Weber (2010) as 'a statistical phenomenon' and, as such, it is not easily or accurately identified by the lay public. This differs from 'the weather' which is a day-to-day, lived phenomenon usually of much more concern to citizens than the climate in their region (Weber 2010). Individuals and communities do not only experience weather; it is also widely embedded into local culture (Paolisso et al. 2012). Indeed, it is evident that a cultural regard for the weather extends far beyond the description of atmospheric conditions. Instead, it becomes engrained in values, folklore, beliefs, morality and work (Harley 2003, Paolisso 2003, Hulme et al. 2009). In the UK context, the 'changeable' nature of the weather has become deeply anchored within the British psyche to the extent that it has become a 'national institution' (Harley 2003, Endfield 2016). These cultural factors then surface to influence perceptions of climate change which, in turn, help to account for interpretations of the scale of 'the problem' and feasibility of solutions (Weber 2010).

It is reasonable to expect concerns about climate change to be uppermost in the minds of UK farmers given that farming livelihoods are clearly bound to physical factors. Continual adaptation to changing climate can be further considered as a 'normal' practice, with adjustment to changeable weather conditions a daily action undertaken by farmers (Houser 2018). However, Arbuckle et al. (2015) have identified that there is a paucity of literature on farmers' understanding and responses to climate change. This is certainly true for the ways in which farmers regard extreme weather and climate in the UK. Therefore, to address this deficiency, it is necessary to draw upon a wider range of research examining risk perceptions and local knowledge.

2.2 Current understandings of risk perception

Risk perception is often referred to as the process by which an individual evaluates their level of risk in view of the information they have sought, received, observed and recalled (Solvic 2010). Risk perceptions are formed from a combined judgement of new information and pre-conceived risk evaluations founded in prior knowledge (Johnson 1993). Attitudes and feelings of risk are intrinsic to risk perceptions (Solvic et al. 2004), as are place-specific 'antecedent conditions' (Cutter et al. 2008).

Risk perception corresponds to beliefs about adverse consequences for valued objects, being socially constructed and transmitted (Arkbuckle et al. 2015, Stern 2002). Differences in worldviews, personal experiences, expectations about technology and trust in institutions are amongst the factors that can influence an awareness and understanding of hazards, the decisions made and actions taken in response (Arkbuckle et al. 2015, Solvic 2010). Perceived risk is a heuristic effect based on experimental learning and emotional response to external stimuli. Hence, it is influenced by factors that may result in an over- or under-estimation of risk (Arkbuckle et al 2015, Solvic 2010, Weber and Stern 2011). It is often assumed that risk perceptions become heightened following the comprehension of scientific information. On the contrary, Kahan et al. (2012) found that members of the public with the highest degrees of science literacy and technical reasoning capacity were not the most concerned about climate change. Rather, they were the ones amongst whom polarisation was greatest. This indicates that there is a complex process of translation of information to risk perception at work; one beyond the simple receipt, comprehension and use of 'objective' scientific information.

Using the above definitions, the formation of farmers' risk perceptions with regards to climate change consists not only of information and knowledge, but also of memories, values, beliefs and attitudes to risk, in conjunction with farm priorities. A recent line of inquiry has emerged which examines farmers' climate change risk perceptions and reactions in developed countries (Fleming and Vanclay 2010, Barnes and Toma 2012, Woods et al. 2017, Houser 2018). Such research has found that ambivalence is, like that of the public at large, not uncommon when assessing a broad spectrum of farmers (Te Velde et al. 2002, Fischer et al. 2013). However, the conclusions drawn have been largely based on the mobilisation of quantitative methods to describe how farmers perceive climate change through attempts to establish a link between perception and reactionary practices (Houser 2018). Such studies are limited in their ability to account for risk as a product of an individual's memories, values, beliefs and attitudes, in line with our established definition of risk perception. In light of projected climate change, there is likely to be greater importance attached to a farmer's ability to interpret information and perceive risk from his/her cultural context; judgements and decisions made from expanding multiple sources of weather information. These considerations will be examined and serve to assist in the development of a typology presented later in this paper.

2.3 Local knowledge in a farm context

A consideration and understanding of local knowledge, including farmers' intrinsic knowledge of the land (Wynne 1992), provides an essential basis upon which risk perceptions are formed and subsequent adaptations to change are made (Adger 2000, Adger et al. 2002, 2003 and 2005). Local knowledge is often seen as the key to coping with greater risk because it utilises a deep understanding of the local environment in which such risks are observed (Islam et al. 2018). Knowledge barriers are portrayed as inhibiting the ability for farm practices to change, undermining farmer motivation to utilise new information (Hu et al. 2006). Further, where there is a void of easily accessible and translatable scientific information, reliance upon local knowledge systems persists. For example, Hu et al. (2006) found that even where seasonal and long-term forecasts were provided, suited to the planning of agricultural operations, farmers typically failed to adopt such information in decision-making due to a lack of familiarity with utilising such forecasts.

Despite the tendency towards conceptual polarisation, scientific and 'tacit' knowledge are fundamentally complementary (Ingram 2008). Kox et al. (2018) demonstrate the value of the prioritisation of user needs derived from local knowledge to enhance the quality of the science-based climate and weather service that is provided, whilst also ensuring that accurate interpretations of the information are facilitated. Indeed, an important user requirement to understanding any weather or climate information is consideration of how local knowledge might be applied to frame the interpretation of that information when received (Kox et al. 2018, Ingram 2008, Solli and Ryghaug 2014, Wynne 1992). Thus, to enable successful adaptations based upon weather and climate information, there needs to be a relationship between scientific climate information and local knowledge (Solli and and Ryghaug 2014). There is emerging evidence that local knowledge systems are increasingly being considered alongside the use of scientifically derived weather and climate information (Naess, 2013, Ingram 2008, Islam et al. 2018). Good contact between existing local expertise and professional knowledge is an important condition for taking preparedness measures and making good adaptations (Solli and Ryghaug 2014).

One major obstacle to the interaction of scientific and local knowledge in reality is that, by definition, local knowledge is highly geographically specific, and therefore is not easy to disseminate in a manner relevant to places far beyond its location of origin. The skills and practicalities established from local knowledge are to be found embedded within individual farming communities. In a UK context, some studies have applied a local knowledge perspective to farmers (Wynne 1992, Burton 2004, Ingram 2008), but there is much scope to build upon this valuable starting point and explore the notion further. This research examines farmers' risk perceptions emergent from their local knowledge, past experiences and information-seeking behaviour in relation to the extreme weather events they have experienced. The combined exploration of these aspects provides an indication of the different ways in which farmers receive and utilise weather and climate information; this is summarised through the creation of a typology to capture the types of farmer-weather relationships that become evident.

3. Materials and Methods

3.1 The Welsh Marches

Place identity is known to be intrinsically linked to both risk perception and local knowledge (Cutter et al. 2008). The adoption of a place-based approach to understanding farmers' weather risk perception is crucial to interpret information-seeking behaviours and risk perceptions within local farming experiences and culture (Cutter et al. 2008, Griffiths and Evans 2015). It serves to demonstrate the importance of a geographical perspective to understanding how adjustment to climate change is realised at a local level (see Ambler-Edwards et al. 2009).

Traditionally, the Welsh Marches are considered to be the borderlands of England with Wales, up to the historic Offa's Dyke 8th Century Anglo-Saxon boundary that divided the two countries (Brabbs 2007). They extend from the River Dee in the north to the Severn estuary in the south (Rowley 1986, Griffiths and Evans 2015). The precise boundary has changed through time, but on the English side they can be considered to comprise the administrative counties, from north to south, of Cheshire, Shropshire, Herefordshire, Worcestershire (enhanced by its former association as the combined county of Hereford and Worcester) and Gloucestershire (Rowley 1986). In broad terms, the area consists of river valleys and plains, uplands and mountains, meaning that the Welsh Marches landscape is one of the most richly varied in Britain. Its agricultural characteristics have been detailed by Evans (2009) and need not be repeated here. However, in essence, every crop capable of being grown in the UK is represented, with cereal-based systems more prevalent in the drier east and livestock grassland-based systems more common in the wetter west (with dairying to the north west; beef and sheep to the south west). Added to this, there are specialities, including orchard production (apples for cider are notable), fruit (especially strawberries) grown using the new innovation of Spanish polytunnels (see Evans 2013), vegetables (with asparagus of particular renown) and hops for the brewing industry. The central southern area of the Welsh Marches (Figure 1) is the specific focus for this study because of their agricultural diversity combined with a recent history of extreme weather events (Griffiths and Evans 2015).

[INSERT Figure 1 here]

Future projections indicate a likely increase in the occurrence of heatwaves (Murphy et al. 2009, Defra 2012), alongside the greater frequency and intensity of heavy precipitation (Defra 2012). Farming communities in all Welsh Marches counties already have been significantly affected (Defra 2012, Murphy et al. 2009). In particular, flooding has been a significant concern for many, as evidenced by the major problematic events of 2007, 2008 and 2014. Griffiths and Evans (2015) demonstrate that a considerable range and frequency of different extreme weather events have been experienced in the Marches over the last 30 years. These have triggered impacts that have delivered considerable shocks to local farming systems. For example, within the ten years 2006-16, there were heatwaves (2006), flash floods (2007 and 2008), prolonged rainfall (2012), heavy spring snowfall (2013) and prolonged flooding (2014).

This entire ‘disturbance to the norm’ has generated a rich evidence base from which to investigate the responses made by the farming community. It opens up opportunities to examine the extent to which risk perceptions of extreme weather have been heightened and to trace subsequent decision-making and information-seeking behaviour. Further, farm businesses within the region are dominated by family-based labour, which have a long history of diversification and other adjustments to changing policy conditions in agriculture (Evans and Ilbery 1992, Evans 2009). Even so, Marches family farms continue to be vulnerable as they face a widening variety of structural pressures (Price and Evans 2009). This means they have a greater need for heightened risk perceptions to inform resilient decisions, helping to justify them as the focus for research attention.

3.2 Research design

In order to explore the way in which farmers experience weather in the Welsh Marches, both quantitative and qualitative methods of data collection were employed, adopting a two-phased sequential approach. Quantitative data (phase one) provided a baseline for deeper qualitative analysis (phase two) which could further explore farmers’ motives and attitudes towards weather-related decisions based upon risk perceptions and information-seeking behaviour.

For phase one, 115 questionnaires were conducted face-to-face with farmers at the Shropshire Agricultural Show held at Shrewsbury and the Royal Three Counties Show in Great Malvern (Worcestershire). Agricultural shows were chosen as a time-efficient means to capture coming together points for Marches farmers, with over 90,000 attendees typical each year at the Royal Three Counties Show alone (Royal Three Counties Show 2018). Agricultural events are seen as moments of convergence, assembling farming people, entities, knowledge and practices (Holloway 2004, Hamilton et al. 2019). A small team of researchers approached farmers across different sections of interest within both agricultural shows to conduct the surveys. Utilising such an event to conduct survey questionnaires is not without its limitations; apparent here is a prevalence towards engaging livestock producers as opposed to those with more arable and horticultural focused farm types. As a consequence, 59% of respondents were from grazing stock farm types compared with 24% from mixed agricultural practices, 7% from dairy farms and 2% each from specialist poultry, pigs, horticulture and cereal farms. Nevertheless, the approach enabled a wide cross-section of UK farmers to be surveyed and was successful in identifying farmers that met criteria for further, qualitative study.

The questionnaire was designed to identify farmers who have experiences of extreme weather on the land they farmed, their information-seeking behaviour and any concerns for the future related to longer-term climate trends. It was deliberately designed to be short, comprising six multi-choice questions exploring: farm location, farm type, length of time on the farm, immediate farming concerns, main sources of weather information consulted and experiences of extreme weather on their farm. There was also one open-ended question allowing for further details to be provided of any extreme weather that respondents had experienced. Moreover, the questionnaire served the purpose of facilitating recruitment of farmers who farmed within the Welsh Marches to share fully their experiences and opinions in a more detailed interview format at a later date.

The distribution of respondents' farms across the UK is shown in Figure 1. The high profile and importance of each agricultural show to the farming community meant that the majority originated from other UK regions. Even so, Marches farmers were found to be significantly represented, with 42% of respondents' farms located in Herefordshire, Shropshire and Worcestershire. This split had the desirable outcome of facilitating comparisons between those acting within the case study area and farmers more widely from across the UK.

Participants for the qualitative interview stage were recruited from a pool of 40 Marches farmers who identified themselves during the questionnaire as having had experience of an extreme weather event together with a willingness to participate further in the research. To be eligible for in-depth interview, they had to meet the requirement of having been a farmer within the area for at least five years. This timeframe was chosen because it would allow for some perception of ‘normal’ weather conditions associated with the locality and meant that experience of a past extreme weather event there was more probable. Farmers who had experience of extreme weather events were selected as this would allow: exploration of their relationship with the weather; their risk perception of such an event; information-seeking behaviour around a perceived risk; and whether such a relationship or perceived risk had evolved or been impacted following an extreme weather experience. Using these criteria, 15 in-depth semi-structured interviews (including one joint interview) were conducted with 16 farmers.

By conducting in-depth interviews, it becomes possible to focus upon the individual (Ritchie et al. 2003). Therefore, such an approach allowed for the further investigation of individual behavioural factors which are influenced by individual risk perceptions. Behavioural factors in farmers known to influence decision-making include: individual motivations; attitudes; impacts and outcomes of previous decisions; levels of understanding; and complexity of issues (Ilbery 1985, Ritchie et al. 2003, Burton 2004, Silverman 2011). The aim of the interview process was to explore and expand upon farmers’ past experiences of extreme weather events, thereby working towards an overall assessment of farmers’ understanding and perceptions of climate change. The interview was structured around the themes of: information about the farm; past weather experiences; knowledge of the weather; weather and climate information use; and interpretation of climate change. During interview, the precise questions were adapted to accommodate a more natural conversational ‘flow’.

Analysis of quantitative data was conducted using SPSS to inform the subsequent qualitative data collection phase. Simple descriptive statistics were deemed appropriate to interrogate the quantitative data, allowing for initial identification of information-seeking behaviour. To interrogate the qualitative interview data, NVivo software was used to generate thematic links which could then be coded amongst common themes. By using this thematic analysis tool, recurrent perceptions and attitudes towards the weather were identified. In the discussion that follows, results gathered from both formats are used wherever appropriate to explore the emergent themes. Note that all respondents quoted in the analysis have been assigned pseudonyms to ensure their confidentiality.

4. Devising a Typology of Farmer-weather Relationships

To characterise different farmer-weather relationships, a richness of data is required that transgresses the limitations of a questionnaire. Nevertheless, where it is appropriate, supporting evidence from the questionnaire has been used to add further evidence to the different characteristics and behaviours identified. From both the qualitative and quantitative survey material, it quickly became apparent that farmers have very personal interactions with the weather. Their local knowledge alongside the way in which they engage with outputs from scientific weather services creates a lens through which the farmer views, receives and processes information to form a risk perception about extreme weather events and future climate change. Each farmer-weather relationship is unique, yet it is possible to identify patterns and similarities of such human-physical interactions amongst the farmers interviewed and construct a typology. Thematic analysis of the interview process using NVivo enables the identification of four broad farmer-weather relationships. These capture farmers' personal interactions with the weather by virtue of them being: *analysts*; *intuitives*; *fatalists;* and *disengagers*.

The type of relationship held is built up through habitual processes in which weather forecasts are (or are not) sought, interpreted and acted upon in a continual feedback cycle that influences perceptions about weather. Therefore, farmer-weather relationships represent the way in which the farmer brings a physical construct into the cultural-behavioural context informing his/her day-to-day decisions; they are a personification of the weather. Just as with inter-human relationships, each farmer-weather relationship is unique: a hybrid artefact co-produced by human-nature interaction (Goodman 1999, Whatmore 2002). Such relationships are formed upon beliefs, attitudes, values and experiences; all of which have been shown to play a significant role in farmers' practices and production (Paolisso and Maloney 2000, Edwards-Jones 2006). Hence, weather relationships are defined based on factors influenced by a farmer's personality, individual experiences and cultural context rather than simplistically determined by farm and farmer characteristics, such as size or type of farm, or age of the farmer (Ilbery et al. 2012).

Table 1 demonstrates the key characteristics observed about farmer-weather relationships in each of the four emergent categories; but is by no means an exclusive list. Inevitably, on occasions, certain farmers will demonstrate some but not all of the characteristics prevalent within that type of relationship. Others may demonstrate characteristics of more than one relationship. Regardless of the relationship, risk in this context is considered as a 'feeling' and so is approached by farmers as such rather than being based on scientifically constructed probabilities (Ilbery et al. 2012).

[INSERT TABLE ONE here].

5. Results

The key characteristics displayed in each type of relationship, as identified in Table 1, together with the differences between them, will now be explored through detailed discussion. This will seek to highlight the essential elements that define a type, followed by an outline of the influence of that relationship upon the way in which weather and climate information typically becomes sought and interpreted. Table 2 evidences how each farmer-weather relationship held by the interviewees has been assigned to its category. Where a characteristic of more than one type of relationship is apparent, up to two categories are assigned, listed in order of the most dominant relationship first (Table 2). This is most often the case with *intuitives* who are seen also to display traits of *analysts* or *disengagers*. This reflects the complexity of attempting to categorise human relationships based on common characteristics, yet which are inherently individual in nature.

[INSERT Table 2 here]

5.1 Analysts

Analysts display a purposeful interest in the weather and actively seek information from scientific sources. These farmers rely upon such information to inform their risk perceptions of extreme weather or climate events. Adopting a scientific approach, analysts are often found seeking to understand the intrinsic climatic conditions for their land through the acquisition and analysis of published data sets, accompanied by gathering information from their social network and by collecting their own data to define the mean conditions that can be expected for their land. This allows an identification of possible risks associated with extreme weather events based upon both data and past experiences. Such farmers demonstrate the use of logical reasoning in response to the acquisition of new information about present atmospheric conditions, informing judgements over future projections. Although scientific in its approach, it is not objective as analysts will still interpret such information based upon their well-developed knowledge of their land; they will act upon risk as a feeling (Ilbery et al. 2012). This approach demonstrates how scientific knowledge is one component combined with local knowledge in the complex response process to a perceived risk.

Results from the questionnaire survey reveal that 12.2% of farmers either collect or record their own weather data. Some 8.7% make use of a weather app and 3.4% keep a formal diary which references weather data derived from secondary sources (e.g. from weather forecasts). Of the farmers interviewed, two were found to keep very detailed, specific ‘weather diaries’ containing regular weather observations that they gathered themselves.

Farm weather data are most commonly found to be gathered on a farm through the use of a rain gauge, allowing for weekly or monthly totals of precipitation to be collated. It appears that such information is utilised by analyst farmers to interpret the variance of the specific micro-climate found on their land in comparison to the rest of the UK. This allows that farmer to establish a local, measurable baseline to gain a perception of the mean farm climatic conditions:

> *"Now our average here is 25 [inches - or 635mm of annual rainfall] because it so happens that in North Shropshire we are in a rain shadow… whereas the average for the UK is around 30-32 inches [760-812mm] which is fine if you're doing other stuff but for cropping 26 [660mm] is more than enough"* (Albert, Shropshire)

Albert's interpretation of the rainfall data he collects on his farm is then used to compare with records kept by another farmer located on the other side of his village. It was found that the personal on-farm data had been closely correlated to regional UK average rainfall observations recorded by the Met Office (the UK Government's executive weather agency) for the nearest observation station for the same time period (utilising the *HadUKP* data series of UK regional precipitation).

> *"I just thought it was interesting to know, it is important… it is vital for farming and if I knew what to expect it is another thing I can take account of"* (Albert, Shropshire)

This systematic process was highly valued by Albert, the data baseline he created allowing him to gain an intrinsic understanding of how the recorded conditions upon his land varied compared with local and national averages. A characteristic of this relationship is evident in the understanding of the mean conditions that would be expected on the land and variability in trends away from this which are likely at different times of year.

From such an analytical understanding, Albert would then make decisions in relation to cropping and haymaking based primarily upon his own interpretation of all information gathered. Thus, analysts assessed patterns and trends in the weather data personally gathered, then interpreted them in a pseudoscientific manner, mobilising decisions based on the results evident from such data. Notably, Enid made the decision to implement a large-scale farm adaptation in response to observations made from her own rainfall data. This had identified a trend of increasing and erratic bursts of rainfall in the spring months:

> *"The main decision I think it informed is that we put up some big sheds. Before that we used to lamb outdoors and that is really hard work to do it outside… lambing indoors is a lot easier"* (Enid, Gloucestershire)

Such displays of analytical relationships by Enid and Albert demonstrate a convergence of local and scientific knowledge, revealing the complexity of actual knowledge held by farmers. They draw upon experiences derived from collecting and analysing information on specific weather conditions combined with those from practising farming on their land. Farmers who adopt such an analytical approach therefore become 'experts' within their own right on the local weather conditions impacting the farm system. Weather event expectations are primarily built up from an understanding of mean conditions and experience of deviations away from it.

Indeed, the role of amateur meteorologists in the production of local weather knowledge is increasingly gaining academic attention (Endfield and Morris 2012). Motivations for collecting weather information appear to originate from a desire for specific and accurate, highly localised data, which are not easily accessible from conventional weather forecasts. Acquisition had often commenced where local deficiencies were perceived in weather and climate information from official sources:

> *"It wasn't very good in those days, but is good now. If I really want to know the weather I would go on the 'XC Weather' website; it is so helpful planning day-to-day if an hourly breakdown is provided"* (Albert, Shropshire)

It is known that key barriers to farmers' successful utilisation of scientific data are the skills and practice required to use such information effectively (Ingram 2008). Analysts are distinctive because they actively gain the skills and experience to overcome such barriers. Further, evidence for increased preparation for changing climatic trends is notable within this relationship. A deep understanding of the local climate and expected variability is likely to heighten risk perceptions that may enable better preparation for extreme events. However, further research would be required to establish firmly this effect on perceptions and preparations to extremes.

Analysts' perceived risk is founded within a high degree of confidence about the specific weather conditions that are likely to occur over their land. As such, the divide between scientific and local knowledge in these relationships is notably blurred (Wynne 1992), supporting the notion of a continuum of local and scientific knowledge (Millar and Curtis 1999). It is apparent that an analyst will mobilise their local knowledge once it is further informed by the scientific information that they have sought out.

5.2 Intuitives

Intuitive farmer relationships with the weather are akin to those already identified from the literature where the emphasis on interpretation of conditions is founded in local knowledge (see section 2.3). Most commonly, it is manifest as the use of intuition combined with informal sources of weather information. Such relationships are reliant upon a farmer's intrinsic knowledge of the land which provides an essential basis upon which risk perceptions are formed (Wynne 1992, Adger 2000, Adger et al. 2002, 2003 and 2005). Intuitives have a seemingly innate understanding of weather and climate conditions on their land. This is apparent through a deep connection with the land, typically based around many years of experience of working on it and, on occasions, enhanced by hereditary knowledge gleaned from their forebears. In this way, intuitives have developed an intrinsic knowledge of how the weather can impact the farm and immediate local area.

Intuitives are often characterised by the sub-conscious role the weather plays in their day-to-day routines, whereby the farmer does not overtly recognise the use of weather and climate information in risk judgements. Some intuitive relationships are distinct from analytical ones by virtue of being driven predominantly by information seeking through a wider variety of different means, but often dominated by informal, local or 'traditional' knowledge sources of information, with some mixing in of the scientific. However configured, information is highly localised depending upon the characteristics of that specific area of land, and so adaptations are made accordingly.

> *"We use everything: we have a barometer in the house… even the old wives' tales; things like 'red sky at night'… and the internet… we've got all the weather apps, and always watch the Sunday forecast for the week ahead [on BBC TV's CountryFile programme]*" (Kate, Herefordshire)

Over half of the interviewees display intuitive traits in their relationship with the weather. In an intuitive relationship, the weather subtly infiltrates and plays a crucial role in all aspects of daily farm life allowing intuitives slowly to develop a deep history and wealth of locally specific information regarding weather and climate impacts on their land. This comes without a purposeful effort by the farmer to rely upon such information to function.

Intuitives can be identified by a background curiosity in, or feelings about, 'the weather'. This is apparent in farming diaries that include a commentary of interest in the weather (constituting 'casual weather diaries'), displaying its almost unwitting role in all aspects of a farmer's everyday life. This is different from a formal weather diary because it is not designed to provide a record of, or commentary on, the weather. Instead, it is one aspect considered amongst many influences on the routine of farming life. For example, Dennis keeps a daily diary of everyday farm events, yet habitually starts the diary with the weather. In this, he begins by describing both the weather conditions he observes together with those as reported in the newspaper. He then compares this with events on the farm, thereby inadvertently keeping a record of specific weather conditions and their influence upon farming operations.

> *"Here you are… I wrote: 23rd March, 4 inches of snow in Shropshire, snow plough was needed then… I do like to record the weather and things like that"* (Dennis, Shropshire)

It is apparent that Dennis defines any one year by the weather that takes place in it and then associates the conditions that are observed with the farm impacts that are experienced. It is this weather-driven mix of events that are recorded in his diary. Such processes serve to demonstrate the intuitive relationship with the weather that, for most, permeates many aspects of farming life.

Where monitoring of weather conditions does take place by intuitives, observation combined with the use of local knowledge dominates. Such information use is considered to be intuitive by virtue of its non-scientific and inherently culturally embedded approach:

> *"I do like to think I can predict the weather, and I was usually right… I will still go up the hill, look across to the border to the Welsh mountains, and I come back and say if it is about to rain!"* (Charles, Shropshire)

From this, Charles demonstrates how direct observation on a daily basis leads to sub-conscious reasoning, building up local knowledge and allowing perceptions of risk to be based upon it. Such farmer responses to different weather conditions are manifestations of learnt behaviours from past experiences and the influences of those around them. As such, assessing the weather risk and potential impacts of extreme weather upon the farm appears to be commonplace amongst members of the farming community:

> *"It is a second nature with farming… gut reaction I suppose you can call it. I think it's something that farmers do automatically know"* (John, Herefordshire)

Regardless of the extent to which he/she recognises it as an influence upon perceived farm risks, the weather plays a significant role in the everyday life of intuitives. Alike analysts, intuitives are seen to process a myriad of different types of knowledge and information to make risk judgements of potential farm impacts caused by extremes in weather and climate within a highly localised area. However, risk perceptions of intuitives are framed by their perspective of past weather events, which leads to a strong sense of 'normal' conditions based on such experience. During the practice of informally recording the weather conditions experienced, it is probable that more extreme events are recorded due to their unexpected nature and the subsequent greater magnitude of impacts that have occurred. Consequently, it seems that intuitives' risk perceptions are more likely to be grounded by extreme weather events.

5.3 Fatalists

Fatalists can be identified by the way in which they seemingly resign themselves to the significant risks and challenges that extreme weather and climate can present, with little or no apparent control over any possible impacts. They show a limited ability to recognise actions that can be taken in response to the impacts of weather events, resulting in a disjointed use of information to inform their risk perception and responses. Indeed, a fatalistic weather relationship is less likely to encourage proactive responses to limit asset damage, both during an event and through longer-term adaptations. Such farmers exhibit dismissive responses to information regarding the weather, with their fatalistic outlook culminating in enhanced vulnerability.

Fatalists, in a way comparable to intuitives, are spawned from a melting pot of cultural-behavioural influences. This includes personality traits; attitudes; values; beliefs; experiences; upbringing; and degree of connection with, and affinity for, 'the land'. This amalgam affects any use of both local and scientific information and so the specific farmer-weather relationship and current perception of risk that is developed. Fatalists differ from intuitives by virtue of the apparent detrimental effect that the relationship has upon them and the subsequent decisions made. Ironically, this can be derived from an over-emphasis on the acquisition of weather information, culminating in an obsession with it. An obsession with the weather is considered in this context to be a constant desire to know when, and to what degree, conditions might change. It is an acute expression of interest in, or fascination with, the weather, but from a perspective of vulnerability and lack of control. Of course, such characteristics of 'obsession' can be apparent within the analytical type relationship already discussed where they are associated with positive influences upon decision-making. However, within fatalists, these become extreme and coalesce to exert a negative influence upon a farmer's ability to perceive and respond to risk. Recognition of the importance of the weather snowballs into an all-consuming pursuit that impinges on, and detracts from, other duties. A fatalistic relationship is then created by an imbalance between interest in the weather and a farmer's ability to make reasoned decisions about farming practice, which the former then further affects:

> *"I think it does become an obsession with farming… I am a bit obsessed with the weather… especially checking the forecasts"* (Melissa, Worcestershire)

When obsession is fed by the process of seeking information, it comes to exert a disproportional influence upon a farmer's day-to-day life, leading to a fatalistic outlook. Melissa herself identified that a need to research the weather at multiple times throughout a single day, from up to ten different sources, actually hindered her ability to make informed decisions. The cause of such an obsession appears to be rooted in a need to have greater control over external influences on the farm business. Yet, it only served to deliver feelings of greater insecurity and less control, thereby fuelling a self-perpetuating dependency on acquiring even more data, at ever more frequent time intervals.

An alternative form of a fatalistic farmer-weather relationship is evident where the weather is seen as having total control over the farming system, limiting the farmer's ability to choose from a range of decisions. In this scenario, the weather is seen to behave in an autocratic way, exerting absolute power over farming operations. The farmer resigns him/herself to having little control; the weather effectively ruling the decision-making process:

> *"The weather in any form of farming dictates what you can do and when you can do it"* (Geoff, Worcestershire)

Unlike other farmer-weather relationships, it is the way in which such variability is viewed with powerlessness that exposes farmers' vulnerability. Such regard for the weather exposes vulnerability by restricting the perceived number of plausible adaptation options available to the individual. There is already research to suggest that farmers possess a fatalistic approach when discussing climate concerns, seeing a lack of control as a reason not to adapt (Mertz et al. 2009); and this assertion is further supported here:

> *"I don't know. I guess I haven't dared to think that far ahead really [to consider climate change]… Everything that we do really, the weather [is] a significant factor - I mean, our whole life is weather dependent, whatever we do…"* (Bonnie, Worcestershire)

Bonnie felt helpless in being able to make informed decisions. Such a fatalistic relationship creates a sense of futility in responding to the challenges posed by the weather. This is found to increase the vulnerability of a farm system as a whole because no viable adjustments or options are foreseen by farmers themselves: they feel completely controlled by the weather. Fatalists often appear helpless in their description of extreme weather events, as apparent in the 'inevitable' regard of possible impacts on the farm system. This therefore emphasises vulnerability, as opposed to resilience, to changes in extremes and the probable impacts of future climate change because adaptation measures are often not considered as a viable option to mitigate climate or weather risks. Fatalists can display a catastrophized and helpless perception of such risk, reduced ability to make informed responses and, ultimately, inaction.

5.4 Disengagers

Having defined and profiled analysts, intuitives, and fatalists, a fourth type of weather relationship is apparent which is more neutral in the influence it exerts upon a farmer. Disengagers are identified as those interviewees who appeared uninterested in discussing the influence of the weather upon their farm system. In such cases, it is apparent that a farmer outwardly does not allow the weather to exert much influence on their farm priorities. Instead, a multitude of other factors dominate risk perceptions about the farm, meaning that they think they have little need to consider the influence of the weather.

Disengagers discount the value of the weather and push its influence into the background of decision-making priorities. The weather then appears to have a covert influence on farm practices, as extreme weather and climate are not seen as a primary concern to the perception of farm risks Amongst disengagers, other factors, such as market prices, supply costs, or animal disease far outweigh the influence of the weather on theirday-to-day decisions and activities.

Disengagers give seemingly passive responses to, or even show disinterest in, climatic information, or the challenges weather can present:

> *"I don't bother with the weather anymore – if it rains, it rains, that's it!"* (Trevor, Worcestershire)

However, a disengaged relationship is not just characterised by an innate lack of interest. Some farmers are found to have evolved this attitude after previously having been far too concerned about the constant 'threat' of extreme weather events; only to have realised this themselves and then consciously retreated away from that position. Survey and interview evidence suggests that a disengaged relationship can develop in response either to specific past events or impacts, or to repeated exposure to extremes which skew a sense of normality. Accordingly, it does appear that the conditions of 2012 in particular, which produced excessive snowfall across southern Britain, encouraged respondents to become disengaged and uninterested in possible weather conditions:

> *"We used to check the weather every day, all the time in any way possible, but now we have given up"* (Spencer, Devon)

This demonstrates how a farmer can change the nature of his/her relationship with the weather; in the case of Spencer, transferring from active information seeking (for example, as in analytical relationships) to a conscious disengagement and subsequent passive regard for the weather. Further analysis of the evidence gathered points towards this retreat occurring most commonly where the previous relationship was fatalistic. In such cases, movement to a disengaged relationship does become beneficial in shifting any fatalistic impasse of inaction held by a farmer towards facilitating the making of appropriate farm adjustment decisions based on other information and priorities.

6. Discussion

Four categories of farmer-weather relationships have been outlined and identified from the experiences with extreme weather events outlined by farmers in the interviews conducted (see Tables 1 and 2). Some relationships, such as fatalistic ones, appear to be founded upon an internalisation of information where most emphasis is given to the extremes that have occurred. Others, such as shown by analysts, are based more on the recognition of a climatic norm, where deviations from it are recognised as such. What is clear from the evidence presented is that the weather has a role which extends beyond a mere physical presence in farm practices. It has been shown that the weather is intrinsically linked to cultural influences, subsequently reflected in farmers' interpretation of weather and climate information, which in turn feeds into their risk perceptions. Judgements are based on how combinations of local knowledge together with scientific meteorological and climatological information are prioritised. It is this interaction which characterises a farmer's relationship with the weather. This study has focused on cultural influences, although it is acknowledged that personality type will also have some effect on the way in which such relationships are displayed (Weiler et al. 2012).

Kahan et al. (2012) concluded that an improvement in the clarity of transmission of sound scientific information is unlikely to impact directly upon the formation of individuals' risk perceptions. Comparably, due to the complexity of influences found in the current study, it is unlikely that refinements to the ways that scientific information is currently communicated will immediately change farmer-weather relationships. Weber (2010) demonstrated that the complexity of risk perceptions is based upon the trust the person receiving such information has in the source. The findings of this research support the importance of this notion of 'trust', be it in scientific information or local knowledge. The level of that trust, which is informing risk perception, depends on a whole range of values, traditions and attitudes (Solvic 2010, Kahan et al. 2012) and fluctuates over time.

The typology of different farmer-weather relationships has been devised based upon a thematic analysis of the interviews conducted. What remains unclear from such qualitative-based analysis is the influence of structural variables such as farm type, age of farmer, gender or location of farm. Asplund (2016) found that climate change perceptions can be explained by demographic variables, people's values, worldwide views and identity. However, no obvious link between a structural variable and specific type of farmer-weather relationship has been found within the datasets compiled during this study. A more extensive quantitative questionnaire survey would be required to establish if such structural variables do have any discernible influence upon the type of farmer-weather relationship exhibited.

Devising this typology has further emphasised that a shift of focus is occurring from regarding climate change as an exclusively physical phenomenon towards a more social and cultural one (Hulme 2015). We have demonstrated that people are not blank canvases in receiving information about climate change. It is inevitably filtered through values and worldviews (Kahan et al., 2012), alongside an understanding of the weather as a process in itself and the application of local knowledge to make sense of information about it that is received. We have also found that farmers in the UK do apply personal experience and associative thinking to understanding weather and climate risk, thereby reaffirming findings from Asplund (2016), Weber (2010) and Weiler et al. (2012).

This typology serves to reject any dualistic distinction that might be made between learning by scientists, who apparently employ abstract and analytical reasoning, and by laypeople, who typically draw upon associative thinking and personal experience, as found by Asplund (2016). Instead, we have demonstrated that there is a continuum between using scientific reasoning and local knowledge based upon personal experience, which is far more blurred than simply being a scientist or a layperson. Under our typology, analysts are shown to think more scientifically, while intuitives blend information to inform risk perceptions based on both scientific and local knowledge sources. When looking at fatalists and disengagers, such a distinction is not so conspicuous, to the contrary of Asplund's (2016) assessment of laypeople. Coping strategies for extreme events are reliant upon local knowledge (Islam et al 2018), regardless of the farmer-weather relationship identified. In the developing world, local knowledge is often treated as a source of inputs to conventional planning processes and science frameworks (Naess 2013). In consideration of how our research has demonstrated the extent to which local knowledge is deployed by UK farmers, policy-makers must come to embrace it more as one of value in developed world contexts.

Perception is not a sufficient condition for adaptation alone because the latter is a two-stage process of perceiving such risk then responding to it (Asrat and Simane 2018, Deressa et al. 2011). This study can inform the understanding of risk perceptions amongst farmers, yet further research would be required to improve our understanding of farmers' adaptation to future climate risk. Even so, the typology presented does work towards understanding successful adaptation as the interplay between scientific climate knowledge and local knowledge (Solli and Ryghaug 2014).

This paper also responds to Bullock et al.'s (2017) identified need for more work into the resilience of food production at the farm scale through its assessment of weather influences on farmers' risk perceptions, the links to climate change adaptation and the long-term development of resilience in farming systems. Increasing frequency and intensity of extreme weather events will impact upon the ability of British agriculture to sustain or increase levels of food production, testing farmers' resilience to new limits. A farmer's ability to perceive risk, interpret information from their cultural context, and make judgements and decisions based upon multiple sources of weather information, will increase in importance in the future. They will need to have the capacity to withstand intense system shocks on a more frequent basis (Griffiths and Evans 2015).

7. Conclusion

This paper has presented a typology of farmer-weather relationships based on analysis of farmers' weather information seeking behaviour and experiences of being impacted by extreme weather events in the Welsh Marches, UK. The distinct role that local knowledge plays in each of the types identified strengthens the argument for establishing greater dialogue and cooperation between scientific-based meteorological services and 'lay' end-users to improve the quality of weather information services. This is especially so in the issuing of future warnings about predicted extreme weather and climate events, where technical accuracy is only part of an end-user's requirements in judging likely impacts (others include comprehensibility and acceptability; the latter being a product of the occurrence of false alarms - see Kox et al. 2018).

This research highlights that the application of a hybrid of scientific data and local knowledge, supported with personal observation, to the interpretation of the effects of the weather is a key process in farming, yet one varying considerably with the individual (see also Wynne 1992, Ingram 2008). This should be given a much higher level of recognition by National Meteorological and Hydrological Services (NMHS) when developing Climate Information Services (CIS) for the agricultural sector, not only in the UK but across the globe (in accordance with WMO Global Framework for Climate Services, WMO 2014). Tailoring such services to account for different personality types, using a typology such as this, could improve the effectiveness of the delivery of climate information to end users (Weiler et al. 2012). CIS need to take account of the different ways in which local knowledge informs the risk perceptions that farmers apply to the information they receive and, ultimately, to their responses and adaptations.

This typology can act as a tool to do so by allowing service providers to take into consideration the different ways in which analysts, intuitives, fatalists and disengagers seek and translate weather and climate information. For example, farmers who display characteristics of fatalistic or disengaged relationships present a much greater challenge for information providers. Both groups are less inclined to seek actively weather and climate information and so are much more likely to be slower to adapt to future climate challenges. If more tangible information were to be directly targeted to these groups, whilst simultaneously taking into consideration other areas of priority in such farmers' decision-making processes, weather and climate resilience could be encouraged. Future research is therefore required to explore which kinds of climate services could best engage hard–to-reach farmers and ensure that resilience to mitigate the potential impacts of future extreme weather events will be fostered and become widespread.

In accordance with this typology of weather-farmer relationships, we support the recommendation from Kahan et al. (2012, p.734) that climate and weather information providers should 'endeavour to create a deliberative climate in which accepting the best available science does not threaten any group's values.' These authors demonstrate although it is effectively costless for any individual to form a perception of climate change risk that is wrong but culturally congenial, it is very harmful to collective welfare for individuals in aggregate to form beliefs this way. Therefore, future research may wish to explore how the different farmer-weather relationships identified here expand individual risk perceptions and are influenced by collective risk perceptions and relationships. This would help to define the credibility of potential 'culturally diverse communicators' and enhance the ability of policy solutions to accommodate group diversity.

This paper has focused upon farmer-weather relationships that exist based on participants' experiences from the recent past and in the present day. To encourage the pull through of science into CIS which seek to improve agricultural resilience, further research is required to explore the influence that local knowledge has in farmers' interpretations of *future* climate impacts on the farm system; and how the typology presented in this paper can be applied in this predictive context of weather and climate services.

8. References

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Figures

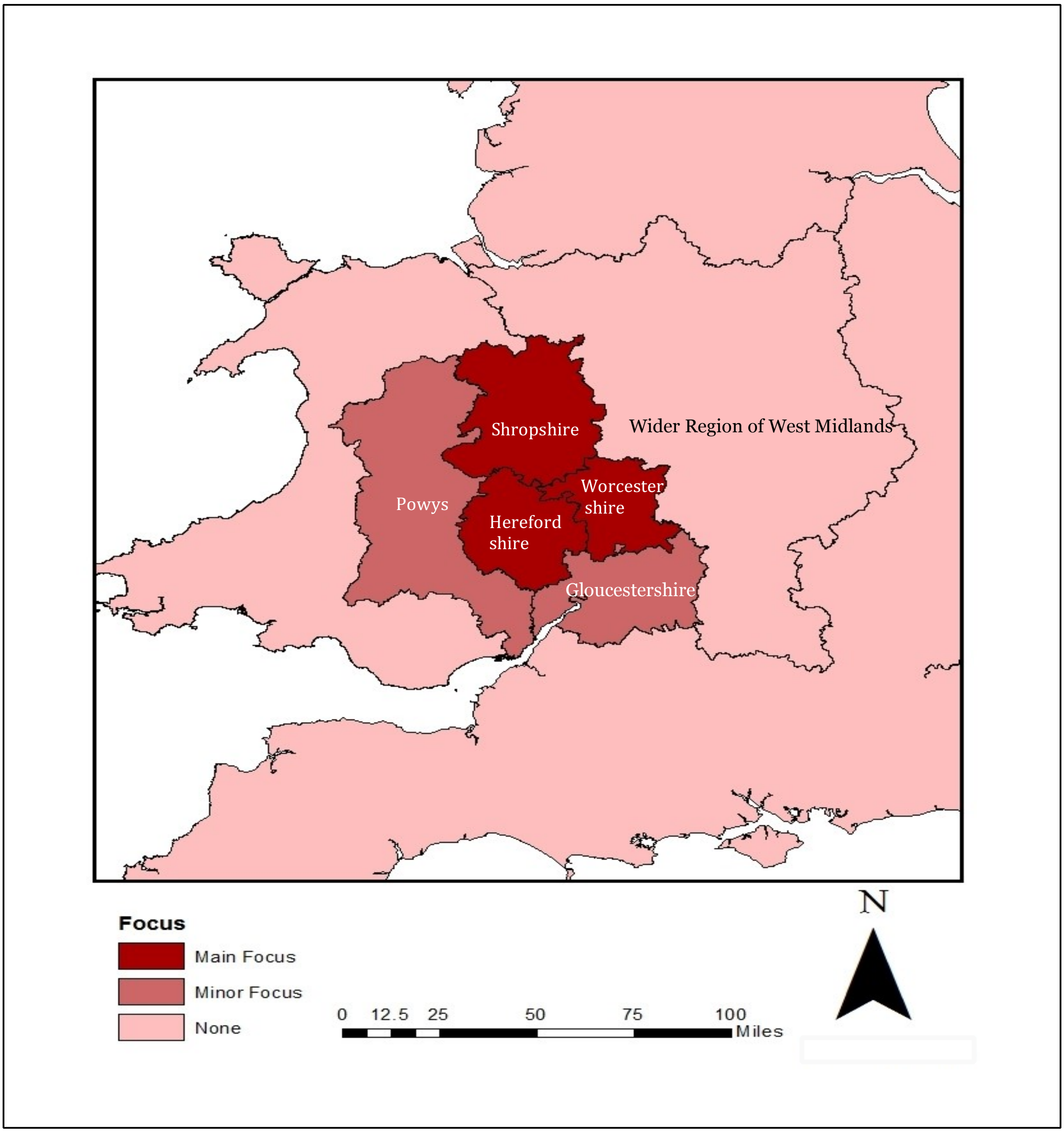

Figure 1. Location of the primary research area within the southern central Welsh Marches, UK.

Table 1: Typology of farmer-weather relationships by characteristics displayed.

Type of Farmer-weather Relationship	Characteristics[1]
Title: Analysts Approach: Analytical	• Overt influence on farm practices • Scientific approach to collecting and utilising structured datasets. • Informed risk perceptions based on official warnings, statistics, forecast and projections. • Reliance upon weather and climate information from meteorological services and other formal weather information providers. • Own weather station or sources of weather data and information. • Risk perceptions formed based upon scientific information and data. • Adaptations often made based on recognition of long-term trends of change and analytical decision-making. • Resilience to a changing climate is apparent.
Title: Intuitives Approach: Intuitive/Intuition	• Use of informal sources of weather information, such as use of weather diaries. • Use of local knowledge in understanding weather indicators and patterns on the land; this is often the primary source of weather and climate information. • Risk perceptions put in perspective of past events, and perceptions of 'normal' based on past experience. • Information is highly localised depending on characteristics of that specific area of land. • Deep connection with the land can be demonstrated, with an intrinsic and substantial stock of knowledge of how weather can impact it, including the use of 'old wives tales' to predict weather. • Adaptations are often made using locally specific information.
Title: Fatalists Approach: Fatalistic	• Some influence on farm practices • Fatalistic attitudes. • Can use local and scientific knowledge to form risk perceptions.

[1] Characteristics are listed as examples that define that farmer-weather relationship described, but this by no means intended as an exclusive list. Some farmers will demonstrate some, but not all, characteristics within that type of relationship. Others may demonstrate characteristics of more than one relationship.

	• Risk perception often heightened with an 'over-perception' of negative impacts. • No apparent control over weather or climate impacts. • Often a helpless or fatalistic description of extreme weather, emphasising vulnerability. • Adaptations are often not considered as a feasible option to mitigate any risk.
Title: Disengagers Approach: Disengaged	• Covert influence on farm practices • The farmer has no apparent connection with the weather. • Other farm priorities and decision-making factors far outweigh risk perceptions or any concerns or attention to the weather. • The weather does not inform day-to-day farm practices. • Extreme weather and climate are not a primary concern or a contributing factor to perceptions of farm risk. • Often other factors e.g. farm income, market fluctuations, animal disease, far outweigh the influence of the weather on a farmer's day-to-day activities.

Table 2: Farmer-weather relationships identified within interviewees.

Interviewee (Pseudonym)	Relationship Identified [2]	Evidence
Albert	Analytical	Scientific approach; rainfall data collected; use of digital weather station to make logical decisions.
Bonnie	Fatalistic	Fatalistic to events experienced and future conditions.
Charles	Fatalistic/ Intuitive	Fatalistic use of local knowledge of weather conditions.
Dennis	Intuitive/ Fatalistic	Fatalistic use of informal weather diaries to assess conditions.
Enid	Analytical	Scientific in approach; rainfall data collected used to make logical changes.
Frank	Intuitive	Spiritual connection with weather; many observations rooted in local knowledge.
Geoff	Intuitive/ Fatalistic	Informal connection and respect for the weather; negative influence upon decision-making.
Henry	Intuitive	Informed regard for the weather; used local knowledge and observations of conditions to adjust and experiment accordingly.
Isaac	Disengaged	No apparent connection with the weather.
John	Intuitive	Informal connection with the weather built upon casual observations; intricate understanding of the way in which 'the weather' impacts locally.
Kate	Intuitive	Informal connection and respect for the weather.
Luke	Intuitive/ Analytical	Informal connection and respect for the weather; informed decisions with digital weather data.
Melissa	Fatalistic	Became 'obsessed' with the weather.
Nathan	Disengaged	No apparent connection with the weather.
Owen	Fatalistic	Little control over influence of weather on decisions; fatalistic attitudes.
Phillip	Disengaged	No apparent connection with the weather.

Source: Authors' interviews.

[2] Where distinct characteristics of more than one relationship category have been identified, the relationships are listed in order of the most dominant first.