Adaptive Management for Peatland Carbon in the Dark Peak

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Executive Summary

The Dark Peak of the Peak District National Park represents a complex socio-ecological system (SES) that is adapting to a changing climate and shifting policy context. This project used an adaptive management approach to understand how the peak district can manage for carbon in the face of chronic scientific uncertainty. Adaptive management emphasises the importance of institutions in facilitating collaborative knowledge production that uses the knowledge of all stakeholders to reach better, more legitimate management decisions. The key results from our project are as follows:

- Stakeholder mapping identified three critical groups of stakeholders in relation to carbon management in the Dark Peak social-ecological system: the scientific community, statutory bodies/policy-makers and land managers/owners. A fourth hybrid group was also identified where the actors had dual or multiple roles.

- Interviews revealed that there is high interest amongst all stakeholder groups for a carbon agenda. However, it is tempered by the scientific uncertainty surrounding peatland carbon dynamics, along with conflicting interests and ineffective collaboration between the different stakeholder groups.

- Social Network Analysis has revealed that carbon stakeholders in the Dark Peak form a very well connected network with strong communication ties. While it appears that no stakeholder is disconnected or completely marginalised, knowledge produced by certain types of stakeholders is simply disseminated, rather than being produced in a collaborative and iterative way.

- Land managers have valuable lay knowledge about the Dark Peak socio-ecological system that needs to be included in the process of knowledge production. Further, land managers are the eventual implementers of knowledge, and need to be involved in knowledge production in order to generate buy-in for decisions taken under conditions of inherent uncertainty.

- Existing collaborative management arrangements between land managers provide great potential for improving and enhancing these knowledge ties that could lead to more successful and stronger collaboration around carbon management within the network.

- Involving all the key stakeholders in knowledge production will produce more robust carbon management and enhance trust amongst those implementing the plans. This will require a shift from the traditional linear model of knowledge production to a cyclical one where all stakeholders are involved in a process of '*learning while doing*'.

- Co-producing knowledge about carbon management strategies requires innovative governance mechanisms and engagement strategies, for example that experiment and learn with different management strategies. Ways in which to facilitate this kind of learning warrant further research.

1. INTRODUCTION

Increasingly, environmental problems of protection and conservation, economic development, social welfare, adaptation to climate change can not sufficiently be addressed by conventional command-and-control policy making, where state actors collect the necessary expertise, develop a regulatory solution and implement it through legislative and executive processes. The uncertainties, complexities, interconnectedness, multiple layers and the numerous potential consequences of any (regulatory) solution necessitate a governance approach that recognizes the complex inter-linkages between social and ecological processes.

An increasingly important approach to governing highly complex and uncertain systems is adaptive management. Developed from ecosystem management (Holling, 1978; Walters, 1986; Pahl-Wostl, 1995; Lee, 1999), "*adaptive management refers to a systematic process for continually improving management policies and practices by learning from the outcomes of implemented management strategies*" (Pahl-Wostl, 2007, p. 51). Adaptive management is a way to increase the capacity of a system to adapt to change under conditions of uncertainty. Adaptive management emphasises the importance of institutions in facilitating collaborative knowledge production that uses the knowledge of all stakeholders to reach better, more legitimate management decisions (Evans, *forthcoming*).

Adaptive management combines insights from institutional theory with those of ecological systems to focus on the role of self-governing institutions in managing common pool resources (Hatfield-Dodds *et al*, 2007). The peat ecosystem of the Peak District National Park (PDNP) is characterised by the dynamic intersection of ecological and social processes, and is ideally suited to an adaptive approach. Peatlands attribute their increasing ecological importance to climate change mitigation through maintaining the carbon budgets at equilibrium. The peatlands of the PDNP, and of the UK respectively, hold a critical position among the Northern hemisphere peatlands as they are located in the most southern position and therefore will act as an early alarm system for the effects of climate change on these ecosystems. Moreover, policy frameworks address peatlands as forests (Parish & Silvius, 2008) and thus fail to recognise their special socio-ecologic characteristics, which are critical in determining whether they behave as carbon sinks or carbon sources (Worrall and Evans, 2009). Furthermore, research and natural resource management policies in the past two decades have focused primarily on the promotion of ecosystem services such as clean water (Agnew and Woodhouse, 2010), the reduction of soil erosion (Worrall and Evans, 2009) and the conservation of biodiversity (Dougill *et al*, 2006; Quinn *et al*., 2008). Hence, as carbon budgets become critical due to climatic change, new forms of management are required to ensure socio-ecological systems adapt and therefore continue delivering the most important ecosystem services.

This project is a first attempt to examine the socio-ecological system (SES) of the peatlands in the Dark Peak area of the Peak District National Park in terms of its capacity to absorb disturbance, self-organize and develop; and finally, increase its ability for learning, adaptation and resilience. We explore how carbon, as a new factor in environmental policy and land management agendas, may be used as an organising principle in order to build a peatland management network more resilient to human and natural disturbances. The project represents an innovative first attempt to apply the framework of adaptive management to a peatland social-ecological system.

1.1. Report structure

Section 2 outlines the theoretical context which underpinned our research. Section 3 presents the research design and detailed information on the methodology, both in terms of the framework for mapping processes of public engagement and dialogue, and methods of data collection. We present the results in Section 4, offering a brief overview of current practice across the SES of the Dark Peak in the PDNP before moving on to the discussion, which addresses the research questions. On the basis of this analysis, Section 5 concludes by offering insights into advice on future development needs in relation to the implementation of adaptive management.

2. CONTEXT

2.1. The Importance of Peatlands

Peatlands are fundamental natural ecosystems. Whilst covering approximately $4 * 10^8$ ha of the Earth (Lappalainen, 1996; Zoltai and Martikainen, 1996; Joosten and Clarke, 2002) they are distributed almost across every country of the world (Figure 1). Peatlands play an important role in climate regulation. Over the past 10,000 years peatlands have absorbed an estimated 1.2 trillion tonnes of carbon dioxide (CO2), attributing to the net cooling process of the earth. It is estimated that peatlands are currently the largest long-term terrestrial sink of carbon by storing twice the amount of carbon in comparison to the world's forests. However, human activities during the last century have degraded peatlands bringing them to the verge of transforming from a net sink to a net source of carbon emissions (Worrall and Evans, 2009).

This process in combination to fossil fuel emissions and deforestation and forest clearance has aided climate change through increased global concentrations of carbon dioxide and other GHG's. According to the IPCC (2001), current changes in global temperatures and rainfall regimes have already augmented peatland degradation and will continue doing so. Further analysis on peatlands and their carbon superiority will take place in the following section 'Peatlands and Carbon'.

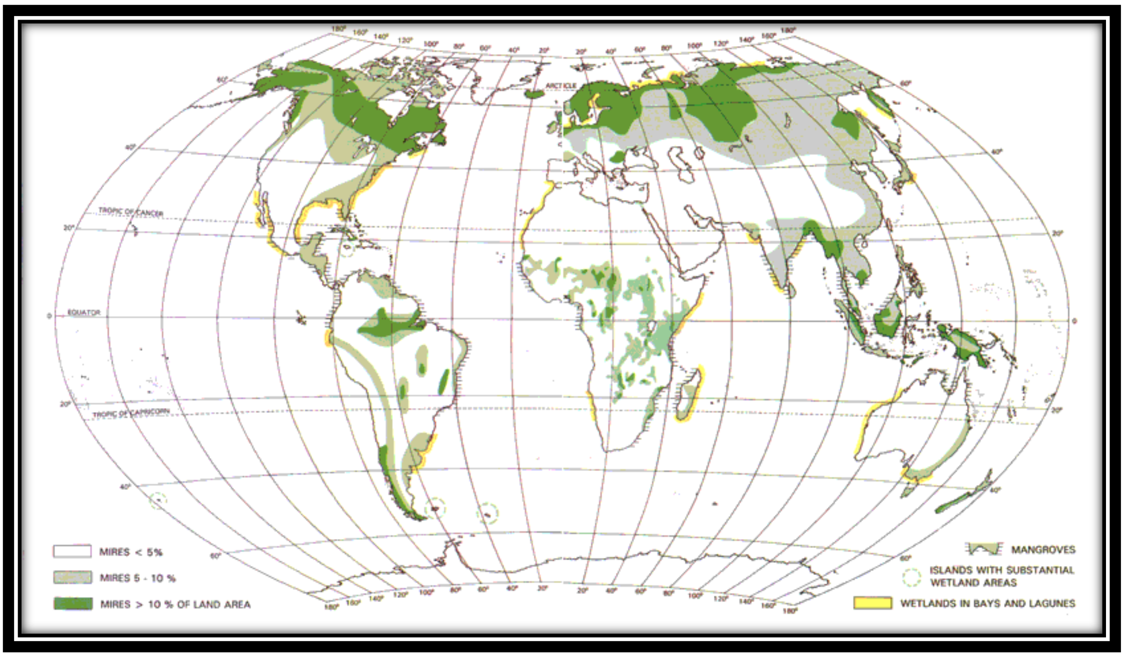

Figure 1. The above image depicts the distribution of peatlands at a global scale. The white areas indicate a prevalence of mire that is below 5%, whereas the light green areas illustrate a 5-10% ranging prevalence. Finally, the dark green parts (>10%) are those that occupy the greatest land cover. (Source: Lappalainen E., 1996. (Ed.) *Global Peat Resources*. International Peat Society and Geological Survey of Finland, Jisky.)

From a social point of view, peatlands hold a unique place within human societies as aesthetic configurations that also provide a wide range of natural resources and ecosystem services (for example, educational, recreational and research visits, water for drinking and irrigation, land for cattle and agricultural cultivation). Humans have exploited the peatland environments for thousands of years, leading to varying degrees of impact. The Minyans drained and subsequently cultivated the Kopais basin in Greece 3.500 years ago (Knauss *et al,* 1984); whereas some centuries later the Babylonians established municipal reed beds and harvested bulrushes for construction purposes (Boulé, 1994). They important socio-economically to many societies, and bear the scars of historical conflicts and contradictions over their use.

Furthermore, peatlands play an important role in catchment hydrology with respect to water storage, water quality, the support to water levels and flood and drought mitigation (Silvius *et al.*, 2008). According to Joosten and Clarke (2002), peatlands regularly constitute important components of local and regional hydrological systems and have the ability to purify water by removing pollutants. Extensive peatlands may govern the surface and groundwaters and abate droughts and floods (Holden, 2009). For example, coastal peat swamps behave as a shield between saltwater systems and freshwater systems, prohibiting saline infiltration into coastal lands.

The water storage and retention ability of peatlands is of great significance for local livelihoods not only because it is, for some regions, the main supplier of drinking water, but also because it is used for irrigation of agricultural lands. For example, in the wider area of East Midlands, West Midlands, North West, Yorkshire and Humber, which accounts for almost 48% of England's population, the water for drinking and irrigation is derived from peat catchments in the Peak District National Park (Peak District National Park, 2004). Unsustainable, ineffective and short sighted land practices of the peatlands have often impacted adversely on local communities and regions leading to broader threats associated with floods, water shortages, air pollution from fires etc (Parish *et al.*, 2008).

2.2. Peatlands, Carbon Cycles and Management

While containing only 3% of the globe's land area, peatlands contain 450 Gigatons (Gt) of carbon in their peat (Table 2.4.1.1) (Gorham, 1991). This is equivalent to 30% of all soil carbon, 75% of all atmospheric carbon, as much as all terrestrial biomass, and twice the carbon stock of all forest biomass of the world (Joosten and Couwenberg, 2008).

Table 1. How peatlands compare with other carbon stores (Source: Parish, F., Sirin, A., Charman, D., Jooster, H., Minayeva, T., Silvius, M. and Stringer, L (Eds.) 2008. *Assessment on Peatlands, Biodiversity and Climate Change: Main Report*. Global Environment Centre, Kuala Lumpur and Wetlands International, Wageningen).

Storage/area characteristic	Statistic
Area covered by peatlands	400 million ha (Joosten and Clarke, 2002)
Carbon stored by peatlands	550-560 billion ton (IPCC, 2001)
Carbon stored by all global plant biomass	694 billion ton
Carbon stored in the world's soils (including peat)	1.600 billion ton
Carbon in the atmosphere	700 billion ton (Gorham, 1995)

This makes peatlands the top long-term carbon stock in the terrestrial biosphere. Furthermore, according to IUCN (2009), damaged peatlands are responsible for at least 7% of the world's carbon dioxide emissions. The same report mentions that the UK has the 17th largest peatland area, out of 175 nations with peat deposits and is in the top 20 countries with the most damaged peatlands.

It has been estimated that more carbon is stored in Britain's soils than in the forests of Germany and France combined (Reed *et al*., 2009). Peatlands hold a significant proportion of around 3 billion tonnes of UK soil carbon (Holden et al., 2007; Worrall and Evans, 2009). Moreover, peat bogs can actively sequester carbon. Studies estimate that all of the peatlands in England and Wales could absorb around 400,000 tonnes of carbon per year if in pristine condition. The large stocks of peatland carbon are an indication of the long term nature of carbon sequestration in peatlands rendering the ecosystem not only a substantial store but also a large potential sink of atmospheric carbon (Worrall and Evans, 2009). However, with the current rate of climate change (Worrall and Evans, 2009) and pressures from upland land policies there is great risk that this important natural carbon depository could be transformed from a net sink into a net source.

In addition to external environmental drivers, many peatlands are subject to land management systems that have not always been conducive to carbon storage (Holden *et al*., 2007). In the UK these management systems typically include: drainage, afforestation, burning, and grazing. Peat drainage has been common in many European countries. In the UK it has been estimated that 1.5 million ha of the country's 2.9 million ha of peat has been drained (Stewart and Lance, 1991). Increased soil CO_2 respiration has been observed upon drainage of peatlands (Silvola *et al*., 1985).

Afforestation has been a significant cause of the net moorland habitat loss over the past century in the UK. Nine percent of upland UK peatland has been afforested (Cannell *et al*., 1994) and while carbon is taken up by tree biomass as the forest grows, there may be severe depletion of the soil carbon store through enhanced decomposition of the organic soil through lowering of the water table (Cannell *et al*., 1994).

In England, it has been estimated that 40% of moorland has received some burn management (DEFRA, 2007). Rotational burning is practiced to maintain a mosaic of heather age classes and maximise heather productivity in the building phases. Plant community species composition and vigour of primary productivity depend upon conditions and burn frequencies. Beyond changing primary productivity managed burning has also been shown to influence water table, DOC concentrations (Worrall *et al*., 2007), POC losses through soil erosion (Tallis, 1987); and overall peat accumulation (Garnett *et al*., 2001).

Grazing on uplands in the UK can be by cattle or deer but is predominantly by sheep. Depending upon its intensity, grazing can reduce competitive vigour, or even kill plants through defoliation and direct damage: overgrazing is thought to be a major cause of: heather moorland loss (Shaw *et al.,* 1996); changes in hydrology (Langlands and Bennett, 1973) and increased erosion of peats (Sansom, 1990).

While land management practices can result in damage to long-term carbon stores in peat soils land management practices can more readily be reversed than external drivers such as atmospheric CO_2 (Worral *et al.*, 2009). For example, Tuittila et al. (2000) illustrated that upon restoring a cut-away peatland there was a statistically significant increase in CH_4 flux. The carbon benefit of peat restoration or changed management can be considered to be threefold. Initially, the peatland could presently be a net source of carbon and a change in management or restoration could result in this source being diminished in magnitude. Such a decrease represents a carbon saving that we can consider as an avoided loss. Subsequently, between the state of a damaged peatland, which is a net source of carbon, and a pristine peatland there is a transitionary stage. This transitionary stage can be of carbon benefit due to both avoided losses and net gains of carbon. For example, this transitionary sink could be the period during which an eroded gully refills with peat. Finally, several researches have indicated that properly managed or pristine peatlands store carbon and provide long-term sinks. This ability for continuous accumulation of carbon makes the peat environment invaluable in carbon-worth terms compared to other ecosystems. Other ecosystems, such as forests, can accumulate biomass and store carbon, but the system will reach a steady-state equilibrium within which there is no continuous carbon sequestration.

The disturbance in UK peatlands caused by ineffective implementation of land policies and management such as over-grazing, excessive burning, clearance, drainage, resulting in erosion and drainage, scientists estimate result to 381,000 tonnes of carbon emissions per year. The Peak District peatlands, in particular, store between 16 and 20 million tonnes of carbon and have the potential to sequester up to 13,000 tonnes of carbon per year (Moors for the Future, 2007). Furthermore, in the Peak District, up to 100 tonnes of carbon are lost annually per km² in some eroding catchments where wildfires have caused large areas of bare peat devoid of vegetation (Evans et al, 2005), whereas the Dark Peak area has been a constant carbon emitter for the past 200 years due to excessive erosion.

2.3. Property Rights and Peatland Management

Ineffective implementation of land policies in UK uplands (including peatlands) is the result of conflicting interests between landowners/managers due to complex property rights regimes that govern natural resource management in UK (Quinn *et al*., 2008). For the purposes of this subchapter the word 'upland' will be used extensively and will encompass the definition of peatlands as well. There are two potential origins of conflict over natural resource management in the uplands. The first originates from the conceived legitimacy of certain rights holders to own those rights and exercise them. It is a fact that many land-owners and tenant farmers-managers who have an extensive family history in upland areas consider their rights unfairly removed or reduced by transformations in government policies. This conflict seems to stem from disparate understandings of property. Most land-owners tend to conceive ownership as having exclusive rights over the land and also the capability to implement their decisions without any legal interference. On the other hand, other land-owners may regard property rights as a movable object that can be allocated to various stakeholders and illustrate that there are various values connected with the land. Furthermore, land-owners still refuse to be reduced or removed of their rights (Quinn *et al,*2008).

The second source of disagreement lies within the different aims concerning management among land holders. Whilst rights holders manage uplands to capitalize on water quality, carbon or conservation this can lead to conflict with other property holders such as grouse moor owners and farmers who manage uplands to maximise production. It is argued that management for production may cause water discolouration, water acidification, carbon loss and reduced biodiversity despite that there is no obvious evidence (Holden *et al,* 2007; Quinn *et al,* 2008). This in turn implies that it may be impossible to manage uplands in order to capitalize on all ecosystem services in tandem. The dispute then revolves around which of the rights holders has the power to override the others in exercising their rights over land management.

Moreover, the current management status quo is unable to affect land management decisions for the whole array of ecosystem services provided. This is partially because of the uncertainty that governs different land management practices of some ecosystem services (Quinn *et al*, 2008). Until these effects become more unambiguous it is difficult to assign accurate property rights to each stakeholder.

2.4. Description and Justification of the Study Area

Established in 1951, the Peak District National Park, subsequently termed Peak District, was the UK's first National Park. It is situated at the southern end of the Pennine Hills (see Figure 2), straddling four Government regions (East Midlands, West Midlands, North West, Yorkshire and Humber) that together contain around 48% of England's population, making it one of the world's most visited national parks with over 22 million visitors a year (Peak District National Park, 2004).

In addition to the demands that these visitors put on the landscape, the area has a resident human population of 38,000 (Office of National Statistics, 2003). As with many other UK uplands, the Peak District has undergone significant socio-economic (e.g. demographic) and subsequently environmental (e.g. climate) changes (Arblaster *et al*., 2009). Many new residents have moved to the Park to retire or to purchase holiday homes whereas younger, unskilled workers have been priced out of local housing markets (Dougill *et al*., 2006). This has created labour shortages for traditional land management practices. Both farming and grouse-shooting activities operate at the margins of financial viability, and are reliant on agricultural subsidies. Some 93% of the Park qualifies for funding under the European Commission Directive for special assistance to Less Favoured Areas 75/268/EEC (ADAS, 2003).

The Park also contains two Environmentally Sensitive Areas (ESAs) that provide payments to land managers to maintain certain landscapes, wildlife or historical features. Of particular ecological interest is the Dark Peak area, characterised by extensive heather moorland and blanket bog habitats, surrounded by enclosed pastures in deep, narrow valleys. Blanket bogs are ecological communities characterised by cotton grasses, sphagnum mosses and dwarf shrubs. They form uniquely on top of hill land that is subjected to heavy and infrequent rainfall over acid peat that is over half a metre deep. This habitat is internationally important, being recognised as key biodiversity habitat (UK Biodiversity Steering Group, 1995), containing a number of 'Sites of Special Scientific Interest' (SSSI) (English Nature, 2003), and listed in the EU's Habitats Directive (92/43/EEC) as requiring special conservation measures as 'Special Areas of Conservation' (SAC) and 'Special Protection Areas' (SPA).

Changes to the farming subsidy system are currently progressing with reform of the EU's Common Agricultural Policy (CAP). The CAP reform has replaced output-based subsidies with Single Farm Payments for 'environmentally sensitive agriculture' that rewards farmers for using more sustainable management practices and promoting wildlife habitat (Lowe et al., 2002). Rural land managers are also trying to adapt to the EU's Water Framework Directive that requires all inland waters to achieve 'good status' by 2015.

Furthermore, as with most UK upland environments, the Peak District is subject to a complicated system of property rights (Figure 3) regimes. While land might be in private ownership, rights of withdrawal, access and management of different resources on that land may be afforded to different stakeholders. This can result in private property regimes, common property regimes and state control overlapping as they seek to manage resources in the same landscape for different objectives, sometimes leading to conflict between the different rights holders. At the same time climate change, as previously mentioned, economic development and changes to agricultural and other policy drivers is an indication that the relative significance of different ecosystem services is changing along with the balance of power between different stakeholders.

This complex and changing background makes the Peak District typical of a range of rural settings within and outside the UK where traditional upland management is under pressure. All of the above reasons made the Peak District a relevant locale in which to examine the adaptive management approach.

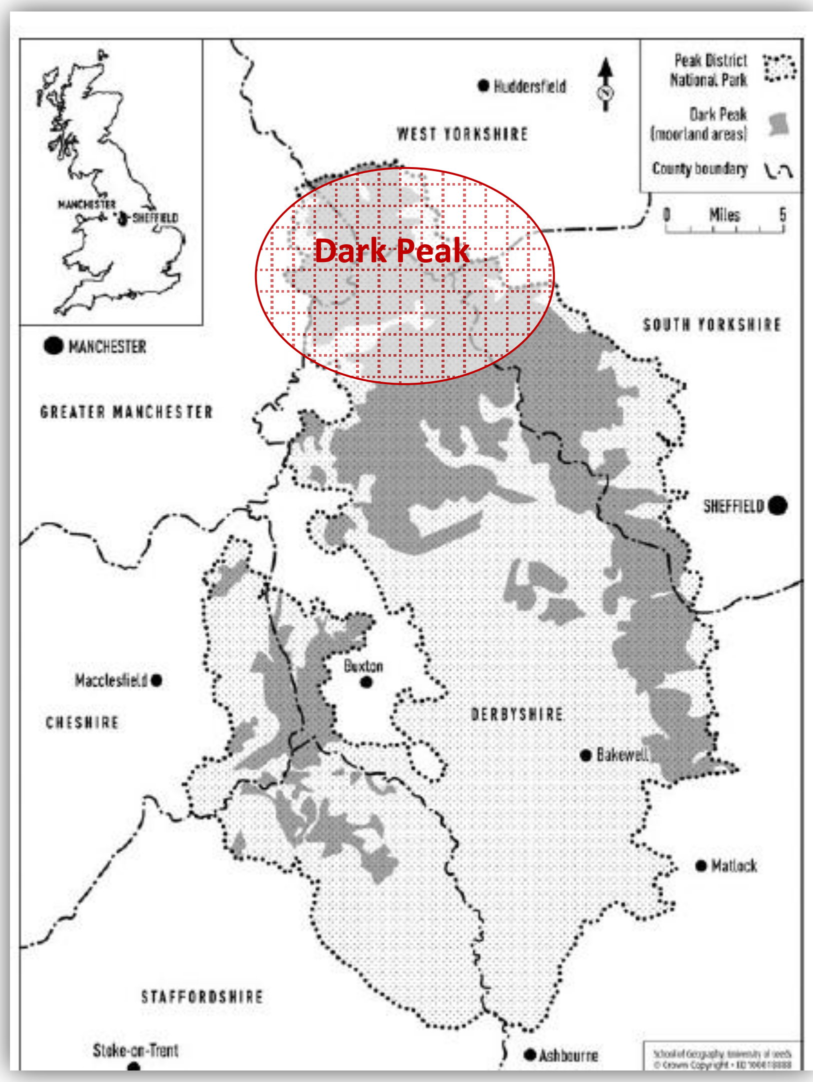

Figure 2. Map of the Peak District National Park. The red circle indicates the area under study (Dark Peak) (Source: Dougill *et al.*, 2006).

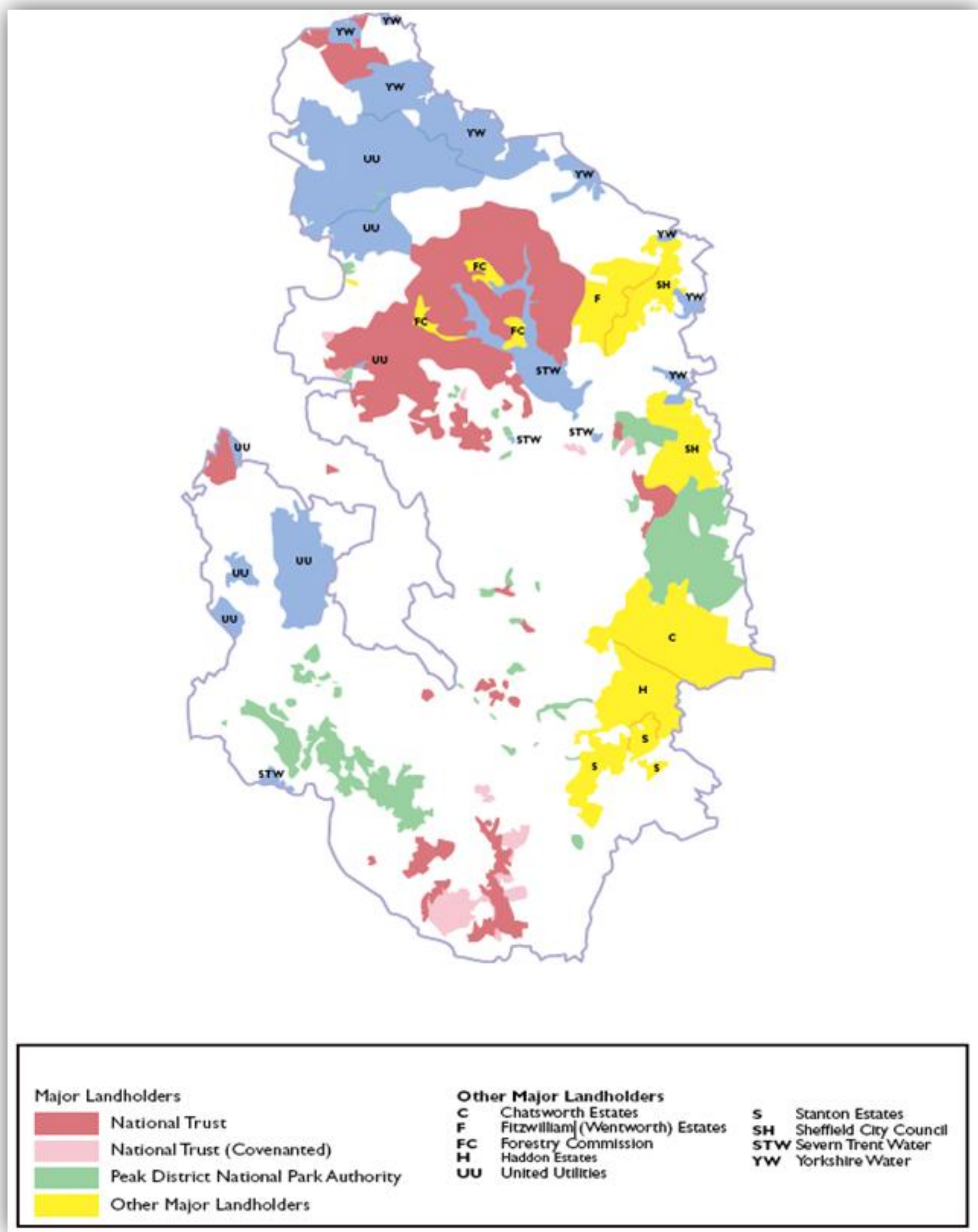

Figure 3. Major land ownership in the Peak District National Park (Source: *Peak District National Park* Authority, 2006).

2.5. Uncertainty, Science and Policy

One of the most prominent areas of concern, that seems to be causing reluctance in terms of risk taking, experimentation and innovation in terms of adaptive management, is the level of scientific uncertainty that governs carbon knowledge (Agnew and Woodhouse, 2011). The origins of uncertainty can be depicted as flowing from sets of assumptions about future socio-ecological activity (Figure 4):

- Changes in socio-ecological activities and controls (adaptation)
- Future emissions of greenhouse gases
- Residence and concentration in the atmosphere
- Global climate change
- Regional and local changes in climate
- Impacts upon carbon budgets
- Carbon budget management

Figure 4. Impacts chain of uncertainty (Adopted from Agnew and Woodhouse, 2011. Source: Agnew and Fennessey, 2001).

Scientific models estimate the rates of gas emissions, their atmospheric residence, computed climate change, some initial patterns of carbon budgets and finally potential regional and local impacts (Worrall and Evans, 2009; Agnew and Woodhouse, 2011). If the models are incorrect then predictions of impacts will be unreliable. Even scientists themselves acknowledge the eventual future for upland peats in the UK to be uncertain. However, as research has indicated so far there are some ground assumptions that appear to have positive effects regarding carbon budget control. Therefore, despite the uncertainty in the long-run, in the short to medium term there are appropriate management practices to support the increasingly disturbed peatland socio-ecological system. The effectiveness of a strategy though depends heavily on its implementers and supporters.

Despite awareness from policy-makers of the environmental and economic importance of this region, serious problems exist. For example, even though approximately 80% of Peak District moorlands are designated as SSSI, many of these areas are classified as being in an ‘unfavourable condition’. This is due to a range of pressures including overgrazing and the use of inappropriate burning methods that fail to maintain the ecologically diverse and economically productive mix of young and mature stands of heather and other dwarf shrubs.

One reason these problems persist is that the broad range of stakeholders place complex and competing demands on the landscape, whereas current management practices fail to integrate the range of socio-ecological and socio-economical pressures. Another problem is that our understanding of the natural processes within these SES remains limited, with reductionist linear scientific approaches unable to provide improved understanding on a landscape scale. Consequently, there is a need for management plans that can adapt to social values, changing scientific understanding and ecosystemic climate change. This requires all stakeholders to collaborate so that different sources of knowledge can be integrated and reconciled. Such co-production of knowledge has the potential to minimise the risk of conflicts (Evans, *forthcoming*), not just between traditionally conflicting ecological and economic values but also among environmental management interests (Walters, 1997). However, collaboration between stakeholders, and in particular between institutions, researchers and rural managers, is often limited by a lack of effective communication and mutual learning (Lee, 1999). As yet, there is no consensus on how to integrate scientific and local knowledge and perceptions (Abelson et al., 2003), let alone on how to incorporate such diverse opinions into policy or land management advice (Folke et al., 2002).

To address these challenges, we have build upon the literature on adaptive management to identify approaches that can actively engage the key stakeholders of the Dark Peak area in a collaborative research process. Adaptive management, sometimes referred to as '*learning while doing*', is a methodological approach that sets up policy options as if they were experiments to be studied (Holling, 1978; Walters, 1986). To accomplish this, experiential learning theory suggests that it is necessary to reflect on and learn from past experiences to ensure that planning captures the complexity of a multi-stakeholder world. These ideas were first presented in Confucius's (c. 450 bc) famous maxim: 'Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand' (as adopted from Dougill *et al*., 2006).

3. RESEARCH DESIGN

This section discusses the epistemological and methodological assumptions, as well as the proposed methods and research design of this research.

3.1. Research Questions

i) Who are the key stakeholders in peatland governance of the Peak District National Park?
ii) How do they use the carbon knowledge produced about peat and how do they assess this knowledge in order to learn?
iii) What opportunities exist to enhance adaptive management?

3.2. Aims and Objectives

The work described in this report forms a part of an ongoing PhD project that aims to employ the adaptive management model in an attempt to understand and potentially enhance the way in which knowledge is produced and used for the management of ecosystem services in terms of carbon storage and sequestration in the Dark Peak area of the Peak District National Park.

The main objective of this research is to explore whether the adaptive management approach it may be able to foster more robust and resilient governance of complex socio-ecological systems that deal with carbon storage and sequestration. As stated in the literature (Walker *et al.*, 2004; Adger *et al.,*2005; Evans, 2009; Evans, forthcoming), managing for resilience enhances the possibility of sustaining desirable pathways under conditions of uncertainty.

The research design comprises of three interlinking elements: a stakeholder mapping exercise, a set of semi-structured interviews with key stakeholders, and a social network analysis. The stakeholder mapping exercise was used to identify key structural elements of the adaptive capacity of the Dark Peak SES. In combination with the workshop the key stakeholder's list was enriched and consequently informed the semi-structured interviews. The social network analysis was conducted using the interview data. All elements of the research design address all three research questions.

3.3. Methodology

3.3.1. Identification of key stakeholders

Much of the stakeholder identification literature has presumed that stakeholders are self-evident and self-construed, and has been primarily preoccupied with categorising pre-identified stakeholders to determine their interests and relationships. However, before this can be done, it is necessary to establish who holds a stake in the system under investigation. This in itself calls for an explicit understanding of the matter under study so that the limits of the social and ecological systems can be configured. This delineation allows then a number of methods to be used to identify the relevant stakeholders.

Identifying stakeholders is ordinarily an iterative process, during which additional stakeholders feed into it as the analysis progresses, for example, using semi-structured interviews, focus groups, snow-ball sampling, expert opinions, or a combination of these. If the boundaries of the system itself are explicitly determined, then stakeholders can be moderately easily identified. However, there is a risk that some stakeholders may be accidently omitted and as a consequence not all relevant stakeholders of the system may be recognized (Clarkson, 1995). On the other hand, it is often not possible to include all stakeholders and a line must be drawn at some point, based on well-founded criteria established by the researcher (Clarke and Clegg, 1998). These may include for example, geographical criteria like the boundary of a National Park or demographic criteria such as nationality or age, depending on the focus of the analysis or even time limitations of a particular research project.

Each stakeholder in the case study area allegedly has an interest and an involvement in the system under investigation. Nevertheless, a fundamental problem lies in deciding whether the system under study should determine which stakeholders are involved, or whether it should be the other way around (Reed *et al*., 2009). This issue is not taken into account very often in stakeholder analyses, possibly due to the difficult dialectic between identifying stakeholders and identifying which aspect of an organisation's activities, which intervention, or which issue to focus on. However, without knowing the issue, it is difficult to know which stakeholders should be involved in identifying the focus (Dougill *et al*., 2006; Prell *et al*., 2008). As a result, the focus is usually identified in a top-down manner by the researchers leading the stakeholder analysis and may therefore reflect their interests and biases, which might not reflect the interests of stakeholders (Clarkson, 1995; Varvasovszky and Brugha, 2000).

Chevalier and Buckles (2008) lists a range of other ways to identify stakeholders, including: identification by experts or other stakeholders (i.e. through conferences, workshops or other academic activities); by self-selection (in response to advertisements or announcements); through written records or census data which may provide information to categorise by age, gender, religion and residence; through oral or written accounts of major events (identifying the people who were involved); or using a checklist of likely stakeholder categories. Who is included and who is omitted may depend on the method used for identifying stakeholders and purpose of the research. This is important, as it affects ''*who and what really counts*'' (Mitchell *et al*., 1997). Generally, if the main objective of the research is the equal distribution of the costs and benefits of a project (e.g. in project planning and implementation), all stakeholders may need to be included (Grimble *et al*., 1995). When the main interest is the effectiveness of a project or organisation (e.g. in a management context), only those stakeholders who are most likely to affect the functioning of the project or organisation given their interests, resources, and influence are usually included (Grimble *et al*., 1995).

Finally, there are a collection of methods that have been developed to investigate the relationships that exist between stakeholders (as individuals and groups) in the context of a particular phenomenon. There are three principal methods that have been used to analyse stakeholder relationships: i) Actor-linkage matrices ii) Social Network Analysis, provides insights into patterns of communication, trust and influence between actors in social networks, and; iii) Knowledge Mapping, analyses the content of information between these actors. This project will employ Social Network Analysis in order to shed light into defining social structures and processes, such as distinguishable subgroups and information exchange, and the adaptive capacity of the governance network.

3.3.2. Stakeholder mapping exercise

To identify the key stakeholders involved in peat governance in the area of the Dark Peak we conducted an iterative stakeholder analysis involving data from: i) previous research projects conducted in the area through the literature (see Doughill *et al*., 2006; Prell *et al*., 2008 and Reed *et al*, 2009), ii) by consulting stakeholder lists from Moors for the Future Partnership (MFFP), iii) by snowballing through a workshop organised by MFFP for PDNP stakeholders and finally, iv) by semi-structured interviews.

The research projects within the Dark Peak area identified through the literature evolved mainly around property rights issues and stakeholder identification methods and processes to improve natural resources management. The stakeholders identified by those projects were grouped together in an excel spreadsheet under these distinct categories: *statutory bodies/policy makers, land-owners, water companies, scientific institutions, conservation groups, recreation groups, tourism*, and *forestry*. Further on, to ensure the process remains as inclusive as possible and no key stakeholders are excluded, additional stakeholders were included after consulting members from MFFP as well as their conference and workshop stakeholder lists from the past 5 years. Moors for the Future Partnership is a joint venture of organisations in the Peak District working together to ensure the sustainable management of the ecosystem services provided by the peatlands of the National Park. Through this process another important category of stakeholders was identified that of '*land-managers*'. In addition, stakeholder data were also collected through snowballing at a workshop, organised during a MFFP Conference in November 2011. This lead to the creation of an initial stakeholder map (Figure 5) which grouped the key stakeholders in three broad categories for the purposes of the analysis as will be discussed in the following section.

3.3.3. Semi-structured interviews

Building upon the conceptual stakeholder map created in the first stage of this project the key stakeholders were approached through semi-structured interviews in order to determine how they generate and use knowledge about carbon storage and sequestration from peatlands. The interview sampling strategy was selective in order to be representative of the main stakeholder groups. Snowball sampling, whereby contacts recommended key potential interviewees, was used to identify the most appropriate people to talk to in each organisation (Bernard 1994:165). The total amount of interviewees was 17 individuals that fell under 13 stakeholder groups (Table 1). They comprise of: government bodies (2), water companies (1), academic institutions (4), local land-managers (2), non-governmental organisations (4), land owners (2), and conservation groups (2). Subsequently, to avoid bias arising from initial data composition, data were finally triangulated through the semi-structured interviews process where a few additional stakeholders were identified.

Table 1. The table below illustrates the list of interviewed stakeholder groups and organisations.

	Stakeholders
01	University of Manchester
02	University of Leeds
03	University of Sheffield
04	MFFP
05	United Utilities
06	RSPB
07	PDNP
08	Land-managers
09	National Trust

10	Environment Agency
11	Penny Anderson Associates
12	Rangers
13	Natural England
14	IUCN

The key stakeholders were approached through email or telephone communication in order to be informed about the research and asked to be interviewed. A consent form and a participant information sheet was provided and signed by all participants to secure ethical research approval and legitimacy of data. The interview process lasted on average one hour and was conducted by the use of a digital voice recorder. This method was chosen as it is the most likely one to create more trustworthy results by reducing the possibility of assembling biased data as the data used will be a direct transcription of the interviewees saying. Furthermore, it also allows easy access for cross-checking in the future. All interviews, except two, took place in the interviewees' offices or in quite public places (i.e. cafés) that allowed the digital voice recorder to clearly pick up the dialogues. Those two were carried out through Skype (internet video-based communication tool) due to inability of meeting with the interviewees in person. The data were transcribed and coded in order to identify the key themes that emerged from the sample.

3.3.4. Social Network Analysis

Social Network Analysis makes use of matrices to organize data on the relational ties linking stakeholders together. Rather than using key words in the matrix cells, SNA uses numbers to represent i) the presence/absence of a tie; ii) the relative strength of the tie. Each matrix represents a unique relation, for example, communication; friendship; advice; conflict; trust, etc. Data is typically gathered through structured interview, questionnaire, or observation (Wasserman and Faust, 1994). The semi-structured interview data were processed using the social network analysis (SNA) software UCINET 6 in order to assess and investigate the key themes that affect how key stakeholders learn from each other. These insights are of relevance when analyzing various actors' abilities to manage environmental challenges. SNA captures not only different kinds of relations (both positive and negative), but also the strength of those relational ties, and records this information in quantitative form that makes it easy for summarization and analysis. Analysis of these matrices uncovers the structure of the stakeholder network, thus identifying which stakeholders are more central; which are marginal; and how stakeholders cluster together.

In natural resources management, Social Network Analysis (SNA) can be used to help identify stakeholders, ensure key groups are not marginalised, identify conflict between stakeholders, and select representatives based on the way that the network is structured. Such information is especially important in natural resources management initiatives that seek to influence the behaviour of stakeholders through key influential individuals (c.f.

Rogers, 1995; Prell, et al., 2008). Both the social network and resource management literature discuss how networks influence individuals and groups. Research on the strength of ties between individuals, for example, shows that ''strong'' ties produce different outcomes to ''weak'' ties. Strong ties (as defined by Granovetter, 1973) are based on a combination of characteristics, such as intimacy, emotional intensity, time, and reciprocity. The higher a tie scores on each of these characteristics, the stronger the tie. There are several advantages of strong ties for natural resources management. Stakeholders who share strong ties are more likely to influence one another, and thus, creating strong ties among diverse stakeholders can enhance mutual learning, and the sharing of resources and advice (Newman and Dale, 2005; Crona and Bodin, 2006). However, the benefits of strong ties may be countered by the redundancy of information that typically runs through them.

In contrast, diverse information and new ideas have been shown to travel best through weak ties. Research has shown that weak ties tend to exist between dissimilar individuals, and as such, offer stakeholders access to diverse pools of information and resources by bridging otherwise disconnected segments of the network. Within the context of natural resource management, weak ties that link diverse individuals and groups together and bridge disconnected segments of a network can make it more resilient and adaptive to environmental change. A potential drawback to weak ties, however, is that they are easy to break. In addition, individuals sharing weak ties may lack the trust and understanding that is needed for meaningful dialogue over environmental issues (Granovetter, 1973; Burt, 1992, 2000, 2001; Newman and Dale, 2005). By quantifying the extent to which the stakeholders trust one another, SNA can identify problematic relationships, and when supplemented with qualitative data, can be used to identify the nature of conflicts between individuals and groups. It may be possible to identify specific individuals who are widely perceived by others in the network to be untrustworthy. This information can be used to select stakeholders to work together who are likely to trust one another, and may help avoid exacerbating conflicts between stakeholders.

The combination of the aforementioned methods has contributed to the creation of a Social Network diagram (see Figure 6 in Section 4), as a final product of this research, and assisted in identifying the paths through which knowledge about peat and carbon is being diffused, as well as the regimes that govern the area under study. Thus, by mapping and analysing the networks of social relations among stakeholders in the peatland ecosystem, important insights were gained about defining social structures and processes, such as distinguishable subgroups and information exchange, and the adaptive capacity of the governance network, that will be discussed in the following section.

4. <u>DISCUSSION</u>

4.1. Who are the key stakeholders involved in managing the peatlands of the Dark Peak when managing for carbon?

Initially we identified all possible categories of stakeholders (Figure 5). However, later on they where narrowed down to three broad categories i) scientific communities, ii) statutory bodies/policy makers, iii) managers/owners to aid the analysis and discussion part with regards to managing for carbon. Nevertheless, there seemed to be five stakeholders that had dual or multiple roles therefore belonging to more than one category, which we called 'hybrid' actors. More in depth discussion on the final major stakeholders can be found under the Social Network Analysis section.

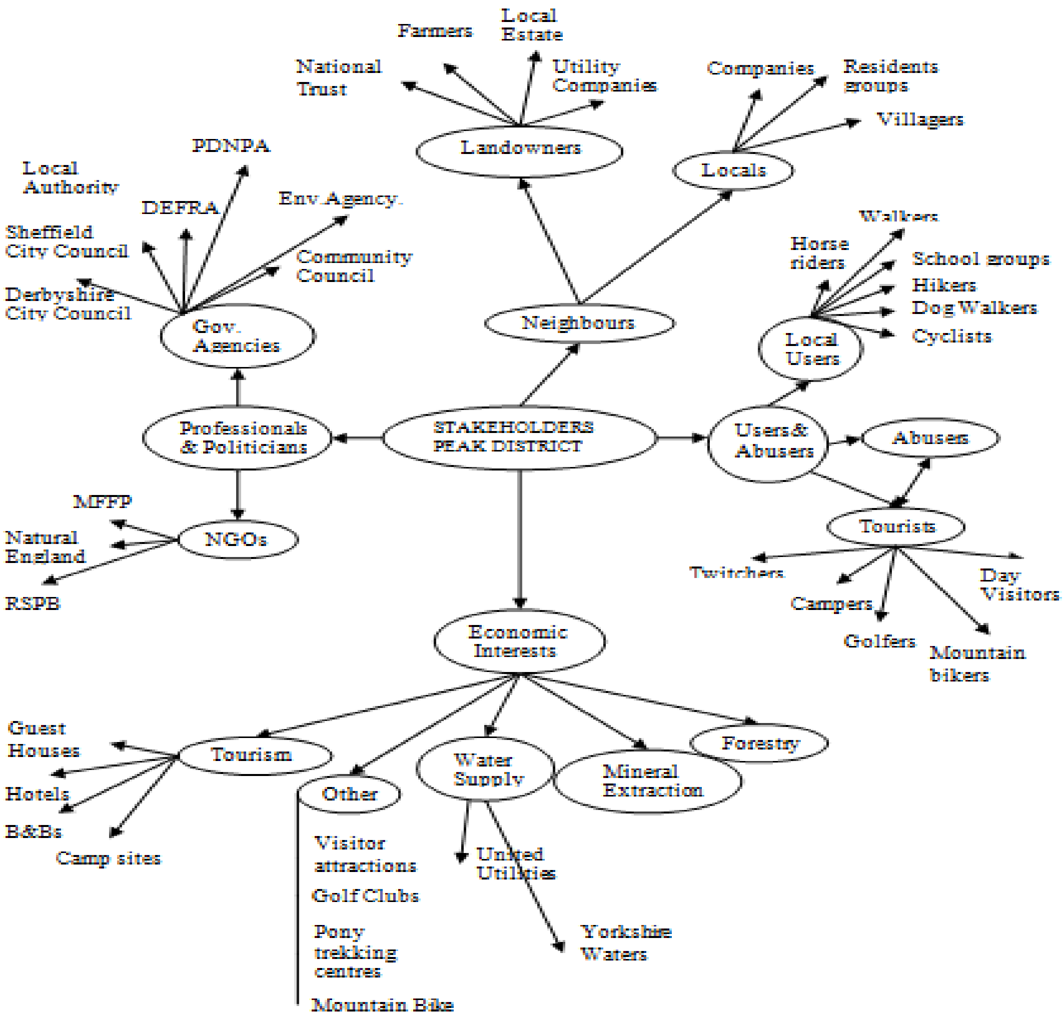

Figure 5. Initial map of the key stakeholders.

4.2. How do they use the carbon knowledge produced about peat and how do they assess this knowledge in order to learn?

Conceptualising Uncertainty

Interest in managing for carbon is tempered by the high levels of uncertainty over the best land-management practices in the SES under study. On one hand hybrid actors whose work is more directly intertwined with ecosystem services and carbon management argue that a potentially successful strategy to mitigate the level of uncertainty would be by prioritising the different ecosystem services within current or new land-management schemes. This would enable people to target their activities according to the ecosystem service's priority, therefore delivering site specific knowledge and aiding in providing small scale answers that combined together can shed light into conceptualising and managing uncertainty at a less local level. Other statutory bodies/policy makers are in favour of Uplands' water quality and flood alleviation and thus not directly affected by the uncertainty underpinning carbon science state that those particular ecosystem services are their top priority. However, they recognise that '*carbon is extremely important'* and since it is scientifically proven to have a direct impact on water colouration they will continue delivering it '*by working in partnership with other people in this case the National Trust, Natural England and the PDNPA*'. This uncertainty however, makes members of this stakeholder community reluctant to make any bold commitments individually yet.

Land-managers, on the other hand, would also like to jump on the coming 'carbon train' (as will be discussed in the following section 4.1.2.2) but according to one member of the managers' community expect to see *'sound science and serious peer reviewed papers before committing to the carbon debate and commission our own carbon budgets*'. Moreover, some seem to be more sceptical and confused over the optimum solution due to the contested array of scientific information that underpins carbon. *'One report says this and another says that. If there is no consensus within the scientific community on what is best how can we commit to anything?*' (Land manager 2). For example, previous scientific information that used to be favoured in the past by rural policies and managers, such as managed burning which has also shaped the peatland landscape of the Dark Peak, have been condemned in recent research studies by some members of the scientific community *'Managed burning has been shown to bring dis-benefits and so individual stakeholders will have to decide what is most important in any particular locality'*; whereas others argue for a sustainable and moderate use of burning that '*may bring benefits for some ecosystem services*'. Consensus therefore within the scientific community on carbon related issues appears to be crucial in mitigating uncertainty among the land managing community. The fact that seems to be uncontested, however, and finds all stakeholder groups agreeing on is the restoration and revegetation work done on the peatlands, which *'can only be a good thing, but managing for carbon not sure until I see the figures on paper*' (another land-manager).

The issue of uncertainty seems to evolve around the quality and communication of scientific data. The stakeholders expect to see collaboration and communication underpinning the processes of carbon storage and sequestration. The scientists conversely attribute uncertainty primarily to insufficient funding both at a national and European level, where projects, such as the Voluntary Carbon Trust, that require research data to be continuous and consistent may run out funding. As has been stated by a member of the scientific community, '*The project I was participating required 5 years of data. The difficulty however was that the funding finished almost every year and we had to apply every year*'. Furthermore, according to another member of the scientific community, '*quite a lot of funding came because policy organisations wanted scientific data to back up their policy*', which also suggests that scientific institutions are not working in one unified front towards, as their research results sometimes '*depend on their contractor*'. This causes inconsistent reports to be produced adding to the uncertainty that underpins scientific knowledge instead of mitigating it. This process, however, seems to be the reverse of the traditional linear model, as it can be traced back to the statutory bodies/policy makers, who also seem to be operating under different agendas. Therefore, their disparate benefits and interests in the way the Dark Peak is managed are also accountable for the contested results and contradicting reports produced by the scientific community.

Finally, another issue that adds to the uncertainty of the socio-ecological system of the Dark Peak is the current property rights and ownership regime, namely, as one hybrid actor has mentioned, the determination of '*who has control of the land use and management of individual areas of peatland, and the extent of this control'*. As a result, there are multiple stakeholders who want to be involved in how the socio-ecological system is managed. However, '*private property regimes still dominate in peatlands, particularly in uplands, and as such, few stakeholders beyond land owners are able to influence management decisions'*. With regards to managing for carbon, the primary question would be *'who would own it?*'. If carbon be treated as a mineral, then the ownership rights would have to be with the freeholder, who owns the minerals of a land. If it would be treated as part of the vegetation then it would be owned by the grazier who has those rights. Furthermore, it could also be for the shooting tenant who owns the shooting rights and can manage the land in any way one sees fit to maximize those shooting rights. Finally, if carbon was found in water company land then it would be owned by the water company who has the rights to the water resources that pass over the land which stores carbon. This type of ownership uncertainty results in many land owners and managers being unrewarded for positive environmental impacts and unaccountable for any negative impacts that they create while managing for ecosystem services. As argued by two different stakeholders, a member of the scientific community and a member of the hybrid actors, in many ways the uplands can be seen as a repository of largely unpriced public goods of major national importance.

Carbon Management

Resources for carbon management are the next most important issue revealed by our analysis that seems to influence the quality and quantity of scientific research. It has been roughly estimated that around £3-£4 millions are required in order for scientists to provide policy-makers with '*the answer*' to the carbon questions. However, *they seem reluctant to invest anything more than one third of that amount and therefore the scientific information they receive reflects their 'willingness-to-pay'* (member of the scientific community). Furthermore, due to the existing uncertainty around ground carbon facts it is quite difficult to draw funds just for carbon management alone. Despite the uncertainty there is great interest from government bodies and the market to enhance carbon research and knowledge as it has great potential for allowing the UK to participate in carbon trading and offsetting schemes. Therefore, since carbon is proven to be intertwined with other ecosystem services such as water quality and conservation of biodiversity *'the funding schemes recently move around multi-benefits and public goods*', according to a hybrid actor, and consequently it has become a trend to attract funds for carbon through water and biodiversity schemes (hybrid actor and statutory body/policy maker). However, there seems to be consensus among most of the stakeholders regarding the '*water story'*, which has started gaining momentum within environmental policy agendas and has caused a clear shift in the financial support and incentives. Improving the quality of the water resources of the Dark Peak has a direct effect on carbon stored and sequestered by the peatlands, which is verified by different scientific institutions as well, as carbon appears to be more closely linked with water quality. Therefore, managing for a good water quality also aids in managing for carbon.

Land-managers on the other hand seemed sceptical initially about the issue of managing directly for carbon and receiving payments for that as they argue that *'we don't know whether we are better off with the carbon thing. I'd be worried about getting all the subsidy payments based on a carbon formula, because the moorland is about more than that. Isn't it?*' (land manager 2). Later on, however, they argue that they would be interested in receiving financial rewards for carbon management as '*in the end it all comes down to money'* and since '*carbon pushes anybody bidding for money has to push the right political buttons and carbon is the big button*' (land manager 2) because *'at the end of the day any farmer, any land-manager is running a business*' (land manager 1). When the potential of a carbon payment scheme was mentioned a common response was that policy-makers or whoever in charge of designing it would have to involve land managers as well by *'floating ideas with me and other land-managers and land-owners as to how you would construct such a payment model based on carbon*' management (land manager 1); because their key concern is not '*to upset the balance*' between them as well as feel involved in the future decisions taken regarding the land they manage. A major land-owner in the Dark Peak, however, has gone out quite vociferously in the public domain and stated that '*the government should be offering money towards the restoration of landscapes because of carbon*', an eventuality some land managers fear. This seemed to be perhaps more important than ascribing a value to carbon in their lands as upsetting the balance between their collaborations would dramatically change the current status quo of the landscape. So far they have learned to manage under the current agri-environment schemes and have achieved to reduce animosity by creating their own community conduct and collaborating. If an additional carbon management plan was to be created alongside other environmental schemes without learning from their views and reflecting them, it could end up being divisive. The incentive of profit could turn managers against each other therefore resulting in disrupting the current balance between them and leading to land mismanagement and further land degradation and carbon emissions respectively.

The scientific community on the other hand believe that the current and future funding packages seem to be politically driven by the importance and priority of carbon in environmental agendas. As argued by one of its members, '*funding for land management is coming on the back of carbon work and you know maybe being able to show there's a link between wildlife and carbon is quite important'*. Another member mentions, '*I don't believe in*

Cost Benefit Analysis (CBA) but if one has to employ it to restore peatlands and the carbon budgets then so be it'. Cost-Benefit Analysis (CBA) would '*differentiate the payments*' (hybrid member) that researchers and land-managers receive according to the level of importance of each specific ecosystem service. Moreover, the scientific community seems to also favour the potential of carbon offsetting schemes based on managing for peatland restoration. This can potentially deliver tradable carbon credits and in return continue funding further peatland research in an iterative manner. Additionally, as argued by another member of the community, for this to be achieved within the current coalition government '*changes in policy are necessary to enable the trading part*'.

4.3. Opportunities for Adaptive Management

It may be a cliché but science will always be underpinned by a level of uncertainty. What our analysis has revealed however is it is not only uncertainty that is causing hesitation in implementing any sort of carbon management plan but also a lack of mutual learning in the socio-ecological system of policy-makers, land-managers and the scientific community.

Policy-makers and scientists argue '*they require more persuasion and more evidence'* to realise that burning is harmful and should be stopped. On the other hand, lay-knowledge holders argue that controlled burning could render the land less prone to wildfires, whose damage can be irreversible; an option which if properly communicated across policy-makers and scientists could potentially result in a future positive collaboration between all fronts. Land-managers feel their expertise and knowledge is undermined when in reality it could add great value to future research and policy-making as *'at the end of the day'* they '*know what the land wants'* (land manager 1)*.*That is not to say, however, that future agri-environment schemes should be designed only according to lay knowledge, but that there should be a co-production of knowledge regarding land management, where all stakeholders (scientific institutions, statutory bodies/policy makers, managers/owners and hybrid actors) would be mutually involved in learning, decision-making and implementing. This will require compromise on all sides, but would enable a consensus to be reached on decisions, producing useful management knowledge. Involving all stakeholders can make management more effective and enhance trust and buy-in within the network.

Policy-makers and land-managers argue that there is a certain role for the scientific community to communicate the evidence on the best practices and what are the best ecosystem services that are provided by the peatlands such as water, carbon and biodiversity. '*It is essential that we are following science for robust evidence, but at some point that has to be communicated and translated into management actions and I think both need to inform one another'* (hybrid actor)*.* Stakeholders seemed keen on managing for carbon as long as they were provided with convincing and robust evidence that would not contemplate the current ecosystem services their land provides nor risk their in-between relations as well as with their suppliers.

Members of the scientific community, in addition, argue that *'consultants promise the world, policy-makers want 'the answer', but we try to be more realistic*'. It is therefore quite obvious the need for enhancing communication and learning within the disparate members of the network. This way each stakeholder group will be able to be informed of the needs of the rest of the members, discuss and reach consensus on the extent to which everyone's needs can be met for the effective land management within the Dark Peak and finally, agree on the potential results from implementing these management actions. For example, many existing land-use management practices such as burning, grazing, forestry and recreation are not under present circumstances compatible with carbon sequestration. It is vital to be unambiguous about the objectives for several land-management practices and appreciate where the main objective is carbon sequestration that this is likely to require '*compromises and accept that stakeholders may not be able to achieve all their objectives all of the time in all the places that they would wish to'* (hybrid stakeholder) otherwise there will never be mutual learning, consensus and hence innovation and progress. Further on, it appears that the scientific community holds a slightly distorted perception of the status quo within the land-managing community, as according to two members of different scientific institutions, when it comes to land management '*foxes cross and grouse cross boundaries but for carbon there is no boundary crossing so there is no collaboration...there is no consensus needed...everybody can do whatever they want basically'*.

The final critical issue identified as necessitating communication is that of the 'value' of carbon. This seems to find many disparate stakeholders agreeing on as it could be potentially a great driving force in order to learn how to manage for carbon, and reach a consensus in the best carbon management practices as '*politically money talks to people'*. The general argument towards that stance is that '*everyone can relate to*' money and the majority of '*people find it very hard to value something purely from an aesthetic standpoint*'. Furthermore, according to the majority of stakeholders, it is also the means that will raise ecosystem service management into a whole new level when it comes to protecting, restoring and sustainably managing the lands. Therefore, it is a necessity *'to translate science into words that are coherent and comprehensible by everyone'* but equally to '*respect and consider everyone's views'* (hybrid stakeholder). The necessity for creating more resilient knowledge paths that allow mutual learning between disparate stakeholders is therefore crucial. Adaptive management enhances collaboration among the different actors through mutual learning from one another, but also allows for experimentation on land-management practices in order to find the most suitable one that will meet the majority's needs. These initial steps will pave the way towards a more resilient socio-ecological system that will be able to tackle and mitigate climate change at a local level.

4.4. Social Network Analysis

Social Network Analysis has revealed the structure of the network organised according to the communication ties between the stakeholders involved in peatland management and governance (Figure 6). We used a traffic light system to distinguish reciprocal ties or else mutual knowledge exchange (green lines) from non-reciprocal or one-way knowledge ties (red). The size of the lines indicates the strength of communication between actors. Therefore, thicker lines stand for stronger communication ties between stakeholders.

However, there can be strong communication between reciprocal and non-reciprocal knowledge ties. The shape of the lines illustrates the number of relationships, where dashed lines stand for one type of relationship and solid lines for multiple.

The network appears to be quite complex, which was already revealed to us by reviewing the literature and interviewing the stakeholders. Nevertheless, a striking and very positive element of the network is that all stakeholders are well connected with each other and no one is left outside the network. This indicates that the particular network seems to have already well established communication and collaboration ties that vary from strong to less-strong among the actors involved.

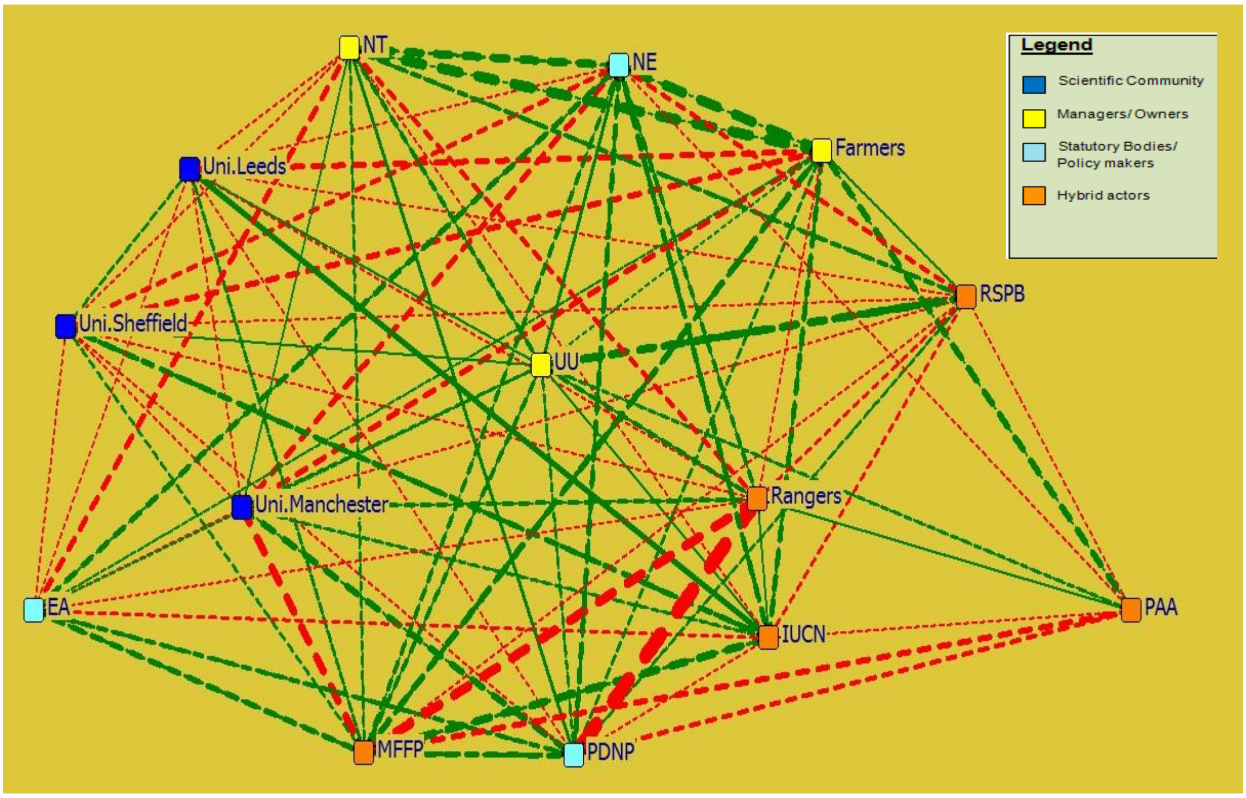

Figure 6. Graph illustrating the stakeholder partnership network composed of 17 key actors involved in peatland governance in the Dark Peak.

For example, it appears that the scientific community (dark blue flag) is well connected with most of the actors (i.e. Farmers, Natural England, IUCN, United Utilities, MFFP, RSPB etc.) and some of the ties are relatively strong (thicker lines). This indicates that knowledge is being exchanged between these groups. However, when examining the colours of the lines, most of them are red; this reveals that despite the strength of the communication and collaboration ties the knowledge exchange is one-way. That is to say, scientific information/knowledge is being communicated but in a non-reciprocal manner. At this point, it is also worth noting the important action of the Moors for the Future Partnership (MFFP), which act as an intermediate source receiving scientific knowledge and communicating it to the rest of the stakeholder groups and organisations in the Dark Peak and particularly to the actors that seem to share one directional knowledge ties with the scientific community (i.e.

Farmers, Natural England, PDNP). Furthermore, the existence of strong ties indicates that there is a higher likelihood for the actors involved to influence one another but again since the ties are non-reciprocal the influence will occur in a one-direction manner again thus not enhancing mutual learning and the sharing of resources and advice. Nevertheless, it needs to be acknowledged that the benefits of strong ties may be contested by the repetition of information that typically runs through them. Finally, what can also be noticed is that on an individual level the scientific institutions appear to share rather weak communication and collaboration ties among themselves, which can imply that the scientific community is not acting as a unified front. This therefore may also have an effect on the scientific knowledge produced by the different scientific institutions and perhaps add to the uncertainty that underpins scientific information regarding the ecosystem of the Dark Peak.

With regards to the statutory bodies/policy makers, they seem to be equally well connected with most of the stakeholders (i.e. MFFP, Scientific Community, Rangers, United Utilities etc). The stronger communication and collaboration ties that seem to be underpinned by reciprocal mutual knowledge exchange can be observed with members of the manager/owners community. In relation to the traditional linear knowledge production model statutory bodies/policy makers appear to act as the knowledge communicators between the scientific community and the managers/owners community. Nevertheless, a lot of one direction knowledge ties can be noted as well; the stronger and non-reciprocal ties, where no mutual learning takes place, are illustrated mainly with the scientific community whereas the rather weaker ones with members of the hybrid group (ie. Penny Anderson Associates, Rangers, RSPB, IUCN). Moors for the Future Partnership's effective action can be observed again at this level, as they have developed rather strong reciprocal knowledge ties and therefore support the communication and collaboration channels that suggest mutual learning and knowledge exchange between the statutory bodies/policy makers, the managers/owners community and the hybrid actors.

The farmers/owners stakeholder group appears to be the most well connected group to all rest stakeholder groups, both in terms of abundance of strong communication and collaboration ties (thicker lines) but also in terms of reciprocity and mutual learning (green lines). One reason for this is the fact that United Utilities and the National Trust are major land owners of the Dark Peak. This illustrates the strong level of influence key land owners may have over land management issues in the area both at a local level, strong communication and collaboration ties with the farmers and hybrid actors (i.e. RSPB), and at a regional level, strong communication and collaboration ties with hybrid actors (i.e. IUCN) and statutory bodies/policy makers (i.e. Peak District Park Authorities). Moreover, most of the ties they share with all other stakeholder members are also underpinned by mutual and reciprocal knowledge exchange which is a sign of a primary and unofficial adaptive management in the area. Finally, judging by the abundance of ties between all stakeholders and United Utilities and in combination with what is found in the literature, another significant piece of information that can be extracted, which is the importance of water provision and management as an ecosystem service of the Dark Peak. This is not unexpected as it has been scientifically proven that managing for good water quality can have an indirect impact on controlling the carbon budgets in the peatlands of the Dark Peak as well. The farmers on the other hand, seem to be connected with the majority of the stakeholders in the network (13 out of 17), which indicates that there is collaboration and communication already taking place. Their reciprocal/mutual learning ties seem to follow a pattern: namely, it appears to be strong with hybrid stakeholders (i.e. MFFP, IUCN, PAA), then growing slightly weaker with members of the statutory bodies/policy makers (ie. NE, DPNP, EA) to result in one way direction learning with the members of the scientific community. This provides insight again into the way knowledge is disseminated among the key stakeholders of the network which seems to follow a linear model.

4. Conclusion

The Dark Peak area of the Peak District National Park represents a complex socio-ecological system (SES) that is adapting to a changing climate and shifting policy context. This project used an adaptive management approach to understand how the Dark Peak can be managed for carbon in the face of chronic scientific uncertainty. Adaptive management emphasises the importance of institutions in facilitating collaborative knowledge production that uses the knowledge of all stakeholders to reach better, more legitimate management decisions. The key results from our project are as follows:

- Stakeholder mapping identified three critical groups of stakeholders in relation to carbon management in the High Peak social-ecological system: scientists, policy-makers and land managers.
- Interviews revealed that there is high interest amongst all stakeholder groups for a carbon agenda. However, it seems to be obscured by a combination of factors such as the scientific uncertainty underpinning primary carbon facts, along with conflicting interests and ineffective communication and collaboration ties within the different stakeholder groups.
- Social Network Analysis has revealed that it is a very well connected network with strong communication ties established across. They can vary from strong to weak while describing one-direction or mutual knowledge exchange between the actors. While it appears that no stakeholder is disconnected or completely marginalised, knowledge seems to be produced by individual stakeholders and simply disseminated, rather than being produced in a collaborative and inclusive way (adaptive management).
- Land managers possess valuable lay knowledge about the Dark Peak socio-ecological system that needs to be included in the process of knowledge production. Further, land managers are the eventual implementers of knowledge, and need to be involved in knowledge production in order to generate buy-in for decisions taken under conditions of inherent uncertainty.
- Existing collaborative management arrangements provide great potential for improving and enhancing these knowledge ties that will lead to more successful and stronger communication and collaboration within the network.

- Involving all network members will enhance the trust among the key actors, building more dynamic land management practices that will make the peatland socio-ecological system more adaptive against climate change, whilst controlling their carbon budgets. This will require a shift from the traditional linear model of knowledge production into a more cyclical one where all stakeholders are involved in a process of '*learning while doing'*, through experimentation with different rural strategies.

- Co-producing knowledge about carbon management strategies requires innovative governance mechanisms and engagement strategies, and warrants further research.

- Moors for the Future Partnership holds a focal role in fostering adaptive management and aiding the learning and collaborative processes within this stakeholder network.

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