FIRES

Interdisciplinary Research
on Ecosystem Services:
Fire and Climate Change
in UK Moorlands and Heaths

Summary report prepared for Scottish Natural Heritage

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Disclaimer: the authors have attempted to capture the range of opinions presented at the four seminars. The views presented in this report do not necessarily represent those of sponsors, the FIRES Steering Group or their organisations.

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1. Purpose

This report summarises the FIRES seminar series, a series of four seminars that took place during 2008-2009, funded by ESRC-NERC through their Transdisciplinary Seminar Series on Ecosystem Services. This report aims to bring together information presented at the seminar series in discussion documents, reports and presentations, all of which are available to download from the project website, www.fires-seminars.org.uk.

It expands on the FIRES Policy Brief, which is also available from the website and in hardcopy form.

2. Background

Fire is historically important in shaping moorland and heathland landscapes. Managed rotational burning is used to maintain heather moors for grouse and grazing animals. In contrast, wildfire – accidental or malicious vegetation fire – increasingly threatens ecosystem services. The environmental, social and cultural ecosystem services provided by moorlands and heathlands include carbon capture and storage (especially on peatland), biodiversity, water provision, flood protection, aesthetic/recreational value, and economic value from tourism, sporting enterprises, forestry and grazing.

The FIRES seminar series discussed the key but equivocal role of prescribed fire and wildfire, and the many controversies for management and policy making. Four seminars were held in 2008/9 on the effects of moorland and heathland fires on ecosystem services in the UK.

The series was funded jointly by ESRC and NERC as part of their transdisciplinary series on ecosystem services. Sponsorship was also kindly received from Scottish Natural Heritage, Game and Wildlife Conservation Trust, the Peak District National Park Authority, Manchester Institute for Mathematical Sciences and the University of Manchester President's Fund. This enabled a public lecture component to be included at each seminar, more international speakers (6 in total), additional early career places (22 in all) and over 70% more subsidised places.

The four seminars created a vibrant cross-sector multidisciplinary forum. The series brought together over 130 different researchers, policy-makers, Fire and Rescue Service (FRS) officers, land managers and other stakeholders. Practitioners comprised more than half the audience. Despite strenuous efforts, the majority of participants classified themselves as having a natural science rather than social science background. Early career participants were encouraged to attend, with an average of five places per seminar reserved for them. Two-thirds of the 22 early career participants were students.

Four seminars were held:

- FIRES1 - The role of managed fire in ecosystem services of UK moorlands and heathlands 31 March – 1 April 2008, Edinburgh;
- FIRES2 - The impact of wildfire on ecosystem services: relationships between wildfire, climate and people, 24 June 2008, Manchester;
- FIRES3 - Forecasting and modelling wildfire risk in UK moorlands and heathlands, 31 March – 1 April 2009, Manchester; and,
- FIRES4 - Adaptive management of wildfire risk: implications for moorland and heathland ecosystem services, 13-14 May 2009, Peak District National Park.

3. Aims and Objectives of FIRES

3.1 Series aims

1. To build capacity for inter-disciplinary research on fire and its impacts on ecosystem services of UK heaths and moorlands;
2. To establish a cross-cutting interdisciplinary research agenda on the relationships between ecosystem services, managed fire and wildfire in UK heaths and moorlands, especially implications of increased wildfire risk under climate change scenarios; and,
3. To incorporate the needs of policy makers, moorland managers and other stakeholders, facilitate knowledge transfer to policy makers and contribute to adaptive management response.

3.2 Series objectives

1. To facilitate dialogue between participants on three levels: (i) socio-economic, environmental and physical scientists; (ii) researchers, academics (international and UK) and postgraduate students; (iii) and researchers, stakeholders and policy-makers.
2. To identify the ecosystem services of UK heaths and moorlands, assess the role of managed fire in maintaining them and the costs and benefits of reductions in prescribed burning.
3. To assess the threats to ecosystem services posed by wildfire, including future threat from climate change.
4. To evaluate the suitability *for the UK* of modelling tools designed to minimise damage to the ecosystem, including evaluating alternative approaches, identifying data needs and implications for policy.
5. To identify alternative strategies for managing wildfire risk, evaluate their relative costs and benefits for ecosystem services, and identify the political and institutional policy drivers.
6. To disseminate findings, e.g. through journal articles, a book, conference presentations and a website, and define an agenda for further cross-disciplinary research to form the basis for future research grant applications.

FIRES has been highly successful, meeting or exceeding all objectives, with the exception of equal participation by natural and social scientists.

4. Main insights from the series

4.1 An under-reported problem: poor evidence base

Wildfire (Figure 1) is a significant semi-natural hazard in the UK. Around 71,700 'vegetation fires' occurred every year in the UK from 1974 to 2005, but these include fires of all sizes and types[1]. Severe fires can occur in any year, but mainly occur in years with particularly hot and dry summers, such as in 1995 and 2003 (Figure 2). However, UK reporting of vegetation fires is poor at national, European and UN level. The evidence base on vegetation fires is poor for two reasons: (i) most vegetation fires do not damage property or cost lives, so, until recently, they have been reported to a lower standard than structural fires; (ii) data collection has not been standardised between the 41 regional Fire and Rescue Services (FRS).

Figure 1: Moorland wildfire (Prendergast, 2009[2])

It is important to collect wildfire data to: (i) provide the evidence base for decision making; (ii) enable analysis and identification of trends and correlations; and (iii) to assist with partnership-building and risk management[3]. Andy Elliott (Dorset County Council) highlighted some of the problems of the poor evidence base and the importance of recording data, and stated that "*We cannot build models without data; we cannot target problem areas without data; we cannot forecast without data*"[4].

[1] McMorrow, J. Lindley, S. Aylen, J. Cavan, G. Albertson, K. and Boys, D. (2009) Moorland wildfire risk, visitors and climate change: patterns, prevention and policy. In: A. Bonn, T. Allott, K. Hubacek, and J. Stewart (eds), *Drivers of Environmental Change in Uplands*, Routledge, pages 410-431.

[2] Prendergast, P. (2009) *Bleaklow Fire 2003*, Presented at FIRES4. Available to download from http://www.fires-seminars.org.uk/downloads/seminar4/fires4_sean_prendergast.pdf

[3] Gazzard, R. (2009). *Vegetation fire data*. Presented at FIRES3. Available to download from http://www.fires-seminars.org.uk/downloads/seminar3/gazzard_fires3.pdf

[4] Elliott, A. (2009). Discussion document on wildfire risk assessment and management at FIRES3, available at http://www.fires-seminars.org.uk/downloads/seminar3/discussant_elliott_fires3.pdf

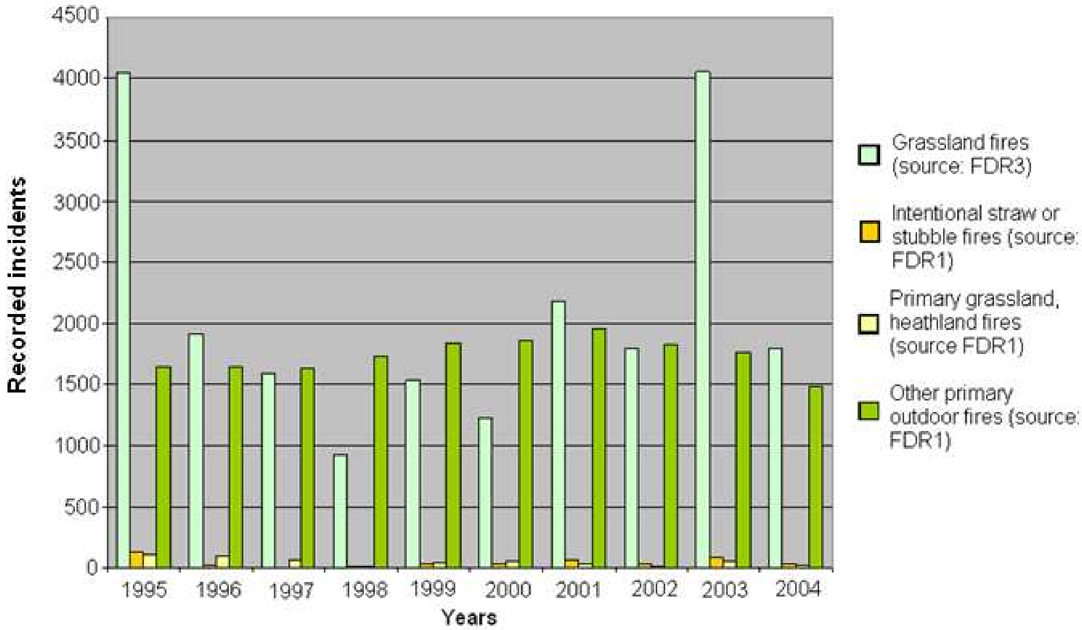

Figure 2: Vegetation fires recorded in the UK between 1995-2004 (Gazzard, 2009).

Data collection of wildfire occurrences was discussed at length at FIRES3. A dedicated session on "Data Needs" discussed issues and problems with the manual recording of wildfires. Andy Newman (West Yorkshire Fire and Rescue Service, WYFRS) provided an account of data experiences within the brigade, where there has been interest in wildfires in the last 2-3 years due to their impacts on resources and costs associated with revised FRS legislation in 2004. They have been one of the brigades trialling the new Incident recording System (IRS), which was rolled out UK-wide on 1 April 2009. Data collected at WYFRS is difficult to work with – it is often not spatially accurate, for example, the location of a wildfire is recorded at an approximate point on the roadside where the FRS tender parked, but not where the fire actually occurred. This is very typical of UK-wide FRS data, as confirmed by Jonathan Walker's experience in working with Greater Manchester and Lancashire FRS data[5].

Recorded data does not include information on the severity of vegetation fires or their cause. Andy Newman highlighted some important issues with the collection of data, such as, what is the difference between categories – when does a grass fire develop into a wildfire? Why do these need to be recorded? What purpose does this serve the FRS? These questions need to be discussed with fire-fighters to help them to understand the importance of data collection, since their understanding (and personal equipment) is of structural fires, not vegetation fires. More guidance on data collection is needed[6].

Rob Gazzard (South East England Wildfire Group and Forestry Commission) presented information on UK vegetation fire data, which included statistics from historical records and provided an example of the fire dates and times that would be useful to record[7] (Figure 3). He proposed a new framework UK Vegetation Fire Statistics (UKVFS) protocol for collecting data on vegetation fires to be used both within the new IRS system and non-FRS fire databases such as the Forestry Commission's. Participants expressed concern that it was too complex in operational terms.

[5] Walker, J. Hewson, W. and McMorrow, J. (2009). Spatial pattern of wildfire distribution on the moorlands of the South Pennines. Moors for the Future report to Pennine Prospects.
[6] Cavan, G. (2009). *Data needs*. Rapporteur report for FIRES3, Day 2, Session 3. Available from http://www.fires-seminars.org.uk/downloads/seminar3/day2_fires3_session3_report_cavan.pdf
[7] Gazzard, R. (2009). *Vegetation fire data*. Presented at FIRES3. Available to download from http://www.fires-seminars.org.uk/downloads/seminar3/gazzard_fires3.pdf

It is hoped that IRS will improve the accuracy of previous manual data collection methods and categories of data collected for vegetation fires, bringing consistency in certain core data collected across all regional Fire and Rescue Services (FRS). Concerns were raised about the effect on consistency and accuracy of data of local implementation of IRS across 41 FRS. The urgent need for training in completing compulsory data fields was a consistent message, emerging again in the discussion following the paper by Cath Reynolds (Department of Communities and Local Government, DCLG)[8]. So too was the need to include a consistent fire ground geo-referenced point (Figure 3).

The UK is not alone in its poor evidence base for wildfire occurrence. In FIRES3, we heard from European speakers including Cristina Vega-Garcia (University of Lleida) and Paolo Fiorucci (CIMA Research Foundation, Italy), who also highlighted the problems of non-homogeneity and inaccurate data as key issues with wildfire records[9,10]. Data collection on wildfires in Corsica, however, is much more advanced, and includes techniques such as forensic tracing of fires, running fire behaviour models in reverse to learn about fire spread, and re-visiting the site with a GPS to record information such as burn scar[11]. This is justified by the need for national statistics to feed into EU fire reporting systems such as the European Forest Fire Information System (EFFIS).

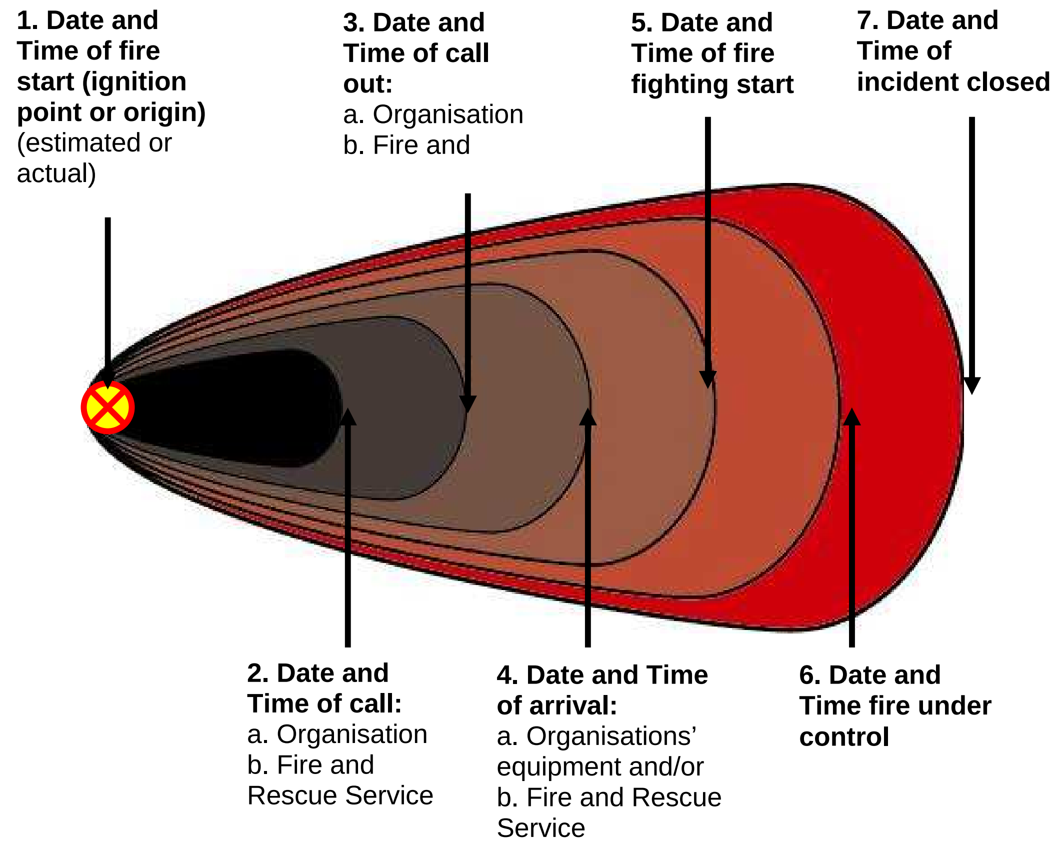

Figure 3: Examples of fire ground locations which could be recorded (Gazzard, 2009[12])

[8] Reynolds, C. (2009). *Wildfire risk and data*. Presented at FIRES 4. Available to download from http://www.fires-seminars.org.uk/downloads/seminar4/fires4_cath_reynolds.pdf
[9] Vega-Garcia, C. *et al*. (2009). *Spatial aspects of wildfire*. Presented at FIRES3. Available to download from http://www.fires-seminars.org.uk/downloads/seminar3/vega-garcia_fires3.pdf
[10] Fiorucci, P. (2009). *Wildfire risk assessment and management*. Presented at FIRES3. Available from http://www.fires-seminars.org.uk/downloads/seminar3/fiorucci_fires3.pdf
[11] Cavan, G. (2009). Report from "Data Needs" session at FIRES3, available to download from http://www.fires-seminars.org.uk/downloads/seminar3/day2_fires3_session3_report_cavan.pdf
[12] As footnote 7.

4.2 Regional variations in fire regime and cause

Fire regime is the frequency, timing and severity of vegetation fires, which includes prescribed burns. At FIRES1, Colin Legg (University of Edinburgh) discussed the three main factors that determine fire regime, as follows[13];

- Weather conditions – the weather conditions set limits on when vegetation will burn and when it will not, and influence the intensity of fire;
- The ecology of the vegetation and dominant species - these determine what fuel is available to burn and interact with weather to determine fire behaviour; and,
- Human behaviour – virtually all fires in the UK are anthropogenic and it is human behaviour that determines where and when fires will be lit and whether they will be controlled.

Discussion on the regional variations in fire regime and causes of fire continued at FIRES2, with a lively session on "Where, when and why do wildfires occur in the UK". Mark Jones (formally Chief Officers' Fire Association spokesperson on wildfire and (then) chair of the English Wildfire Forum) noted that wildfires are not only a rural problem. Whilst large, highly damaging and long burning wildfires do occur in rural areas, many smaller and more frequent wildfires occur in our most urban areas in the UK[14]. Causes of wildfire are also thought to vary regionally. They include escaped prescribed burns, discarded cigarettes, barbecues, and sparks from ordnance or trains, and arson.

Climate change may influence the incidence of moorland wildfires. The key message of 'hotter, drier summers' is clearly of concern. In a keynote paper for FIRES2, Clare Goodess (CRU, University of East Anglia) and Mark Gallani (Met Office) highlighted that hotter and drier conditions are likely to have a direct effect on wildfire occurrence and on the length of the wildfire season in the UK[15]. Indirect effects of climate change include: impacts on ecosystems (affecting type and volume of combustible material, and also land cover/use); human behaviour (e.g. more visitors during more inclement weather); and, fire fighting (e.g. shortage of water and hot working conditions)[16]. Further, extremes and persistence of events such as drought also need to be considered.

A session at FIRES2 on "How will climate change affect wildfire risk, hazard and fire regime?" included a respondent report from Matthew Davies (University of Washington, formerly University of Edinburgh), which outlined the impact of climate change on fire hazard, specifically, through affecting fuel moisture content and fuel structure. For example, drier summers and increased drought conditions would reduce the fuel moisture content and therefore increase fire hazard. In addition, there may be effects of climate change on peat flammability[17]. Discussion of the impacts of climate change on wildfires concluded that there is a complex relationship between climate, vegetation response, fuel load and fire characteristics. Further, consideration of indirect effects is particularly difficult in analyses. An interdisciplinary approach is favoured to investigate such complex direct and indirect relationships, and discussions initiated within the FIRES seminar series were said to provide a good opportunity for continuation of such work[18].

[13] Legg, C. and Davies, M. (2008). *Managed fire and fire regimes*. Abstract from FIRES1, available from http://www.fires-seminars.org.uk/downloads/seminar1/fires_sem1_abstracts.pdf
[14] Jones, M. (2008). *Where, when and why do wildfires occur in the UK. Keynote discussion paper*, FIRES2 programme and abstracts booklet, page 9, available to download from http://www.fires-seminars.org.uk/downloads/seminar2/fires2_programmeabstracts.pdf
[15] Goodess, C. (2008). *Climate change scenarios for uplands. Keynote discussion paper*. FIRES2. Available: http://www.fires-seminars.org.uk/downloads/seminar2/fires2_programmeabstracts.pdf
[16] As footnote 15.
[17] Davies, G. M. (2008). *How will climate change and vegetation vulnerability interact? How will fire regimes change?* FIRES2 respondent paper. Available to download from: http://www.fires-seminars.org.uk/downloads/seminar2/fires2_programmeabstracts.pdf
[18] Krivtsov, V. (2008). Rapporteur report from FIRES2, Session 2. Available to download from http://www.fires-seminars.org.uk/downloads/seminar2/rapporteur_session2_krivtsov.pdf

The issue of fire behaviour was briefly discussed at FIRES2, principally highlighting that we still know little about fire behaviour in a UK context. A session at the following seminar, FIRES3, open to the public and including presentations from two distinguished international scientists, helped to further discussion on this topic. Carlos Fernandez-Pello (University of California at Berkeley) began the session with a discussion of wildfire propagation through spotting – the way in which wildfires spread by burning embers ejected from the fire front, especially with high winds[19]. Domingos Xavier Viegas (University of Coimbria) then presented analysis of eruptive fire behaviour, which is related to many accidents with fatalities of fire-fighters in the USA and Europe. He showed the behaviour of fires e.g. how fires burning up slopes can generate their own wind, with the result that fires can propagate faster than someone can run. This was demonstrated through a particularly valuable video of a laboratory simulation of a fire front turning into an eruptive fire, uncovering the extreme behaviour of a fire. He concluded that such knowledge and experience obtained so far is a powerful weapon, which should be used to avoid the loss of lives in future[20]. A discussion continued on how the scientific knowledge explored during FIRES3 should be applied into practice, for example, through training (Figure 4).

Figure 4: Training of Fire Fighters at Domingos Xavier Viegas' Forest Fire Research laboratory of ADAI in Coimbria, Portugal, in collaboration with the National Fire Brigade School (Viegas, 2009).

There is very little forensic examination of the causes of wildfires in the UK compared to Europe. At FIRES3, delegates heard how education campaigns had worked in reducing wildfire incidents in Dorset[21]. Dorset have also been successful in prosecuting arsonists, which has significantly reduced the number of wildfires.

4.3 The role of land management prescribed burns

Prescribed burns can lower wildfire risk by reducing fuel load and creating fire breaks, but can become wildfires if poorly managed. Research is required on their spatial relationship with wildfire over the UK; are prescribed burns associated with fewer or less severe wildfires, or the reverse? Prescribed burns and wildfires need to be considered together in defining UK fire regimes and how they are changing. One of the major messages from the series was the concern expressed by land managers that changes in

[19] Tsitsopoulos, V. (2009). *Fire behaviour modelling*. Rapporteur report for FIRES3, Day 1, Session 3. Available to download from: http://www.fires-seminars.org.uk/downloads/seminar3/day1_fires3_session3_report_tsitsopoulos.pdf
[20] As footnote 19.
[21] Elliott, A. (2009). Discussion document on wildfire risk assessment and management at FIRES3, available at http://www.fires-seminars.org.uk/downloads/seminar3/discussant_elliott_fires3.pdf

the rural economy are already increasing wildfire risk (most notably the policy panel and Geoff Eyres in an impromptu talk, both at FIRES4). They felt that the build up of fuel load, coupled with a changing climate will soon result in a series of very severe fires.

4.4 An ecosystem disservice?

Fire is considered an integral aspect of management in most heathland and moorland habitats, but its impact and the extent to which it is essential for their dynamics is in review, particularly in light of changes in upland farming and the growing concern over carbon management[22]. The impact of fire on biodiversity, carbon budget and water colour is controversial. It is not always negative and is thought to vary with fire regime, yet most research relates to single fires with relatively little consideration of fire severity and fire history.

Ecosystem services were introduced at FIRES1. Althea Davies (University of Stirling) contributed to the debate by providing the longer-term context for these current issues. She presented historic evidence relating to ecosystem services, including the history of burning, biodiversity, rural livelihoods, and carbon budgets[23]. This prompted a debate about how far back to set the baseline for the desired ecosystem, since Britain's uplands are semi-natural ecosystems which have responded to changing climatic and human influences over time.

Stefanie O'Gorman (Jacobs) presented the framework from the Millennium Ecosystem Assessment[24], which takes a service-based approach to the valuation of ecosystems, and divides ecosystem services into four types: provisioning (e.g. crops); regulating (e.g. carbon sequestration); cultural (e.g. recreation); and, supporting services (e.g. pollination)[25]. The ecosystem services that moorlands and heathlands provide is outlined in Table 1. This approach enables the benefits of each service to be outlined and valued, to enable better decision making.

Table 1: Ecosystem services provided by upland heathlands (Haines-Young and Potschin, 2008[26] cited in O'Gorman, 2008)

Provisioning	**Regulating**	**Cultural**	**Supporting**
Food	Carbon sink	Spiritual	Pollination
Wool	Natural hazard protection / water regulation	Aesthetic	Nutrient cycling
Biodiversity		Recreation	Promotion of soil function and formation
Natural medicines		Historic culture	
Fresh water		Employment	

[22] Davies, A. (2008a). *Where do we set the baselines? A long-term perspective on fire management and moorlands.* Abstract for presentation at FIRES1. Available to download at http://www.fires-seminars.org.uk/downloads/seminar1/fires_sem1_abstracts.pdf

[23] Davies, A. (2008b). *Where do we set the baselines? A long-term perspective on fire management and moorlands.* Presented at FIRES1. Available to download at http://www.fires-seminars.org.uk/downloads/seminar1/fires1_althea_davies.pdf

[24] O'Gorman, S. and Bann, C. (2008). *A valuation of England's Terrestrial Ecosystem Services*. Final report to Defra. Available to download at http://www.fires-seminars.org.uk/downloads/valuation_englands_ecosystem_services.pdf

[25] O'Gorman, S. (2008). *Ecosystem services and valuation.* Presented at FIRES1. Available to download at http://www.fires-seminars.org.uk/downloads/seminar1/fires1_stefanie_ogorman.pdf

[26] Haines-Young, R. and Potschin, M (2008). *England's Terrestrial Ecosystem Services and the Rationale for an Ecosystems Approach*. Full technical report to Defra. Available to download from http://randd.defra.gov.uk/Document.aspx?Document=NR0107_7336_TRP.doc

The focus for debate at FIRES1 was the extent to which managed fires contribute to the maintenance of these ecosystem services or pose threats to them, especially with changes in climate. Andrew Walker (Yorkshire Water) outlined the implications of moorland fires for fresh water. Dissolved organic carbon causes discolouration of water and is a significant challenge for water authorities. He outlined the primary causes of colour generation as habitat type, grazing, burning and drainage, and illustrated the impacts of managed burns on colour release[27].

Fred Worrall (University of Durham) presented recent research on carbon storage and sequestration in upland peat soils following managed burning[28]. The results of the research illustrated that burning under controlled conditions does not always have negative impacts on soil and water quality, and under some conditions it might be possible for burning to lead to increased carbon sequestration. Fred noted that the risk associated with such management is unknown and confirmed that "hot" fires (those that burn into peat, especially) do lead to overall carbon loss. Experimentation is continuing on cut sites and wildfire sites.

Graham Sullivan (Scottish Natural Heritage) noted that the impacts of managed fire (or wildfires) on biodiversity vary not just according to the characteristics of individual fires and fire regime, but also with the way that impacts are assessed[29]. Thus, elements of fire regime, such as location, extent and intensity, and the factors that drive changes in regimes are important to consider, as these will determine the future impact on biodiversity and conservation. Such drivers of change include:

- Land management objectives;
- Effort and resources available;
- Traditions, experiences, and views of practitioners;
- Legislation, policy, and incentives; and,
- Direct and indirect effects of climate change.

More research is needed on UK fire regimes and their impact on ecosystem services. Ecological impact also depends on the baseline[30], time scale over which recovery is measured, and management objectives. We need to know the optimum fire regimes to manage different ecosystem services, and how to prioritise between them. In managing ecosystem services, the unwanted knock-on effects on the risk of severe wildfires must be considered.

4.5 Economic costs of fires

Fires are costly and challenge FRS' resilience to tackle other incidents. Helicopters (Figure 5) are costly but effective if called out early. Chris Ruddy (Pennine Helicopters) showed how fire scar size in the Peak District is related to the time before a helicopter is called out[31]. Long-term cost implications include loss of ecosystem services and cost of

[27] Walker, A. (2008). *Moorland fires – the implications for water.* Presented at FIRES1. Available to view at http://www.fires-seminars.org.uk/downloads/seminar1/fires1_andrew_walker.pdf

[28] Worrall, F. (2008). *The consequence managed burning for carbon storage and sequestration in upland peat soils*. Presented at FIRES1. Abstract available to download at http://www.fires-seminars.org.uk/downloads/seminar1/fires_sem1_abstracts.pdf

[29] Sullivan, G. (2008). *The implications for biodiversity and conservation of changes in managed fire regimes*. Presented at FIRES1. Available to download at http://www.fires-seminars.org.uk/downloads/seminar1/fires1_graham_sullivan.pdf

[30] Davies, A. (2008a). *Where do we set the baselines? A long-term perspective on fire management and moorlands.* Abstract for presentation at FIRES1. Available to download at http://www.fires-seminars.org.uk/downloads/seminar1/fires_sem1_abstracts.pdf

[31] Ruddy, C. (2009). The role of the helicopter in moorland fire fighting. Presented at FIRES4. Available to download at http://www.fires-seminars.org.uk/downloads/seminar4/fires4_chris_ruddy.pdf

landscape restoration after damage. Prevention and suppression costs need to be set against the cost of avoided damage to ecosystem services. This will require treating ecosystem services as property assets in the same way as buildings.

Figure 5: Helicopter with kestrel bucket in use at Bleaklow 2003 fire (Prendergast, 2009[32])

A session on the "Economic impacts of wildfires" at FIRES4 included a series of talks that provided an overview of the costs of wildfire suppression, their 'costs' on ecological services, local economies, and costs to restore wildfire sites. These talks were based on research carried out for the case study wildfire at Bleaklow, Peak District National Park in April 2003, introduced by Sean Prendergast[33] (Peak District National Park Authority). Jonathan Aylen (University of Manchester) presented research on the costs of suppressing fires[34]. He concluded that the suppression costs of the Bleaklow wildfire was around £550,000, which included a cost of £450,000 to the Fire and Rescue Services and £55,000 attributed to helicopter call-out (civilian and RAF)[35].

Claire Quinn (University of Leeds) then provided an assessment of the local economic impacts of this wildfire. Estimated costs included £35,000 for farming (store lambs at £35 a head for 10 years), £350,000 for grouse shooting (estimated loss over 5 years), and £850,000 for tourism (all 30,000 visitors deterred, assuming a spend of £5.60 per person per day)[36]. This highlighted the serious lack of quantitative information regarding the impacts of wildfire on the local economy, and Claire posed the question to the seminar attendees: "How do we begin to go about compiling the right information?" Government costing of wildfire is acknowledged as simplistic, ignoring costs to the environment.

[32] As footnote 2.
[33] Prendergast, S. (2009). *Bleaklow Fire 2003*. Presented at FIRES4. Available to download at http://www.fires-seminars.org.uk/downloads/seminar4/fires4_sean_prendergast.pdf
[34] Aylen, J. (2009). *Costs of suppressing wildfires*. Presented at FIRES4, Available to download at http://www.fires-seminars.org.uk/downloads/seminar4/fires4_jonathan_aylen.pdf
[35] As footnote 34.
[36] Quinn, C. (2009). *Local economic costs of wildfires*. Presented at FIRES4. Available to download at http://www.fires-seminars.org.uk/downloads/seminar4/fires4_claire_quinn.pdf

Restoration costs relating to the Bleaklow 2003 fire were analysed and presented by Jonathan Walker (Moors for the Future Partnership). He outlined the restoration project undertaken by the Moors for the Future Partnership (MFF) which has so far restored 4.3 km^2 of Bleaklow (around half of the area damaged in 2003 in addition to damages from historic fires) at a total cost of around £1,235,000 (approximately £2,900 per hectare)[37]. Restoration costs are therefore great, but should be offset against the need to restore ecosystem services and reduce the risk of future fires.

The issue of who should bear the costs was raised at FIRES3[38]. Regional FRS currently bear suppression costs, and landowners bear losses to property and livelihood in addition to costs of helicopter call-outs. It was suggested that strategies employed by other countries with higher fire risk should be studied. However, Albert Simeoni (University of Corsica) noted that in countries with high fire risk, there is also an increased risk to life, so more money is invested in wildfire.

Economic evidence of the impact of wildfire was strongly identified as a key driver of future wildfire policy reforms at FIRES3. Robust and reliable evidence on the full economic impacts is therefore a priority, both to further develop best practice in wildfire mitigation (land management, improving preparedness) and suppression (fire-fighting), and inform and drive future policy reforms.

4.6 Climate change and recreational access

Climate is changing and will affect wildfire risk (Figure 6). Its effects are complex, but are expected to mean more summer droughts with more frequent severe wildfires, like those of 2003, and a later fire season. Climatic changes will initiate a range of impacts on fuel structure and moisture content that can both increase and decrease fire hazard[39]. Warmer, wetter winters are likely to bring increased fuel accumulation and fewer suitable days for prescribed burns. Warmer summers are likely to increase visitor numbers and ignition sources. This is expected to bring further challenges for public access, which is already restricted on Access Land at times of high fire risk. These effects must be considered alongside changes in land management and rural policy. Any policy change which results in increased fuel load or increased public access potentially increases wildfire risk. The increase in access since the CRoW Act[40] has not in itself increased the overall number of fires, nor, from experience in the Peak District, does it appear to have significantly altered their distribution[41].

The problem of recreational access and its link to arson and accidental fires was discussed at FIRES2. In severe drought conditions, footpaths can be closed to access, but there is little evidence to suggest that this helps to reduce the risk of wildfire. If anything the presence of people may arguably even serve to reduce the length of time between outbreak and report[42].

[37] Walker, J. and Butler, M. (2009). *Fire site restoration costs: the Bleaklow 2003 fire*. Available to download at http://www.fires-seminars.org.uk/downloads/seminar4/fires4_jonathan_walker.pdf

[38] Karunasaagarar, A. (2009). *Economic impacts of wildfires*. Rapporteur report for FIRES3, Day 1, Session 2. Available to download from http://www.fires-seminars.org.uk/downloads/seminar4/fires4_day1_akarunasaagarar.pdf

[39] Davies, G. M. (2008). *How will climate change and vegetation vulnerability interact? How will fire regimes change?* FIRES2 respondent paper. Available to download from http://www.fires-seminars.org.uk/downloads/seminar2/fires2_programmeabstracts.pdf

[40] Countryside Rights of Way Act (2000)

[41] Prendergast, S. (2008). When, where and why do wildfires occur in the UK. FIRES2 respondent paper. Available to download from http://www.fires-seminars.org.uk/downloads/seminar2/fires2_programmeabstracts.pdf, page 10.

[42] As footnote 41.

The effectiveness of education programmes was also discussed in a workshop session on "Access" at FIRES2. In Dorset after a 3-year education programme, there was a reduction of 62% in wildfires. However, experience in Wales is different, and the cultural context seems to be important[43].

Redefining land as property within the legal system was a theme raised several times during discussions at FIRES2. This would allow prosecution of persistent offenders. It would also move vegetation fires up the FRS priority list of life, property and environment.

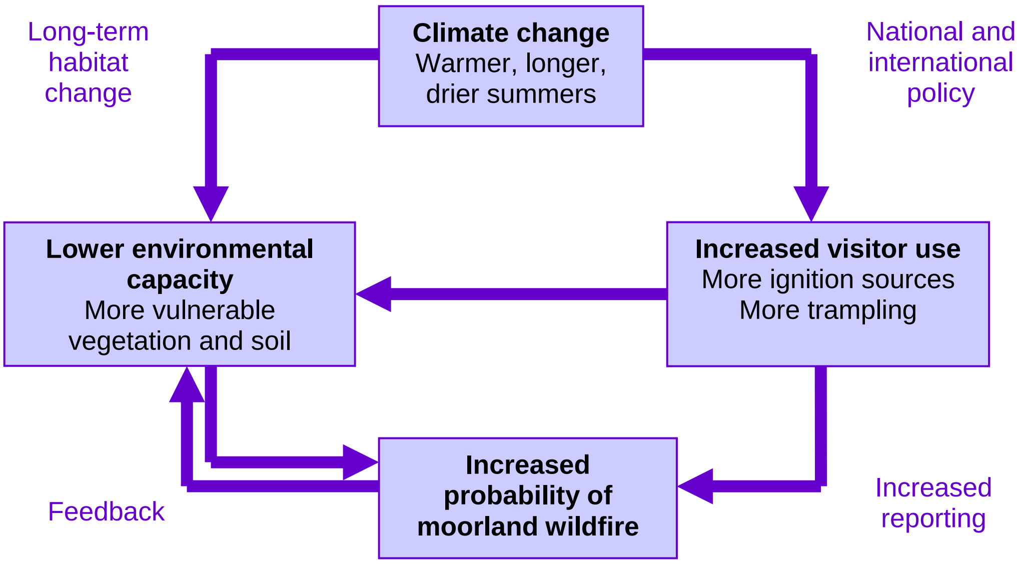

Figure 6: Relationship between climate change, wildfire and people (McMorrow et al., 2008[44])

4.7 Combined wildfire management strategies

Management of wildfire risk requires a combination of: fuel load reduction; reducing risk of ignition from human sources; reducing the flammability of vegetation in dry conditions; and improving suppression. Over-suppression without other measures increases the risk of severe fires, as has occurred in the USA and the Mediterranean. Fuel load management is critical. This was brought out strongly in the FIRES4 wildfire management scenario workshop, where one group was asked to consider the impact on other ecosystem services of improving wildfire suppression and controlling public access; it was stressed that frequency could be reduced, but without also managing fuel load, fire severity would increase. There is a need to review policies which inhibit fuel load management. Land mangers say that current UK land management policy is allowing fuel loads to become dangerously high, but policy-makers require evidence at a national scale.

[43] Wright, S. (2008). *Access break-out group*. FIRES2, Session 3. Available to download from http://www.fires-seminars.org.uk/downloads/seminar2/rapporteur_access_breakout_group_wright.pdf

[44] McMorrow, J. Lindley, S. Aylen, J. Albertson, K. and Cavan, G. (2008). Wildfire risk and climate change in the Peak District National Park. Poster presented at FIRES2. Abstract available to download http://www.fires-seminars.org.uk/downloads/seminar2/fires2_programmeabstracts.pdf, page 29.

4.8 Equipment, training and technical tools

Most FRS are neither well equipped nor well trained to deal with vegetation fires. Research and knowledge exchange on UK fire behaviour, especially for peat fires, is needed to improve the efficiency of fire suppression. Tools for forecasting and modelling wildfire risk in UK conditions are required, ranging from fire risk maps based on past fires and satellite remote sensing, to an improved fire danger rating system and fire behaviour models for UK conditions.

The focus of FIRES3 was on tools for forecasting and modelling wildfire risk. This seminar included two excellent European speakers, who presented wildfire modelling work in progress in Spain and Italy.

Paolo Fiorucci (CIMA Research Foundation, Italy) introduced the wildfire risk assessment and management work carried out in Italy[45]. He presented the modelling work undertaken to inform each of the risk assessment stages of planning, preparedness, response and restoration, which incorporated static, dynamic and active fire risk assessments, and burn scar mapping assessment after a wildfire event (Figure 7).

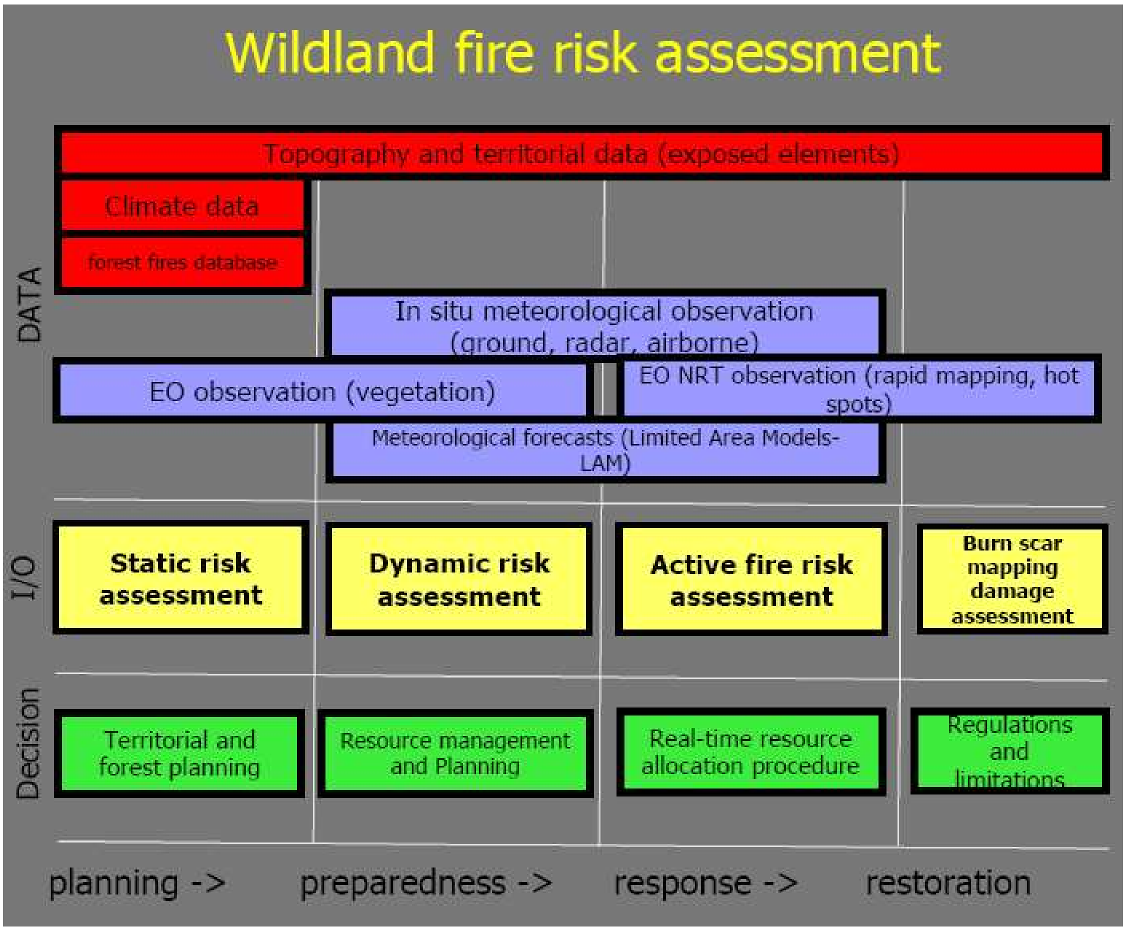

Figure 7: Wildland fire risk assessment in Italy (Fiorucci, 2009[46])

Cristina Vega-Garcia (University of Lleida, Spain) then outlined the fire problem in Spain and wildfire occurrence prediction using spatial models. She noted that severe fires are rare

[45] Fiorucci, P. and Gaetani, F. (2009). *Wildfire risk assessment and management*. Presented at FIRES3. Available to download from http://www.fires-seminars.org.uk/downloads/seminar3/fiorucci_fires3.pdf

[46] As footnote 45.

events, but they are not completely random: they tend to cluster in certain areas where they periodically recur, which suggest that human risk is not completely unpredictable[47].

A useful session on Day 2 at FIRES3 focussed on Prediction Systems. The ability to forecast fire outbreaks helps to reduce fire damage by fire watching, public warnings of fire risk and deployment of resources such as fire crews and temporary ponds.

Tim Donovan (UK Met Office) outlined the global and local models that underlie the Met Office's weather forecasting system, including 70 levels of atmosphere at a spatial resolution of 4 km for the UK. This set of unified models underpins two sets of prediction models for wildfires. The Fire Severity Index is a five day prediction system for wildfires in England and Wales. Public Weather Service advisors are also able to respond to a Category 1 incident with detailed advice taking account of factors such as topography and sunshine. The Met Office Fire Severity Index is used by some FRS to confirm local information. Forecasts raise awareness of fire dangers and encourage deployment of extra fire-fighting resources at times of high risk[48].

Jonathan Aylen (University of Manchester) outlined a statistical model for wildfire risk in the Peak District which takes account of both present and past weather conditions and the level of visits to the area. Key factors accounting for fires include current temperature and precipitation, dry spells and the level of visits to the Peak District. April and May are fire prone, especially bank holidays and weekends. Key issues were the portability of the model to other locations and the neglect of variables such as wind strength and direction and plant moisture[49].

Finally, there was some discussion about climate change and wildfire models – could they help with obtaining funding for moorland fire-fighting resources? The key problem here is that it is not only the climate that is being projected forward. Land use is also particularly important, such as changes in vegetation type, onset of spring and moisture levels in vegetation. In addition, other considerations include increasing visitors and therefore sources of ignitions, resulting from indirect impacts such as policies for a low carbon economy and promotion of use of the countryside for health benefits[50].

4.9 Research and knowledge exchange

FIRES demonstrated the value of knowledge exchange. The seminar series highlighted the mutual benefits of cross-disciplinary working and how much academics and practitioners can learn from each other. Our European visitors in particular noted how extremely valuable it was (and quite unusual to them) that attendees included such a broad range of academic disciplines and practitioners, who all considered the issues of wildfire as a serious topic, and were (almost always!) speaking the same language[51].

However, more research and exchange of knowledge is required. The seminar series identified a number of knowledge gaps, which include:

1. A comprehensive, accurate, spatially robust and accessible evidence base on UK wildfires. Ideally it should combine improved nationally-consistent FRS

[47] Vega-Garcia, C. Padilla, M. and Martinez. J. (2009). *Spatial aspects of wildfire*. Presented at FIRES3. Available to download from http://www.fires-seminars.org.uk/downloads/seminar3/vega-garcia_fires3.pdf

[48] Aylen, J. and Cavan, G. (2009). *Prediction Systems.* Rapporteur report from FIRES3, Day 2, Session 2. Available to download from http://www.fires-seminars.org.uk/downloads/seminar3/day2_fires3_session2_report_aylen_cavan.pdf

[49] Aylen, J. (2009). *Science into practice: Prediction systems for wildfires*. Presented at FIRES3. Available to download from http://www.fires-seminars.org.uk/downloads/seminar3/aylen_fires3.pdf

[50] As footnote 41.

[51] Views presented on comments on seminar feedback forms and in personal communication.

records of attended vegetation fires, with fire databases kept by land owners and remotely sensed data.

2. Acceptable multi-disciplinary criteria for assessing and measuring fire severity. Should this be a physical definition using fire radiant intensity and duration, or one focussing on impacts (as suggested by Graham Sullivan in FIRES1), for instance on biodiversity, water quality, scheduled ancient monuments and carbon budgets? The need to clarify existing criteria is demonstrated by the difference in interpretation of the terms ‘cool’ and ‘hot’ burns. To land managers, a ‘cool burn’ is one which passes quickly through the vegetation canopy and does not burn into the soil, whereas a hot burn by implication is a more damaging fire burning down into the duff and soil layer. To fire scientists it is reversed; the ‘cool’ burn is flaming combustion, whereas the ‘hot burn’ is likely to be smouldering combustion and actually occurs at *lower* radiant temperatures. Land managers are referring to the fire behaviour and longer-term ecological impact, whereas fire scientists are referring only to the physical properties of the fire.
3. Further, what proportion of prescribed burn and wildfire burn scars show signs of severe burning? There is a tendency to over-simplify and regard prescribed burns as always mild (‘cool’) burns and all wildfires as severe (‘hot’) burns. In fact, we need to be able to assess fire severity *within* a burn scar.
4. Regional fire regimes and how they are changing; the relationship between frequency, severity and timing of prescribed burning and the frequency, severity and timing of wildfires. For instance, are prescribed burns associated with fewer and less severe wildfires, or with more frequent and severe wildfires? Does this vary over the UK? How are changes in land use and grazing intensity, etc. affecting fuel load and wildfire?
5. Appropriate fire regimes to achieve management objectives for each ecosystem service under climate change scenarios.
6. Synergies and conflicts between policies for managing ecosystem services and polices for managing wildfire. The FIRES4 workshop showed that optimising management of certain ecosystem services could increase fire risk, and equally, prioritising reduction of wildfire risk (in the same way as flood risk reduction) would impact negatively on some ecosystem services, but positively on others (Claire Quinn, FIRES4[52]).
7. Appropriate costing tools for ecosystem services, especially for regulating and cultural ecosystem services. Using such tools, what are the indirect costs of a vegetation fire on ecosystem services set against the direct costs of fire-fighting and active fire prevention?
8. The extent to which stakeholders’ attitudes to wildfire are changing in response to climate change scenarios and changes in the rural economy. What evidence is there that climate change actually increases visitor pressure and incidence of fire? What is the best way of influencing the public to minimise arson and accidental fires?
9. Improved tools for forecasting wildfires, which can be used to guide timing of prescribed burns.
10. Other technical tools such as fire risk mapping, fire danger models and fire behaviour models for UK conditions, especially for peat fires.

[52] Quinn, C. (2009). Wildfire Management Scenario Workshop Report. FIRES4, Day 2. Available for download from www.fires-seminars.org.uk/programme/seminar4/

11. FRS officers' knowledge of: vegetation fire behaviour; tactics for fighting wildfires (including use of suppression fire); use of geospatial technologies such as GPS and visualisation; and knowledge required to complete compulsory key data fields in IRS.

4.10 Partnership working

The partnership approach of shared wildfire training and resources pioneered by the Peak District Fire Operations Group (FOG) and now in operation by Northumberland and several other wildfire groups is an efficient and effective 'grass-roots' approach to the wildfire issue. FOG's activities include cross-sector and FRS brigade incident planning, and compatible suppression equipment and techniques. This approach should be supported by central government. It is helpful both in planning, preventing and responding after a fire.

The value of research in wildfires was highlighted throughout the seminars. However, scientists need to make information available to fire-fighters in an easily usable form and at different levels, e.g. for fire-fighters or technical support personnel. This was a discussion point at FIRES3, where it was suggested that, at the tactical level, it would be most effective if science was translated into simple core concepts, such as, "fire travels faster uphill" and "ridges near the head of steep valleys are the most dangerous locations if eruptive fire occurs"[53]. These simple messages need to be translated into operational processes, and could be prioritised into 'must know', 'should know' and 'nice to know'. For more detailed advice, Incident Commanders (Senior FRS Officers) need to be able to call upon an expert, who perhaps has access to Geographic Information Systems and modelling software, in the same way that this happens with structural fires. Scientists can also have a valuable role in fire-fighting training, as the laboratory of Domingos Xavier Viegas illustrated (Figure 4). This has already begun in the Peak District National Park, where an informal knowledge exchange group was set up at the request of FOG, and academics contribute to wildfire officers training courses.

5. Conclusion

Fire has a long history in UK moorlands and heaths, and is an integral part of moorland management. However, management priorities are changing, which will alter fire regimes and affect the complex interactions between fire, climate, land use and people. The importance of land abandonment in increasing wildfire risk through its effect on fuel load was highlighted as a serious issue in Spain, and poses a greater long-term threat than climate change. There are parallels in the UK, for example, the reduction in grazing intensity. There are different perspectives on fire; however, not all fire is bad, for example, fire can be used to manage fuel load. More data is required on biodiversity, carbon and water quality to set the best fire regime for new ecosystem management objectives[54].

Wildfires are resource-intensive and challenge FRS resilience. However, wildfires have a lower priority than structural fires. The importance of redefining moorland and heathland ecosystem services as 'property' with costed asset values was highlighted. This would

[53] Zinoviev, A. (2009). *Science for fire-fighting strategies*. Rapporteur report for FIRES3, Day 2, Session 1. Available to download at http://www.fires-seminars.org.uk/downloads/seminar3/day2_fires3_session1_report_zinoviev.pdf

[54] McMorrow, J. Legg, C. Aylen, J. Walker, J. Cavan, G. Quinn, C. and others. (2009). *Fire, Interdisciplinary Research and Ecosystem Services: Some reflections on the FIRES series*. Presented at FIRES4. Available to download from http://www.fires-seminars.org.uk/downloads/seminar4/fires4_fires_series_summary.pdf

make it easier to prosecute arson cases. Practitioners need simple tools, communicated plainly, to help with forecasting fires and understanding fire behaviour. People are a major cause of wildfires. However, we need to know more about public attitudes to fire risk. This would help to improve effectiveness of public education on wildfire risk without encouraging arson. Appropriate valuation tools are needed to judge costs of prevention and suppression against benefits of ecosystem services saved. There are potential conflicts in policy, and there are likely to be trade-offs between ecosystem services and wildfire policies, e.g. policies which result in changed fuel load are likely to change wildfire risk[55].

The national needs for wildfires include improved reporting of vegetation fires, and training and knowledge exchange. There is local best practice, but there is a need for a UK national policy towards wildfires. Finally, there are lessons to be learnt from Europe[56].

This report summarises the presentations and discussion at the FIRES events, and information available on the website. Much more material is available at www.fires-seminars.org.uk. Comments or questions should be addressed to Julia.McMorrow@manchester.ac.uk

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Appendix 1: Steering Group

Julia McMorrow, University of Manchester (Principal investigator, ESRC-NERC Transdisciplinary Seminar Series on Ecosystem Services)
Colin Legg, University of Edinburgh (Co-investigator)
Jonathan Aylen, University of Manchester (Co-investigator)
Jonathan Walker, Moors for the Future Partnership (Co-investigator)
Klaus Hubacek, University of Leeds
Claire Quinn, University of Leeds
Simon Thorp, The Heather Trust
Marion Thomson, The Heather Trust;
Mark Jones, Chief Fire Officers' Association
Gina Cavan, University of Manchester (Administrative Assistant).

[55] As footnote 57.
[56] As footnote 57.

Moorland wildfire scar at Colne. Lancashire, July 2006, 9 km^2 burnt (Chris Ruddy, 2009, The role of the helicopter in moorland fire fighting. Presented at FIRES4. Available to download at http://www.fires-seminars.org.uk/downloads/seminar4/fires4_chris_ruddy.pdf