Harmonising approaches to evaluation of forest fire risk

Result of a study tour to New Zealand supported by TRANZFOR

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Tranferring Research between EU & Australia, New Zealand on Forestry and Climate Change

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Executive Summary

This report is the result of a four week study tour in November/December 2012 to explore the need and potential for harmonising wildfire danger and prediction systems between New Zealand (NZ) and the United Kingdom (UK). The visit was kindly hosted by Scion, the New Zealand Forest Research Institute, where there has been over twenty years of development of fire danger systems, supported by research and Knowledge Exchange activities. It was support financially by the Forestry Commission, and the EU through its TRANZFOR Programme.

The research has shown the evolving need for the management of forest and wildfire risk in the UK. This has been brought about by changes in forestry policy and practice, and by likely changes in climate. Available data on forest fires show a similarity in the scale of the challenge between NZ and UK. They also reveal that these fires are posing an annual management cost to the Fire & Rescue Services in many tens of millions of pounds, irrespective of losses of a wide range of forestry goods and services. However, the research also demonstrates a different approach and scale of management response to rural fires between NZ and UK, with the latter comparatively unprepared, notably in the context of risk reduction.

NZ have evolved a range of tools to manage fire risk and a number of these are considered suitable for the UK. However, the research also suggests that it is more important to engender a culture and policy environment supportive of fire risk management. Without it, the development of similar tools may fail to make much difference. There is a growing need for leadership within government to bring together all agencies involved in both wildfire and land management so that a multidisciplinary plan for action be developed.

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Introduction

The main objective of the visit to Scion[1] during November – December 2012 was to study the New Zealand (NZ) context for, and approaches to, the prediction of forest fire risk. This was based on the fact that forest fire systems there have been evolving actively over the last two decades, and are now being used to make predictions about possible changes in risk as a result of climate change. In addition, there are many similarities in forestry policy and practice, and in climate, between the United Kingdom (UK) and NZ. It was considered a very valuable opportunity to explore what of NZ fire risk management experience and infrastructure might be capable of being transferred to support UK needs. Significant savings in time and the cost of development can be made by adopting an existing fire danger rating system (Fogarty et al., 1998), and a need for enhanced collaboration in wildfire science at national and international levels has been recently voiced (Stoof et al., 2012).

In the UK, wildfires occur in a range of habitats, and only about 10-20% affect forests *sensu stricto* (see p.15). Nevertheless, understanding of the risks posed by forest fires has risen up the agenda in recent years, partly as a result of improved fire data recording (DCLG, 2011; Jollands et al., 2011). In addition, research has shown the likelihood of significant increase in risk as a result of climate change (Moffat et al., 2012). This report will attempt to review these issues and make recommendations for changes in UK forestry policy, practice and research in order to reflect these trends.

Context for fire risk management in NZ and UK

This section identifies similarities and differences between the two countries in order to understand the way fire risk systems have evolved, and the degree to which harmonisation might be possible.

New Zealand

NZ has a comparatively recent history of land clearance, much of which involved the use of fire. Although wildfires have always occurred as a result of natural fire causes (e.g. lightning and volcanic activity), there was approximately 85-90% forest cover in 3000 BP (McGlone, 1989). Substantial deforestation by Polynesian settlers, notably the Maori, is considered to have begun at around 800 to 400 B.P. This reduced the forest cover from about 80% to around 50% by the time the first Europeans arrived (Ogden et al., 1998). Further forest clearance occurred following European settlement in the early decades of the 19th century (Wardle, 1985). Today, NZ has a forest cover of about 31%, with a 10% cover of 'shrubland' species (FAO, 2010). With a human population of under 4.5 million and a land area of 268,021 km^2, it has a dominantly rural culture over the vast majority of its land surface.

Today, New Zealanders possess a culture of using and living with fire much more than in the UK. Fire is widely used for land clearing, to improve grazing, and to remove cropping residues and other wastes (e.g. hedge trimmings). It is no longer regularly used in forestry to remove harvesting residues and aid replanting due to land management planning rules and environmental concerns (air pollution, nutrient loss) Fire is also used for disposal of wastes from habitation in areas where urban waste recycling services are poor or absent. Fire remains a part of Maori culture. Rural dwellers are mainly aware of the 'dos' and 'don't' of rural fire management, though, inevitably, this understanding is weaker amongst urban populations, some of whom are moving out of towns and cities as a lifestyle choice. Agricultural intensification, for example with irrigation, has also reduced the use of fire in the rural landscape.

Figure 1 shows the main vegetation types in New Zealand. Based on statistics derived from the NZ Land Cover Database[2], New Zealand's land cover is:

- 50 per cent native forest, native vegetation and other native land cover;
- 39 per cent pasture (high-producing and low-producing grassland land-cover classes);
- 9 per cent exotic forest and exotic shrubland;
- 1.6 per cent horticulture (horticultural, viticultural and cropping land-cover classes);
- 0.8 per cent artificial surfaces such as urban and built up areas, landfills and transport infrastructure.

The main 'exotic' production species in managed forests is *Pinus radiata* with a rotation length of approximately 26-28 years, followed by Douglas fir (*Pseudotsuga menziesii*) and Eucalyptus spp. Most plantations are managed as high forest systems, with clearfell followed by replanting. Native vegetation is classified as shrubland, with vegetation of ferns, Manuka and Kanuka, Matagouri, broadleaved indigenous hardwoods, sub alpine shrubs, and grey scrub and mangrove. Such vegetation is regarded for habitat provision and there is a strong presumption towards its preservation, maintenance and improvement, enshrined by appropriate legislation and government infrastructure. Fire risk is significant in many of these vegetation types, and recovery following fire is slow or absent. In addition, there are significant areas of non-native gorse, broom and mixed exotic shrubs which are also highly flammable.

New Zealand's climate is temperate maritime with an average of roughly 2000 sunshine hours a year. January and February are the warmest months, with July the coldest. Overall, the climate is fairly mild with few extremes of temperatures. The average temperature ranges from 15°C in the upper regions of the North Island to 10°C near the bottom of the South Island. Average temperatures range from 7°C in winter to 16°C in summer, although temperatures can reach the 30s. Annual rainfall varies from less than 400 mm in parts of Central Otago to more than 12,000 mm in the Southern Alps. In the Koeppen-Geiger classification, New Zealand has a Cfb climate; a temperate humid climate with the warmest month under 22°C, the coldest month between 18 and -3°C and four or more months more than 10°C[3].

New Zealand has a robust set of legislation to help manage fire risk in forests and other rural areas, most notably the Fire Service Act 1975 and the Forest and Rural Fires Act 1977, with subsequent amendments in 1987, 1989, 1990 and 2005. These Acts provide for the role of the NZ Fire Service Commission as the National Rural Fire Authority, responsible for overseeing policy, standards and coordination of Rural Fire Authorities (RFAs), as well as the urban NZ Fire Service. The RFAs (currently 73) are responsible for the *fire protection* of approximately 97% of New Zealand's land area that lies outside of the urban fire districts. RFAs are generally territorial authorities, but also take in the Ministers of Conservation and Defence, and rural fire committees comprising mixed membership, including forest owners. Annex 1 contains recent overviews on the NZ Fire service and the NZ Rural Fire Authority.

It is important to stress the role of fire protection, as distinct from fire fighting – RFAs have distinct responsibilities for educating the public on fire risk, issuing permits for use of fire, ensuring that land owners exercise appropriate fire protection measures, as well as co-ordinating fire-fighting operations when these are necessary. There is thus a significant workforce trained and experienced in rural fire protection and control, and this is supplemented by a number of volunteer staff (c. 7,400)[4] who undertake both protection and fire-fighting operations. Hence, there is a broad societal and political understanding of the relative risk posed by forest and rural fires, with education and Knowledge Transfer programmes that are well developed and reasonably successful.

To support rural fire policy and practice, NZ has a well established rural fire research group based at Scion in Christchurch. Research into fire behaviour and management began in 1992, and since then a major focus has been to develop and validate a Forest Danger Rating System (Anderson and Pearce, 2008). Today, fire research also takes in fire safety, social research around community interaction, as well as research continuing to understand fire from an ecological, biophysical and meteorological perspective. There is an extremely effective Knowledge Exchange and extension provision coupled with research undertaken. In the 2012-13 financial year, the Scion fire research budget totalled c. $1M (ex GST), comprising $460k 'core' funding from Ministry of Science & Innovation, $160k from the fire sector, $280k from other commercial customers, and $130 'one-off' government funding. This currently supports around four FTEs, comprising two full-time and three part-time researchers, plus contract staff as required. Research is overseen by a NZ Rural Fire Research Advisory Committee, drawn from relevant national stakeholders, and formalised in a Collaboration Agreement. This provides strategic direction and governance, as well as financial and in-kind support (which in turn is effective in leveraging government funding).

Reporting of forest and other rural fires is somewhat variable in quality (Anderson et al., 2008a, 2008b). The most reliable national wildfire reporting system is based on an annual return of fire records from the RFAs to the National Rural Fire Authority each year. New Zealand is able to report forest fires to the FAO Forest Resources Assessment based on a sound system of reporting, at least since 2000 (FAO, 2010). Figure 2 shows the areas of grassland, scrub and forest burnt in recent years. These total around 6000 hectares each year from 3000 rural fires (Doherty et al., 2008). The economic cost of these wildfires in NZ has been recently reviewed by Wu et al. (2008). They based their analysis on pre-suppression and suppression costs (e.g. public campaigns, fuel management costs, administration and operational costs, machinery and equipment) and 'after fire' costs (e.g. environmental impacts, costs to forestry-related industries, damage, health costs, carbon emissions). They estimate an annual average total cost (2002-2007) of $97.7 million, equivalent to £36 million p.a. at the time of the analysis. It is estimated that approx 15% of the total wildfires in NZ are escapes from land clear burns started to clear crop stubble, grassland and woody vegetation, and between 5 and 20% are deliberately lit vegetation fires[5].

United Kingdom
In contrast to NZ, the UK has a history of forest clearance dating back into the Mesolithic, but especially the Neolithic periods of prehistory. It is estimated that following a post-glacial maximum of around 70-80% forest cover, this had been reduced to between 50 and 60% cover by 5000 BP (Quine et al., 2011). However, by the time of the Domesday Book, only 15% cover was recorded for England (Rackham, 1986). Deforestation continued steadily during the following centuries to reach a low of c. 4-5% as early as 1300. Fire would have been used extensively during prehistoric forest clearance, though use of timber for construction and charcoal became increasingly important reasons for woodland loss in historic times. Today the UK has a forest cover of 12.8% (Forestry Commission, 2012), a similar land surface to NZ (243,600 km²), but a much larger population (63 million).

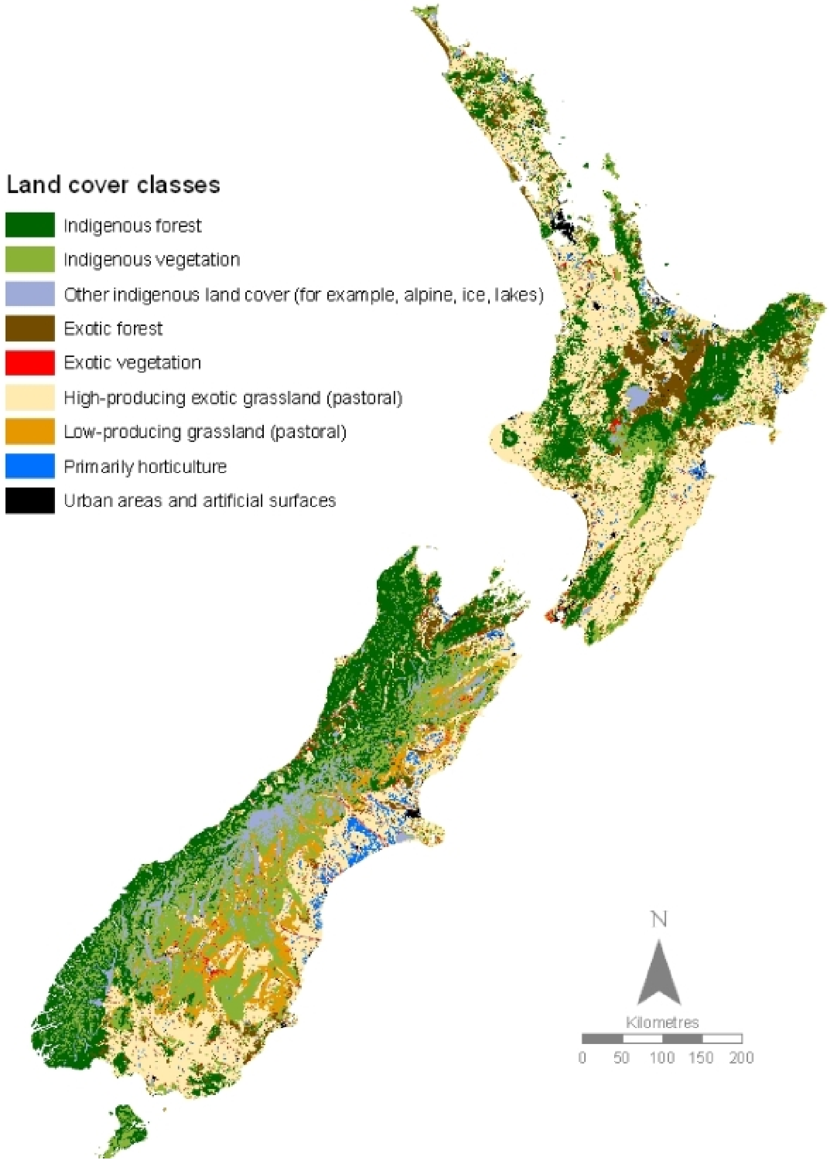

Figure 1. Land cover in New Zealand in 2002 (LCDB 2), grouped into nine major land-cover classes[6].

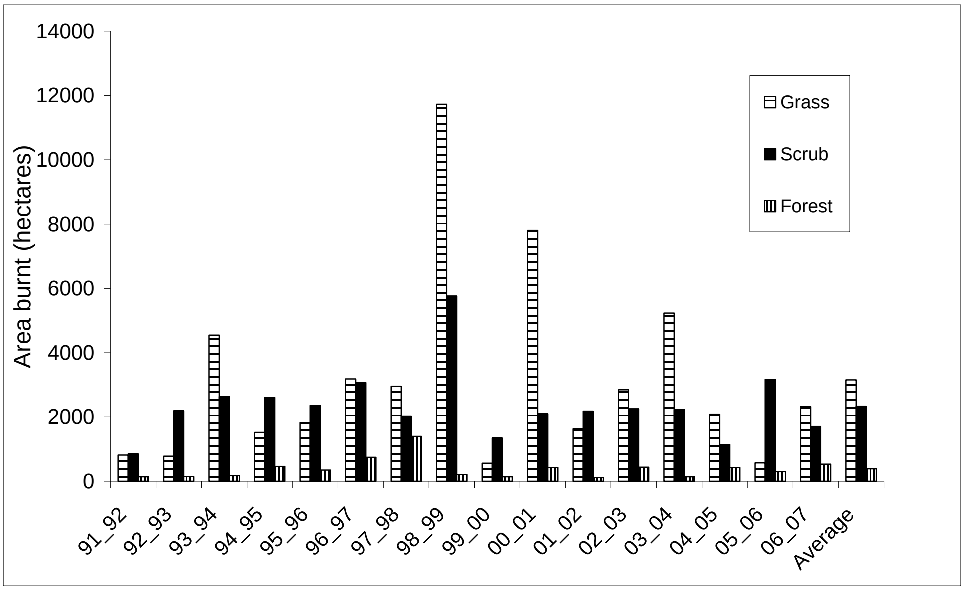

Figure 2. Areas burnt by wildfires in New Zealand, 1991-2007.
Derived from Doherty et al. (2008).

Fire is still used in particular facets of land management, for example, reducing brash and harvesting wastes in some forests, and stubble burning on farms (only allowed in Scotland), and most extensively in heather moorland regeneration. However, these uses of fire have reduced significantly over recent years, with a consequent ‘knock-on’ effect on skills and experience of managing fires safely. Moorland is comparatively inextensive (c. < 40 000 ha in England and Wales), but much more extensive in Scotland (estimated at 3 million ha[7]). It is important for wildlife and game sports.

England’s climate can be described as temperate maritime, because the Gulf Stream ensures mild, maritime influenced weather. Average annual rainfall in the north is more than 1,600 mm, but central and southern England receive an average of less than 800 mm. The coldest months are December, January and February, when the temperature is usually between 3 and 6°C. In July and August, the temperature averages between 16 and 21°C.

Like the rest of the UK, the climate of Scotland is also subject to the moderating influences of the Gulf Stream, although the temperatures are generally lower than in the other parts of Great Britain. Temperate winters and cool summers are typical, and extreme seasonal variations are rare.

In the western coastal region, where the moderating effects of the Gulf Stream are strongest, conditions are somewhat milder than in the east. The average January temperature of the eastern coastal region is 3°C, and the average January temperature of the western coastal region is 4°C; general July temperatures are 14°C and 15°C.

In the Koeppen-Geiger classification, the climate of England can be classified as Cfb, similar to much of New Zealand (p.5). The mountainous areas in Wales and Scotland have a Cfc climate which is similar to a Cfb climate, but with less than four months above 10°C over average.[8]

Compared to NZ, legislation on rural fires in the UK is comparatively weak. The main Act, the Fire and Rescue Services Act 2004 focuses on fire safety and fire-fighting in the urban environment and only acknowledges the importance of fire protection in the wider environment in one small section. The Regulatory Reform Order (Fire Safety) 2005 requires a duty for general fire precautions, including risk assessments, prevention, fire safety arrangements, elimination and reduction of risk, fire fighting and fire detection, emergency routes etc., but it specifically excludes both forestry and agriculture. Protection of the environment is only latterly built into Fire and Rescue Authority Integrated Risk Management Plans (DCLG, 2008a), but it is debatable whether fire and rescue services prioritise this responsibility particularly highly. Infrastructure for rural fire prevention is very weak, and that for rural fire fighting is also relatively immature, and there is no agency with specific authority to manage wildfire. Thus, urban fire-fighting forces are used to cover most rural wildfires, despite being primarily equipped and trained to deal with structural fires in urban settings (McMorrow, 2011). Nationwide, approximately 18,000 ‘retained’ firefighters to provide fire and rescue cover to around 60% of the UK in support of full-time staff, particularly in rural areas[9]. However, general societal preparedness for wildfires is poor.

In the UK, forest fire research has been rather uncoordinated, and historically the Forestry Commission (FC) has only focussed on fire control and suppression from a work study perspective. Latterly there has been some interest in exploring reasons for arson in South Wales (Jollands et al., 2011), but there is now no dedicated FC forest fire research programme, with only a small component of the climate change adaptation programme examining forest fire risk. Outside the FC, there has been significant fire research centred at Manchester and Edinburgh Universities (e.g. Albertson et al., 2009; Davies et al., 2008), as well as the UK Met Office (e.g. Kitchen, 2007; Thomas, 2008).

Forest fires are currently given relative low priority in risk management within the Forestry Commission and its forest management agencies ‘Forest Enterprise’. In Corporate Risk Registers, forest fires are not recognised separately, and are regarded as “*natural*[10] phenomena”. Societal interest in rural fires is generally very low. However, it is possible that with recent occurrence of wildfires in the Home Counties, forest and other rural fires will be acknowledged in the next review of the UK National Risk Register[11] (R. Gazzard, pers. comm.).

Until recently, the reporting of forest and other wildfires has been very poor, with the UK ceasing to report fires to FAO in the National Resources Assessment (last report in 2006, and likely to be extremely inaccurate). Since 2009, outdoor fire data have been captured more effectively in some countries of the British Isles, notably England and Scotland (see p.15).

Fire danger systems in UK, NZ and the EU

To explore the possibilities for harmonising systems across the UK and NZ, it is necessary to review them. In this section, the main systems that have been or are in use in the UK and NZ are described. No attempt is made to look in detail beyond these two countries in this report, although it is acknowledged that many other systems exist in other parts of the world. However, a pan-European system is provided by the EU (Alexander, 2010), and the merits of this for the UK are briefly discussed too.

United Kingdom
One of the earliest fire systems in the UK emerged from a programme of observations mainly in south-west England in the late 1950s. Claimed to be based on 'extensive trials' over the course of only one year, the scientific basis for the system offered by Rouse (1959) is questionable. The system was based on assessments of climatological variables, notably rainfall, mean daily maximum temperature, relative humidity, and wind. Values for these generate scores which were combined empirically to produce a fire danger rating index and with season to produce a 'Degree of Fire Danger'. Connell and Jeffers (1965) suggested the tables could be used 'with complete confidence' but the underlying fire model is inaccessible except in prosaic terms, and no evidence is presented to suggest that the index was tested against evidence of fire occurrence. Although the chosen climate variables have much in common with more modern systems, the system offers no opportunity for further development.

Another, more sophisticated system was used in the Forestry Commission in the 1980s and 1990s, and appears to be in use in some parts of Forest Enterprise today (p.25). 'Fire hazard' is developed from measurements of four variables: ground vegetation type and condition, relative humidity and windspeed, though a more detailed methodology requires rainfall and temperature data too. 'Fire risk' is based on season, day of week, time of day and weather conditions as they affect people in the forest. The 'Fire Danger Rating' is derived from a combination of the fire hazard and fire risk.

The methodology has elements which are found in modern systems, notably the separation of hazard and risk, and the use of information on the degree of public use of a forest together with fuel quality. However, it is not clear what the basis of the empirical model is, nor the underlying purpose of the rating. That the system was modified between 1988 to 1991 suggests some comparison between prediction and experience but no scientific publications have been identified associated with it.

A more modern UK system developed outside of the Forestry Commission, but which uses a forest fire danger rating as the basis for its fire model is the **Met Office Fire Severity Index (MOFSI)**[12]. This is based on the Fire Weather Index (FWI) module of the Canadian Forest Fire Danger Rating System (CFFDRS)[13], a national system for rating the risk of forest fires in Canada. Forest fire danger is a general term used to express a variety of factors in the fire environment, such as ease of ignition and difficulty of control. Like the model described above, MOFSI incorporates weather elements such as rainfall, relative humidity, windspeed and rainfall, together with information on moisture levels in the soil and the nature of antecedent weather. However, it currently only uses the final Daily Severity Rating (DSR)[14] component of the FWI system (derived from the FWI value itself), and information provided by the other six components of the system is not utilised. No attempt is made to explore fire risk, nor has fire behaviour been modelled or predicted. MOFSI was primarily developed to support management of heathland environments for people access. Kitchen (2007) considered that the underlying basis for calculation of fuel moisture codes based on Canadian forest floor data was probably sufficient to be used under UK conditions too. Unlike previous models, MOFSI has undergone some testing and validation under UK conditions (Kitchen, 2007; Legg et al., 2007; Thomas, 2008). Currently, MOFSI provides daily and five day forecast estimates of the likely severity of a fire should one occur for a grid of 156 locations across the country[15]. So far, little work has been performed to specifically explore the value of MOFSI for forest fire policy and management needs, though there is no doubt that it has the inherent capability to deliver a range of useful fire information products.

Research to further explore the use of MOFSI as a fire weather index, and to devise additional models of fire behaviour, notably in heather moorland, was undertaken by Legg et al. (2007) and Legg and Davies (2009). Considerable progress was made during a comparatively short period of intense fire research, including preliminary analysis of fire occurrence datasets against fire location and vegetation type, and relationship to component parts of the Canadian FWI system. Unfortunately, the work under this project has not been taken up and further developed by a consortium of appropriate administrations.

In addition to the development of MOFSI, Gazzard (2012) has provided useful guidance on assessment of fire risk. However, it is uncertain how widely this has been taken up as it lacks endorsement by the Forestry Commission or other government department.

New Zealand

The history of development of fire danger systems in NZ is described well in several publications including Fogarty et al. (1998), Majorhazi (2003) and Anderson (2005, 2009). Like the UK, the Canadian Forest Fire Danger Rating System also supports fire danger rating systems in New Zealand, and *adoption* of the Fire Weather Index module was much earlier, in 1980 (Valentine, 1978; Anderson, 2005). However, the Canadian FWI system wasn't *adapted* to the NZ fire environment until 1992 when the renewed rural fire research programme began. The current New Zealand Fire Danger Rating System (NZFDRS) comprises two main components, a Fire Weather Index (FWI) system and a Fire Behaviour Prediction (FBP) system.

The Fire Weather Index (FWI) system is considered nearly identical in structure (Figure 3) to that of MOFSI, not surprising given the derivation of both from the same Canadian origin. Its purpose is to give a rating to the potential for fire to occur, given the nature of the weather, and is thus a hazard rather than risk assessment. In this regard, all components of the FWI system are used and published, in contrast to MOFSI.

Like MOFSI, the system requires daily inputs of a range of weather data, and relies upon a set of assumptions about changes in forest floor fuel moisture in the reference fuel type, *Pinus banksiana* and *P. contorta*, and the relevance of these to species used in pine plantations in NZ. Extension of what is effectively a forest-based system to non-forest fuel types (grass and scrub) has caused problems in NZ (Fogarty et al., 1998; Anderson, 2009), but has been supported by an ongoing programme of research to validate it to these other vegetation types (e.g. Anderson and Anderson, 2009, 2010).

Daily (and hourly) data are collected from a network of 170 weather stations located across the country by the National Rural Fire Authority, and used to calculate values of the FWI System components[16]. This weather station network includes stations owned and maintained by Rural Fire Authorities in more remote rural areas, as well as climate stations managed by the NZ MetService and National Institute of Water & Atmospheric Research (NIWA)[17]. The archive of fire weather and fire danger data obtained from these stations has proven to be an invaluable resource for numerous studies on the fire climate severity of NZ (see Pearce and Clifford, 2008; Pearce et al., 2011b).

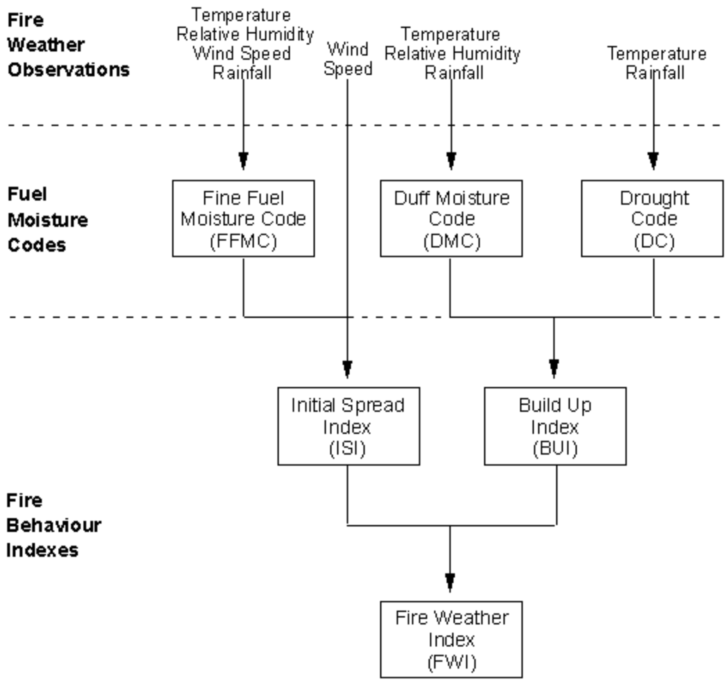

Figure 3. Structure of the NZ Fire Weather Index. From Anderson (2005), after Anon. (1993).

The Fire Behaviour Prediction (FBP) system is constructed to support operational planning (readiness and reaction) in the event of fire breaking out. Its purpose is to provide quantitative estimates of fire behaviour based on specific combinations of fuel and terrain, as well as weather. Primary outputs consist of predictions of rate of fire spread, fuel consumption, head fire intensity and fire description. There are also a number of secondary outputs, such as fire area and perimeter length. The system developed in NZ (Pearce and Anderson, 2008) is similar to one in Canada (Forestry Canada, 1992; Taylor et al., 1997), but in each country the system has been based on different fuel types to reflect different vegetation types. In both cases, however, the suite of models available have been based on correlation of FWI System values against fire behaviour observations collected from an extensive programme of experimental burns and wildfire documentation. These models have then been used to develop an impressive range of fire behaviour prediction tools to support readiness and response planning, including paper-based look-up tables, software calculators for PCs and smart phones, and a GIS-based fire growth simulation model (Prometheus)[18]

The FWI and FBP systems are combined in order to produce a five scale fire danger classification (Anderson, 2005), based on the methodology of Alexander (1994). This is designed to provide a broad-area rating of fire danger in terms of expected burning conditions for each of the three predominant fuel types – Forest, Grassland and Scrubland. The outputs are used for public information and area based fire management (Anderson, 2009). In addition, information from land-use and vegetation mapping has been combined with these systems within the **Fire Weather Monitoring System (FWSYS)** to produce spatial maps of potential fire behaviour in a GIS environment[19]. These maps can be used for operational and strategic planning purposes. Dedicated (paid) weather forecast services are also used to calculate forecasted fire danger ratings that are provided to fire managers to assist short-term planning (e.g. preparedness planning for prescribed burning) and incident management (Pearce and Majorhazi, 2003). However, the currently separate archived, current and forecast FWSYS modules are presently been upgraded in a new integrated system that will provide a single "one stop shop" for fire managers to access required fire danger information in the form of maps, graphs and tables via a modern, multi-window graphical user interface[20]

Scion are also active in working with other agencies to maximise and optimise access to fire danger information, including maps, reports and forecasts via the internet, and 'apps' for smart phones. Scion support these outputs with a wide range of 'tech transfer' activities and materials, such as 'Rural Fire Research Updates', 'Research Reports, and 'Fire Technology Transfer Notes'. They also organise workshops, seminars, training courses and other face-to-face activities for fire end-users to promote uptake and use of tools and research findings.

In tandem with the evolution of the NZFDRS, a system for **Wildfire Threat Analysis** (WTA) has been evolving. This is a national methodology for quantifying the extent and levels of the factors that contribute to wildfire threat (Majorhazi, 2003). Threat is defined as a cumulative combination of ignition potential (risk), potential fire behaviour (hazard) and values threatened by wildfires. A conceptual diagram is given in Figure 4. Elements of the Hazard component in particular utilise information from the FWI climatology and FBP models for fire behaviour in different vegetative land cover types.

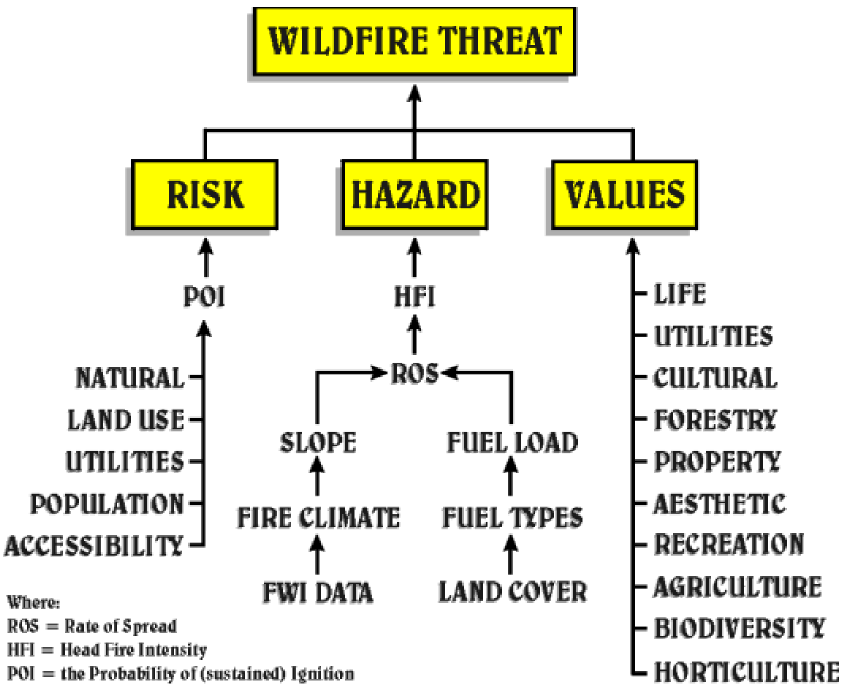

Figure 4. Structure of Wildfire Threat Analysis, including components of the risk, hazard and values modules. From Majorhazi (2003, 2006).

WTA has been developed as a rural fire management strategic planning tool for the Rural Fire Authorities to use in support of their work on fire protection (see p.6). Outputs from WTA can help managers with decision making at multiple levels, including strategic, tactical, and operational planning. Prevention activities supported by WTA include risk reduction and hazard mitigation, allowing focussed fire prevention activities. The system is built around a GIS platform for combining data from various input layers, and it thus provides an excellent means of promoting decision making for areas specifically at risk from wildfire whilst taking into account other potential impacts and potential consequences. It enables fire managers to "drill down" to determine the particular factor(s) that are contributing to a high overall threat, so that appropriate mitigation actions can be developed and undertaken. Majorhazi (2006) suggests that WTA is 'a systematic, defendable and repeatable process that can be used to identify the level of threat from wildfire'.

Unlike some other international WTA systems, the NZ WTA system does not currently include a fire suppression component. This was done purposefully to allow the system to be used to independently determine required suppression resource levels, and the most efficient and cost-effective placement of fire fighting resources to ensure that fire suppression performance standards are achieved (Majorhazi, 2003; Gibos and Pearce, 2007). However, with the inclusion of real-time information on resourcing and current (as opposed to climatological) fire weather information, WTA systems can become an operational risk assessment tool used to support pre-suppression planning, as in the case of the Tasmania Parks & Wildlife Service's Bushfire Risk Assessment Model (BRAM) (D. Taylor, pers. comm.)

EU

The European Forest Fire Information System (EFFIS) has been developed under the auspices of the European Commission. The fire danger forecast module of EFFIS generates daily maps of 1 to 6 days projected fire danger level in EU using weather forecast data. The module is active from March 1st to October 31st and is fed with meteorological forecasted data received daily from French and German meteorological services (Meteo-France and DWD). After a test phase of five years, during which different fire danger methods were implemented in parallel, the EFFIS network finally adopted the Fire Weather Index (FWI) developed in Canada in 2007 as the method to assess the fire danger level in a harmonized way throughout Europe. Fire danger is mapped in five classes with a spatial resolution of about 45 km (MF data) and 36 km (DWD data). Individual components of the FWI (e.g. Drought Code, Fine fuel moisture code, etc) are also given accessible values[21].

In addition to standardized fire danger classes, EFFIS offers maps of FWI anomalies and absolute ranking, which are based on the comparison of the daily fire danger level with the last 50 years of daily FWI values which have been recalculated using the ECMWF ERA40 dataset. The maps of forecasted fire danger level can be consulted through the web mapping interface of EFFIS and are also emailed daily to the users.

The EFFIS FWI system has many of the merits of the NZ system, but the quality of the input meteorological data is currently unknown, and the underlying assumptions built into the FWI model need to be better understood. For UK conditions, the start date is also a little late in the year (see Jollands et al., 2011).

The current position of UK forest fire risk

Compared to Mediterranean countries, forest fires have not been considered a significant problem in the UK to date, although such fires can be very damaging where they occur. Such a position of low regard is probably a consequence of a range of factors, some of which are listed below:

- A large interest during the main afforestation programmes in the second half of the 20th century, as a result of newly established and young plantations being at significant risk from fire, especially in adjoining areas to land where fire was routinely used for management purposes. With the demise of significant planting programmes in the 21st century, such interests have naturally waned.
- A realisation that with the vast reduction in the Forestry Commission workforce over the last two decades, the previous ability to roster staff to fight fires at any time of day and night became impossible, and that responsibility for fire-fighting would need to rest with the Fire and Rescue Services. As a result, the issue of fire has fallen down the list of policy priorities within the forestry departments across the UK.
- Other impacts to forests have grown and helped to push fire down the list of policy priorities. For example, as forest stands matured and became susceptible to windthrow, a significant programme of windthrow research was begun, in order to provide understanding and tools to support managers at site and regional level. In more recent times, the arrival of a number of destructive pests and microbial pathogens has drawn attention away from the risk of fire, together with research funding.
- Poor and fragmented reporting of forest fires has led to a (challengeable) appreciation that they are comparatively rare and affect only small areas – thus are commercially of little relevance. For example, Forestry Commission statistics[22] only identified an annual average of 182 forest fires between 1998 and 2002, covering a mean annual area of 173 hectares. These are likely to have been gross underestimates of affected forests (see below).

However, new understanding on the importance of forest fires is emerging, clearly and persistently. Firstly, the number of wildfires is being recorded to a much greater level of precision by the Fire and Rescue Services, and there has been an increasing trend of fire frequency over the last three decades (DCLG, 2006). It is revealing that there were 58,400 unplanned wildfires recorded in 2010-11 across Great Britain (DCLG, 2011). The cost of responding to these modern wildfire incidents has been estimated at up to £55 million per annum[23] (R. Gazzard, pers. comm.). Data for England have been processed by Forestry Commission England and are shown in Figures 5, 6 and 7.

It is clear that there are significant occurrences of wildfires in England, including nearly 5,500 that did occur within land defined as woodland or forest, covering c. 700 ha, per annum. In Wales, grass and forest fires have been estimated to cost an annual average of £6.1 million in the three years from 2004 to 2007, with an average annual cost to Wales society of £12.3 million (Joint Arson Group, 2007). For south Wales, wildfire data have been obtained from relevant Fire and Rescue Services and mapped over the period 2000-2008 (Figure 8). No distinction is made in these data between forest and other wildfires but it is evident that the risk, both potential and actual, to forests in the region is significant. Data for the last three years for Scotland are shown in Figure 9. They complement those for England and Wales and show that nearly 20% of all Scottish wildfires occur in woodland and forest. Substantial areas can be affected - over 3000 hectares of forest were lost in just five weeks in the Highlands and Islands FRS in 2011[24] **Taken together, the modern data on forest fires in Great Britain strongly suggest a fire issue very similar, and perhaps in excess of that found in New Zealand at the present time.**

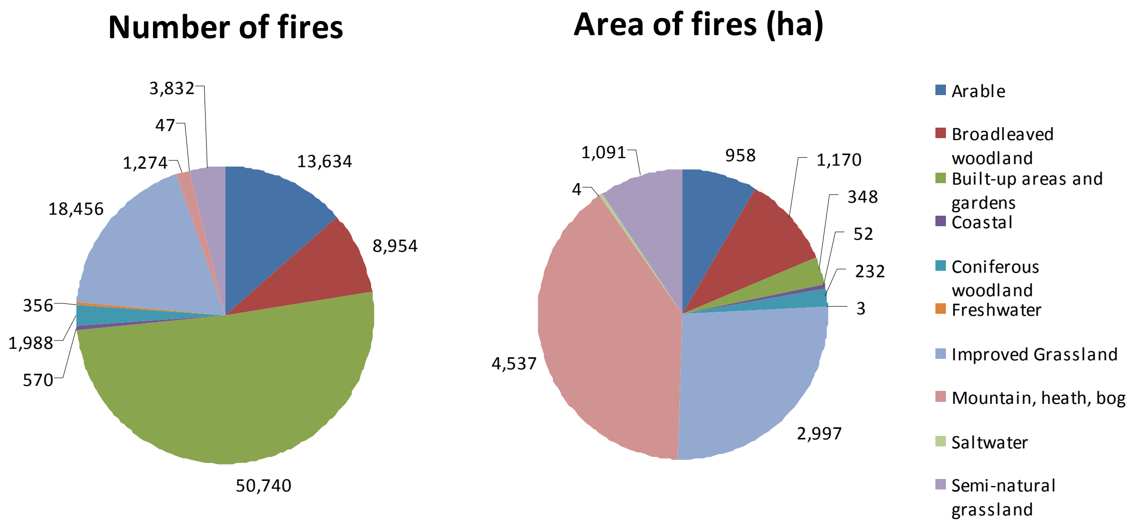

Figure 5. Occurrence of wildfires in England, 2009 and 2010. Data kindly provided by DCLG. (Total area affected by fire = 11, 390 ha; total number of fires = 99, 851).

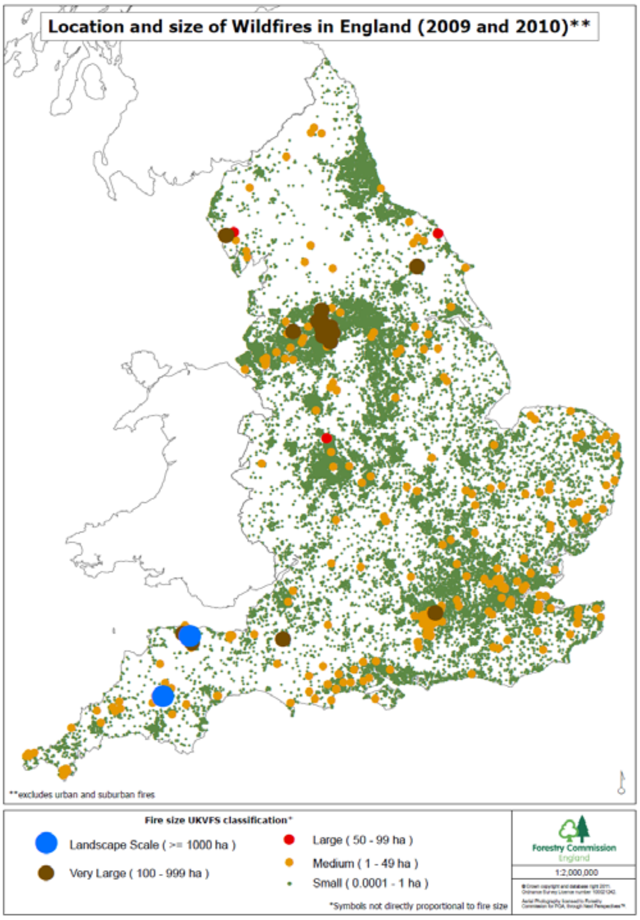

Figure 6. Location and size of wildfires in England 2009 and 2010. From Finlay et al. (2012).

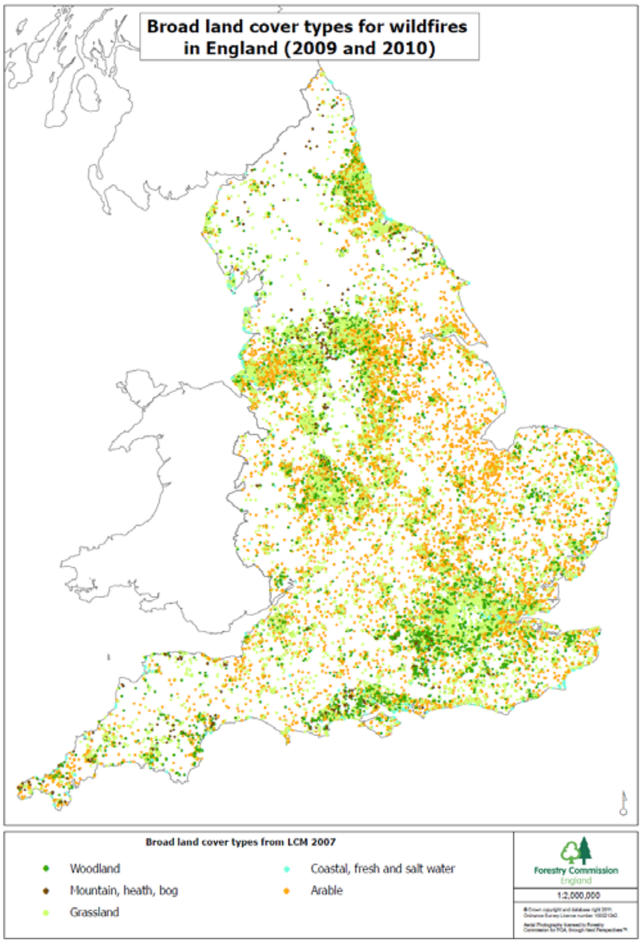

Figure 7. Land types burnt in English wildfires 2009 and 2010.
From Finlay et al. (2012).

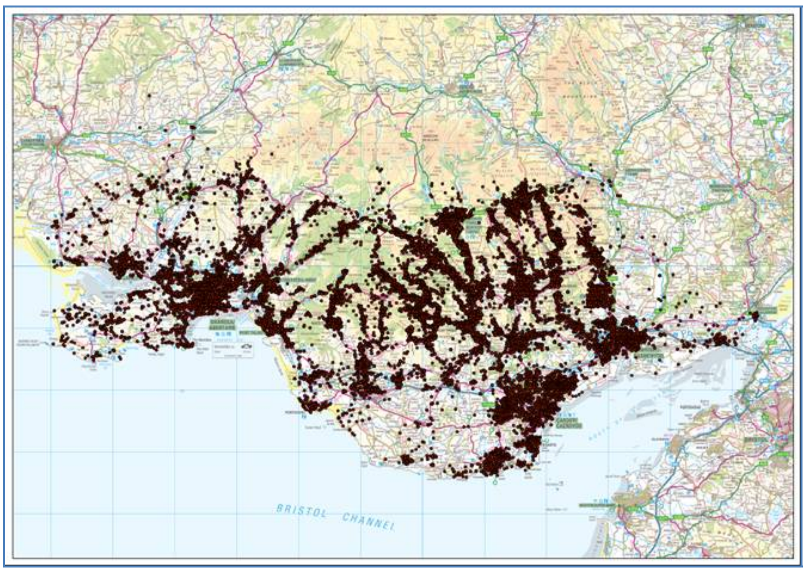

Figure 8. Occurrence of wildfires in the South Wales region, 2000-2008.
From Jollands et al. (2011).

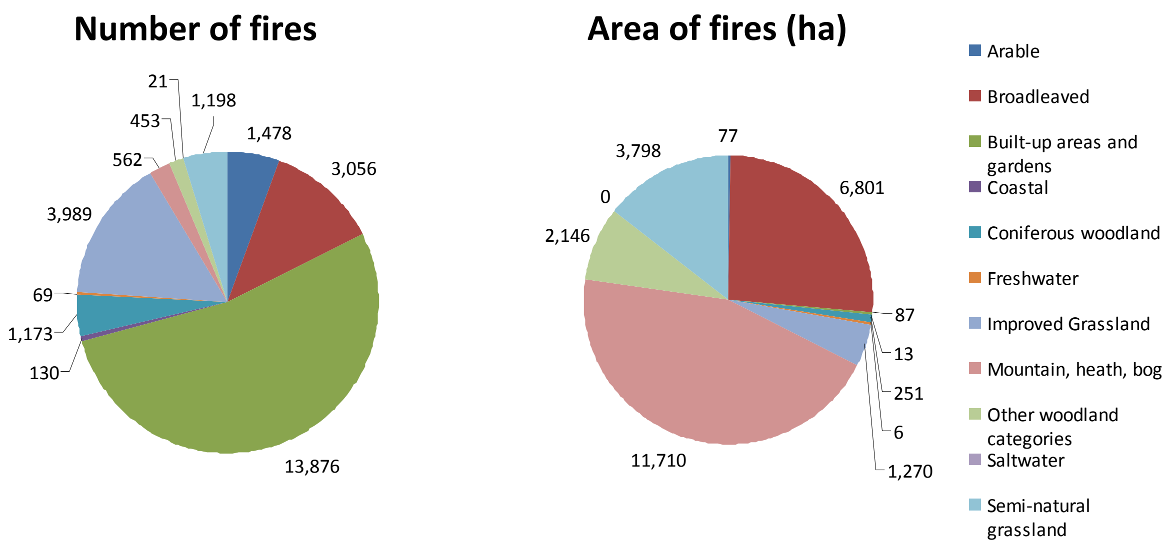

Figure 9. Occurrence of wildfires in Scotland, 2009/10 to 2011/12. Data kindly provided by DCLG. (Total area affected by fire = 26,180 ha; total number of fires = 26,033).

The importance of forest fires has also been recognized in the first national assessment of risks posed by climate change to forestry (Moffat et al., 2012). In a process which sought to quantify current risks, as well as predict future ones, forest fires were scored the same as windthrow on the basis of potential environmental, economic and social impact. Forest fires are usually caused by man, accidentally or on purpose, but the magnitude of these fires is related to weather conditions, and exacerbated by drought, high air temperatures and wind. Climate also affects the provision of ‘fuel’, in the form of leaf and needle litter to the forest floor and also helps to determine the nature and occurrence of ‘mast’ years (Övergaard *et al.*, 2007) and thus further provision of fuel. Forest fires occur in both conifer and broadleaved forests, especially young woodlands where there is substantial ground vegetation. Intense forest fires may pose a risk to standing trees and the timber resource, but recent fires in Britain tend to be located in the understorey where most damage is caused to wildlife habitat, recreational opportunity and if on organic-rich soils, to carbon storage. In addition, reduction in air quality can cause nuisance and pose a risk to human health, especially if fires are located close to urban communities (Finlay et al., 2012). Fire can also increase the susceptibility of surviving trees to insect attack, for example secondary bark and ambrosia beetles in conifer forests. For example, pines damaged by fire are vulnerable to attack by pine shoot beetle *Tomicus piniperda* and possibly the pine bark beetle *Ips sexdentatus* (Långström *et al.*, 1999; Fernandez, 2006).

Fire as a threat to forestry goods and services

In the early days of developing forest fire danger ratings in Britain (as in NZ and other countries), the major purpose, apart from seeking to prevent harm to people and property, was to minimise the risk to forests as commercial timber growing reserves. Today, understanding of multifunctional forestry, sustainable forest management and the growth of the ecosystems framework (e.g. Quine et al., 2011) all identify the need to consider forests holistically. In that sense, forest fires should be regarded for all the other impacts they may have. Table 1 shows possible effects, based on the classification of ecosystem services recognised by the UK National Ecosystem Assessment (2011). It identifies that fires can have serious effects on a wide range of services – even if a fire remains within the understorey and doesn't cause tree mortality per se. Some of these services are easier to place a monetary value on than others, but those difficult to do so shouldn't be ignored. Unfortunately, the full cost of forest fires has yet to be explored within the ecosystem framework in the UK.

The relative importance of managing fire risk in British forestry

The review above has demonstrated that in the past, whilst locally important (e.g. South Wales), forest fires have not been regarded as of particularly high priority, sufficient for significant investment in infrastructure and research. Indeed, the reverse is true. However, it is also evident that the importance of the impact of forest fires is likely to grow, partly as a result of climate change (see below), but partly as a result of other factors, themselves driven by evolving forestry policy. Some of these factors, which could affect fires more than climate change, are considered briefly below:

- Transition from the use of high-forest to continuous cover systems, and thus opening the stand up to the likelihood of increased understorey vegetation growth which may increase the risk of forest fires (Ireland et al., 2006), including crown fires (Stokes and Kerr, 2009). More research is needed on this issue.
- Restoration of heathland in close proximity to pre-existing woodland (mainly coniferous) will increase the risk of forest fires, given that fires often begin in more flammable heathland and then spread into forest.
- Encouraging access of visitors to woods and forests may increase the risk of fire in some localities.
- Managing forests to enhance habitat connectivity (e.g. Watts et al., 2005) is likely to increase the risk of fire spreading once established.
- The presumption against burning brash and harvesting residues (Forestry Commission, 2011) may increase the fuel loading in forests, and thus increase the risk of more serious fire episodes.

Future forest fire risk – the role of climate change

From as early as the late 1980s, postulated increases in global temperatures associated with climate change have been related to possible increases in fire weather severity and fire danger. In Canada, determination of the possible impacts of climate change has been aided through use of the FWI System. For example, Flannigan and Van Wagner (1991) suggested that fire danger (represented by the Seasonal Severity Rating from the FWI System) could increase by nearly 50% across Canada with climate warming, with a similar increase in area burned. Wotton and Flannigan (1993) predicted that fire season length across Canada would increase by up to 30 days in a 2×CO_2 climate. Fosberg et al. (1996) showed a significant increase in the geographical expanse of worst fire danger conditions in Canada and Russia under a warming climate. In one of the more comprehensive studies, Stocks et al. (1998) used the FWI System to look at seasonal and monthly fire danger levels across Canada, Alaska and Russia. They showed increases in fire danger across the entirety of this region, together with large increases in the number of high severity days, which are the periods when most burned area is likely to occur. Flannigan et al. (2000) suggested increases of 10-50% in fire season severity across the U.S. by 2060, although also reported areas of little change or where Seasonal Severity Rating decreased under future climate. Flannigan et al. (2001)

showed similar increases in fire danger (expressed using mean FWI values) across most of Canada to previous studies, but reported significant regional variability including a decrease in much of eastern Canada. A more recent global review of the likely effects of climate change by wildfire is given by Flannigan et al. (2009). Similar concerns have been raised in Europe (e.g. Camia et al., 2008; Schelhaas et al., 2010).

In NZ, useful work has been undertaken to explore the possible effects of climate change on fire risk and danger, notably the studies by Pearce et al. (2005, 2011a). In these studies, the NZ fire climatology database and fire models (notably the FWI) were coupled with projections of future weather inputs (temperature, humidity, wind speed and rainfall) from regional climate scenarios so that possible future FWI and component parts could be explored and mapped. Detailed methodologies for these studies are given in the relevant publications.

Some of the results from these studies are shown in Figures 10 and 11. Collectively they indicate that NZ fire climate severity is likely to rise significantly with climate change in many parts of the country. This is primarily the result of increases in temperature and decreases in rainfall, although higher wind speed and lower humidity are contributory factors too. Longer fire seasons are also likely to occur in some parts of the country, with consequent number of fires and greater areas burned together with increased fire suppression costs and damages. Of especial value was the ability of the studies to identify areas at greatest, and at lowest risk of increased fire danger. It was also important to understand the likely rate of change, with rapid increases in fire danger predicted in many parts to 2040, and then slower changes to 2090. Work is also underway to correlate current fire statistics (on number of fires and area burned) with present fire danger, as the basis for predicting potential future fire risk based on projected fire danger levels (G. Pearce, pers. comm.). It may also be possible to estimate future fire suppression costs, as has been done for some other parts of the world (e.g. De Groot et al., 2003).

In the UK, the only comparable study is that in the recent UK Climate Change Risk Assessment (Brown et al., 2012; Moffat et al., 2012). Figure 12 shows the predicted change in wildfire risk from 1980 to 2080, using a development of the Australian McArthur Forest Fire Danger Index (FFDI) coupled with the UKCP09 climate projection for 2080. The results need to be interpreted with caution as they provide only change in annual mean values; it would be assumed that likely changes would be greater in the summer months. In addition, the coarse resolution of the soils and land cover data used in the modelling mean that the fuel (biomass) component that is the key element in wildfire risk is probably poorly represented. However, the results show increased fire index values across the UK, with much of southern England moving into index values indicating moderate risk. Nevertheless, the outputs are indicative only and very restricted compared with those from the NZ studies, and without further work it is impossible to give strong guidance regarding the degree of change in fire statistics, and consequent implications for policy and practice.

It is worth pointing out, too, that all the prediction studies have used models which do not and cannot embrace possible and probable change to forests as a result of adaptation and other policies during the intervening years – they represent worst case scenarios and are useful inasmuch as they can be used to target mitigation measures.

Type of Ecosystem Service	Examples of delivery affected by fire
Provisioning Services	
Forests for timber production	Timber production will be seriously affected if crown fires occur in mature stands; stands up to canopy closure are at more risk, but easy to replace
- for construction / substitution	Fires may facilitate insect attack and thus degrade timber quality
- for bio/woodfuel	Fire may take out windrowed materials stored within the forest, compromising security of supply; SRC and SRF plantations present low fire hazard
Forests for non timber products	Non-timber forest products (NTFPs), for example meat, berries, honey, and could be seriously affected by fire
Regulating Services	
Forests for pollution mitigation	Fire will create pollution rather than mitigate it. Fires will pollute local atmosphere, but may have significant effects down wind
Forests for soil protection	Soil erosion risk is heightened after fire, especially if organic layers are burnt off, and canopy protection to rainfall is lost.
Forests for flood and water protection	Water quality can be seriously compromised by the combustion products and by soil erosion (see above). Soils can become water repellent, further exacerbating run-off
Forests for carbon sequestration	Fire can seriously deplete the forest ecosystem, notably of soil carbon which may have taken centuries to reach pre fire levels
Forests (and trees) for climate (change) mitigation	Loss of tree cover will seriously affect the delivery of this service.
Forests for archaeological protection	Not known what the effect of fire might be, but likely to be minimal to buried artefacts.

Type of Ecosystem Service	Examples of delivery affected by fire
Cultural services	
Forests for social cohesion, personal strength	Woodland suffering from forest fire will not attract visitors and may be a reminder of environmental threat for some.
Forests for amenity/ recreation/ health	Woodlands suffering from forest fire may pose a hazard to human health, even months after the fire event.
Forests for landscape, historic environment	Fires will seriously damage the landscape character of an area, and may deplete a woodland of veteran trees as connections with the past.
Forests for education	Forest fires may threaten forest schools, either directly if cherished woodlands are lost, or through raising anxiety about safety for children.
Trees and woodland as inspiration for the arts	Burnt woodland offers little to inspire.
Supporting services	
Soil formation, nutrient cycling, water cycling, oxygen production	Soil formation and other biogeochemical processes may be seriously compromised with loss of organic matter, nutrients and soil fauna and flora.
Forests for biodiversity	Woodlands suffering from fire will be impoverished ecologically for a significant period afterwards.

Table 1. Possible impacts to forestry ecosystem goods and services from forest fires. Note: no adaptation measures are factored into this analysis.

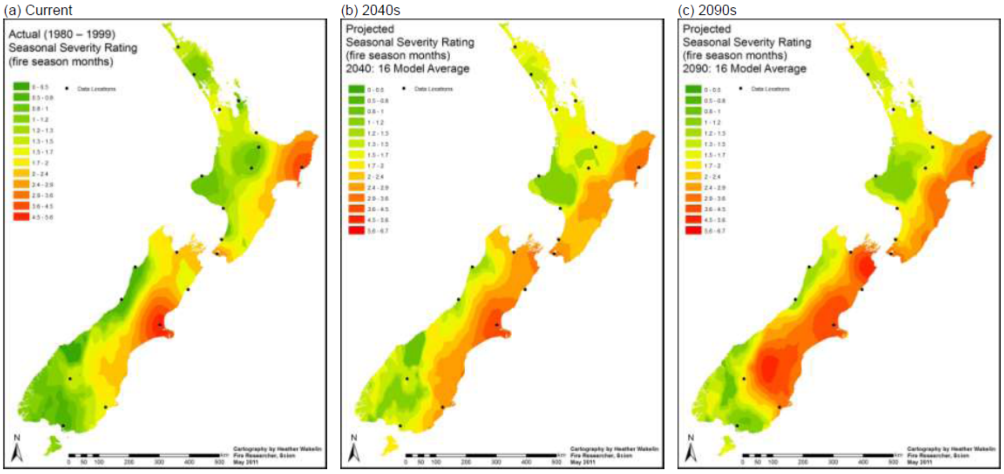

Figure 10. Projected changes in Seasonal Severity Rating over fire season months (Oct-Apr) from (a) current climate, (b) the 2040s, and (c) the 2080s. From Pearce et al. (2011a).

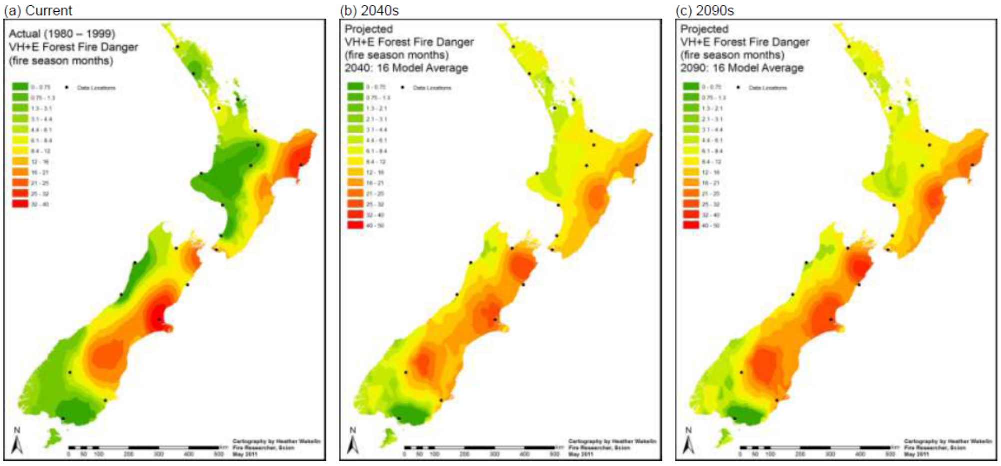

Figure 11. Projected changes in the mean number of days/year of Very High and Extreme (VH+E) Forest Fire Danger over fire season months from (a) current climate, (b) the 2040s and (c) the 2090s. From Pearce et al. (2011a).

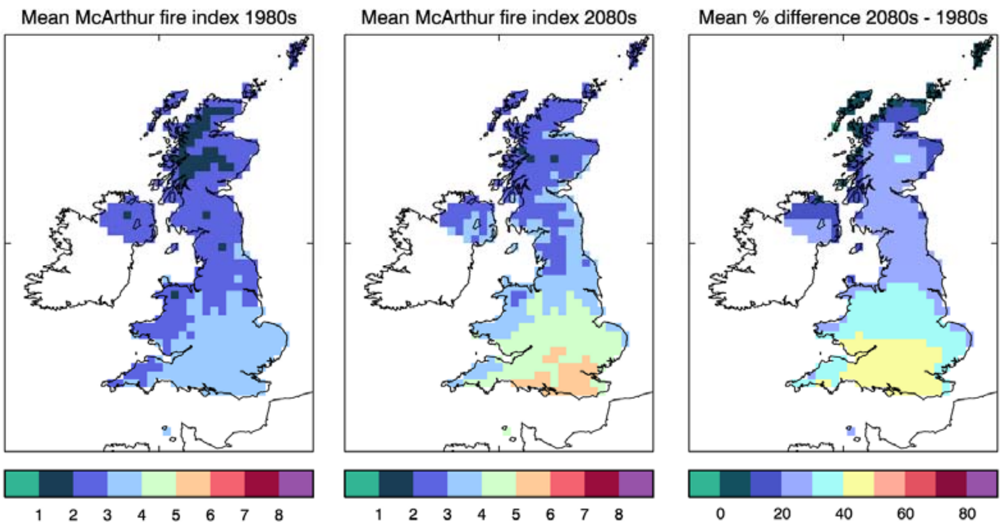

Figure 12. Potential changes in the McArthur Forest Fire Danger Index for the UK from 1980 to 2080 projected using UKCP09 RCM data. From Moffat et al. (2012).

Forest fires as part of modern Risk Management

Forest fire risk in NZ is placed in the context of an agreed framework for risk management (Figure 13a), taken from Standards Australia and Standards New Zealand (2004). It has many similarities with the risk assessment procedure set out in the UK Climate Change Risk Assessment (CCRA) (Figure 13b) (Moffat et al., 2012).

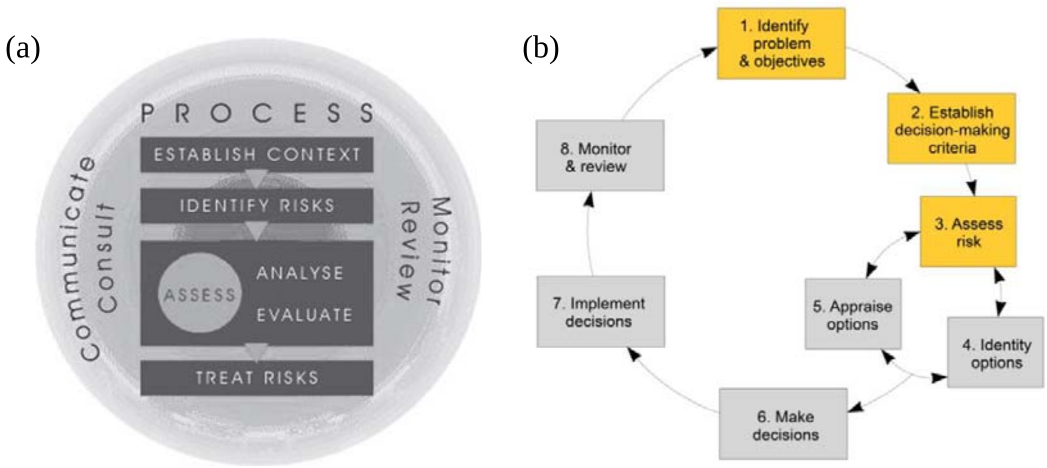

Figure 13. (a) Risk management process in Australia and New Zealand (Standards Australia and Standards New Zealand, 2004), and (b) risk assessment process for UK Climate Change Risk Assessment (Moffat et al., 2012).

Risk management is not simply about eliminating risks but rather identifying risks, deciding how serious they are and taking steps to manage them. In the context of NZ's approach to fire management, the country has adopted the Emergency Management cycle (Britton, 1994), with a focus around the four 'R's of emergency management, namely Reduction, Readiness, Response and Recovery (Figure 14). As Dudfield (2011) puts it: "Better decisions [about wildfire] will be made if they are developed through the consistent application of contemporary *risk management* concepts…". This contrasts starkly with the UK forestry sector's overall approach to wildfire, which is perceived as a *natural* phenomenon (see p.9), or something that is best managed through contingency planning via guidance in the '*Dealing with the unexpected*' booklet (Forestry Commission, 2010). Here, very little consideration is given to Reduction, but almost all to Readiness and Response. There are no scientifically defensible statistics, but the bulk of evidence suggests that the overwhelming majority of wildfires in Britain are man-made rather than natural (DCLG, 2008a). It is therefore possible to consider Reduction in this context. However, in contrast to building resilience into forests and other combustible vegetation via appropriate land management policies and management operations, UK interpretation of resilience (DCLG, 2008b) is centred on F&FS 'readiness' for fire-fighting and emergency call-out action. This contrasts starkly with the NZ view that "managing fire-related risk to land is fundamentally an issue of land management and not fire management" (Dudfield, 2011).

Internationally, principles behind Disaster Risk Assessment such as those supported under the United Nations Hyogo Framework for Action[25] are built along similar lines, with a focus on:

- Make Disaster Risk Reduction a priority;
- Know the risks and take action;
- Build understanding and awareness;
- Reduce risk;
- Be prepared and ready to act.

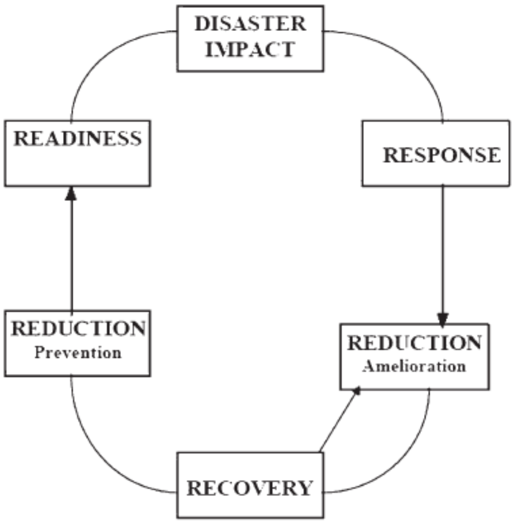

Figure 14. The Emergency Management Cycle (after Britton, 1994).

These actions have yet to be formalised for forest fires in the UK, though their relevance for New Zealand wildfires was recently endorsed (Basher, 2012, pers. comm.). Similarly, the ISO Standard for Risk Management (ISO 31000:2009) is published as a unifying procedure for risk management at a global level, and it is being used as the framework for revision of the NZ Wildfire Threat Analysis next year (G. Cameron, pers. comm.). Other international WTAs are also based around this ISO 31000 risk definition (e.g. Tolhurst et al., 2008). There is little evidence that either the Forestry Commission or the UK Fire & Rescue Services have adopted ISO 31000 for use as a Risk Assessment framework, for forest fires at least. Nevertheless, 'Strategic Risk Appraisal' is slowly becoming embedded in a range of UK forestry processes, notably through recent engagement with Cranfield University's expertise in this area[26]. To date, however, fires remain outside this form of consideration in the UK, except via the CCRA process mentioned above. In contrast, other risks to forestry have received much more attention. For example the risks of invasive pests and pathogens are managed via the Forestry Commission Biosecurity Strategy Board, together with a significant regional infrastructure and multimillion annual research budget. Windthrow has been tackled by a lengthy research campaign over several decades, including soil mapping of much of the public forest estate in order to establish windthrow hazard class ratings, and the generation of a purposeful tool to quantify the risk (ForestGALES; Gardiner, 2004).

A new fire risk system for the UK

This report has so far compared the nature of forest fires in NZ and the UK, and shown that the threat and challenge of managing fires in the UK is already tangible, is getting worse and will continue to do so in the face of climate change. The previous section attempted to place fires in the context of a broad risk management framework and also compared the fire risk to some other risk factors to forests. This section explores options for developing an appropriate fire risk system for UK forestry such that the risk can be quantified and managed more effectively, in particular from a proactive land and forest management perspective, and preferably alongside other climate change adaptation policies. Four options are offered and the advantages and disadvantages of each is considered in turn. The options are:

1. Maintain the status quo
2. A 'sticking plaster' approach
3. Towards a full NZ-scale system
4. A modular, progressive approach

1. The status quo

A very small email survey of selected staff in FC England Forest Districts in 2010 revealed that the Forestry Commission Fire Protection Memorandum No.6 system (Forestry Commission, undated) was used in some locations but has been discontinued from use in others. No strong support for the system was elicited, and one member of staff suggested:

> *"on many occasions [it] does not reflect the true hazard. I have no idea where it came from but we have to use it in the absence of anything else."*

Another colleague reported:

> *"This system was discontinued a few years ago when we stopped collecting data and the reading we have is a "best guess" based on observations/gut feelings".*

It is clear that the current system is discredited in the eyes of some of its users, gives erroneous guidance and is laborious to use, notably if weather data are not to hand (historically, the Forestry Commission used to manage a range of weather stations across the country, but no longer does so). There are other problems with the system, as mentioned on p. 10. The scientific model behind the system is unknown and thus from a Quality Assurance perspective, the outputs have very little value. They certainly could not be professionally defended today. In addition, the ratings generated by the system are of little use for forest management. There is no guidance on appropriate actions relative to the different ratings that might be identified. Equally disturbing is the lack of use of a system in some sensitive and relatively fire-prone districts where fire danger is currently (and preferably) assessed by 'gut feeling'.

The lack of tie-in with a range of international systems is also considered a severe weak point – there is no opportunity to incorporate the large body of fire research that has accrued since the UK system was launched. Nor has it any real capability for modelling change in risk as a result of climate change. In addition, no datasets of recorded fire danger ratings are known to exist, and it is impossible to consider any form of evaluation against recorded fire occurrence. For these reasons, it is strongly recommended that an alternative system is developed. It is also suggested that operational guidance supporting the use of the current system is withdrawn as soon as possible, and that in the interim, before the launch of a successor system, Forestry Commission staff are given guidance on how to use the Met Office Fire Severity Index (MOFSI). It is suggested that this guidance is written as a small joint project including the Forestry Commission (e.g. Forest Enterprise) and the Met Office with support from the Fire and Rescue Service and other agencies who have helped to develop MOFSI. Such guidance could also be published in order to support the wider forestry and land-use sectors.

2. A ‘sticking plaster’ approach

If the recommendation to cease use of the current Forestry Commission system is adopted, it is important to put a reasonably robust system in place as soon as possible. A promising approach, influenced by the NZ systems, is to explore how to utilise (as above) or develop the Met Office MOFSI system for forestry, in order that it becomes the basis for a national FWI system. The strong advantage of using MOFSI is that it is supported by a wide range of weather stations across the UK for which both current and forecasted data are available – no other agency could conceive of drawing this information together in real time. It is also relatively easy to compile an historical climatology of fire weather and fire danger information, as has been done to inform a wealth of research on NZ’s current and future fire climate. However, NZ experience suggests that sole reliance on a single index (e.g. DSR or FWI) fails to exploit the power of the information that contributes to its calculation (for example the weather input variables together with information on Fine Fuel Moisture Code, Duff Moisture Code, Drought Code, Initial Spread Index and Build up Index (Figure 3)). It is recommended that discussions with the Met Office take place so that more of this information be published on a daily basis, and that guidance be drawn up on its interpretation. Such guidance is likely to benefit from input from fire scientists from Scion (and/or Canada), should this be possible. In addition, it is important to establish how the Met Office have taken and used the Canadian Forest Fire Danger Rating System in developing MOFSI, and to what extent the assumptions made in this process bear scrutiny from fellow fire scientists, especially in the context of forest fire hazard prediction. It is recommended that a similar investigation of the EU EFFIS FWI takes place concurrently with that focussed on MOFSI.

An additional component of a ‘sticking plaster’ approach could be to explore whether existing UK forestry datasets are capable of helping to generate information on fire fuel load. The Biosoil[27] survey (Vanguelova et al., in press) database contains valuable information on the nature of organic layers in British forest soils. Similarly, the Forestry Commission SubCompartment DataBase (SCDB) contains information on every stand (Compartment and sub compartment level) in the public forest estate, including planting year, species or species mixture and (in some cases) soil and terrain type. In addition, records of thinning, and planned thinning regimes have been included since 2011, although this aspect of the SCDB is poorly populated at present (P. Weston, pers. comm.). It is suggested that a small project explore how this information be captured such that it might support the evolution of a UK Fire Behaviour Prediction (FBP) system, akin to that used in NZ (p.12). Again, liaison with Scion and/or other international fire scientists is strongly advised.

3. Towards a full NZ-scale fire risk system

Taking some or all of the recommendations made in the previous two sections will markedly improve the UK’s ability to signal daily fire danger at a regional and local level. It will give managers (sufficiently trained) the understanding they need for readiness planning, probably the main purpose of previous UK systems. However, this position fails to deliver important elements of an integrated fire management system, namely the ability to:

- evaluate forest vulnerability to fire hazard at a regional and national scale, and thus to instigate appropriate forest mitigation measures to build resilience through reduction of fire risk, and readiness should fires occur;
- couple fire systems with projections of future climate[28] so as to better prepare for future risk;
- explore the impact of fire and fire risk at local, regional and national levels via an understanding of likely effects to forest ecosystem services;
- develop effective operational tools to support fire-fighting – e.g. FBP tools for predicting fire behaviour during incidents (such as the NZ FBP Toolkit calculator and smart app, 'Prometheus' fire growth model; or Tas PWS BRAM);
- develop an understanding of fire risk issues through evaluation of fire information and a targeted plan of research in order to ensure tools are fit for national purpose.

The NZ fire systems and associated infrastructure (research, communications and extension services) demonstrably achieve these aims, and it is worth exploring how the UK might move to adopting some or all of those reviewed in this report.

The NZ Fire Weather System (FWSYS). It is possible that negotiations with the NZ Fire Service/National Rural Fire Authority and NIWA could lead to the importation of the NZ FWSYS for further development in the UK. This would involve seeking approval to mount the software on UK Government ICT systems, for example in the Forestry Commission. Setting up the NZ FWSYS as an alternative or rival to MOFSI would require negotiations with others involved in rural fire planning, notably SNH, CCW and Natural England, as well as the Met Office itself. Whilst there is a demonstrable need for the forestry sector to be supported by a functional fire risk system, the nature of rural fires in the UK strongly suggests that an integrated system should live up to its name and embrace all vulnerable vegetation types. It is more advantageous to bring relevant parties together in order that work accomplished so far on MOFSI be continued in order to meet a revised set of objectives beyond those originally conceived for it (p.10). It is therefore recommended that this approach be followed, but that NZ or Canadian fire expertise be sought during negotiations and the drawing up of a modern Action Plan for further development.

NZ Fire Behaviour Prediction System. Similarly, it is possible to import a version of the FBP from NZ (or Canada), and then modify it for UK conditions. This was the approach adopted by NZ when it sought to build an FBP system through adaptation of the Canadian one. Like the evolution of the NZ system which began with a forestry focus, and following the line of discussion above, it seems most appropriate to build a system based on a wider range of vegetation types, in conjunction with other land-use agencies (including the Ordnance Survey for information on topography and slope). A new map of UK vegetation types has recently been published by CEH[29] and the classification of habitat types used could form a useful basis for considering UK fire vulnerability. An integrated GIS approach is also called for, linked to the ability to evaluate FBP with occurrence of actual wildfires using a simulation tool such as the Prometheus fire growth model used in NZ (and Canada). It is suggested that DCLG be approached for their support and co-ordination to take this forward.

NZ Wildfire Threat Analysis. It is suggested that discussions take place with DCLG about the desirability of the UK moving to partial or complete adoption of the NZ WTA system.

The nationally compiled ‘Hazard’ component of the WTA describing fire behaviour potential is regarded in NZ as the most important part (G. Cameron, pers. comm.), and it is a useful unification of the FWI and FBP systems discussed above. It also contributes to the consequence component of the risk definition from ISO 31000:2009. Again, it is strongly advised that such discussions should include architects and maybe users of the NZ system. It is likely that further work is necessary to evaluate the ‘Risk’ component and to establish a system that is appropriate to UK conditions. This would require further research on fire data, akin to that undertaken by Jollands et al. (2011), but to build a national approach capable of regional interpretation. In addition, some social research might be required. It seems pragmatic to consider the development of a UK ‘Values’ component alongside the further development and implementation of the National Ecosystem Assessment (NAE) (UK National Ecosystem Assessment, 2011)[30], again in conjunction with relevant agencies (e.g. LWEC, DCLG).

4. A modular approach. This is a pragmatic way to bridge the gap between maintaining current UK systems and trying to move too quickly to adopt best practice from NZ or elsewhere. Given the rapidly increasing complexity, involving a significant range of partners, as one contemplates systems beyond the ‘status quo’, it seems inevitable that a modular approach to construction and adoption of system components be taken, but *in the context of an overall programme for the provision of an agreed system for fire risk management*. There is a *prima facie* case for development to adopt the equivalent of the NZ WTA Hazard component early in this process, and this would necessitate building UK FWI and FBP components. Given the general utility of the WTA model for threats other than wildfire (e.g. wind, flooding, disease outbreak, etc), it may be more prudent to consider broadening any adoption to embrace multiple threats, as a possible ‘follow-on’ project to the NAE, if this hasn’t already been considered. Joined-up thinking has very recently become evident at the level of Response[31] to emergencies in the UK, but there needs to be a commensurate approach at the levels of Reduction and Readiness too. It is encouraging that some interest has already been shown in this approach across a range of UK Government Departments following a presentation on the NZ WTA by Rob Gazzard (Forestry Commission) during 2012.

Discussion

It seems clear that the UK needs to urgently consider an infrastructure for managing wildfire risk. Current and projected future risks are now sufficiently known that reliance on pre-existing and fragmented systems is unacceptable. There are some differences between NZ and UK, such as the distribution and nature of native vegetation and plantation forests, and the probable causes of wildfires. However, it is considered that the two countries are sufficiently analogous for further partnership working to take place so that the UK can modernise its fire risk systems as efficiently as possible. One advantage of failing to do this over the last two decades is that the UK can now develop new systems based on a modern IT and internet-based infrastructure, and this should strengthen the opportunity for partnership working, both within and between countries. Experience from NZ suggests that it is also possible to save time and resources by exploiting foreign research and development that has applicability in one’s home country.

The UK has made some significant progress in some aspects of fire risk management in recent years, which will put it in good stead if recommendations to go further are followed. For example, in recent years, a new system for recording vegetation fires has been adopted by the UK Fire & Rescue Services (Gazzard, 2009), and this promises to provide fire occurrence datasets which are much more capable of scientific interpretation. Similarly, the UK has developed a robust set of climate change projections with which future modelling of forest fire risk can be undertaken – the 11-member RCM datasets based on the Met Office Hadley Centre Regional Climate Model (HadRM3-PPE)[32] seem analogous to those used in similar NZ studies. However, more could be done to support fire risk modelling, in particular the further development of the Forestry Commission 'Inventory Forecasting and Operational Support (IFOS)' 'FORESTER' database, and its examination as the way to communicate fire risk systems to foresters who manage the public forest estate. Again, using the NZ FWSYS as a model for delivery of fire information in a 'one stop shop', it seems sensible to continue to learn from NZ expertise and experience when attempting to bring all relevant UK datasets and systems together.

Inevitably, there will be a need for scientific expert input, and a research campaign to support the development of the fire risk infrastructure. In these times of austerity, this is difficult to argue for, but lessons recently learned from the impact of non-native pests and pathogens in the UK suggests that comparative complacency will be regretted later on – a rebalancing of research effort may be sufficient to move things forward. Globally, fire scientists and policy makers are very motivated towards sharing ideas, systems and best practice, and such strong support should be tapped in order to make UK investment in fire research cost effective. Within the Forestry Commission Corporate and Forestry Support allocation to Forest Research, funds to support a minimum of one new Pay Band 4 scientist at 'project leader' level are suggested. In addition, opportunity should be taken to consider fire risk as a new integrated project involving social and economic science input as well as biophysical and silvicultural. For example, the Social and Economic Research Group in Forest Research should be invited to consider the relevance of community and stakeholder preparedness for wildfire (cf. in NZ; Jakes and Langer, 2012) and attitudes to fire risk and possible mitigation measures. More broadly, fire risk science could form the basis of a Research Council(s) research programme, possibly co-ordinated through LWEC. It is important that the commissioned research is guided by a form of Advisory Group of relevant stakeholders, as is the case in NZ.

Investing in fire risk management shouldn't been seen in isolation. Fire risk is only one issue which contributes to vulnerability, whether for rural ecosystems or urban communities. Building resilience in the context of environmental and other risks should be seen as an opportunity as much as a challenge. National Planning Policy Frameworks (e.g. DCLG, 2012) could be employed to help in the integration as they support the need for a joined-up approach.

Beyond the technical and scientific recommendations identified above, experience of working alongside Scion colleagues and rural fire stakeholders under the TRANZFOR visit in 2012 suggests the urgent need for leadership amongst the range of UK government departments and agencies involved in rural fire matters. The position is inevitably complicated by the devolved nature of some land-based policies and the weakness of the legislative framework in the UK. Certainly there is a case for reconsideration of the legal basis for rural and forest fire policy – without it, progress is uncertain and may be slow.

Nevertheless, the NZ model for rural fire risk management demonstrates that a range of agencies and interested parties can be brought together to provide a successful unifying infrastructure.

To support such development, further quantification of the true costs of current wildfires (in terms of the 4 ‘R’s (p.24)) would seem to be essential. Under the political infrastructure perceived above, funding will be needed to help develop the technical infrastructure, ensure its continued development around ‘fitness-for-purpose’ principles, and ensure that those that need to use it know how to (e.g. via an appropriate communication and extension provision). The NZ systems have benefited from sustained financial maintenance over many years, but support for this work remains strong, and there is a consensus that it has been an extremely worthwhile investment (Box 1). The UK is in a good position to gain from this know-how and whilst it is unreasonable to expect a quick transformation of fire danger systems to those now on offer in NZ, their experience can help plan the way forward.

Box 1. Considered opinions about the value of fire research and its outputs and outcomes in New Zealand

“The small Rural Fire Research team provides the core capability for rural fire research in New Zealand. Over the last ten years it has established a track record of quality research and effective technology transfer to end-users. In this time, New Zealand has experienced approximately a 50% reduction in the annual area burned by wildfires, due at least in part to research outcomes from the Rural Fire Research programme. End-users have embraced the research outcomes, and are using this knowledge and the associated tools in their day-to-day fire management decisions and planning.”

“We’ve got clear evidence on the ground that we’re doing better. The area burned in New Zealand by wildfires has halved since the 1980s. This has been achieved through increased awareness and sound risk management decisions. Science has been a big part of this mix. People are much more informed out there now about rural fire than they were 20 years ago.”

Murray Dudfield, National Rural Fire Officer, National Rural Fire Authority

"The Department of Conservation manages a third of New Zealand’s land area and has a responsibility to conserve natural and historic resources. Increased understanding and management of fire is important to conserving these resources. The Scion based Fire Research Group have provided and continue to provide research findings and tools to support the Department’s fire management activities in a pragmatic and timely way. The research helps to better understand the implications of fire management, fire fighting, and to develop cost-effective social marketing campaigns to contribute to the prevention of fire. From the Department’s perspective, increasing our knowledge of the role of fire in the sustainable management of New Zealand’s ecosystems is also a high priority, and fire research is increasingly being used to identify vulnerable environments and model the relationship between fire and the condition of natural biodiversity. It is also being used to increase community understanding of the consequences of fire on the landscape. Information from the research on fire directly supports improving or developing best practice. This is taken up across all aspects of fire management, including readiness and response systems, as well as reduction and recovery from fire events. The Department therefore strongly supports the Scion rural fire research programme."

Dave Hunt, National Fire Co-ordinator, Department of Conservation

Conclusions

The study visit to Scion in New Zealand, supported by TRANZFOR, has been invaluable as a means of examining and exploring the different approaches to wildfire risk management by the United Kingdom and New Zealand. In several respects, the two countries have similar climate, land-use and silviculture, and this study has also shown a close correspondence in wildfire occurrence. In contrast, there is a wide difference in the ways that the two countries approach wildfires, wildfire risk, and its management. It is suggested that the UK has much to learn from New Zealand's experience of managing wildfires and wildfire risk. Further interaction to help develop a modern UK fire danger system based on New Zealand's knowledge is recommended.

Recommendations

The following recommendations are drawn from this analysis, and are split according to agency most responsible for considering them.

The Forestry Commission should:

- Review the place of forest fires in its corporate Risk Registers, and identify appropriate mitigating Actions; allocate proportionate responsibility for fire risk at appropriate levels in devolved administrations;
- Work with other Government Departments and Agencies in order to set up an appropriate national framework for managing fire risk that is land-based rather than fire-based;
- Seek to include forest fires as an important element in National Adaptation Plans, and consider how to build forest resilience through revision of the Forest Design Plan process;
- Include fire research as a discrete element in the revised Forestry Commission Science and Innovation Strategy to be published in 2013; help to sponsor a multidisciplinary research campaign with major research funders ;
- Withdraw the current forest fire danger rating system and work with the Met Office to put in place an alternative as soon as possible, using Forest Research resources as appropriate;
- With other agencies, undertake or commission economic research to establish operational and ecosystem services costs of the current level of forest and rural wildfires, in order to present to Treasury;
- Continue to collect and analyse Fire & Rescue Services wildfire statistics, at devolved and at GB/UK levels, in order to support the development of risk management systems;
- Work with other Government Agencies to explore the integration of threat analysis, as exemplified by the NZ Wildfire Threat Analysis, across the range of emergencies and disaster management processes;
- Seek to influence LWEC regarding the importance of wildfire in environmental change;
- Examine how it might benefit from further Scion involvement through appropriate contractual and/or exchange processes.

Forest Research should:

- Prepare a case for a multidisciplinary research project to address the priority issues raised in this report, for submission to the Forestry Commission and other potential funders;
- Be proactive in seeking external funding in order to progress research and build capacity on forest fire risk infrastructure, notably the further development of a Fire Weather Index, in association with the EU JRC, Met Office, Scion and other relevant parties;
- Prepare a project plan for research to begin the development of a Fire Behaviour Prediction system, in association with IFOS and Scion as appropriate;
- Renew contact with the Met Office to explore how to use MOFSI in predicting long-term fire danger as a result of climate change, seeking Scion support as appropriate; jointly explore external financial support.

Forestry Commission IFOS should:

- Explore the roll out of fire information through 'FORESTER';
- Using SCDB information, work with Forest Research to develop Fire Behaviour Prediction and 'Hazard' layers for FORESTER and/or other platforms.

Scion should:

- Consider how far it can and wishes to support UK development of national fire danger systems, and the best ways to achieve this.
- Consider a possible return exchange using the TRANZFOR replacement or similar scheme, to gain a better understanding of wildfire risks, current risk assessment systems, and associated developments and research in the UK.

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Annex 1. Overviews of the NZ Fire Service and NZ Rural Fire Authority
(from NZ Fire Service Commission Briefing Paper to Minister of Internal Affairs, April 2012).

Organisation Overview - The NZ Fire Service

The NZ Fire Service is headed by a Chief Executive (CE) who employs, on behalf of the Commission, all of the staff of the NZ Fire Service. The Act provides that where the CE has senior firefighting experience the CE may also be appointed to the role of National Commander. The National Commander is the operational head of the Fire Service. The present CE, Paul Baxter, is also the National Commander.

The operational building block of the NZ Fire Service is the gazetted urban Fire District. The Act requires the National Commander to "make provision in every Fire District for the prevention, suppression and extinction of fires" and for the Chief Fire Officer of the Fire District to respond to every alarm of fire in the Fire District.

The NZ Fire Service comprises:

- 348 fire districts within which are located 437 fire stations and 800 plus fire appliances
- 25 Fire Areas which provide operational support to the fire districts
- 5 Fire Regions which provide management support to the fire areas and districts
- National Office/Command HQ which provides strategic support to the Fire Regions
- Three emergency communication centres which process 111 and private alarm calls

The Fire Area and Fire Region structures are of relatively recent vintage and were the subject of extensive consultation exercises. They are designed to increase the support provided to volunteer fire districts, improve engagement with communities outside the metro cities and major provincial centres by better utilizing existing management resources, sharpen the focus on performance and accountability and standardise support levels for fleet, fire safety and volunteers across the country. The implementation phase of the Fire Region restructure and realignment will be completed in the first half of 2012.

Volunteers. The NZ Fire Service relies heavily on some 8,000 volunteers attached to 400 volunteer and composite brigades across the country. The relationship between the Fire Service and the volunteers is established by way of an Agreement of Service with a registered brigade rather than directly with the individual volunteer. Volunteers attend approximately 30% of all incidents to which the NZ Fire Service is called and 50% of certain categories of incident such as motor vehicle accidents. Neither volunteers nor their employers receive any recompense for their contribution without which the cost of operating the NZ Fire Service would be many times present levels.

Fire Safety / Fire Engineering The NZ Fire Service employs some 80 specialist fire risk management staff who are responsible for public fire safety education as well as promotion of building fire safety and the administration of the Evacuation of Buildings regulation. The Building Act 2004 also requires the Fire Service to provide building consent authorities with advice on certain classes of buildings and a small team of fire engineers based in Auckland discharges this obligation for all consent authorities.

Organisation Overview – National Rural Fire Authority

The Forest and Rural Fires Act 1977 requires rural fire authorities (RFA's) to promote and carry out effective fire prevention, control, restriction and suppression of fire in rural districts. There are 80 RFA's.

National Rural Fire Authority (NRFA). The Commission is the NRFA for the purposes of the Forest and Rural Fires Act. The role of the NRFA is to support and co-ordinate the work of the RFAs, to establish national standards, to audit and evaluate the performance of RFA's, to administer (as the Commission) the Rural Fire Fighting Fund, to operate a grant assistance scheme for RFA's, to monitor the forest and rural fire danger and to promote effective fire control measures. The NRFA employs five staff in the national office in Wellington and five staff in other main centres throughout NZ.

Strategic Drivers. The NRFA has adopted the following strategic directions to guide planning priorities. They were developed and endorsed by the National Rural Fire Advisory Committee which includes representatives from Local Government NZ, NZ Forest Owners Association, Federated Farmers of NZ, the Department of Conservation and the NZ Defence Force.

- Strategic leadership of the rural fire industry
- Effective working relationships with partners to deliver equitable outcomes
- Information and research to inform

Current Issues for the Commission in its NRFA role

- **Establishment of enlarged rural fire districts** Progress in this area has been encouraging but as noted elsewhere the Commission is keen to see the strategy accelerated.
- **Wildland firefighters' competencies and fitness**: Compliance with increased occupational health and safety and duty of care responsibilities and implementation of best practice recommendations arising from recent inquiries into injuries and near misses
- **Ownership of rural fire costs** Reinforcing liability for rural fire costs rests with landowners to encourage risk mitigation through better management of fuel loads
- **Voluntary Rural Fire Forces** Clarifying the role of small NZ Fire Service volunteer brigades versus Voluntary Rural Fire Forces and establishing the appropriate level of resources need to protect small rural communities
- **Extended duration wildfires** Building capacity through the National Incident Management teams and seasonal firefighter roles
- **Changing fire environment** Retirement of high country pastoral lands for conservation purposes and the development of life style blocks in formerly rural areas has increased fuel loads, increased the risk of large wildfires and increased the costs of suppression
- **Forest Management** Changes in the ownership structure of NZ's largest plantation forests have significant implications for forest fire management. The sector continues to generate rural firefighters competent in the use and management of chainsaws, aircraft and heavy machinery but numbers are declining.

Annex 2 Discussions with NZ and Australian personnel

During the four week stay, Scion organised the opportunity to meet with a range of scientists and policy people involved in managing rural fires. These include the following:

- Dr Reid Basher, Victoria University of Wellington. reid.basher@vuw.ac.nz
- Geoff Cameron, Wildfire Threat Analysis co-ordinator. geoff.cameron@paradise.net.nz
- Fiona Carswell, Ecosystems and Global Change Science Team Leader, Landcare Research. carswellf@landcareresearch.co.nz
- Dr Jenny Christie, Adaptation Scientist, Department of Conservation. jchristie@doc.govt.nz
- Murray Dudfield, National Rural Fire Officer, National Rural Fire Authority, Wellington. murray.dudfield@fire.org.nz
- Dr Rod Hay, Ecosystems Science Manager, Department of Conservation. rhay@doc.govt.nz
- Dave Hunt, National Fire Co-ordinator, Department of Conservation. dfhunt@doc.govt.nz
- Gary Lockyer, Manager Rural Fire Operations, National Rural Fire Authority. gary.lockyer@fire.org.nz
- Glen Mackie, Senior Policy Analyst, NZ Forest Owners Association. glen.mackie@nzfoa.org.nz
- Douglas Marshall (LGNZ), Local Government New Zealand. douglas.marshall@selwyn.govt.nz
- Dr Matt McGlone, Leader Ecosystems and Global Change, Landcare Research. mcglonem@landcareresearch.co.nz
- Dr Brett Mullan, Principal Scientist, National Institute of Water and Atmospheric Research. b.mullan@niwa.co.uk
- David Taylor, Fire Management Planning Officer, Parks & Wildlife Service, Tasmania. david.taylor@parks.tas.gov.au

Scion staff

- Veronica Clifford, Rural Fire Scientist, Scion. veronica.clifford@scionresearch.com
- Dr Peter Clinton, Science Leader, Forest Environment and Economics, Scion. peter.clinton@scionresearch.com
- Dr Richard Parker, Rural Fire Senior Scientist, Scion. richard.parker@scionresearch.com
- Lisa Langer, Social Scientist, Scion. lisa.langer@scionresearch.com
- Grant Pearce, Senior Fire Scientist, Scion. grant.pearce@scionresearch.com
- Dr Tara Strand, Atmospheric Scientist, Scion. tara.strand@scionresearch.com
- Dr Michael Watt, Senior Scientist, Scion. michael.watt@scionresearch.com

Endnotes

[1] Scion is the trading name for the New Zealand Forest Research Institute, the NZ government institute responsible for forestry research (the equivalent of Forest Research, UK).
[2] http://www.mfe.govt.nz/issues/land/land-cover-dbase/
[3] From www.weatheronline.co.uk/reports/climate/New-Zealand.htm
[4] http://www.ufba.org.nz/about/interesting_facts
[5] Data kindly provided by Murray Dudfield, NZ NRFA.
[6] From http://www.mfe.govt.nz/environmental-reporting/land/cover/
[7] http://www.jottercms.com/files/moorland/030601_Principles_of_Moorland_Management.pdf
[8] From http://www.weatheronline.co.uk/reports/climate/England-and-Scotland.htm
[9] http://www.fireservice.co.uk/recruitment/retained-firefighters
[10] My italics!
[11] http://www.cabinetoffice.gov.uk/resource-library/national-risk-register
[12] http://www.ccgc.gov.uk/pdf/Fire_Severity_Index_Leaflet.pdf
[13] http://cwfis.cfs.nrcan.gc.ca/en_CA/background/summary/fdr
[14] The Daily Severity Rating (DSR) indicates the increasing amount of work and difficulty of controlling a fire as fire intensity increases (Van Wagner, 1987)
[15] http://www.metoffice.gov.uk/weather/uk/firerisk/
[16] http://www.nrfa.org.nz/fire_weather/weather/FireWeather.asp
[17] The Meteorological Service of NZ (MetService) is the equivalent of the UK Met Office, whereas NIWA is the government institute for climate and water research (approximately equivalent to CEH in Britain)
[18] See http://www.scionresearch.com/research/forest-science/rural-fire-research/tools for information and download.
[19] http://www.nrfa.org.nz/fire_weather/weather/FireWeather.asp
[20] Based around NIWA's EcoConnect climate forecasting platform, http://ecoconnect.niwa.co.nz
[21] http://forest.jrc.ec.europa.eu/media/cms_page_media/82/EFFIS%20User%20Guide%20ver1.pdf
[22] www.forestry.gov.uk/pdf/Table9UKReport.pdf/$FILE/Table9UKReport.pdf
[23] http://www.frsug.org/reports/Wildfire_Statistics_2012.pdf
[24] http://www.ruraldevelopment.org.uk/files/rdi/Wildfire%20in%20the%20UK%20A%20Strategic%20Position.pdf
[25] http://www.preventionweb.net/files/1217_HFAbrochureEnglish.pdf
[26] http://www.cranfield.ac.uk/sas/cerf/strategicrisk.html
[27] http://www.forestry.gov.uk/fr/INFD-73VA4R
[28] http://ukclimateprojections.defra.gov.uk/
[29] http://www.ceh.ac.uk/news/news_archive/uk-land-cover-map_2011_44.html
[30] http://uknea.unep-wcmc.org/
[31] http://www.jesip.org.uk/
[32] http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__dataent_12178667495226008