Quality Assurance of Peak District National Park Wildfire Management and Planning Document 2022

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Foreword

The meteorological conditions most closely associated with wildfire events are predicted to occur more frequently with a warming climate. One of the challenges is to identify the best way of assessing wildfire risk and what management either of land, people or resources, will reduce the occurrence and severity of wildfires. One of the first attempts at assessing wildfire risk at a landscape scale has been produced within the Peak District National Park and this review has been commissioned to examine the approach to and conclusions from that work.

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Summary

Climate change is predicted to result in an increase in wildfire risk across the UK. The number of fires (likelihood) and the impacts (consequence) that these have on people, property and the environment are expected to increase as climate patterns become more extreme. Understanding the evolving nature of the wildfires hazard and the risks these pose to the UK now and in the future requires a strongly multidisciplinary approach including underpinning science from fields of fire science, meteorology, and ecology to name a few. It must also be recognised that there is a large body of knowledge held by landowners, managers and other stakeholders who have a unique understanding of landscapes and fire behaviours. The UK has a unique hazard profile for wildfires shaped by our landscapes, land uses, vegetation and climate. The impacts of wildfires vary significantly over the geographic area of the UK reflecting different and changing land uses. These aspects contribute to a complex and diverse wildfire risk profile across the UK.

Therefore, designing a wildfire risk assessment is a complex task. The Peak District National Park Wildfire Risk Assessment 2022 by Anthony Barber-Lomax, Ruth Battye, Steve Gibson, Marc Castellnou & Mercedes Bachfischer is an attempt to evaluate the risk of wildfire across a large focus area of the Peak District National Park. Recognising the challenge, the authors use a tiered approach comprising an indexing system based on expert solicitation (Tier 1), historical data (Tier 2) and computer modelling (Tier 3). At a high level the logic of the approach is sound however while the report set out to define the “risk of wildfire” an objective measurement of this risk is not given, and the constructs of likelihood, intensity, hazard and consequence are, at times, blurred. This poses a challenge to application and interpretation of the findings and generalisation of the approach. While a tiered approach is valuable, the three tiers of the approach are not fully independent: the historical data in Tier 2 cannot be independent of stakeholder views relied upon in Tier 1. The report also highlights the challenges of designing an indexing system (Tier 1) as there is double counting and dependencies between categories highlighting the complexity of the processes which underpin wildfire risk. The numerical modelling tools used in Tier 3 while having

the potential to be predictive are constrained by the lack of evidenced applicability to UK vegetation types.

These are not intended as criticisms of the authors. Indeed, as stated in the report, and as is true for all risk assessments, the process is just as important as the outcome. This review is intended to highlight the work that is still required to develop the underpinning knowledge to deliver wildfire risk assessments for the UK. Agreement on the objectives of a risk assessment should consider different approaches to fire management and the assets at risk defined at a local level in consultation with the relevant authorities. In this regard, the report does an excellent job of highlighting the role of engaging with a range of stakeholders from land management, scientific and public bodies. The review also highlights the limited information available on vegetation cover, and the ability to apply existing predictive models of wildfire spread in fuels relevant to the UK. While predictive modelling is a powerful tool in the assessment of wildfire risk, translation of existing approaches to the UK context is challenging and an area of significant ongoing research. These tools will require sustained development and operational support, if we are to be able to predict future risk in a paradigm of changing climate and changing land uses.

Contents

Introduction

This document is a review of the Peak District National Park Wildfire Risk Assessment 2022 by Anthony Barber-Lomax, Ruth Battye, Steve Gibson, Marc Castellnou & Mercedes Bachfischer (the Report). The Report presents an overview of wildfire in the Peak District National Park (PDNP) and sets the scene by identifying challenges associated with wildfire occurrence and describes the need to have appropriate methods to identify the risks posed by wildfires in the PDNP. The report is centred on describing a method to evaluate wildfire risk in the PDNP.

The risk assessment methodology proposed in the Report is briefly reviewed before the individual aspects of the Requirement of this contract are addressed.

Overview of the risk assessment methodology

The method presented in the report uses a three-tier approach to identify wildfire risk. These tiers capture input from different stakeholder groups, use different assessment tools and operate at different scales. Tier 1 is an indexing method based on metrics that are deemed to be important by local stakeholders. There are a total of 12 scoring categories (ranked from 1 to 5) accounting for what the authors group into 'ignition', 'combustion' and 'control' aspects of the wildfire.

Tier 2 is an assessment of historic spatial data which overlays quantitative data on the study area. This data pertains to historic ignition events, combustion, and control. There is a degree of overlap between the data obtained in Tier 2 and Tier 1 assessments. The conclusion of Tier 2 is an "Overall Vulnerability" assessment that identifies areas in the interior of the focus area to have highest vulnerability to wildfire.

Tier 3 is an assessment of the fire behaviour that may arise in a given location. This assessment comprises an analysis of historic weather patterns, to derive weather scenarios of interest and assessment of the fuel to provide input to a numerical fire modelling tool. The model outputs flame length, rate of spread and fire line intensity are spatially mapped. These metrics are then further interpreted using a system in which the focus area is subdivided into polygons in which fire behaviour is expected to be uniform. An assessment of the connectivity of these polygons is made to define "fire highways".

In each of the Tiers, a review of the limitations is provided by the authors.

Finally, the Tiers are combined, and commentary is provided on the aspects of ignition, combustion, and intervention.

The requirement

The Project Requirement set out the following issues for review in the context of the Report.

1. The assumptions made for the development of the model, including all three tiers of the approach.

2. The appropriateness to the UK of data used to weight factors, develop and train the model.

3. The strengths and weaknesses of the approach.

4. The robustness of the findings of the model including the magnitude of uncertainty associated with the results and their applicability (including appropriateness to extrapolate regionally) to the UK.

5. If appropriate, recommend any additional work that could strengthen the existing report.

These issues are addressed in the following sections of this document following an initial overall commentary on the Report. Some of these issues are interlinked and these are highlighted throughout the report.

General remarks

The authors have tackled a complex and challenging issue of identifying wildfire risk in the context of a focus area in the Peak District National Park. At a high level, the logic of the approach is sound. The use of information from different sources is a necessary step in such assessments and the explicit recognition of this is of huge value to ensuring robust assessments by ensuring that the knowledge held by different groups is captured and to contextualise outputs from the modelling tools.

However, the approach also seems to lack a clear articulation of the objectives. It sets out to define “risk of wildfire”, but this requires that there is an objective measure of the risk. It is implied that the main risk is a large wildfire occurring, but there is no discussion of the negative impacts that may arise and how the proposed approach may be used to mitigate these. This is required to justify the focus of the modelling effort and the interpretation of the output from this as it is likely not possible to design a risk assessment system that can cover all possible objectives. Occasionally, the methodology tips over into issues that are consequences of a wildfire but this is not consistent. For example, there are a number of statements made regarding ignition of deep peat (and associated carbon loss and ecosystem damage) but there is no explicit statement of which values-at-risk the method seeks to protect. This would help frame the approach and the more clearly.

The approach combines information derived from those with knowledge of the landscape with quantitative analyses of historic events and predictions of fire behaviour on the landscape. However, there are a number of issues with the implementation of the approach on each of the Tiers which must be addressed.

Tier 1 is a fire risk indexing system. These systems generally rely on user experience to define the risk by assigning scores to criteria and combining these. In doing so, several implicit and explicit assumptions are made. Designing an indexing system requires careful consideration of the criteria which are scored to ensure these provide robust and independent assessments of the risk. Generally, these systems should be designed to be simple and to ensure that changes in the scores of categories has appropriate and meaningful impacts on the final score.

The use of an ordinal scoring system presents challenges to this approach because (without weightings) it implies an equal level of importance of each of the categories if they are scored equally. Given the choice of categories it is not clear that this will necessarily be true. It is also curious that in this tier, the wind – which is widely acknowledged as a key driver of wildfire behaviour and hence risk – is not included in the assessment. The authors justify this decision because four scores are generated based on wind direction could have “disproportionate impact on the overall total score”. This could have been managed through appropriate weightings informed by historic fire occurrence and weather patterns. This is highlighted because manipulation of one individual score will not have a significant impact on the overall risk index. This means that the risk model cannot always be relied upon to help users identify the most appropriate ways to reduce or manage risk. In this Tier, there are also some semantic issues which may reduce clarity of the overall framework.

Tier 2 presents a mapping exercise using historically informed spatial data. This approach is extremely valuable however it seems that this information will have informed the knowledge of the participants in the Tier One assessment perhaps anchoring the discussion on specific areas. More value could be obtained if the stakeholder activities were used to augment the quantitative data and identify gaps in these data.

Tier 3, presents an ambitious use of numerical fire modelling however, the state of the art cannot deliver adequate solutions for reliable implementation. The primary issue in this regard is that there are no fuel models within the selected modelling tool that specifically apply to UK vegetation. The models selected may in some cases share some similarities with UK vegetation but there has been no rigorous study (to my knowledge) of the applicability of these to the UK context. Indeed, recent work has identified that translation of these international approaches to the UK context may be extremely challenging[1]. In addition to this, the reliance on historic weather data for the assessments is problematic in the context of climate change when new, potentially more extreme, weather patterns are expected. The polygon approach, though published in peer reviewed literature, has not been shown to be effective in the UK context. The idea of breaking up the landscape into areas of similar expected fire behaviours requires an additional level of interpretation (and complexity) that might not be necessary or warranted where more easily accessible information such as vegetation type and loading, and slope are available. The Report also does not present any information on how the connectivity of the polygons was assessed. Furthermore, the value of this is not clear as the output ("fire highways") does not add much more data beyond the prevailing wind information.

Considering the combination of the tiers, there is a degree of redundancy in the method. For example, the use of historical ignitions in Tier 2 is not independent from the Ignition History category in Tier 1 (albeit more quantitatively). The modelling inputs in Tier 3 are similarly factored in Tier 1. Whilst this appears to be reassuring, the high degree of overlap in the information used to generate the assessments at each of the Tiers limits the value of such an assessment. It may also be the case that conflicting results could arise in each tier (given the uncertainty associated to some of the inputs) which may cause confusion in interoperation of the risk assessment.

Finally, there are a number of areas in which the terminology used may present issues of both clarity and technical correctness. These are discussed in more detail in the following sections. One significant positive step that the authors have taken is to provide a clear overview of their view of the limitations of the approach. This is an extremely important aspect of any modelling tool.

[1] Taylor AFS, Bruce M, Britton AJ, Owen IJ, Gagkas Z, Pohle I, Fielding D, Hadden R: Scottish Fire Danger Rating System (FDRS) Report. This report explains the process followed to develop the FDRS: https://www.hutton.ac.uk/research/projects/scottish-fire-danger-rating-system-sfdrs

Assumptions

Tier One - Individual Moorland Assessments – Matrix

Tier one is based on an assessment of 16 (12 are used in calculating the final score) criteria on 1 km OS grid squares. The 12 assessed criteria are divided into groups named Ignition, Combustion and Control, comprising 3, 9 and 4 categories respectively, each of the categories are awarded scores between 1 and 5. Summation of the scores in each of the groups provides an overall assessment for that group. Implicit in this approach is that each of these categories carries equal weight in the fire risk assessment.

Section 8.3 provides an example of the scoring matrix in Figure 26. There is some ambiguity in the calculation procedure between this example and the method presented later in section 8.7 (the arithmetic seems incorrect in Figure 26 and scores for wind are included). The calculation of the final scores in section 8.7 is based on the sum of Total scores for each of the groups i.e. a total score for each group is calculated based on the summation of the individual categories and this is used to define the Total for that group and assigned as score between 1 and 5. Section 8.7 then indicates that these totals are summed to define an overall score and associated rating (again between 1 and 5). In the example given in Figure 26, the individual categories are summed to generate a Combined Total and then this is assigned a band. A consistent approach to this calculation procedure must be clearly presented in this report. The statement that the "process itself was seen as being as important as the output" is extremely pertinent.

One of the most challenging aspects of developing an indexing system is identifying equivalency between the categories. In this approach, no weightings are used and therefore careful consideration must be given to the scoring of different aspects to ensure that their impact on the final scores is appropriate and balanced.

The authors acknowledge that these assessments are subjective, and this will necessarily be the case for such a tool but, more work must be done to simplify this matrix and to minimise double counting and acknowledge dependencies. This could perhaps be done by creating a hierarchy to structure the questions. Furthermore, some of the criteria used to differentiate between areas of risk are relatively arbitrarily (e.g., the distance from rights of way, distance from water sources). This is not a problem per se, but such criteria need to be carefully evaluated when translating this approach to other geographical areas. The other hazard with such an approach is in defining how this will be used and the acceptability limits. A score of 2 or 3 may not seem to present a significant hazard but it does not mean that this grid area will not have a significant fire. Commentary or advice on how to interpret these scores is required before this can become operational.

The individual criteria are reviewed in the following sections.

Ignition

This section assigns a score based on an assessment of the proximity to public access, parking and ignition history.

The rationale given is that “The greater the number of people in a location, the greater the risk of accidental fire ignition” (page 43). This is a key assumption, and this statement is not supported with evidence. While there is some logic to this, a more rigorous justification is required. For example, in the highest scoring of this category (“Honeypot location”) it is possible that inappropriate behaviours would be spotted and challenged and therefore the risk would be lower than an area with relatively fewer people present. Unfortunately, data which can adequately, independently verify the importance of these metrics may not be available. The authors present some data in Figure 16 and the associated discussion, but this does not seem to be analysed in a way that would justify (or otherwise) the categories listed in Table 3. This is also an area where the tiers are not independent as a user’s opinion will be informed by experience of real fires.

The data on parking availability seems to overlap very closely with public access. It is not clear what is gained by considering these as separate categories and there may be an opportunity to simplify the index by combining these. Arguments could also be made to consider risks associated with proximity to population centres in this category.

The ignition history category is a valuable metric however a broader view of this to enable stakeholder-based extrapolation to other sites is required. These data are gathered through experience of the stakeholders (bur are also quantitatively assessed in Tier 2). This will reduce the value of this as an independent metric. The result is that this may focus scoring based on historic data only, and not areas of perceived future ignition risk (which by definition are not captured in historic data). This overlap in data limits the input from the stakeholders who may be able to fill gaps in the quantitative data. Furthermore, this component may be counterintuitive. An area which has recently burned is potentially likely to attract fewer visitors and will have reduced fuel loading and hence may be less susceptible to ignition. It does not necessarily follow that frequent ignitions will result more serious fires. The effect of historic fire occurrences should be explicitly captured in this assessment. It is acknowledged that this is subjective but nevertheless it is important that the whole system is explicitly captured. This indicates that this category may require additional refinement to identify independent drivers of ignition risk. It is not clear how a scores of 2 or 4 would be awarded in this category and this may introduce unintended bias into the rating.

The Total is given as an addition of the scores in each of the three categories and re-indexed on a scale of 1-5. This reindexing seems somewhat redundant and introduces “rounding” to the scores which is not explicitly addressed.

Combustion

This section comprises 9 categories (5 which are included in the assessment). This section conflates established principles in assessment of wildfire risk: fuels and fire behaviours and weather. These principles are linked but they present differently in risk assessments and present different opportunities to impact the outcomes of a risk assessment. A review of this section to fit the established ideas and uses of fuels, fire behaviours and weather should be undertaken. This is supported by these topics being significant components of existing international Fire Danger Assessment systems[2,3]. It is striking that fuel type and loading are not explicitly considered in this part of the assessment. These are known to be key drivers (and it is implicit in the assessments in Tier 3) of fire risk in the context of extreme fire behaviour. It is understandable that this may have been omitted (or conflated with other ideas) due to the relatively constrained geographic focus area which will mean that fuel types will be well known, and seasonality well understood but this is a limitation in applying this assessment method in other areas.

Current management

The assumption is made that specific land management approaches will reduce fire risk. This is a significant assumption and is not necessarily supported by relevant evidence. For example, a rotationally burned piece of moorland may not result in a lower score than a site where cutting or grazing has taken place, but these may achieve the same outcome from a fire management perspective. It is worth noting that much of the managed burning in the UK is done outside the explicit context of managing fire risk. It is important that the aims of land management practices are explicit fire risk reduction and metrics are in place to quantify the effectiveness of treatments. This could be assessed using a fuel type and load measurement.

Existing breaks

This section suffers again from a lack of contextualisation. A break may be effective under specific fire conditions and may not be effective under others and as such this must be considered with the expected fire behaviours. Given firebreaks include roads, this may

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[2] Canadian Forest Fire Danger Rating System, https://cwfis.cfs.nrcan.gc.ca/background/summary/fdr

[3] National Fire Danger Rating System (USA), and explanation of the system can be found here: https://www.fs.usda.gov/detail/cibola/landmanagement/resourcemanagement/?cid=stelprdb5368839

result in double counting the categories in the Ignition component. It is not clear how the scores of 2 or 4 would feature in this category.

Peat depth

It is not clear how the authors intend for this to factor into the risk assessment. If the approach is intended to address the consequences of a wildfire (such as loss of carbon from deep peat), then this needs to be clearly reflected in the aims and objectives of the model. The ignition of deep layers of peat presents a different hazard and is governed by different phenomena, comparted to an intense, fast spreading surface fire and these events are driven by very different processes.

Volatility

This term is not an appropriate descriptor for the behaviour of a wildland fuel. The use of flammability is recommended. This is again a descriptor of the fuel not combustion. The ranking given does seem logical, but these are assumptions and there are few data sources that could provide quantitative data to substantiate this raking. This aspect also combines with the Ignition criteria as the type of fuel is very important in defining the likelihood of ignition (and how this changes in response to external variables).

Growth rate

This parameter seeks to provide a subjective assessment of how rapidly a fire will grow after ignition. The user is guided to use their experience. It seems that this parameter is conflated with fuel load which would be a better, less subjective metric to use instead. Additional quantitative factors such as aspect, slope and ground conditions could also be used to replace this. Fire growth rate is a very complex process, and the use of more quantitative measures would provide a more robust, less subjective, metric.

Wind

This is a very important aspect determining the hazard posed by a wildfire and should be included in an assessment of the risk. Higher windspeed will generally result in faster rates of spread (under conditions typical of the UK) and there are considerations also for impacts of smoke. A more nuanced approach may be possible to reframe the issue in combination with other factors such as the terrain or fuel breaks to identify locations where wind will have additional contributing impact. Alternatively, or additionally, a scoring metric could be devised where wind from a particular direction represents a significant additional risk, and this could be included in the assessment. A probabilistic assessment could be made based on the prevailing wind direction during periods of high fire likelihood. The comment from the authors for discounting the disproportional impact of four categories is again an indication that weightings could be used.

Total

The total is calculated by the sum of these categories. The scoring is out of 25. This is used in the Overall Total.

Control

This section deals with the ability of responders to tackle a wildfire. There are four categories: water availability, equipment, personnel and accessibility. Including this as a component is curious given the previous statement that reliance on the use of direct firefighting with water may be a reason for ineffective firefighting. This highlights the need for consistency and clear justification of the values considered. The categories here are interdependent. For example, what is the purpose of equipment if there is no appropriate water supply? How does having appropriate personnel help if there is not appropriate equipment? This again could be handled with weightings or by a structured approach to the problem. This section needs to be reconsidered in light of more clearly articulated aims and to reduce interdependencies.

The total is calculated addition of the scores in each of the three categories and re-indexed on a scale of 1-5.

Summary

The use of experiential data to inform fire risk mapping is a good idea. The authors are correct to note that "the process is as important as the outcome". However, with the aim of building a risk assessment methodology there are opportunities for improvement before applying this more widely.

The categories included in the risk matrix need refinement. This should focus on reducing the number of categories and eliminating the interdependency and multiple counting of similar features. Such an approach is acknowledged to be subjective, and this is necessarily the case however the result of this is that the model should be as simple as possible and as clear as possible.

A significant concern with this model is that likelihood, intensity and consequence of a fire are merged without a clear differentiation or discussion of this. This can lead to confusion when the system is used more widely with a range of stakeholders. The aims must be clearly articulated, and the categories used to develop the scoring system must be explicitly linked to these aims.

Despite being subjective the model should be reproducible. The statement that "[t]he distinction between individual assessments is clear in some locations indicating the different sensitivities of some respondents" suggests that there is a lack of reproducibility which will impact the results. Methods to minimise this should be considered.

The model should also be able to differentiate between actions that will result in improvements. The statement that "removal of factors has very little bearing on the combined total combustion map" indicates that the method contains more categories than are useful to help differentiate between different risk levels.

Tier Two – Wider Mapping Assessment

This tier presents an assessment based on historic and spatial data. This is a quantitative data set based on previous research.

The inclusion of historic data on ignitions and wildfire occurrences means that this tier is not independent of Tier One which also draws on (stakeholder experience of) historic data. This overlap means that this additional layer of information is at least partially redundant and does not add new information.

In terms of the overall approach, it might be logical to consider this approach as the first tier, then use the local stakeholder knowledge to augment this dataset. This would provide an evidence-based set of criteria in the stakeholder engagement tier. This would provide justification of the categories which are scored, and the rationale behind the criteria selected for the different scores[4]. This would then increase the value of the stakeholder assessment by generating new data that is not captured in the quantitative data sets.

The Combustion component of this tier relies on assessment of two components: presence and depth of peat. These components are used to generate assessment of risk based on "Land use and habitat" in which deep peat is indicative of higher risk. It is implied that this is due to less intensive management on these locations. A "combustion vulnerability zone" is also defined based on the area with deep peat. It is not clear if these components are used together (in which case there is redundancy) or if they are intended to provide complimentary information.

The rationale to include this metric conflates the ideas of likelihood, intensity and consequence (as mentioned previously) and as a result it is not clear how this can be used to manage risk. Peat (deep or otherwise) will only have a marginal impact on surface fire

[4] The statement "BBQs etc. which represent perhaps the greatest ignition risk" must be justified. Causes of ignitions of wildfires are notoriously hard to identify and there is a need to present strong evidence of this to inform public awareness.

spread but is a significant factor in the consequences of a wildfire. These issues are not adequately discussed in this assessment.

The Control component maps access routes and water sources and defines regions around these. The use of roads in this sense seems contradictory to the logic of the ignition assessments and it would seem that these potentially cancel out in this approach.

Tier Three – Fire Behaviour Analysis

This tier develops an analysis that is based on predictions of the fire behaviour using a numerical model. The modelling approach uses FARSITE which is an established tool in this field to generate information on flame length, rate of spread and fire intensity. These data are then used to construct polygons in the landscape of similar fire behaviour. The connectivity between these polygons is then used to define “fire highways” which are used to explore the landscape-scale fire behaviours.

All models need inputs and the results from the modelling exercise will be constrained by the accuracy of these inputs. The chosen fire model requires inputs primarily pertaining to weather, fuel (vegetation) and topography. The results from a modelling exercise must be interpreted and presented in a manner which recognises the limitations of the input data.

The introductory section of this section introduces the distinction between a fire and a wildfire, but this is not clearly presented. The concepts of values that need to be protected is also introduced here but this logic is not used in Tiers 1 or 2. The aims of these tiers (which are ultimately combined) need to be consistent.

Weather

The weather scenarios chosen are based on historic data. In defining future risk, it is necessary to explore systematically likely climate scenarios to ensure future risk is adequately captured with the input data. Alternatively, it is necessary to be explicit about the reference weather used. This requires refinement and further development before this approach is implemented. The cumulative impacts of periods of weather are acknowledged however the statement that “the effect is cumulative but peaks around 12 days” cannot be correct. An appropriate time window is essential to allow for a proper assessment of the effects of weather on the condition of the vegetation.

Figures 57 and 58 show the same weather system but make different interpretations of the data. This is unclear.

Fuels

Data on the vegetation present is obtained using the Land Cover Map (LCM). These data are converted to “fuel models” for use in the numerical model. The Rothermel model is a well-established fire spread prediction tool which has been implemented in a computational tool called FARSITE which is managed by the US Department of Agriculture Forest Service. The Rothermel model (and therefore FARSITE) require the user to identify and select “fuel models” to represent key characteristics of the fuel (vegetation) that is burning. There are a limited number of fuel models available for implementation in FARSITE. The authors present the conversion from the LCM to Rothermel fuel models in Figure 59.

The fuel models used are identified by number. The authors identify fuel numbers: 0, 1, 2, 3, 6, 9, 10, 98 and 99 as present in the PDNP. The descriptions of these models are given by Scott and Burgan (2005)[5]. For convenience the conversion between numbers and descriptive fuel types is given in Table 1. It is noted that the numerical descriptions are not given in the Rothermel 1972 reference stated in the report.

Table 1 The descriptions of the fuel models used in the fire modelling assessment Scott and Burgan (2005).

[5] Scott, Joe H., Burgan, Robert E. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. Gen. Tech. Rep.RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.72 p.

Fuel model number	Description
0	[Not given]
1	Short grass
2	Timber grass and understory
3	Tall grass
6	Dormant Brush
9	Hardwood litter
10	Timber (Understory)
98	Open water
99	Bare ground

These descriptions highlight the challenge of using existing tools to model fire behaviours: the input data that are required do not exist for UK vegetation. While it may appear that there are similarities in the nomenclature, there have been no studies which allow these fuel models to be used with confidence or which are suitable to generate new model classes for UK fuels, and no explanation is given in the report. Although efforts have been made to obtain higher resolution spatial information on the fuel types, the resulting maps are not well described in the report. Furthermore, it is not at all clear how this improved data resolution helps with understanding fire behaviours if the existing fuel models have not been verified for use with the vegetation types in the UK or if bespoke models have not been developed. This is a significant limitation in the implementation of this aspect of the risk assessment. This extends to the results presented for the study areas in the appendices. To be clear, the approach is in principle a good one, but it exceeds the current state of the art in modelling fire behaviour in UK fuels and as a result the model outputs cannot be relied upon. Consequently, the results of individual fire behaviour indicators cannot be relied upon.

The fire behaviour predictions are then used to create polygons on the landscape in which fire behaviour can be assumed to be homogenous. It is stated that this is done based on thresholds of the fire behaviour, but details are not provided to allow assessment of the appropriateness of this approach. It is likely that the scales at which this approach can be applied will vary based on the terrain, fuel and other factors so choice of scale seems arbitrary.

The polygons are assessed for connectivity across the landscape. How this is done is not reported so the appropriateness of this approach cannot be determined. Overlaid on this connectivity is the ability of the Fire and Rescue Service to intervene. This assessment is repeated for different weather scenarios. Finally, an additional layer of interpretation is overlaid to generate “Fire Highways”. These are presented for the different weather scenarios. It is clear that these align with the dominant wind in each case. The added value of this analysis seems therefore to be very limited.

The methods used to generate the polygon connections and the fire highways are not communicated in the report and so cannot be reviewed. The referenced papers in the scientific literature use the same concept but applied in a different context (firefighting) so the rationale needs to be clearly explained in this report. It is also important to note that this method has not been verified in the UK context.

The polygons of similar fire behaviour are used also to identify areas where there may be extreme fire behaviours (based on the average properties of flame length, fire line intensity and spread rate from the model and so subject to the limitations stated earlier). Using these to identify areas of high fire intensity is a useful insight but is not in itself a risk assessment.

Summary

An approach that could be used while appropriate models are developed would be to integrate a fuel mapping exercise with a more detailed assessment in Tier 2. This could be enhanced to also include other data that are available around climate predictions and terrain.

Summary of the approach

In principle the three tiers presented in this approach address the fire risk assessment at different spatial scale and include a range of different data sources. However, these data sources are not all independent and therefore there is redundancy (double counting) across the tiers.

Tier One provides useful information at high resolution however there is a need to provide justification for the categories which are scored and to reduce redundancy between these categories and with Tier Two. Swapping the order of these tiers would provide an evidence base for the categories in the current Tier One while also providing rationale behind some of the scoring indexes. The scoring system in Tier One should be revised to ensure equivalency of impact between the scores across categories.

The spatial data used in Tier Two allows for an assessment of historic fires. This tier would benefit from an enhanced exploration of the fuel (vegetation) coverage. These data may not always be available but an assessment at this tier of vegetation, terrain and weather would allow for a simple, but physics-based, evaluation of the fire risk (without the need to numerically simulate the fire) through evaluation of these three criteria.

The additional value obtained through the methods presented in Tier Three is not clear. This is a complex set of data with a large degree of uncertainty introduced through the use of a numerical model, which requires a significant degree of interpretation. The result is an assessment that does not add further refinement beyond that obtained from the other tiers. The methods used here are not sufficiently described to offer a view on their appropriateness.

Appropriateness of UK data

There are several data sources that are required to accurately assess wildfire risk. These data sources are complimentary however there are significant gaps that make applying this risk assessment method challenging.

Experiential knowledge

Within the context of the UK, significant understanding of wildfire risk (and management) lies with local landowners/managers. This knowledge can be accessed through organisations such as the England and Wales Wildfire Forum, or local gamekeeper organisations. Often translating this knowledge to complement quantitative sources presents a challenge but using it as presented here can provide crucial contextual information to enhance quantitative fire danger assessment methods (such as those presented in Tiers Two and Three). However, capturing this information must be done carefully. Another of the key challenges associated with this data is sustaining this knowledge as policy and land management practices evolve. Capturing this knowledge is therefore essential in the skills and experience of assessing wildfire risk (and controlling wildfires).

Wildfire occurrence data

Wildfire occurrence data is used to determine historic patterns in wildfire behaviour. The European Forest Fire Information System (EFFIS) provides standardized information about forest fires including location, size intensity and behavior. These data must be interpreted carefully as they are largely generated from remote sensing techniques (and may be augmented by ground-based observations). For example, EFFIS cannot differentiate between managed (prescribed) fires and wildfires.

Wildfire occurrence is also recorded by Fire and Rescue Services in the UK however the standardized reporting does not capture many of the key elements that would be desired to inform decision making. However, dialogue or post-fire analysis of burned areas is performed by a range of stakeholders but there is significant variability in the quality of this data.

The use of historic data gathered from these systems is challenging when applying to a changing climate as using this to make forecasts under different weather or climate.

Fuel mapping

A key aspect relating to assessing wildfire risk is accurate fuel mapping. Fuel type and fuel load are key drivers of wildfire risk, and these data are not generally available at appropriate (or consistent) resolution. This limits the ability to make assessments of likely ignition potential, and fire behaviours at the local scale, or the use of numerical modeling tools to make predictions of fire behaviour under different scenarios. Attempts have been made in this report to do this for areas within the PDNP, but the methodology used for classification has not been presented.

Fire behaviour

There is a growing but incomplete quantitative understanding of fire behaviour in UK fuels. Although this has been studied since at least the 1960s, the interactions of fuel, terrain and weather are still not well defined for most vegetation relevant to the UK. Locally this knowledge is held by landowners/managers.

Ignition

Investigation of wildfires is an extremely challenging process with little basis in the established technical literature. The complexity of fuels, weather, terrain mean that interpreting a wildfire event is extremely challenging. The complexity increases the closer to the point of ignition. Therefore, the identification of ignition sources may be anecdotal and certainly good statistical data do not exist in this area.

Weather and climate

The changes to weather and climate are perhaps some of the best understood data that are available to help inform wildfire risk assessment. Trends can indicate the changes in periods of drier weather (which will increase fire risk) and wetter weather (which may increase fuel load). However, the degree to which these aspects change fire behaviours are not well known.

Summary

There are significant challenges in the data available to assist with making assessment of wildfire risk. Arguably the most valuable sources are local landowners/manager however this is experiential knowledge and may not be appropriate to predict future wildfire risk under a changing climate and landscape. As with all experiential data, there is the obvious risk of bias which must be acknowledged and accepted as part of any system incorporating information of this kind. The challenge of fuel type and load mapping is significant but necessary to make assessment of wildfire risk on the landscape. One of the key aspects in dealing with data is having consistency of data across spatial and temporal scales. This data must also be commensurate with our level of understanding of fire behaviour and fuels. This is necessary in order to allow reliable prediction of wildfire risk.

Strengths and weaknesses

A high-level review of the strengths and weakness of the approach taken in the report is given here. It is important to note that many of the weaknesses are not the fault of the authors but rather limitations in the data or methods available.

Strengths

- The work draws on relevant data sources and includes interaction across stakeholder groups. This is important to ensure that all sources of information (experiential knowledge, quantitative data) are captured. This is a significant strength.

- The use of different spatial scales allows the wildfire risk to be assessed at scales appropriate for the interests of different stakeholders. This also allows a tiered approach which means the assessment can be made using data or information commensurate to the scale of interest.

- The process being more important than the outcomes is an essential acknowledgement in this approach. This could be developed further to ensure that unexpected outcomes or ideas which are identified are captured as areas for further investigation.

- The approach does not attempt to use existing “fire danger” assessment tools. Instead acknowledging the context of the landscape for which it was developed.

Weaknesses

- The aim of the approach is not clear. It seems to seek to define risk as all of likelihood, intensity and consequence of a wildfire. This often leads to a slightly confusing interpretation of input data.

- The tired approach is an appropriate idea but may exceed the capacity of available data. This results in the use of data which are not independent across the tiers resulting in redundancy (or overinterpretation) of the data.

- The approach in Tier One needs to be improved. The categories should be refined as there is redundancy and double counting. The outputs from this are not sensitive to all the inputs. This has implications for the efficacy of the method but also to enable informed decision making about risk management.

- As with all scoring systems there needs to be significant education around the meaning of the outputs. A score of 2 or 3 might sound good but it does not mean that a wildfire will not occur.

- Tier two provides useful quantitative information, but this is not explicitly used to inform the process of Tier One. These could be reordered such that the current tier one provides complementary information for the more quantitative data used in Tier Two.

- Tier Two is dependent on data of vegetation mapping, but this is not always available at the resolution needed.

- Tier Three is the weakest of the tiers. Fire behaviour modelling cannot be reliably used due to limitations in the input data and the fuel models available. There are currently no validated fuel models for vegetation types common to the UK.

- The methods employed to divide the landscape into polygons is not adequately described, nor has it been tested in the UK context. This data also requires thresholding (which are not evidenced in the report) to generate the fire polygons. The final analysis of this Tier seems to not provide information beyond that which could be obtained from an assessment of prevailing wind direction.

- The complexity of this tier seems to be misaligned with the data that are used to inform the approaches.

Robustness of the findings

The findings of this approach may identify areas of higher wildfire risk but there is no assessment made of this by the authors. This ought to be a step in the development of any modelling or risk assessment tool. Since this evaluation is not made it is difficult to comment, with confidence on the findings.

Evaluation of the robustness of the findings by comparison of the risk identified across the tiers is not possible due to the lack of independence of the data available/used.

The robustness of Tier One findings is limited by the implementation of the scoring system (as identified above). Tier Two is limited by a paucity of required data. Similarly for Tier Three with the addition of the lack of description of the creation of fire polygons and the interpretation of the connectivity of these.

Further work

Developing a system to make reliable assessment of wildfire risk is a challenging endeavour. In the context of the UK there is much work to be done in this space. There are several recently completed or ongoing research projects in this area. These projects will inform wildfire risk assessments, but it is unlikely that they will complete this process.

Internationally, wildfire risk assessment tools are developed and maintained by government bodies. Ownership and ongoing development of these tools is essential to ensure they are trusted by those who rely on the outputs to make decisions. Future work should therefore consider how these tools will be managed and who will be responsible for the necessary ongoing development.

Regarding the current approach, specific further work is required before this could be adopted more widely. This is detailed below.

- The aims of the fire risk assessment must be articulated. This should include what is considered and what is not considered in defining wildfire risk. This is necessary to ensure a simple, functioning system. A system which seeks to encompass likelihood, intensity and consequence is unlikely to be able to capture all of these aspects equivalently while maintaining simplicity.

- Review the overall structure of Tier One and consider the literature on the development of Indexing Systems to ensure that the system is developed knowingly.

- Refine and adapt the categories used in Tier One to minimise double counting and interdependency. This should also focus on reducing the number of categories and ensuring that these have a meaningful impact on the final ranking.
- In Tier One, the development of a hierarchical structure, or weightings will allow the risk assessment tool to also inform choices around land management practices.
- The structuring of the Tiers could be rearranged to maximise the available data sources: using the current tier two as a starting point would allow stakeholders to augment (rather than duplicate) this information while also providing justification for the categories which are scored. This would also get around some of the challenges of adapting the system for different geographical areas as the quantitative data would serve as a starting point for the assessment.
- Tier Two should be reworked to include assessments of likely weather patterns, higher fidelity fuel mapping and assessment of terrain. These are the primary drivers of fire behaviour so could be used to make relative fire behaviour assessments without the need to use predictive numerical tools.
- Useful information can be derived from numerical tools provided appropriate input data are used. This will require development of specific fuel models for UK fuels.
- Models or risk assessment tools which are developed in one geographical area should be tested in new geographical areas to determine their dependence on the training data.
- Information justifying the use of existing fuel models with UK vegetation types is required to maximise the use of the data generated from the reclassification of fuels in the report.
- Bespoke fuel models for UK vegetation types should be developed to improve the potential to benefit from modelling tools.

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