Wildfire Threat Analysis (WTA):
NERC-funded scoping project with Forestry Commission

1. Context

The Natural Environment Research Council (NERC) funded Julia McMorrow, Jonathan Aylen and Aleksandra Kazmierczak from Manchester University to undertake a 6-month scoping project on Wildfire Threat Analysis (WTA), from 1st Dec 2013 to 31 May 2014. It was part of NERC's Probability, Uncertainty and Risk in the Environment (PURE) Associates programme (award ref. PA13-3015). The project was carried out with the Forestry Commission England (Rob Gazzard) and Forest Research (James Morison and Andy Moffat).

WTA has been used successfully to map wildfire threat at a national level in Canada and New Zealand. WTA sees wildfire threat as a combination of three separate modules: *Risk of Ignition* (RoI) of a vegetation fire, regardless of size; *Hazard* of fire spread (head fire intensity, rate of spread), and *Values at Risk* (VaR), *i.e.* the assets potentially affected. It uses GIS to develop and combine map layers for each of the three modules.

2. Aim

The aim was to evaluate the potential of WTA for the UK, using a forest-urban interface case study.

3. What we did

We adapted the New Zealand framework to suit the UK (Figure 1). A local-scale WTA using a 25m cell size was developed for an 11x12 km area centred on Crowthorne Wood/Swinley Forest (near Bracknell, southeast England). The study area is characterised by large areas of open woodland and heathland used for recreation, but surrounded by housing, commercial property and military installations. A high profile crown fire occurred here in April-May 2011, which damaged 110 ha – the most resource-intensive fire in Royal Berkshire Fire and Rescue Services' history (Figure 2).

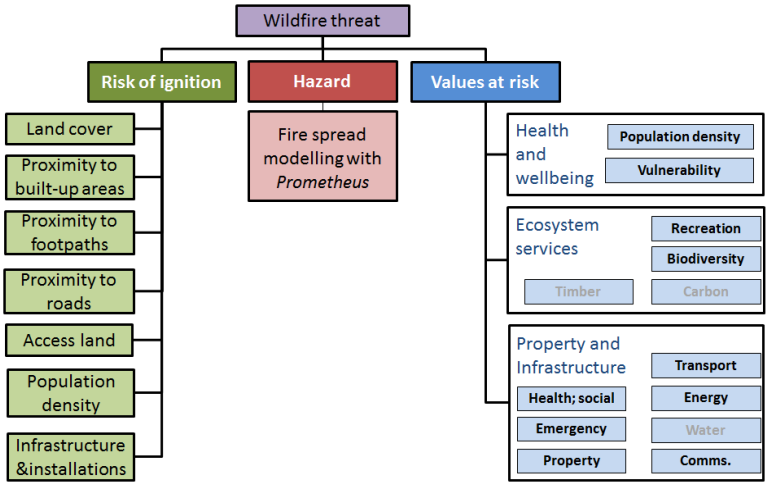

Figure 1: Modified WTA framework. Grey indicates data not available within the timeframe of the project

Figure 2: April/May 2011 crown fire at Crowthorne Wood, best known as the 'Swinley Forest fire', (Photo courtesy of R. Gazzard)

We used a GIS-based approach known as Multi-criteria Evaluation (MCE), guided by two stakeholder workshops to solicit expert opinion. Participating organisations included the Forestry Commission,

Crown Estates, Ministry of Defence, EM Highways Services, Natural England, Heathland Conservation Society, Surrey Fire and Rescue Service, Royal Berkshire Fire and Rescue Service, and Bracknell Forest Council[1]. MCE is a four stage process (five if seeking views on how the data should be mapped is counted separately):

1. '*Select'*: guided by expert knowledge from two stakeholder workshops, we adapted New Zealand's list of WTA map layers to select those suitable for the case study area.

   Score': to capture how RoI or VaR varies spatially, each map layer at a cell size of 25m was given scores using a combination of stakeholder knowledge and the locations of the past four years of fires from the Fire Service's Incident Recording System (IRS) (shown in Figure 4). For instance, a relative RoI score was allocated for each land cover type as a proxy for fuel and land use. Scores were also allocated to each type of Access Land to represent degree of human access, and decreasing scores were used with distance from urban areas, roads and paths.

2. '*Weight'*; guided by expert opinion (Figure 3), weighted combinations of layers were added to produce a RoI map (Figure 4) and three VaR maps; one for each of social vulnerability, infrastructure and ecosystem services (combined in Figure 5).

3. '*Test'*: the maps were evaluated by different stakeholders sectors (Forestry, other land managers, Emergency Planners, Fire Service). The maps were refined using their feedback, including the number and type of categories mapped.

Figure 3: Score sheets for pairwise weighting of layers

4. What we found

1. RoI and VaR modules were successfully developed (Figures 4 and 5). This local scale WTA provides sufficient detail for operational decisions. For instance, the Forestry Commission can identify 'hotspots' of high RoI and high VaR where fire risk management of forest compartments is needed. FRS can target areas of high RoI for public education, and high VaR to protect when fighting a vegetation fire.

2. The Hazard module could not be developed due to a lack of fire climate data at the time, and lack of resources needed to use an alternative technique of multiple runs of a fire behaviour model. However, Dr Tom Smith of Kings College, London University (KCL) simulated seven fire perimeters for the Crowthorne Wood 2011 fire. They show that if the wind had strengthened, the fire would have been pushed southwest into houses at Crowthorne and to the doorstep of Broadmoor High Security Hospital. A change in wind direction would have allowed the fire to spread northwest into the Transport Research Laboratory or eastwards into Swinley Forest and beyond.

3. MCE, used with expert elicitation (stakeholder knowledge), is a suitable technique where there are uncertainties about data or processes, but it is subjective. For instance, scores and weights vary between stakeholder groups, especially for VaR. They may also vary with type of environment, so need to be locally-defined.

[1] Bracknell Forest Council kindly provided the venue and catering for the two workshops.

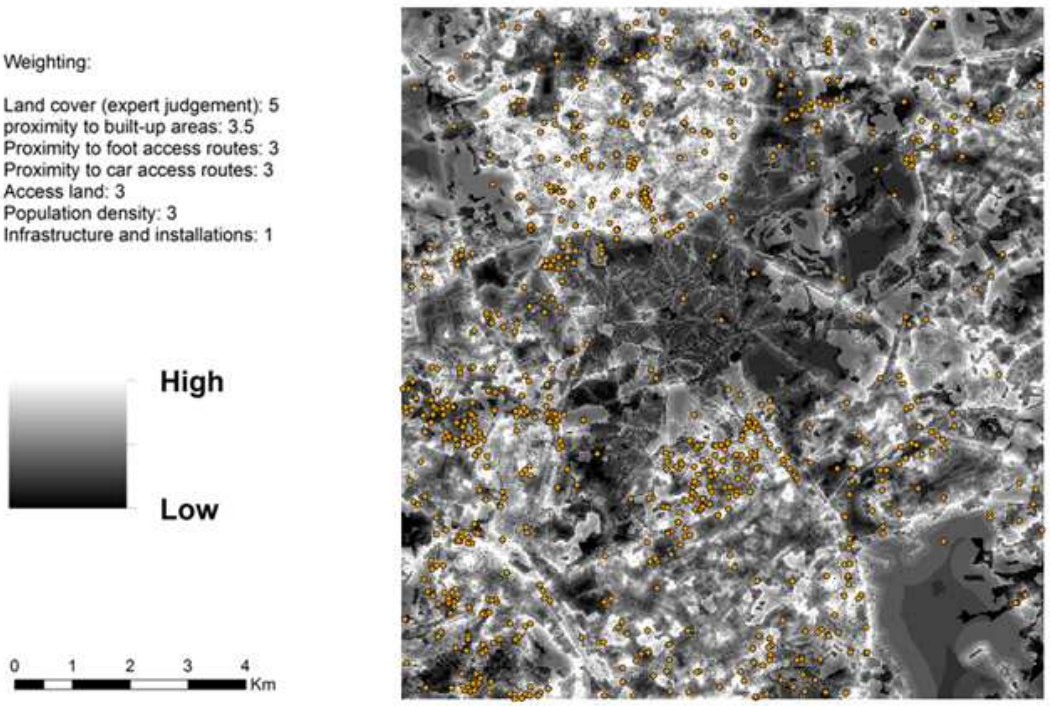

Figure 4: Final Risk of Ignition map with the IRS recorded fire locations superimposed (yellow points)

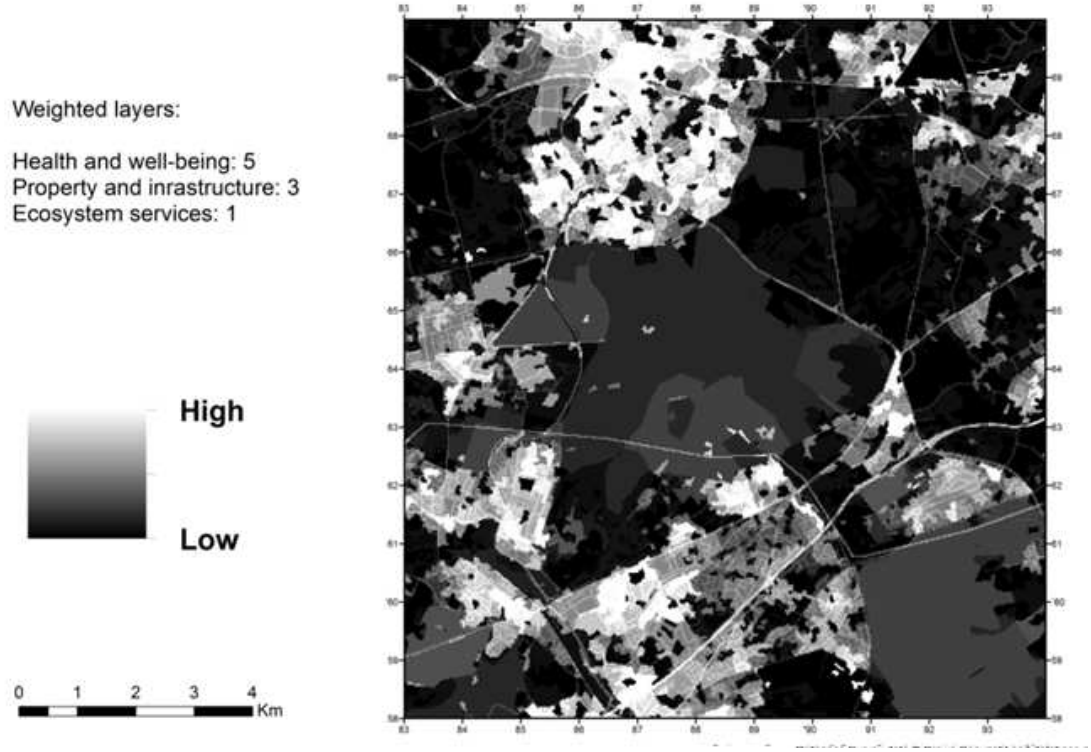

Figure 5: Final Values at Risk map, combining social vulnerability, infrastructure and ecosystem services

4. The IRS data provided a valuable alternative to expert knowledge. There are some concerns about the spatial accuracy of IRS data, but these would be less significant if WTA is developed using a coarser cell size of ≥1 hectare. IRS is a national dataset so should be the starting point for a national scale WTA. Vegetation fires not attended by FRS (so not recorded in IRS) should ideally also be included.

5. We have compiled a data catalogue of over 90 digital map layers and a report (available on request). Most of the datasets are publicly available, so a WTA could potentially be implemented for other areas by Fire and Rescue Services, emergency planners, the Forestry Commission, or other land management agencies.

5. Where next?

1. Appropriate authorities, especially the Forestry Commission and the Fire & Rescue Services, should evaluate these findings and consider the recommendations for further development below, which would require further resources.
2. Further ecosystem services need to be added to the VaR sub-module.
3. The GIS layers were developed for the immediate pre-2011 Crowthorne fire conditions. They should be updated to post-fire. Comparing pre- and post-fire will allow the effect of fire itself on RoI and some VaR to be demonstrated; for example, positive effects in reducing fuel load. 'What if' future scenarios could be modelled, such as changing scores to simulate the effect on wildfire threat of planting fire-resistant species, or of restricting or increasing public access.
4. Overlaying the actual and simulated perimeters of the Crowthorne Wood 2011 fire on the VaR maps will allow actual and potential areas affected to be identified for each VaR. VaR within a certain distance of the fire could also be quantified. More work is needed to calibrate fire spread models for non-forest UK fuels. If this can be done with sufficient confidence, actual and simulated losses could be compared to provide an estimate of *avoided* losses. Moving the focus away from incurred towards avoided losses is a way of evidencing the benefits of good practice in wildfire risk management.
5. Mathematical modelling of RoI using IRS data, for instance, logistic regression, is a more objective alternative than MCE combined with stakeholder knowledge. The low spatial accuracy of IRS data points, however, means that it is likely to be more suitable at coarser scales*, i.e*. at larger cell sizes than the 25m used here.
6. More accurate RoI models will be possible if the geo-referenced point recorded in IRS is standardised to the estimated point of ignition, or another nationally-consistent point within the fire ground. Routine collection of fire perimeters would allow a central point to be derived by GIS, actual VaR to be quantified, and fire spread models to be tested for estimating avoided losses.
7. WTA needs to be tested for other typical types of UK rural-urban interface environments where wildfires are common, notably moorlands. It should also be tested at a landscape scale, for example using ≥1 hectare cells. Methods and input layers may need to be adapted for coarser cell sizes; *e.g*. road density or presence/absence replacing distance from roads. Stakeholder feedback suggests that VaR are best understood at local level.
8. The 2km probabilistic fire severity sub-indices recently produced by KCL and the Met Office in a parallel PURE Associates project, should be incorporated. Fine Fuel Moisture Code data at 2km is still too coarse for local scale (*e.g.* 25m cell) and landscape scale WTA (*e.g.* 1 ha). It could, however, be incorporated into a regional or national scale RoI module resolution to model the probability of *sustained* ignition at 2km. Other fire severity sub-indices could contribute to a 2km national or regional scale hazard module by combining with terrain data from a digital elevation model and fuel data from land cover maps.
9. A nested approach should therefore be explored, *i.e.* developing national or regional-scale strategic RoI and wildfire hazard WTA modules (less so VaR) to identify hotspots, at which a finer, landscape or local scale full WTA (including VaR) would be recommended.

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