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Thresholds for fire development in gorse

A study has recently been completed to determine the threshold conditions under which fires will ignite and develop into spreading fires in gorse scrub. It is well-known that fires in gorse, like other scrub fuels, appear to almost be controlled by an “on/off switch” – fires will either fail to develop, or will develop and spread at very high intensities that make suppression difficult. These intensely hot, fast-moving fires can pose safety risks for firefighters, landowners and communities. There does not appear to be any level of moderate fire behaviour or gradual build up to these high intensity fires. Previously, very little research has been carried out into defining these thresholds for fire development in scrub fuels.

Key Findings:

- The moisture content of the elevated dead fine fuel layer determines ignition and fire spread success in gorse.
- The threshold moisture content for ignition was 36% (FFMC 69.5); and for fire spread it was 19% (FFMC 82.7).
- These values are higher than those for ignition and fire spread in some other fuels, such as forests.
- Fires are capable of spreading at high intensity in gorse in the elevated dead fuel layer only, even when near-surface and surface layers are saturated.

Background

Gorse (*Ulex europaeus*) has been estimated to cover nearly 3% of the land area of New Zealand – up to 700,000 ha. It usually represents a significant fire hazard, with large amounts of elevated dead fine fuels suspended from branches within the canopy layer and large amounts of dead litter on the ground. Wildfires in scrub fuels (including gorse) account for around 40% of the total annual area burned in New Zealand. In many cases fires in gorse develop and spread in the elevated dead fuel layer only, i.e. independently of the surface litter layer below.

Gorse appears to have a very narrow threshold for fire development, below which fuels may ignite but do not spread (i.e., burn individual bushes or clumps), and above which ignitions rapidly develop into fast-spreading and very high-intensity fires that are difficult to control. Fires in gorse, like other scrub fuels, can often burn at very high rates of spread and at extreme fire intensities. This can occur even under levels of fire danger that would not be considered extreme in other fuel types, such as forest and grass.

This study aimed to determine the threshold conditions for ignition and fire spread in gorse. Knowledge of these conditions is critical for effective fire management. This information also aids the development of safe and effective prescriptions for controlled burning operations.

Methods

Field experiments were carried out at two locations near Christchurch. The first set of experiments aimed to determine the threshold conditions for fuel ignition only. These experiments were carried out in scattered gorse fuels in a stony riverbed, and involved attempts to ignite the elevated dead fuel layer of individual gorse bushes from early morning under conditions of low wind speed and high fuel moisture.

Fuel moisture samples were collected prior to each ignition experiment and onsite weather conditions monitored with a portable weather station. Ignitions were conducted with a cigarette lighter. Experiments continued until it was clear that the fuels ignited easily with each successive test.

The second set of experiments was designed to determine the threshold conditions under which fires would spread, i.e. whether an ignition would actually develop into a spreading fire. These experiments were carried out in larger plots of continuous gorse fuels, where fire spread was deemed to be successful if a flame front developed from the line ignition (using a driptorch) and spread to the end of the plot. Weather conditions were measured onsite and fuel moisture samples collected prior to each ignition.

Data were analysed using logistic regression to determine the probability of ignition and fire spread success, based on weather parameters, moisture content of fuel layers, and Fire Weather Index (FWI) System outputs.

Results

The moisture content of the elevated dead fuel layer was the factor that determined both ignition (Figure 1) and fire spread success (Figure 2). Fires were observed in many cases to spread in this fuel layer only, independently of the near-surface (lower elevated) or surface fuel layers. In some cases, these lower fuel layers were damp and did not burn at all, yet fires spread successfully in the elevated dead fuels in the canopy layer.

The moisture content values (thresholds) at which fires ignite and spread are also significantly higher than those for other fuel types, such as forest and grass.

Application

The results from this study provide useful guidelines for fire management decision-making in relation to gorse fuels. The fact that fire development was wholly dependent upon the moisture content of the elevated dead fuel layer is significant, in that fire behaviour models for other fuel types (particularly forests) assume that surface moisture content is critical to fire spread. Fires are also capable of igniting and spreading in gorse under conditions that would not support fire spread in forest or even grassland fuels. For fire management, it is the conditions under which fires will develop and spread that are important to determine preparedness and response levels. The findings are also relevant for developing prescriptions for safe and effective prescribed burning operations. The study is significant because it was based on "actual" conditions in the field, and therefore provides sound science to support decision-making.

The threshold values of moisture content that determine ignition and fire spread success were converted into the corresponding values of the FWI System Fine Fuel Moisture Code (FFMC), and are shown in Table 1. This table provides fire managers with a quick and easy method to determine the risk of fire (or safe burning conditions) in gorse scrub. Marginal burning conditions represent a boundary or transitional phase, where fuels are moving towards the moisture levels at which ignitions and fire spread will occur – in some cases ignitions will be successful and result in fires spreading under these conditions.

Next steps

- Further validation and testing under a broader range of conditions (weather, slope, fuel structure/age class).
- Repeat this work in manuka/kanuka to determine the fire thresholds for these scrub fuels.
- Review the Scrubland Fire Danger Class scheme based on these findings – the current system assumes a threshold FFMC value of 60 (representing the ignition threshold), below which fire danger is always Low.

Table 1. The threshold values of moisture content that determine ignition and fire spread in gorse.

Elevated moisture (%)	FFMC	Ignition	Fire Spread
> 36%	< 69.5	NO	NO
30 – 36%	69.5 – 73.9	MARGINAL	NO
26 – 30%	74.0 – 77.0	YES	NO
19 – 26%	77.0 – 82.7	YES	MARGINAL
< 19%	> 82.7	YES	YES

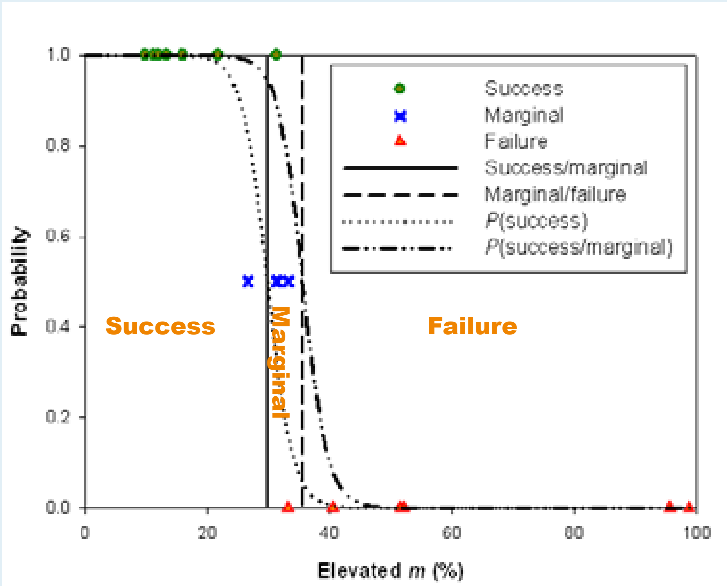

Figure 1. Plot of ignition data (categorised into success, marginal or failure), with the probability plots and the lines demarcating the success/marginal and marginal/failure boundaries

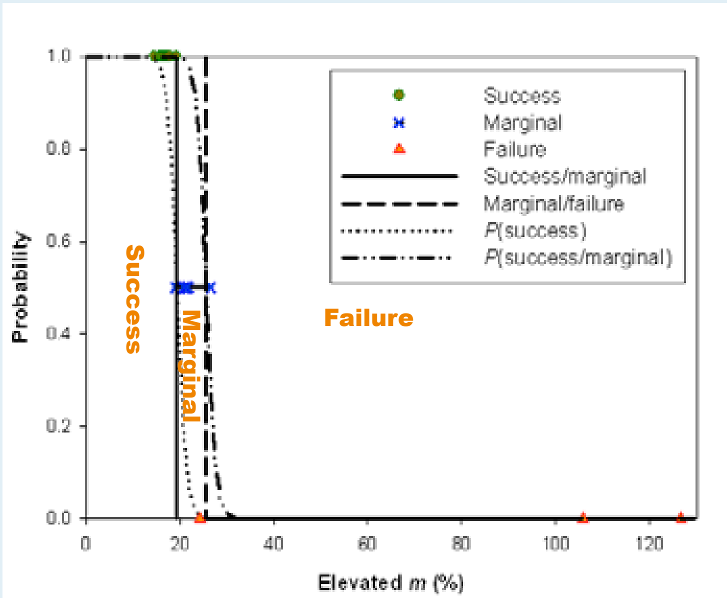

Figure 2. Plot of fire spread data (categorised into success, marginal or failure), with the probability plots and the lines demarcating the success/marginal and marginal/failure boundaries.

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Further information

Anderson, S.A.J. 2009. Fuel moisture and development of ignition and fire spread thresholds in gorse (*Ulex europaeus*). MForSc thesis, University of Canterbury.

Anderson, S.A.J & Anderson, W.R. 2009. Fire development in gorse (*Ulex europaeus*) shrublands. Proceedings: 16th Annual AFAC Conference and Bushfire CRC Conference, 22-24 September 2009, pp 601-604.

Predicting fuel moisture

Related work looked at methods to accurately predict fuel moisture content of the elevated dead gorse layer. This was based on sampling of moisture content in the field over a range of days and weather conditions. Firstly, the actual (sampled) moisture content was compared with that predicted by the Fine Fuel Moisture Code (FFMC) of the FWI System. The FFMC predicted moisture content in gorse very poorly, which is one of the main reasons for the poor performance of the Scrubland Fire Danger Class scheme. This is probably not surprising, given that the FFMC has been developed in Canada based on field data from the needle litter layer on the forest floor under a mature conifer forest canopy. Elevated gorse fuels are very different, being elevated and more exposed to drying from the surrounding air (and wind and sunshine).

A new model has been developed to predict moisture content. This was based on modifying the FFMC equations to better represent the drying and wetting rates of the elevated gorse fuels, and also included a physical model of moisture transfer between the fuel and the air. Initial results are promising, and further work will be undertaken to determine whether this model can be implemented operationally for scrub fuels to better reflect the moisture content and flammability of these fuels – providing fire managers with more confidence in the accuracy of fire danger rating predictions for this important fuel type.

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