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Creating Forests That Thrive in a Changing Climate:

Drought and Fire Resilience

Written by:

Byron Braithwaite NSch

September 2024

A NUFFIELD FARMING SCHOLARSHIPS REPORT

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NUFFIELD Farming Scholarships

"Leading positive change in agriculture. Inspiring passion and potential in people."

Date of report: September 2024

Title	Creating Forests That Thrive in a Changing Climate: Drought and Fire Resilience in the United Kingdom
Scholar	Byron Braithwaite
Sponsor	John Oldacre Foundation
Objectives of Study Tour	1. To investigate the likely effects of drought and fire on the UK forest industry by observing forests in drier climates across the world. 2. Identify techniques and practical measures to increase the resilience of young trees at the establishment phase. Determine best practice for fire management and community and landowner resilience and preparedness.
Countries Visited	Canada, France, Spain and New Zealand
Messages	1. Action to create drought and fire resilient forests must start immediately. 2. Tree breeding, particularly for diverse conifer and productive broadleaf species, must be adequately funded through public and private sector investment to enable diversification. 3. Wildfire is almost always started by humans. Cultural change must commence immediately to ensure that we are a fire aware nation in the future. 4. Vegetation control to reduce fuel loads should be focused on high use public areas and important infrastructure or habitats.

EXECUTIVE SUMMARY

This report examines key areas for building resilience in UK forestry practices in the face of climate change. It focuses on drought tolerance and fire management strategies, on which there is currently only limited work underway to address these issues.

Drought Tolerance and Resilience

While established practices for planting and cultivation remain important, renewed focus on optimising each stage can significantly improve survival rates. This includes improvements in packaging, cold dispatch, and planting during optimal periods based on plant type and site conditions.

A critical factor for long-term resilience is tree breeding for drought tolerance and diversification of species. However, current funding for public and private breeding programmes, particularly for native broadleaf trees, is insufficient. Implementing a government levy on timber sales, similar to the French model, could provide a sustainable funding mechanism.

The fragmented ownership structure in the UK hinders large-scale data collection for genotype and site-specific planting assessment and learning. Again, funding to gather and assess data will be a key constraint. The UK's Ecological Site Classification tool however does offer potential for data comparison and refinement at a broader scale.

Finally, the report explores improving tree resilience through the potential of mycorrhizal fungi to enhance nutrient and moisture uptake.

Fire Management and Resilience

Public awareness and responsible behaviour are crucial for mitigating fire risk. Educational initiatives targeting children and outreach programmes for outdoor enthusiasts are recommended. Utilising social media and digital channels can broaden the reach of fire safety messaging.

Best practice documents for forestry work during high-risk periods, similar to those implemented in New Zealand, should be adopted. This may involve temporary work stoppages in extreme conditions.

Given the fragmented mixed land use environment in the UK, the risk of large-scale wildfires is lower compared to other regions of the world. However, targeted vegetation control in high-public use areas, around critical infrastructure, and near sensitive ecological areas remains critical. This report argues that controlled grazing, low-intensity fires, and mechanical methods can be effective tools for managing fuel loads without compromising biodiversity.

Recent changes to the Wildlife Management and Muirburn (Scotland) Act and the Heather and Grass Burning Regulations (England) 2021 are commended for promoting responsible burning practices.

In conclusion, this report emphasizes the importance of continuous improvement in traditional forestry practices, increased investment in tree breeding for drought tolerance, and proactive fire management strategies to ensure the long-term health and resilience of UK forests and our society as a whole.

CONTENTS

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Please note that the content of this report is up to date and believed to be correct as at the date shown on the front cover.

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1. PERSONAL INTRODUCTION

Figure 1. Author: Byron Braithwaite. Source: Author's own.

A childhood spent in South Africa led me to a fascination with the outdoor environment. The plants, animals and varied landscapes invited opportunities to learn, grow and explore constantly. This enthusiasm continued through my youth as my family transitioned to live in Buckinghamshire.

This love for the outdoor environment led me to an opportunity to study Forestry at Bangor University, Wales and at the University of British Columbia, Canada. My initial interest in this subject was tied to a conservation mind set, whereby forest ecosystems can offer opportunities for an abundance of plant and animal species to thrive. However, following a sandwich year placement with Forestry Commission Scotland and a graduate job at a leading forestry company, my eyes were opened to the opportunities of sustainable commercial forestry in the UK. Producing British Timber, whilst diversifying our forests and providing habitat for a range of UK species has become more than a job, it is a passion that I am keen to share.

Undertaking a Nuffield Farming Scholarship has not only offered me the opportunity to share my passion, it has challenged me to learn and develop new technical skills, pushed me outside of my comfort zone and allowed me to experience new cultures and experiences that will continue to inspire me long into the future.

I am now lucky enough to live and work in South Scotland with my wife and two daughters. As a family we continue to enjoy as much time as possible outside cycling and walking the dog. Following years of travel with my wife, we are doing our best to pass on our passion for the beautiful world we live in to our children.

2. BACKGROUND TO MY STUDY SUBJECT

2.1 Climate Change Forecast

Climate change impacts are clear. Since the 1950s, temperatures have risen 1°C, with the UK's warmest years on record all occurring since 2002 (Met Office 2024). For the UK, climate change means more frequent heatwaves, wetter winters, drier summers, and increased flooding risk (Met Office 2024). Overall, weather events will be more extreme.

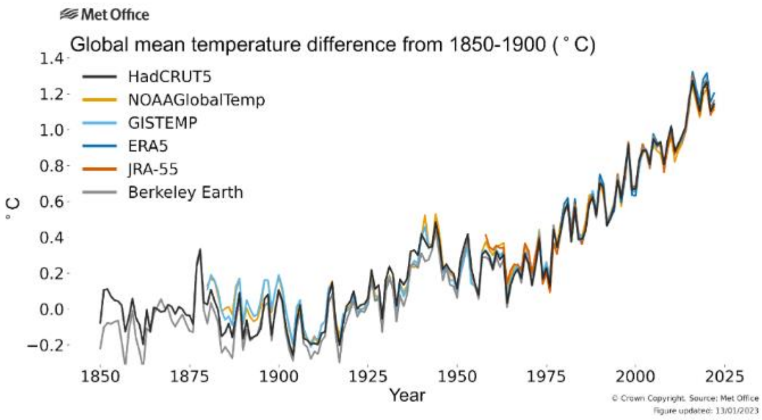

Figure 2. Global mean Temperature Change from 1950 - 2022. Source: Met Office (2024)

	Changes in intensity or frequency so far	Is this linked to climate change?	What is expected in the future?
UK warm spells	Increase	Yes	Increase
UK cold spells	Decrease	Yes	Decrease
UK heavy rain	Increase	Inconclusive	Increase
UK dry spells	No trend detected	Inconclusive	Increase (summer)
UK wind storms	No trend detected	Inconclusive	Increase*

Figure 3. Changes to the UK climate and weather events. Source: Met Office (2024) *Some, but not all, evidence supports an increase.

2.2 UK Forest Industry

The United Kingdom has diverse range of forestry practices. Conifer crops are grown for timber production and account for 48% of the UK forest area (Forest Research 2023). Broadleaf woodlands largely serves habitat and diversity objectives, but does offer some timber production and accounts for 52% of the UK forested area (Forest Research 2023).

Unlike agricultural crops, the rotation length of forests lies between 35 years and 100 years (depending on species), with native woodland persisting indefinitely. Interest in carbon markets and government grant aid means that new woodland planting has increased significantly over the past decade.

As the climate changes, drought and heat waves will become stressors for new and existing forests, and create an environment where wildfire risk is higher (Forest Research 2024). Although UK forests will also face increased windblow and pest and disease threats, this report addresses the threats from drought and fire and the potential solutions to mitigate the negative effects.

2.3 Forest Establishment and Drought

Traditionally planting dormant bare root seedlings was undertaken in the winter and early spring. A limited labour resource and an increase in planting has pushed planting into the margins of the traditional season, with more planting happening in the drier spring and summer months where seedling mortality is likely to be higher.

The question I hope to answer is whether we are doing enough to protect our forests in their early years from the effects of drought, or can we mitigate some of the risk by adapting or changing our current practices?

2.4 Fire Management

With the likelihood of hotter summers and drought in the UK, fire risk can be expected to increase between two and four times (UK Climate Risk 2021). Currently, with planting of considerable areas of new woodland and in managing the existing forests structure some, but limited, steps are being taken to address this future risk. What more can be done to reduce the risk and spread of wildfire?

3. MY STUDY TOUR

Country	Date	Why I visited
Canada	Mar-23	Commercial Forestry in the UK uses a range of tree species that originate in the Pacific North West, hence British Columbia (BC) offered the opportunity to see some of the species we utilise in the UK in their natural environment. The topography of the province also creates interesting geoclimatic zones - the wet coastal region, and the drier east in the rain shadow of the Coast Mountains. This variation offers research opportunities and leverages the genetics of the species that span the mountain ranges. Fire is a considerable factor in the forests of BC.
France	Jun-23	Forestry here is at a similar scale to that in the UK, with fragmented plantations and native woodland. My study visit focussed on the South West around Bordeaux due to significant wildfire events in recent years and an active commercial industry. Also, it is drier and warmer than the UK, and therefore a good indicator of future conditions.
Spain	Jul-23	Catalonia, in dry North Eastern Spain, where there are significant areas of native woodland to be observed. Opportunity to join the Firelogue annual conference with stakeholders from across Europe to discuss fire management and its impacts.
New Zealand	Oct-23	A thriving forest industry comprised of plantations, and extensive areas of native woodland. A similar climate to the UK, but warmer summers and higher fire risk.
United Kingdom	23/24	A wide range of visits, virtual meetings and general discussions to inform the current position in the UK.

4. DROUGHT RESILIENCE

4.1 Observed Factors Influencing Drought

While climate change may in some areas cause greater drought occurrence, it is outside the immediate control of timber growers. However, there is much to be done in identifying aspects of drought tolerance or resistance that must be considered when establishing young trees. On my travels I visited several areas where trials on drought resistance or tolerance were being conducted.

Marie Vance and Greg O'Neill provided a tour of the BC Ministry of Forests Kalamalka Research Station's ongoing drought tolerance trials, as well as discussing the challenges surrounding the establishment of truly isolated test environments. These challenges, which have complicated data collection to some extent, include water ingress from polytunnel edges, uneven bed temperature distribution, and aspect-related survival disparities. However, these confounding factors offer an indication of factors affecting drought and its impact on trees, namely temperature, aspect and moisture availability.

Despite these challenges, initial results suggest a positive correlation between breeding for tree vigour and growth rate with enhanced drought tolerance. Although further research is needed to confirm these findings, it provides initial reassurance that decades of breeding for productivity offers a degree of drought resilience already.

Figure 4. Marie Vance and Greg O'Neill, and the drought trials at Kalamalka Research Station. Source: Author's own

Vanessa Foord, also a researcher at the Kalamalka Research Station, presented the Stand Level Drought Hazard Tool, which utilises site data to estimate soil moisture content and predict future drought risk for specific tree species. The tool offers foresters an indication of how natural site factors influence the risk of drought and helps to inform species choices.

Interestingly, field observations revealed that Western Red Cedar and Western Hemlock exhibited greater drought tolerance than predicted by the model. This indicates the importance of genetic variation and adaptation in these species.

Both Steve Gatenby (Timberlands Ltd) and Mark Forward (One Forty One) highlighted the potential of machine learning to analyse large datasets and improve crop efficiency. Data collection aims to capture information to determine the performance of different genotypes across diverse site types. Ultimately, the project aims to optimise species and genotype selection for specific sites to maximise productivity and survival rates.

4.2 Species Selection and Tree Breeding

4.2.1 Species Selection

Globally, the timber industry often relies heavily on a single, dominant tree species. This tendency is typically driven by factors such as rapid establishment, fast growth rates, and the production of valuable end products.

Paul Millen (New Zealand Dry Land Forest Initiative) presented a perspective on establishing a hardwood (eucalypt) industry in New Zealand, where productive forestry is currently dominated by Pinus radiata. He emphasised the importance of targeting diversity at specific end markets, establishing sufficient size and age diversity for a continuous timber supply to markets within a 40km radius of the forests. This approach advocates integrated planning and industry development encompassing growers, processors, and end users (e.g. vineyards, house builders) Creating promised value to these diversification efforts.

There is a growing recognition of the potential drawbacks associated with extensive monoculture plantations. In the interior of British Columbia there is an acknowledgement that too much *Pinus contorta* is being planted. The BC Ministry of Forests and practitioners are exploring landscape-level diversification with a focus on additional broadleaf species and a diverse mix of conifers to increase resilience. In Southwest France, Laurence Degoul of Société Forestière also highlighted the slowly increasing use of *Pinus taeda* on suitable sites.

Figure 5. A well thinned stand of Pinus taeda growing well in South West France. Source: Author's own.

Mike Crone (Cabin, Vernon, BC) and Greg O'Neill (Kalamalka Research Station, BC) provided an overview of the Biogeoclimatic Ecosystem Classification (BEC) system, a mandatory tool in British Columbia that ensures that ecologically and genetically appropriate seed is selected for planting sites. Additionally, the program prioritises advanced genetics to optimise production and minimise pest and disease susceptibility by reducing environmental stress on the tree by targeting the genetics to the site conditions. Notably, the BEC program has been recently updated to account for climate change, advocating for man-made seed movement northward or upslope to align genetic requirements with future climate conditions on these sites.

4.2.2 Tree Breeding

Chapter 4.1 reported that improved genetics create a more drought resilient tree. However, historically, tree breeding has been a very protracted process due to the number of years (decades) it takes for trees to begin displaying the preferred genetic traits, and to produce viable seed. As with any long-term research, costs are high. These cost and time implications, combined with the previously discussed preference for single species production means that the efforts and funding have generally been focused on a very small number of species.

However, genetic technologies are advancing with techniques such as somatic embryogenesis and the ability to map full genomes to identify specific markers to focus breeding on. These technologies increase the progression of genetic improvement by allowing researchers to identify preferred traits at the genetic level and progress the next generation of plants via somatic embryogenesis within much shorter time frames. Unfortunately, these techniques do not assist with the cost of genetic improvement, meaning funding remains a challenge to overcome.

Funding models and programmes in BC and France offer potential solutions to increase funding for tree breeding in the UK. Firstly, the BC Ministry of Forests in Canada funds research and manages seed orchards as commercial entities. This aligns with the Provincial Government's understanding of how important Forestry, as an industry, is to their province's long-term prosperity.

In France, Marion Mercadal of the FCBA Institut Technologique explained the Contribution Volontaire Obligatoire (CVO), a tax paid by forest owners which currently stands at 0.5% of the amount of the sale of standing timber, 0.33% of timber sold at roadside, and 0.25% for timber delivered-to-factory. A portion of this tax funds genetic improvement.

Figure 6. Image 1 and 2: Government funded seed orchards growing genetically improved seed in British Columbia. Image 3: Marion Mercadal, FCBA Institut Technologique, in a Maritime pine seed orchard funded by timber levies.

Hybrids also have a part to play in the genetics argument. Joe Taylor and Dom Clearly of Forest Management Ltd (New Zealand) showcased a newly planted stand of *Pinus attenuata/radiata* hybrids. This hybrid was specifically developed for drought, frost/snow tolerance, and to minimise the risk of "wilding" (invasive spread). Similar efforts are underway in the UK with a Sitka/White spruce hybrid promising vigour and drought tolerance. However, regulatory approval is still pending in the UK, preventing its legal planting.

4.3 Nursery Practice, Plant Handling and Shipping

Nursery practice

4.3.1 Cell Grown Trees:

Once the genetics are as good as they can be, it is over to the nurseries to grow the trees. I noted that nurseries in all countries I visited are increasing the production of cell grown (containerised) stock as opposed to bare root stock. Cell grown stock offers a number of benefits, which are discussed below, and all relate to improving drought resilience:

- Root system: The established root system remains undamaged, compared to bare root stock which is lifted directly from the ground.
- Nutrient availability: Slow-release fertiliser in the growing medium encourages additional root growth, in turn improving moisture uptake. However, it is noted that on poorer soils above ground growth was more abundant than the root growth, leading to young windblown trees in some circumstances in New Zealand. However, this may be attributed to the tree roots being 'bound' in the container. Growing techniques such as the Ellepot product, and trays with root pruning holes appear to reduce the risk of container bound growth, by air pruning all side roots.

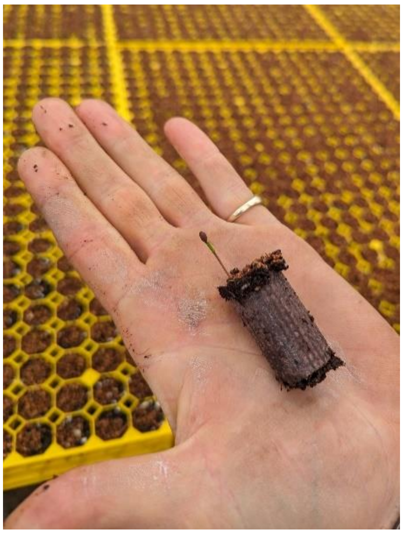

Figure 7. Left: Ellepot production demonstrating handling of young seedling at very early stage. Right: Trays with root pruning holes air prune side roots and force roots down. Both at Premier Plant Producers Nursery, Hull UK. Author's own.

- Immediate growing: In spring, cell-grown trees start growing naturally, while bare-root stock remains in cold storage to keep it dormant. When planted, cells are already growing, potentially obtaining water and nutrients faster for better drought resistance.
- Flexibility: Bare-root trees need to be dormant before lifting/storage (less damage). Climate change delays dormancy, making autumn planting less ideal. Cell-grown trees can be planted in fall as they do not need to be dormant, but may face harsher winter weather and increased deer browsing.
  Planting into the spring and summer is also possible, as trees can be watered on site, unlike bare root trees.
- Additives: Steve Gatenby of Timberlands Ltd discussed trials they are undertaking to add hydro gels to the planting medium to hold additional moisture on drier sites.
- Handling and planting: The root systems of young trees are subject to damage as they are lifted/planted. Cell grown stock appear to be more resilient to handling, and the shaped root systems are easier to plant.

4.3.2 Mycorrhizal fungi

Mycorrhizal fungi were present at all the nurseries I visited and have a notable part to play in drought resilience. These fungi form a symbiotic relationship with trees, improving their access to moisture and nutrients through mycelium.

Timberlands Ltd nursery (New Zealand) actively collects "puff balls" (the fruiting bodies of mycorrhizal fungi) and mixes these to encourage fungal development in their containerised stock. At Appleton Nursery in Wakefield New Zealand an alternative approach was offered. At sowing stage the seed is inoculated with Trichoderma species of fungi to improve growth by up to 20% in the nursery.

Figure 8. Left: Puff balls collected at Timberlands Ltd Nursery, for application of cell grown stock. Right: Mycorrhizal growth visible on young seedlings at Timberland Ltd Nursery. Source: Author's own

Figure 9. Rob and James Appleton with the Author at their Nursery in Wakefield, New Zealand.

Rhizocore Technologies, a UK-based mycorrhizal startup, presented a contrasting perspective. Their studies suggest that mycorrhiza present in commercial nurseries may not persist in the harsher forest environment. Their product offers an alternative solution, sourced from suitable sites and demonstrably forming beneficial relationships with specific tree species. They propose incorporating fungi pellets into seedlings (cell grown) at the nursery or directly at the planting site.

 

Figure 10. Rhizocore pellets being quality checked demonstrating hyphae growing, and product bagged ready for dispatch. Source: Author's Own.

4.3.3 Plant Handling:

In the United Kingdom, young trees are typically despatched from the nursery in plastic bags. Timberlands nurseries, however, utilise Correx boxes to package their seedlings, which are then placed into pods for transport to the planting site. Minimising handling by utilising machinery for loading/unloading, coupled with the use of sturdy, protective packaging, helps to minimise damage to fine root systems, and thereby maintains as much root mass as possible to gather moisture.

Figure 11. Boxes and pods used by Timberlands Ltd, as well as other Forest Management companies in New Zealand. Source: Author's own.

Krista Copeland, BC Ministry of Forests, explained the dispatch processes in BC. As the planting season is often short, after snowmelt in the summer, conditions are often very warm and dry. To maximise survival rates trees are transported in refrigerated trucks to reduce the risk of overheating.

4.4 Cultivation and Planting Technique

Cultivation, across forestry and farming, is known to increase growth rate and minimise weed competition for crops. Laurence Degoul (Société Forestière) and Steve Gatenby (Timberlands) both discussed ripping compacted sites to increase growth rate and maximise rooting depth. Steve suggested growth rates increased 10 - 40% in some cases.

As indicated in chapter 4.1, increasing growth rates was a key factor in the drought studies, however cultivation must be suited to the site. On organic and clay rich soils creating an elevated planting position can cause the planting position to dry out rapidly as the weather warms in the spring. Laurence went on to indicate that they consider the soil type of each site due for planting, and focus on getting drier sites planted in the winter, with wetter sites planted later if required.

Dom Clearly (Forest Management Ltd) demonstrated a hand planting technique that involves two or three cuts with the spade, cultivating the soil and creating a wider planting position for the tree roots to be placed into, enhancing root establishment and access to water and nutrients. Generally, in the UK, one cut with the spade is used to plant the tree, which can in some cases lead to poor planting technique and root damage.

5. FIRE MANAGEMENT AND RESILIENCE

Eduard Plana Bach, Centro de Ciencia y Tecnología Forestal de Cataluña (CTFC), offered an insight that sets the scene very well for this chapter. He suggested that the concept of resilience, rather than resistance, takes centre stage in understanding how to coexist with wildfires. This approach acknowledges the inherent power and inevitability of these natural phenomena, similar to forces like tornadoes, earthquakes, volcanoes, and tsunamis. Just as we cannot directly fight these earth processes, so too must we adapt and build resilience to wildfires, fostering coexistence rather than seeking absolute control.

This chapter explores a number of ways to build resilience with communities, industry and landowners.

5.1 Public Awareness

In the UK, human activity is the most common reasons for wildfires starting, therefore public awareness is crucial when considering resilience. Engaging citizens in fire management plans fosters a sense of shared responsibility. Discussions at the Firelogue Conference in Catalonia suggested focusing on a common cause, e.g. protecting valuable carbon stores, biodiversity or homes and property.

Reg Steward, a B.C Provincial Ranch Safety Consultant, encouraged resilience groups in rural communities to support each other during wildfire events. He made it clear that it is not just fire fighters that are required, chefs, telephone operators and childcare workers are equally important.

Figure 12. Left to right: Author and Reg Steward pictured at Nuffield CSC, Vancouver. Source: Author's own

However, we must also consider the impact of tourism and changing populations in this discussion. In France, Marion Mercadal and Laurence Degoul both commented on the movement of people from the city to rural locations after the Covid 19 pandemic. This was echoed in the discussions at Firelogue. For these changing communities with diverse demographics, targeted fire education campaigns are necessary. There are a range of possible ways to do this, separately or in combination:

5.1.1 Engagement Tools

Serious Games:

Reaching younger generations with fire safety knowledge is crucial to long term cultural change. "Serious games" are educational at heart, but appeal to younger generations that are familiar with gaming and are more likely to engage and learn in this setting.

Media:

Although the media often focuses on tragedy and problems, there is an opportunity to shift the focus to positive fire management successes and benefits. We observed a number of good examples of this including:

- The Republic of Ireland's 'Be Summer Ready' campaign offers advice for fires at home and abroad, and in simple terms helps members of the public understand the risks.
- The New Zealand MetService App provides fire danger indicators in the main forecast daily.
- In Southwest France fire forecasts are available in the local paper and at the town hall.
- Fire Safe BC campaign in BC

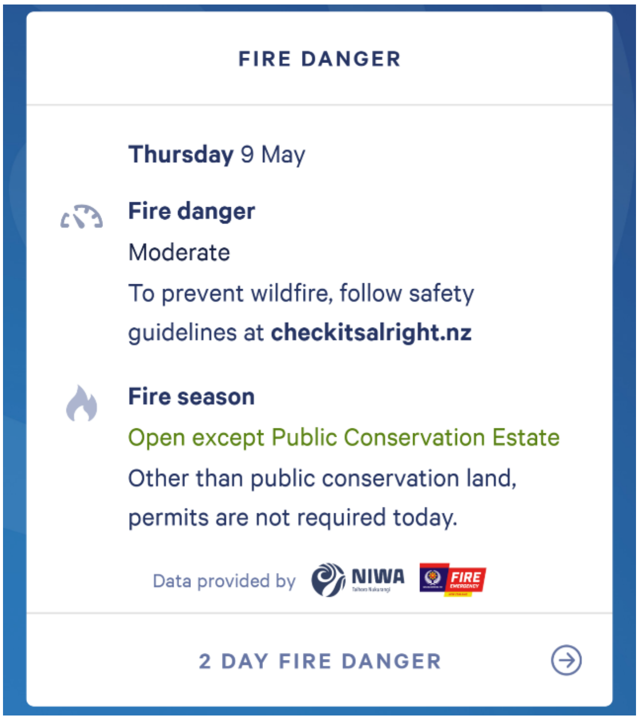

Figure 13. 1. Current fire danger in the New Zealand MetService App. Source: New Zealand Met Service.

2. Be Summer Ready Campaign. Source: Government of Ireland. Source: Government of Ireland.

Signs:

Signage targeted at higher risk areas (busy roads, picnic sites or popular hiking routes), was prevalent in all locations visited. These signs varied from being quite basic warnings, to being educational or providing up to date risk information. However, Researchers at SCION (New Zealand) suggested that the manual signs showing current fire risk were of limited use as they often display incorrect information. A digitally updated sign would be more efficient and minimise labour resource required.

Figure 14. Fire signage at high risk locations. Source: Author's Own.

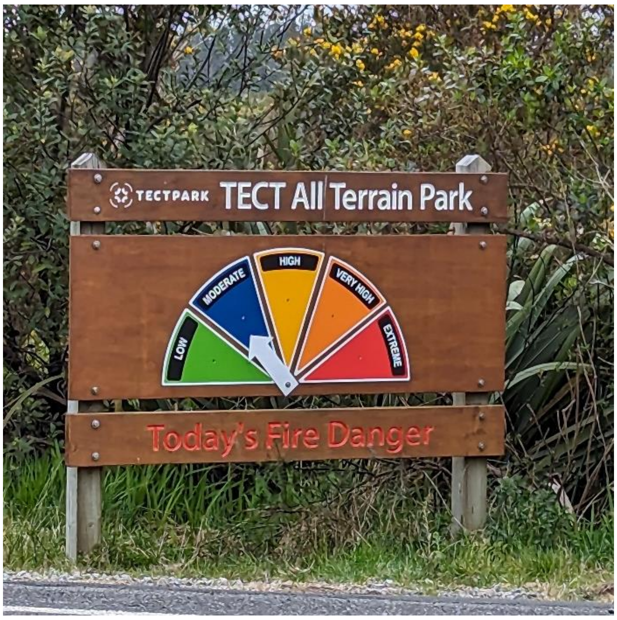

Figure 15. Manually operated fire danger signs are difficult to resource, and if incorrect can distil complacency into members of the public. Source: Author's Own.

5.1.2 Group communication networks

Another communication tool mentioned by Laurence Degoul in France was her strategy of setting up specific WhatsApp groups with key communities to share fire risk information. However, two-way communication should be encouraged to allow them to report any suspicious activity or smoke directly to the landowner/forest manager or the fire service. This was echoed by Mark Forward of One Forty One, where a culture of smoke reporting aligns well with fire lighting legislation/licensing in New Zealand.

5.1.3 Law and Enforcement

Finally, law and the associated enforcement is very effective at communicating the fire danger message. In Spain, where the constitution allows a 'right to roam' similar to that in Scotland, public lands are out of bounds during high fire risk and active fire. Although effective at reducing fire risk, there is a significant impact on local businesses and tourism as insurers do not cover precautionary measures. In France a similar system is in place but is perhaps more considered as a risk assessment can be undertaken to allow tourism activities.

5.2 Forest Operations

Working in the forest creates additional risk during periods of high fire danger. This may be due to fine material accumulating on hot engines or exhausts, personnel smoking, or sparks being generated by flails etc.

In all countries visited, there are limitations or prohibition periods for operational work and staff during periods of high fire danger.

A good example shared by Mark Forward (One Forty One New Zealand) was guidance from the New Zealand Forest Owners Association that must be followed when working in the forest. This document offers clear guidance on specific operational tasks and associated mitigation measures. See Appendix 1 for more detail.

It is also important to consider being aware of and dealing with the possible consequences following a fire. In France, discussions suggested that *hylobius spp. (weevils)* pressure increases due to the levels of dead wood present over large areas. Lionel Procedes of Société Forestière also adds that there is high fire risk when harvesting burnt sites due to the abundance of dry fuel present. Work is also slow, due to ash on the ground creating clouds that reduce visibility and clog up filters on the machinery.

5.3 Vegetation Control

This section addresses vegetation control and its critical role when considering fire danger and management. In Spain, BC and Portugal, change in land management, or absence thereof, is leading to expansive areas of dense vegetation that are not managed by grazing animals (as it had been for millennia in Europe), or has had low severity fire suppressed for decades.

An example of this in Catalonia was the abandoned village visited on day two of Firelogue 2023. There was clear evidence of wood pasture that has now become dense woodland, increasing the risk of extreme fire in this area in the future. We also observed significant areas of land previously used for wine production that has returned to dense woodland around Montserrat, Catalonia. The land is largely unproductive, and now poses a significant fire risk to the Montserrat Natural Park due to the high fuel loads that are present.

These examples highlight the need for control at a landscape level. Interaction with neighbours and communities is essential to the success of this management technique and a number of these observed techniques are explored below:

Figure 16. Abandoned village in Catalonia, with dense forest developing following the removal of grazing animals. Source: Author's own.

Figure 17. Land use change in Catalonia leading to the establishment of dense forest (foreground), creating significant fire risk to the Montserrat Natural Park (background). Source: Author's own.

5.3.1 Legislation:

There are examples in France and Spain, where, in specific areas, homeowners are legally required to clear vegetation around their homes to facilitate control of wildfires by fire professionals.

France:

Residents within 200m of the forest must clear vegetation within 50m of their property and within 10m of their access track. They must maintain a running surface width of 4m on their access track to facilitate access for fire apparatus.

In some cases, the volunteer fire prevention charity, Défense de la Forêt Française Contre les Incendies (DFCI), funded by a government levy paid by forest owners, can undertake this work. However, their efforts are generally focused on timber and forest infrastructure protection due to the source of the funding.

Figure 18. Mandatory vegetation guidance in France. Source: Défense de la Forêt Française Contre les Incendies (DFCI) 2024.

Spain:

Similarly in Spain, all infrastructure must manage a 25m strip around houses/buildings.

However, comments from Eduard Plana Bach (Science and Technology Centre of Catalonia (CTFC)) suggested that pooling money for substantial fire breaks to protect towns/groups of houses would be a more effective solution. He also suggested that National Parks and protected areas should contribute to protection outside their boundary to facilitate protection of sensitive features within the parks.

5.3.2 Methods:

Mechanical control:

In France I observed a specific example that worked very well with the lighter soils. Jean Luc's rouleau landaus machine travelled between the rows of trees (set at 4m to allow inter-row vegetation control) to suppress vegetation and expose some of the mineral soil. This action reduces the fuel loads in forests, minimising the chance of severe fire and enabling fire control.

The machine can complete seven hectares (two passes) daily, is affordable and effective.

Figure 19. Rouleau landaus machine clearing inter row vegetation, France. Source: Author's own.

Livestock:

Although mechanical intervention may be required in the first instance, follow up control using livestock can be very effective. Precision grazing, such as that witnessed in Catalonia with Ramats de Foc (Fire Flocks) offers an innovative solution to this issue.

Wildfire management services identify critical management areas. Following this assessment, traditional Mediterranean shepherding practice is used to implement the prescribed control measures. This is generally done with a mixture of sheep and goats to ensure that all vegetation types are grazed to acceptably low levels.

Although the Spanish government partly funds the Ramats de Foc initiative, the funding is not wholly sufficient to maintain the business. Landowners top up the funding by paying for the shepherd's services, as he provides the labour and livestock. Additional income can be gained by the shepherd through the sale of meat, cheese etc. under the 'Ramats de Foc' label. Although there was little evidence that this label attracted a premium sales value, it does give the consumer clarity on the source and the value that the animal is offering their community.

At €400/ha/year it was suggested that this type of livestock intervention was more cost effective than mechanical control.

Figure 20. Ramats de Foc shepherd and his herd of sheep and goats, Montserrat, Spain. Source: author's own.

Steve Gatenby (Timberlands) discussed the half mile strip of land grazed by sheep and cattle in their Kaingaroa forest. This large firebreak is a contingency against the most extreme fires. It is important to use this example to dispel the myth that the 'fire breaks' discussed in the UK Forestry context (c. 10 – 30m wide) will not be effective in a wildfire scenario. The fire will simply burn through these areas.

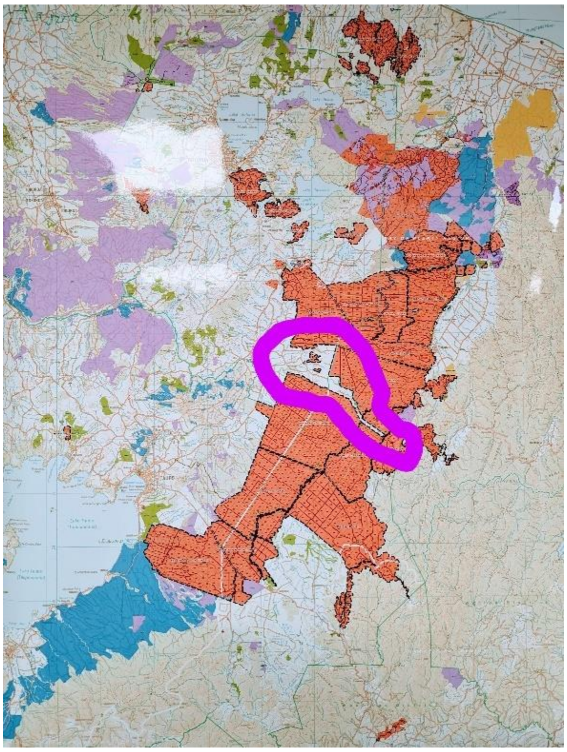

Figure 21. Half mile firebreak highlighted in purple in Kaingaroa forest estate. Source: Timberlands Ltd

5.4 Being Prepared

As stated in the introduction to this chapter, foresters, land managers and authorities must move away from fighting fires towards a position with living with fire, like any other natural disaster. The prevention measures discussed above are pertinent to reducing the damage to communities and ecosystems, however all must still be prepared for wildfire. The discussions below offer some insight into the experiences gained in the countries visited as part of this scholarship.

5.4.1 Collaboration and planning:

Firstly, it was evident that identifying key roles and responsibilities from the highest level (government) to the lowest (community) ensures that there is no ambiguity or time wasted in an emergency.

Integrating development planning that considers fire risk ensures that infrastructure is protected, and considers fire and smoke spread as part of the design process.

Collaboration between landowners regarding vegetation type and management assists with fire spread modelling and effective control points. An example shared by Mark Forward at One Forty One offers a valuable lesson from an active fire.

Vegetation type was reported as pine, and the models suggested a relatively slow spread. All parties were surprised to find that the fire had moved very quickly. Later it was established that the dense concentration of gorse in the understorey had promoted rapid fire spread.

Lessons such as these are important to share after major events. This was echoed by the comments by Shana Gross and Veronica Clifford (SCION, Fire and Atmospheric Sciences) who produce reports following fires. These are shared with all stakeholders to reflect on the successes and learning points.

An example of excellent planning is Timberlands Ltd fire strategy. They have clearly defined roles, with a strategy to respond quickly. This is enabled by a series of lookouts and staff patrols through the forest. Their stated response time is 30 minutes, with a helicopter in the air and heavy machinery (excavators, bull dozers, harvesters and skidders) on the move. This strategy works as they maintain positive communication and training with their staff and contractors.

5.4.2 Communication during wildfires:

During an active fire, real time, clear and all-encompassing communication is critical to keep all stakeholders informed and safe. Community contact lists and governmental community response systems must be kept up to date.

5.4.3 Training and equipment:

Residents in high-risk areas, such as the wildland-urban interface, need training on how to react to wildfires and must carry basic protective equipment and firefighting tools.

Fire fighters and forestry staff must engage with annual simulation exercises (using fire in controlled burn operations is best) to prepare for and test their resilience. This may involve dispatching staff into active fire zones periodically. Comments from One Forty One and Timberlands staff indicated that not everyone is suited to dealing with active fire, but it is impossible to establish who is without putting all trainees in real fire scenarios first.

Standardised equipment with uniform fittings ensures everyone can use it effectively. This was particularly important in the examples witnessed in New Zealand, where Fire and Emergency New Zealand (FENew Zealand), Timberlands and the One Forty One independent fire equipment was shared. This makes training simpler and ensures that anyone using the equipment can respond quickly.

Fire ponds can be important in remote, dry landscapes to ensure that adequate water is available for fire appliances. Setting aside some land to create a pond ensures that water is available, however access to the pond must be sufficient to accommodate large vehicles.

Finally, developing technology in remote sensing offers opportunities for real time smoke and fire detection using cameras and AI detection. This enables the most rapid response and eliminates the need to recruit fire lookout personal for short periods.

5.5 Financial considerations

There are costs associated with the implementation of fire planning, community engagement and fire prevention. Generally, damage cost is measured in monetary value. However, the wider cost implications of wildfire should also be considered including:

5.5.1 Environmental Costs:

Wildfires significantly impact ecosystems, for example Agnes Szuda (OECD) reporting 40% of critically endangered habitats in Chile being damaged in 2017. Carbon loss is also a major concern, with potential financial implications brought about by the changing climate and the associated weather extremes.

5.5.2 Societal Costs:

With 340,000 premature deaths being reported annually due to smoke inhalation, Agnes Szuda (OECD) highlights the need to consider societal issues beyond the impact of the fire alone. Loss of infrastructure and communication has an impact on quality of life, as well as damaging the local economy through disruption to business and livelihoods.

Considering the cost factors listed above, as well as undertaking the research required to determine the value of the carbon and ecosystem services implications, enables stakeholders to establish a route to fund fire planning, community engagement and fire prevention by undertaking a cost/benefit analysis to determine the costs saved by spending on prevention.

Another option, as exemplified by Timberlands Ltd, is to redistribute funds. They do not insure their timber due to the considerable premiums. Instead, money is set aside for spending on fire prevention and preparedness. This is a valid consideration, and an option for landowners to act independently without seeking funding support.

There is also an argument for sharing the financial burden across borders in an EU/Global context. There is a clear cross-border interest in preserving natural ecosystems and services, biodiversity and carbon emissions. This would be politically challenging, but worth considering.

There is also a discussion to be had on where funds are spent. Historically, expenditure has been focused on suppression of fires but some countries, such as Portugal, are now targeting their expenditure on prevention. For example, in 2021 54% of the total wildfire budget was spent on prevention.

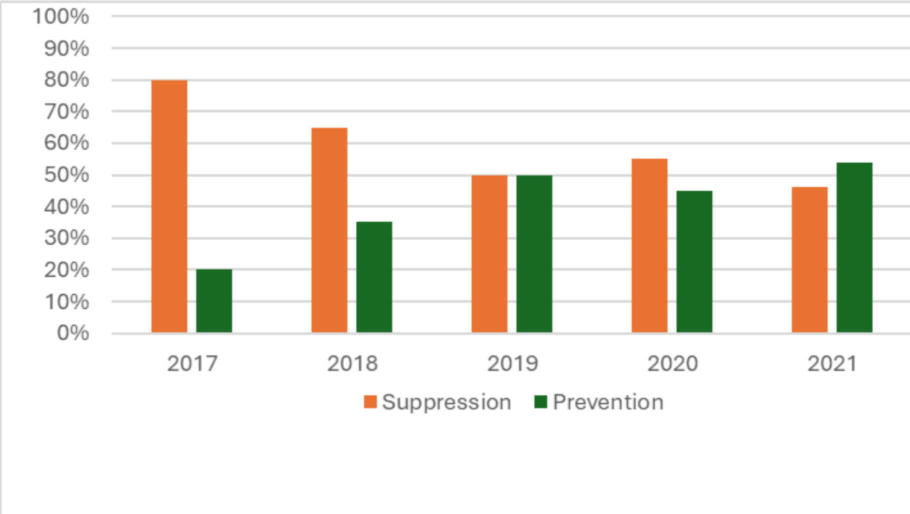

Figure 22. Growing prevention spending in Portugal. Source: Agnes Szuda, AGIF, 2021

6. DISCUSSION

6.1 Drought Resilience

Much of the information in Chapter 4 is common knowledge to foresters in the UK. Plant handling, planting technique, fertilising and cultivation are important aspects of what has been drilled into us for years. However, it is worth reflecting on the small gains that can be made by focusing efforts on getting as much of the process right as you can: retraining for foresters, planters and nursery staff on the best way to undertake these tasks will ensure compliance and improvement.

However, there are key points to be picked out from our findings that could be improved in the UK.

Tree breeding: Firstly, a renewed focus on tree breeding in the public and private sector is essential to build the drought resilience and productivity. Not only does tree breeding offer the opportunity to produce timber quicker with less risk (disease resilience), it offers opportunities to grow a diverse range of species that meet this requirement.

Diversity: The UK Forest Standard, which dictates the level of diversity required in UK forests, ensures that owners and managers are moving towards diversification. However, tree breeding for a wider range of species is not well enough developed. Work is needed to make these alternative conifer and broadleaf species more commercially attractive, incentivising forest owners and managers to plant more of them. At the same time directing diverse species on to unsuitable sites, where they are less resilient and prone to stress, disease or failure should be avoided as this will not create resilient forests.

One of the challenges that diversification efforts often face is overcoming the established economic advantages of the dominant species. Steve Wakelin (Scion, New Zealand) emphasized research highlighting the awareness of climate change risks. However, the lack of clear quantification regarding opportunity costs for failing to diversify disincentivises adaptation to more diversified practices. Work is required to quantify (in £s) the cost of failing to diversify now.

Funding: The Conifer Breeding Cooperative (CBC) is the driving force for this change in Great Britain (GB), with a renewed commitment to focus 1/3 of their funding on developing improved seed for *Picea abies, Pinus sylvestris* and *Pseudotsuga* menziesii. The Future Trees Trust, and others, are invested in developing the genetics of native broadleaf trees in the UK. However, funding for these projects is not sufficient and a wider species focus should be considered.

The funding levy in France on all timber sold would be a viable solution to this issue. Forest owners should understand the financial reward of growing resilient, fast-growing trees. Investing in this process by way of timber proceeds acknowledges the need for this work.

Data collection to aid management: Although the CBC is conducting trials across GB, including for drought resilience for *Picea sitchensis,* wider scale data could be collected in line with Timberlands Ltd and One Forty One's ambition to collect specific site and genotype data to target specific genotypes and species to site types. However, the advantage that these two companies have lies in the extensive area they own and manage. The fragmented ownership and management structure in the UK does not lend itself to accurate, consistent data collection. Nevertheless, it could be argued that a number of larger forest owners and the public forest estate could collaborate with their management companies to achieve this goal. Again, funding options will need to be explored to ensure that this analysis can yield useful results.

The Ecological Site Classification tool developed by Forest Research as a decision support tool for species choice in the UK may offer an opportunity for generalised data comparisons with actual growth rates achieved being recorded against the value provided by the tool pre-planting.

The BEC system employed in Canada, offers specific seed and site requirements based on future climate scenarios. However, the timber harvesting process allows for forward ordering of trees years in advance, allowing nurseries to grow specific stock for specific sites. The uncertainty of the planting requirement in the UK does not allow landowners or foresters to forward order trees, meaning forest nurseries grow what they think will be required annually. Inevitably, sites are planted with seed collected from less-suitable parents. On my travels I have not come across a way to address this complex issue.

Mycorrhizal fungi assist the tree by improving nutrient and moisture up take, improving resilience to drought. By all accounts the evidence is convincing, but the price point is difficult to justify at the moment at roughly the same price as the tree and labour. Field trials are ongoing, and we eagerly await the results from rhizocore.

6.2 Fire Management and Resilience

Communication: In the UK, fire is not yet a widespread threat that the public is concerned about. We are in an advantageous position, whereby we can implement cultural change now, for example, targeting children at school age through innovative ideas in serious games, or appealing to outdoor users to use fire safely, or not at all.

There are already good examples of the impact that can be had through clear messaging through different channels. As in the New Zealand MetService App example, clear communication through Met Office or BBC weather apps/websites is a very simple way to share fire risk information. Using social media and digital news channels may be a more effective communication channel than traditional media. Good examples of this include social media posts from DEFRA and FRS. It is important that these messages come from reliable sources to distil confidence into the population.

Work practices: Whether to carry out work in high fire risk periods should be considered, with best practice guidance produced to reflect that provided in the New Zealand Forest owners Association. There may be a significant cost to some contractors as part of this process, however costs are generally passed to forest owners.

Consideration should be given to vegetation control in high public use areas where fire is more likely to start. This also applies to critical infrastructure where wildfire is likely. Sensitive ecological and rewilding areas should also consider fire protection as the management scheme is often based on no intervention. This differs from hundreds of years of grazing and low intensity fire in the uplands.

Rewilding is likely to increase fuel loads over large areas which may result in larger scale wildfire in the future. Managing the vegetation is safer and protects the sensitive species and habitats present. Some may not agree that this is the best for the environment. However, a mosaic of managed habitats leads to diverse range species of plants and animals.

Collaboration with neighbours at a landscape scale is critical to the success of any vegetation control, small firebreaks are of no use in wildfires.

The recent changes in Scotland under the Wildlife Management and Muirburn (Scotland) Act 2024, are, in my opinion, a positive change to ensure that any burning is undertaken responsibly. The reference to wildfire in the Heather and Grass Burning Regulations (England) 2021 also goes some way towards raising awareness.

7. CONCLUSIONS

7.1 Drought Resilience

The UK is already taking steps in the right direction with tree breeding and site/species selection. The UK Forestry standard is also moving our forests towards a more diverse, and resilient position. However, significant funding is required to ensure that the diversification of species is done by promoting commercial attributes in these species as well as ensuring that we do not compromise the resilience of our forests by planting diverse species on unsuitable sites.

Using decision support tools and collecting growth data will help to identify specific genotypes to focus on. Mycorrhizal fungi and other water retention additives can play a key part in improving the resilience of young trees at establishment and research should continue.

Refocusing on the basic plant handling and planting techniques may improve the survival and resilience of young trees.

7.2 Fire Management and Resilience

A programme of public communication through signage, apps and a variety of media should commence immediately to start cultural change in the UK now. This change may take a generation, by which time we will be in a higher fire risk period.

Work practices and equipment must be considered more carefully during periods of high fire risk, with mitigation measures made clear at an industry level through best practice guidance.

Vegetation control should be considered around high-risk public areas, as well as around sensitive habitats. Rewilding must consider the increasing fuel loads that will develop from the removal of livestock. Some grazing or controlled burning to manage the risk of severe fire should be considered to prevent damaging the ecosystem that has developed.

Recent changes to the Wildlife Management and Muirburn (Scotland) Act 2024 and Heather and Grass Burning Regulations (England) 2021 are positive and will encourage training and responsible controlled burning.

8. RECOMMENDATIONS

1. Refocus efforts on the items that practitioners already understand to impact plant survival at establishment. Plant handling, delivery, stock type (cells/bare root), planting technique and timing.

2. Explore funding opportunities for tree breeding, to make improvements to the genetics of all forest trees in the UK.

3. Explore possibilities to collect data from large forest owners to develop a dataset of growth rates by genotype on specific site conditions. Collaboration with the public sector and Forest Research will be an essential part of this process.

4. Continue to fund and explore the role Mycorrhizal fungi has to play in building resilience in our forests.

5. Encourage weather service providers to include fire data and guidance in their forecasts.

6. Develop best practice guidance on working in the forest in periods of wildfire risk. This should include equipment requirements and working times.

7. Vegetation control should be implemented around vulnerable infrastructure and sensitive habitats, as well as in high use public areas.

8. Rewilding community must consider the fuel loads within their control.

9. AFTER MY STUDY TOUR

Although I have learned a significant amount from all the people I have met and places I have been, there is still more to learn and understand. I intend to continue to engage with professionals in the UK and abroad, to stay up to date with new information of fire and drought resilience.

Nuffield has given me a platform, and an opportunity to develop my communication skills, and I intend to use these to share the messages in the report with the forest industry. This will be done through the various discussion forums available to foresters such as the Royal Forestry societies, and through the Institute of Chartered Foresters.

Although change will be challenging, and subject to significant engagement from all stakeholders, I am buoyed up by the principle described in Roger's Innovation bell curve (2003), whereby early adapters are always in the minority. As we continue to push this agenda forward more people will begin to adapt to a more resilient perspective.

10. ACKNOWLEDGEMENTS AND THANKS

First and foremost, I would like to express my deepest gratitude to my wife and family. Their unwavering support and encouragement throughout this Scholarship journey were instrumental to my success.

I extend sincere thanks to my employer, Scottish Woodlands Ltd, for their generous support in providing me the time to dedicate myself to this research.

To the exceptional staff of Nuffield UK, I am grateful for your unwavering belief in our potential. You consistently challenged us to exceed our own expectations, while also providing a truly enriching program of training and support.

My heartfelt appreciation goes out to my fellow scholars for their camaraderie and support throughout this year. I cherish the friendships we have formed and look forward to staying connected with each of you.

A special acknowledgement to Jim Baird, my dedicated mentor. Your kindness, unwavering support, and encouragement, even during periods of less frequent interaction, were invaluable. Thank you for your time and guidance.

To the countless individuals who generously shared their knowledge and experiences on drought, forestry, and farming, I offer my sincere thanks. Your openness and willingness to help were deeply appreciated.

I am particularly grateful to those who offered their hospitality, welcoming me into their homes for meals and accommodation. Your generosity will not be forgotten. I hope to have the opportunity to return the favour in the future.

Finally, I express my profound gratitude to my sponsor, the John Oldacre Foundation. The financial support enabled me to further develop my understanding in this field. I am committed to using this knowledge to contribute meaningfully to Nuffield and the UK forestry industry.

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12. ABBREVIATIONS AND DEFINITIONS

BC: British Columbia

Bare root: A tree grown in the earth, lifted once at product specification with no soil attached to the roots.

CBC: Conifer Breeding Cooperative

Cell grown: A tree grown in a small container. The plant is dispatched with roots/soil intact.

DEFRA: Department for Environment, Food and Rural Affairs

GB: Great Britain

Restock planting: Following felling of mature timber, the site is replanted.

UK: United Kingdom

APPENDIX 1.

Extract from the New Zealand Forest Owners Association Forest Fire Risk Management Guidelines (2018).

New Zealand Fire Danger Classes & Codes

NZ's fire scientists have devised a Fire Danger class system that uses fire intensity as an indicator of fire suppression difficulty. These Fire Danger classes translate into six Fire Risk Management Code levels – green, blue, yellow, orange, red and purple (see Tables 1 & 2).

Table 1: Fire Danger Class system

Fire Danger Class	Fire Intensity (kW/m)	Control Requirements
L	>10	Ground crews with hand tools
M	10-500	Ground crews with back-pack pumps
H	500-2000	Water under pressure and/or heavy machinery
VH	2000-4000	Aircraft using chemical fire suppressants/retardants
E	**4000-10,000**	**Difficult to contain head, can suppress flanks and back of fire**
VE	**>10,000**	**Difficult if not impossible to control around most of fire perimeter**

This data can be translated into a Forest Operations Fire Risk Management Code, depending on the fire environment features in each catchment, as shown below:

Table 2: Fire Risk Management Code levels

Code Level	BUI Range	Fire Weather Index (FWI) Code Calibration of the BUI Range
Green	< 40 or other code	If FWI > 25 – Elevate to Code Blue
Blue	40.1 – 60	If FWI 25 > – Elevate to Code Yellow
Yellow	60.1 – 80	If FWI > 25 – Elevate to Code Orange
Orange	80.1 – 100	If FWI > 25 – Elevate to Code Red
Red	100.1 – 120	If FWI > 25 – Elevate to Code Purple
Purple	> 120	

Notes

- These Codes potentially apply all year round. Risk must be managed all year
- These indicators are generic guidelines. Forest managers and FENZ are encouraged to discuss local triggers based on local climate data and fire statistics

Appendix 3:

Forest Operations Fire Risk Management Codes

The Buildup Index (BUI) and Fire Weather Index (FWI) levels for each Code in this Appendix are indicative only and are presented as an example of what is possible.

These figures are used for the Nelson/Marlborough region and were provided by the former Waimea and Marlborough/Kaikoura Rural Fire Districts (RFDs).

These Codes are for use during the official Fire Season. They may potentially apply all year round.

The Forest Managers' Fire Committee recommends that:

- At an appropriate regional or district level, forest managers jointly approach FENZ and Scion fire scientists with regards to using the same scientific, climate-based approach to setting the Code levels they are comfortable with for their fire environment and risk profile
- Forest managers more closely define the actual and practical mitigation measures most suited to their area/district/region. Note that some forests may have unique risk profiles and have Code levels of their own
- These Code levels are included in the FENZ Fire Plans so that FENZ understands the basis of their compilation and the science behind them.

FENZ can make a weekly forecast of fire weather conditions from selected Remote Automatic Weather Stations (RAWS) available to forest managers. Forest managers can then plan weekly operations based on the best available information and arrange mitigation measures to suit.

The same Fire Weather System (FWSYS) can provide alerts, so that forest managers can be made instantly aware if a particular fire weather component exceeds a level previously indicated.

EXAMPLES ONLY

Fire Risk Management Code levels: Green, blue, yellow, orange, red and purple

Note that additional risk management features are progressively added to each Code in BOLD type

Code Green:	BUI < 40 ISI: Use appropriate figures depending on local conditions FWI < 25
Activity	**Recommended mitigation measures**
Welding/gas cutting/abrasive wheel cutting	Work only on bare earth Have a minimum of 20 litres of water, along with an appropriate method of applying that water, within 5 metres of the work area Patrol for 30 minutes after completion Comply with Code of Practice (NZS 4781:1973)
Smoking	Only in appropriate designated areas

Code Blue: BUI = 40.1 – 60 ISI = FWI < 25

Activity	Recommended mitigation
Welding/gas cutting/abrasive wheel cutting	As for Code Green Wet down work area with soapy water
Smoking	As for Code Green No smoking in cutover
Inspections & maintenance requirements	Contractors to consider: • Check chainsaws and machinery for debris build up near hot working parts such as belly pans and radiators • Check engine bay hydraulic hoses for leaks • Inspect hauler blocks for heat, and ropes for binds, rock strikes • Backline blocks cleared of surrounding vegetation to mineral earth 1.5 m radius. Keep shovel on site for this purpose Inspections should be noted in diary
Chainsaw thinning	Review site hazards (undergrowth fuels, aspect, and escape routes) Move chainsaw thinning to areas with lower hazard where possible
Fire starts	Notify 111 of any fire start regardless of size
Emergency planning	Notify FENZ of any road closures or weekend work Inform the workforce about Code Blue requirements and preparation for future elevation to Code Yellow at, for example, tailgate meetings
Forest access	Review public access to forest. Alert recreation permit holders, hunters, bikers etc

Code Yellow: BUI = 60 – 80 ISI = FWI < 25

Activity	Recommended mitigation measures
Welding/gas cutting/abrasive wheel cutting	As for Code Blue No Hot Work unless on a 20 metre radius of bare ground
Smoking	As for Code Blue
Inspections & maintenance requirements	As for Code Blue
Chainsaw thinning	As for Code Blue
Fire starts	As for Code Blue
Emergency planning	As for Code Blue Inform the workforce at tailgate meetings about Code Yellow requirements and preparation for future elevation to Code Orange Escape plans: Consider covering in tailgate meetings
Forest access	As for Code Blue
Mowing and slashing (roadside and ground)	Stop road side mowing and slashing

APPENDIX 3 CONTINTUED

Code Orange: BUI = 80.1 – 100 ISI = FWI < 25	
Activity	**Recommended mitigation measures**
Welding/gas cutting/abrasive wheel cutting	As for Code Yellow
Smoking	As for Code Yellow
Inspections and maintenance	**Daily** **Assess daily weather at 1300 hours by forest to determine need for elevation of readiness level** **Weekly** **Inspection of all fire equipment (including extinguishers)** **Regular cleaning for all machines and especially chainsaws**
Chainsaw thinning	As for Code Yellow
Fire starts	As for Code Yellow
Emergency planning	As for Code Yellow **Inform the workforce about Code Orange requirements and preparation for future elevation to Code Red at tailgate meetings** **Consider covering in tailgate meetings: Escape plans, initial response actions, check fire competencies** **Identify suitable water points (for ground and helicopter) around work areas**
Forest access	As for Code Yellow **Consider putting up signage at access points warning of fire danger** **Restrict all hunting and firewood gathering**
Mowing and slashing (roadside and ground)	As for Code Yellow
Machines	**List all machines that do not have working inbuilt engine compartment fire suppression systems. You may choose to cease work in cutover at 1300 hours** **Check mobile tail holds are clear of vegetation** **Ensure suitable water supplies are located on work sites**

Code Red: BUI = 100.1 – 120 ISI = FWI < 25	
Activity	**Recommended mitigation measures**
Welding/gas cutting/abrasive wheel cutting	As for Code Orange **No Hot Work unless on a 20 metre radius of bare ground**
Smoking	As for Code Orange
Inspections and maintenance	Daily – As for Code Orange Weekly – As for Code Orange
Chainsaw thinning	**Consider no chainsaw thinning after 1200 hours**
Fire starts	As for Code Orange
Emergency planning	As for Code Orange **Inform the workforce about Code Red requirements and preparation for future elevation to Code Purple at tailgate meetings** **Consider covering in tailgate meetings: Escape plans, initial response actions, check fire competencies** **Identify suitable water points (for ground and helicopter) around work areas and maintain as appropriate** **Patrol sites for at least one hour after machine shutdown** **Consider having a 3-person quick response crew with smoke chaser based at a central location.** **Liaise with FENZ to determine FENZ initial response plans in case of fire**
Forest access	As for Code Orange
Mowing and slashing (roadside and ground)	As for Code Orange
Harvesting – Chainsaws	**Stop all chainsaw operations in cut over after 1200 hours, except on landings and when log-making**
Machines	As for Code Orange

APPENDIX 3 CONTINTUED

Code Purple	BUI = 120.1 + ISI = FWI>25
Activity	**Recommended mitigation measures**
Welding/gas cutting/abrasive wheel cutting	As for Code Red **Consider stopping all Hot Works for a defined period unless a smoke chaser plus crew can be located nearby, OR** **Work before 1000 hours and after 1600 hours; OR wet the area before and after the Hot Works; maintain 1000 litres of water plus pump on site for two hours following the final wet-down** **Maintain observation presence for two hours afterwards**
Smoking	As for Code Red
Inspections and maintenance	Daily – As for Code Red Weekly – As for Code Red
Chainsaw thinning	**Stop all chainsaw thinning operations**
Fire starts	As for Code Red
Emergency planning	As for Code Red **Consider short response standby helicopter** **Extensions to working hours on bare earth or processing sites are subject to appropriate readiness and emergency response planning**
Forest access	As for Code Red
Mowing and slashing (roadside and ground)	As for Code Red
Harvesting – chainsaws	As for Code Red
Machines	**Consider a Stop for all machines working in vegetation or cutover from 1200 hours** **Stop all machines working on bare earth or processing sites at 1300 hours, unless 1000 litres of water plus pump are on site, or a smoke chaser is nearby**
Cable harvesting	**Consider a Stop on moving ropes between 1200 and 1700 hours**
Slash raking & fire breaking	**Inspect pulleys etc to ensure that friction has not left smouldering vegetation** **Stop all slash raking and fire breaking**

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