NEW ZEALAND

Journal of Forestry

Volume 65 No 4
February 2021

In this issue

Port Blakely LiDAR inventory
Structure-from-Motion photogrammetry
Satellite imagery
Recent climate impact on fire danger levels
Education and safety updates

New Zealand Institute of Forestry
– Te Pūtahi Ngāherehere o Aotearoa Incorporated –

ISSN 1174 7986

Published quarterly by the New Zealand Institute of Forestry Inc.

Te Putahi Ngaherehere o Aotearoa

www.nzif.org.nz

Editor

Trevor Best
Email: Editor@nzif.org.nz

Assistant Editor

Helen Greatrex

Subscription inquiries and changes of address

Administrator
NZ Institute of Forestry
PO Box 10-513
Level 9, 93 The Terrace
Wellington 6143
Phone: 04 974 8421
Fax: 04 473 9330
Email: admin@nzif.org.nz

Subscriptions

Annual rates covering four issues

Individuals:	New Zealand, $90
	overseas, NZ$120
Institutions:	New Zealand, $150
	overseas, NZ$190

Design

Jenny Palmer Graphics

Printing and distribution

The Printroom

Advertising

The Administrator
Email: admin@nzif.org.nz
Phone: 04 974 8421
Fax: 04 473 9330

Contents

NZ Journal of Forestry
Volume 65, Number 4
February 2021

Editorial

2 Remote sensing – evolution or revolution?
Trevor Best

Theme – remote sensing

3 Port Blakely Tree Farms – five years of LiDAR inventory (a practitioner's perspective)
Aaron Gunn

6 Structure-from-Motion photogrammetry as a tool for harvest residue pile measurement
Luke Riedinger and Campbell Harvey

12 The impact of recent climate on fire danger levels in New Zealand
Murray Dudfield, H. Grant Pearce and Geoff Cameron

19 Identifying post-harvest soil disturbance using satellite imagery
Jim Walsh and Rien Visser

26 Preliminary estimation of catchment capacity to develop debris flows and their runout distances using high resolution Digital Elevation Models (DEMs)
Mark Bloomberg and David Palmer

Professional paper

32 2021 – another New Zealand forestry centenary
Michael Roche

Education and safety updates

37 School of Forestry update
Bruce Manley

41 FISC update
Fiona Ewing

Last word

44 The dangers of invisibility
Jeremy Fleming

Front cover photo: Toroawhi Wade Brunt out visiting crews. Photo courtesy of FISC

Back cover photo: Helicopter logging Arthur's Pass National Park. Photo courtesy of Trevor Best

Remote sensing – evolution or revolution?

Trevor Best

A few years ago, a young acquaintance of mine having decided to study engineering came looking for some insights into what engineering practice would become his focus. His own investigation had whittled the choices down to civil and forest engineering and he wanted to know which I thought he might be best suited for. Keen to capture a good mind for the cause I engaged. A bit more questioning clarified that he loved thinking that involved numbers rather than words and phrases (good start), but his preference was for mathematics rather than statistics (oh dear). When I questioned him about why that was the case his answer centred on certainty: he liked to know his thinking was correct with a small but known risk of being incorrect. When I explained to him the level of uncertainty imposed on forest engineering decision-making by imperfect knowledge about tree size, stem breakage points and landform he decided to go with civil engineering.

However, I am not sure that I would now respond in the same way. The increasing availability of remote sensing technology is making that insight obsolete and disrupting the practice in the process. No longer can we say with certainty that measurement of all trees within a crop is too time-consuming, expensive and unlikely to be correct, and that using statistics to estimate key crop attributes is likely to produce a more cost-effective and reliable answer. Tasks like post-harvest assessments, or post-establishment stocking assessments that were once assigned to the 'eyeometer' or the 'walk-over' (due to the lack of a cost-effective and reliable plot-based alternative), now have remote sensing alternatives that could make measurement-based assessment more practicable.

And if that is the case, what does it say for the future of the actual work that forms the basis of the field forester's practice? Where does plotting fit in that future? Will that work be replaced by flying UAVs as a skill requirement for early career foresters? What will the time balance be between the office and the field? What level of investment in technology will now be required for forest management consulting practices? And those questions only scratch the surface. If the measure of a disruptive shift in practice is the level of uncertainty that shift creates about the future of current practices, then remote sensing technologies are giving the practice a good old shake.

This shift in practice is the sub-text to this edition, which sets out to explore some of the ways in which remote sensing technologies are overcoming the barriers to increasing the level of certainty over the imperfect information that drives the practice, and to consider what that might mean for the actual work done as part of the practice. Aaron Gunn kicks things off by outlining the experience of Port Blakely Tree Farms in implementing a LiDAR (Light Detection and Ranging)-based inventory system across a relatively variable resource, and in the process replacing a key activity within the practice (plot-based inventory) with a way of providing better quality information with several different benefits.

Then there are more papers that feature activities that are only made cost-effective and reliable through remote sensing technologies. Mark Bloomfield continues with the use of LiDAR to estimate the capacity of catchments to develop debris flows and their runout distances. Luke Riedinger and Campbell Harvey use a different technology to generate Digital Elevation Models (DEMs) and look at the potential of Structure-from-Motion photogrammetry (SfM) for determining the bulk volume of piled harvest residues. Gunn notes in his article that SfM could replace LiDAR in some inventory applications, given the ease of access made possible by its UAV platform. Finally, Jim Walsh and Rien Visser explore the use of satellite imagery to assess post-harvest soil disturbance. These are all applications with a more environmental focus, but the emphasis on minimising erosion and sedimentation in the National Environment Standards for Plantation Forestry makes having ways of quickly and cheaply assessing post-harvest residues and soil disturbance critical risk management tools essential.

While the focus of the edition is on what's new in the remote sensing world, it is worth reminding ourselves that foresters have a history of adopting remote sensing technologies to meet our management needs. Murray Dudfield, Grant Pearce and Geoff Cameron provide an interesting review of what 40 plus years of weather station data can tell us about forest fuel availability for combustion. The paper highlights the capacity of large digital datasets to tell a story over time.

Finally, contrary to its relatively conservative reputation, foresters in New Zealand have always been rapid adopters of new technology. The very existence of radiata pine as a commercial forest crop is proof of that. I am sure that the adoption of remote sensing technologies (and all its acronyms) will prove to be just another turn of that wheel. I hope this edition conveys a real sense of that opportunity.

Port Blakely Tree Farms – five years of LiDAR inventory (a practitioner's perspective)

Aaron Gunn

Abstract

Port Blakely has been using LiDAR for inventory purposes since 2015 and this technology has now become the company's primary option for forest inventory. Although there have been challenges to implementing this technology, the benefits have been found to far outweigh these, including being a game changer for harvest reconciliations. The company has undertaken five LiDAR inventory projects to date with future capture and recapture plans in place. The precision of the LiDAR inventory projects has been found to be comparable to, if not better, than traditional mid-rotation and pre-harvest inventory estimates. LiDAR inventory projects also provide benefits, such as numerous GIS spatial surfaces that aid forest management and information that can assist with future growth modelling and site classification purposes. This technology has an exciting future and the process of completing LiDAR imputation projects is constantly developing and evolving.

Introduction

Port Blakely has been using LiDAR technology for the past nine years, including the last five years for the purpose of LiDAR-derived inventory. The company developed an interest in LiDAR with the specific intent of providing accurate tree height measurements for approximately 9,000 ha of Douglas-fir resource. LiDAR was captured in 2011, and Canopy Height Models (CHMs) were created from the LiDAR Point Cloud that were used to accurately stratify five individual forests by tree height and prioritise the timing of the waste thinning operations. After gaining experience of what this technology could do – specifically highly accurate Digital Terrain Models (DTMs) and CHMs – the company looked for options to progress the implementation of LiDAR in other areas of its forest resource.

In 2015, Port Blakely partnered with Scion to undertake a LiDAR imputation project on Matakana Island. This project was followed by a joint project in 2016 with Land Information New Zealand (LINZ), Scion and Interpine, and used Port Blakely's Geraldine Forest as a forestry case study to support the LINZ business case for government investment in national LiDAR capture. The company has since captured a further three projects and has recently completed the recapture of one forest area. These later projects have been completed by Interpine, an international innovator in the development and utilisation of LiDAR technology for inventory purposes.

Approach taken and challenges in transitioning to LiDAR inventory

Port Blakely's approach to implementing LiDAR inventory systems has been to complete projects at the forest level, with later projects merging forests within proximity to each other. To date, the focus has specifically been on radiata pine in the age class range from 15 to clearfell, but in 2021 the company is planning to capture two Douglas-fir forests using a LiDAR imputation approach. Once the initial LiDAR capture and imputation project is undertaken, the intention is to recapture forest areas on a four to five-year return frequency where scale and forest structure allows.

The road to implementing a LiDAR inventory system has been one of trepidation. If you had a highly uniform resource with scale, making the decision to use a LiDAR imputation system would be relatively easy. However, this has not been the case for Port Blakely's forest resource, especially in the South Island where climatic conditions (such as wind and snow) increase the variability of the resource. Each LiDAR inventory project has its unique challenges that need to be considered, which largely relate to the variability of the resource from a regime, age-class and productivity perspective. Consideration therefore needs to be given to the weighting of plots in different stratum to provide the best estimates for key areas of interest, with the recognition that this approach will likely provide less precise estimates for areas less intensively sampled.

Precision achieved from LiDAR inventory

From a simplistic perspective, the key point of difference between a traditional mid-rotation and pre-harvest inventory and a LiDAR imputation inventory is that the traditional approach has a considerable number of ground plots installed within the area of interest (AOI), but only samples a low percentage of the total AOI. In contrast, a LiDAR imputation project has a lower number of ground plots installed in the AOI (in some cases none), but the LiDAR captures 100% of the AOI.

From Port Blakely's experience, this difference results in a more precise capture of the variability of the resource and an improvement in Total Recoverable Volume (TRV) predictions. Typically, a downgrade adjustment of between 6–15% would need to have been made for mid-rotation and pre-harvest inventories to align with harvest actuals, but this adjustment has not been necessary for the LiDAR inventory projects completed so far. Log grade level precision may be partially compromised depending on the variability of the resource. However, the harvest reconciliations that Port Blakely have completed to date have shown that the LiDAR inventory is providing an adequate prediction of aggregated log grade products (Pruned, Saw1, Saw2, Saw3 and Pulp). Pre-harvest calibration and validation inventories that have been undertaken in stands where LiDAR inventory has been captured also support this finding.

Additional benefits of moving to a LiDAR inventory system

A LiDAR inventory project provides the traditional yield table outputs and associated precision estimates that you would expect from a pre-harvest or mid-rotation inventory. However, in addition to these products, there are a number of spatial surfaces that can be produced that aid in understanding the variability of the resource sampled and provide benefits to other areas of resource management. Port Blakely typically requests the following spatial surfaces from LiDAR inventory projects and incorporates a subset of these layers into the company's GIS for operational access, Site Index, 300 Index, basal area, stems per hectare, height, TRV and aggregated log grades. Figure 1 shows a small section of a TRV surface (note the scale of the pixels on the edge of the surface are at 25 x 25 m).

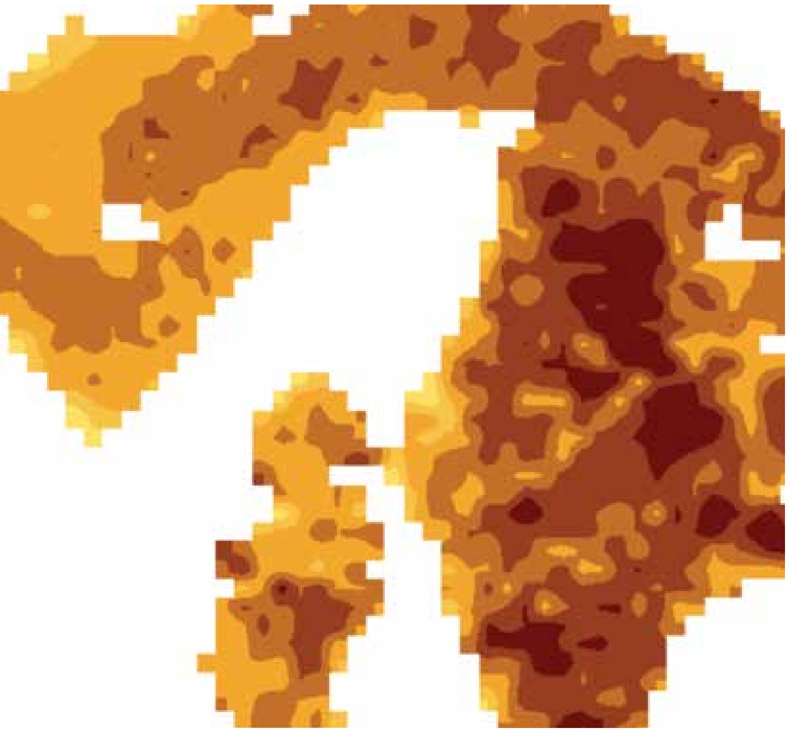


Figure 1: Total Recoverable Volume (TRV) surface

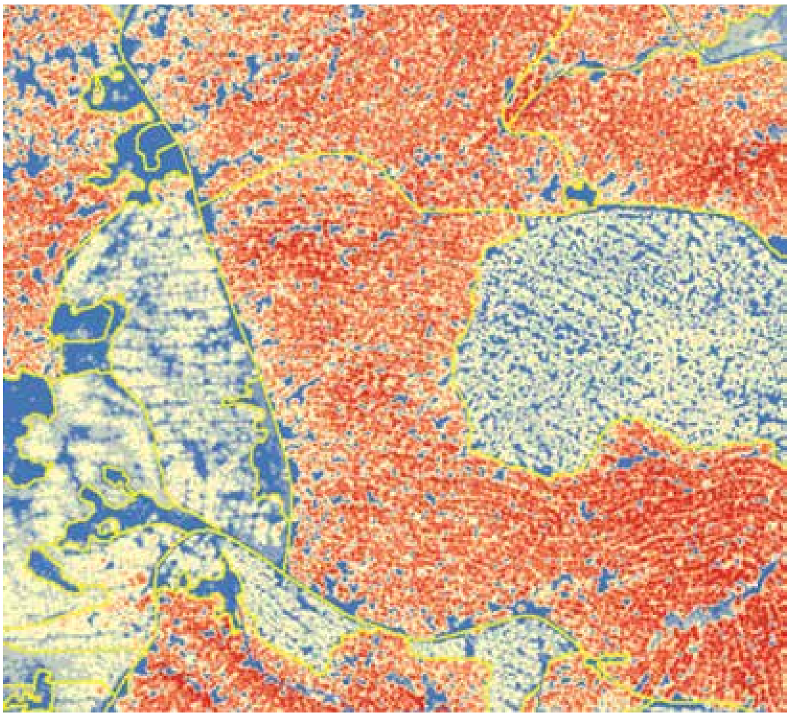


Figure 2: Canopy Height Model (CHM)

In addition to these products, the LiDAR captured for inventory projects also allows the ability to create useful terrain and vegetation surfaces. Port Blakely publishes the following LiDAR generated surfaces in the company's GIS – CHM, aspect, Digital Terrain Model (DTM), hillshade and slope. Figure 2 shows a small section of a CHM.

By moving to a LiDAR inventory system, the yield predictions are no longer bound at the stand level. A LiDAR inventory provides a yield prediction at a pixel level, typically 25 x 25 m, and inventory predictions can be extrapolated to any AOI defined within the bounds of the project area captured. This is especially useful for harvest reconciliations as inventory areas can be cookie-cut to fit harvested areas post-harvest. Also, during the harvest planning phase this system allows the assessment of harvest volumes for defined areas, which can then be fed into financial and operational models to assess the optimal harvest timing for different harvest unit options. A recent project of this nature also allowed the estimation of recoverable volume from planned road lining operations.

As mentioned, Port Blakely plans to complete a recapture of forest level LiDAR inventory projects at a four to five-year return frequency. When completing recapture for previously captured areas, there is the potential to reuse the plots from the previous capture, which will provide huge financial savings. Port Blakely will be testing this approach for the first time in 2021 in the company's Geraldine Forest, and plans to install 60 new plots as well as utilise the 200 plots installed in the previous LiDAR project from 2016.

Lastly, Port Blakely has found that a LiDAR inventory system provides a level of simplicity relating to inventory management. Although the individual projects are more complex, there are many stands captured within a single LiDAR inventory project and there is no longer the need to complete multiple age-based mid-rotation and pre-harvest inventory at the stand level (with the exception of validation and calibration inventories as required). A LiDAR inventory system also allows the capture of small stands that may not have been considered viable to capture using traditional mid-rotation and pre-harvest inventory techniques.

Potential use for growth modelling and site productivity classification

Port Blakely expects that the LiDAR inventory datasets that are being collected will have significant benefit for future growth modelling and site classification purposes. The company is now starting to recapture forest areas with new LiDAR imputation projects that were previously captured four to five years ago. If the company continues this recapture cycle it will not take long to accumulate a collection of sites where 100% spatial capture has been completed multiple times over the same forest area. For these areas, there will be a time series prediction of how this forest area is growing at a fine resolution. This dataset could then be used to calibrate and project future growth simulations that have the ability to account for variation across a site associated with different features on it (e.g. aspect, ridge tops, valleys).

Over the last five years, Port Blakely has been working with Professor Euan Mason from the School of Forestry at the University of Canterbury in Christchurch to create high resolution site productivity surfaces for the company's radiata pine sites using hybrid mensurational/physiological modelling (see Mason, Holmstrom & Nilsson, 2018). This year we have started to understand the relationships between the Site Index layers produced from Euan's work and the Site Index layers produced from the LiDAR imputation projects. The intention is to use the Site Index layers generated from the LiDAR imputation projects to calibrate and validate Euan's Site Index layers, which will then be used (along with other GIS spatial surfaces and operational forester knowledge) to create a new generation of site productivity classifications for the Port Blakely radiata pine resource.

How could this technology be developed further?

From Port Blakely's perspective we would be interested in the following aspects of this technology being developed:

- **The potential to replace LiDAR with photogrammetry**:
  Overseas examples have shown that there is the potential to replace the LiDAR Point Cloud used for inventory projects with a photogrammetric Point Cloud (created from aerial imagery) for subsequent imputation projects once an initial LiDAR DTM has been obtained. If this was proven to be effective for the New Zealand capture environment, there could be significant cost savings achieved
- **Improvement in log grade prediction:**
  Although the harvest cut-outs that Port Blakely has completed have shown that LiDAR inventories are providing an adequate prediction of aggregated log grades, this area could still be developed further. The move to a single-tree inventory, as opposed to plot-based, is likely to further improve log grade prediction and is an option that Interpine are working on and could be available soon
- **Plot number requirements:**
  Currently there is a rule of thumb that approximately 200 plots need to be installed per LiDAR inventory project. It would therefore be useful to further understand the sensitivities around this number, especially regarding significant regime variations and how plot numbers could vary depending on the precision required.

Summary

In summary, Port Blakely has been fortunate to have had opportunities to enter the world of LiDAR imputation projects by leveraging off research projects and a national business case project for forestry capture. We are also fortunate to have had Scion's expertise in developing aspects of this technology, and the help of a company such as Interpine who have taken an exemplary lead in deploying this technology to industry. We have learnt a lot about the implementation of this technology on the journey so far, but we still have a lot to learn on the way ahead as this area evolves.

If you are interested in entering the world of LiDAR inventory, please feel free to contact me to discuss this further. It may also be of interest to consider what LiDAR is being captured in your area as part of the Government's national LiDAR capture project. This LiDAR will be freely available and could be a good way to kick-off a LiDAR inventory project.

Reference

Mason E.G., Holmström E. and Nilsson U. 2018. Using Hybrid Physiological/Mensurational Modelling to Predict Site Index of *Pinus sylvestris L.* in Sweden: A Pilot Study. *Scandinavian Journal of Forest Research*, 33(2): 147–154. Retrieved from: http://dx.doi.org/10.1080/02827581.2017.1348539

Aaron Gunn is Resource & Technical Manager at Port Blakely Ltd based in Christchurch. He is also Co-Chair of the Remote Sensing Cluster Group and a Committee Member of the Technical Steering Team at Forest Growers Research Ltd's Resilient Forests Research Programme. Email: agunn@portblakely.com

Structure-from-Motion photogrammetry as a tool for harvest residue pile measurement

Luke Riedinger and Campbell Harvey

Abstract

The issue of harvest residue management has been brought to the forefront of public knowledge after recent storms. Key to managing residue piles is the ability to measure them in a repeatable manner. This work aims to evaluate the method of Structure-from-Motion (SfM) photogrammetry for determining the bulk volume of piled harvest residues. A series of piles were photographed and reconstructed as Point Clouds and Digital Elevation Models (DEMs) using SfM for the measurement of bulk volume.

True dimensions of the piles were well preserved in the models, with most models reproducing to within 0.1 m of actual dimensions. The DEMs, from which bulk volumes were determined, had resolutions ranging from 3.36 to 1.51 cm/pixel. The combination of these factors indicates that the volumes determined from the models were accurate representations of actual pile volumes.

It is concluded that SfM photogrammetry is a reasonable method to be employed by harvest managers looking to determine the volume of piled forestry slash. Due to the time involved in processing the imagery, which ranges from 30 minutes to over three hours, it is likely that its use is targeted at high-risk residue piles or as a part of a residue monitoring study.

Introduction

The impact of recent cyclones has highlighted shortcomings in harvest residue management in commercial production forests. Cyclonic weather events have resulted in large volumes of harvest residues being discharged from steepland forests to coastal river flats. The extensive media coverage following these events has brought the issue to the public eye and added to pressure on the forestry industry to better manage its by-products and harvest practices (Bayne, 2019).

The Environmental Code of Practice (ECoP) for New Zealand Forestry (NZFOA, 2007) includes in its operational rules for slash management that it is necessary to, 'monitor slash piles to ensure that they are always stable and fully utilise the available space.' The National Environmental Standard for Plantation Forestry (NES-PF) (2017) states similarly to the ECoP that, 'Slash from harvesting that is on the edge of landing sites must be managed to avoid the collapse of slash piles' (MPI, 2018). Neither the NES-PF Regulations nor the ECoP allow for uncontrolled movement of harvest residue piles.

Key to managing a problem is the ability to measure it in some quantifiable and repeatable manner. Previous work by Peter Hall for the Logging Industry Research Organisation (LIRO) in the 1990s established knowledge of harvest residues, both in the cutover (Hall, 1999) as well as on harvest residue piles (Hall, 1994; Hall, 1998). By measuring the residues generated on four cable yarder landings, Hall's work established an approximate estimate of bulk residue volume as a proportion of recovered volume (Hall, 1993). Simply multiplying the total recovered volume extracted to the landing (in m^3) by 0.2 can give a harvest manager an estimate of the bulk volume of the residue pile (i.e. 5,000 m^3 of logs made at a landing yields an estimated pile volume of 1,000 m^3).

Currently, the method for obtaining the volume of piled harvest residues involves approximating the shape of the pile with a geometric solid (Hardy, 1996). This method is capable of providing an estimate of the volume of a pile and has been used in the US for post-harvest residue pile burn planning, but it is not accurate due to the irregular shape of piles. Structure-from-Motion (SfM) photogrammetry, utilising images captured with cameras mounted on Unmanned Aerial Vehicles (UAVs), can be employed as an alternative to the geometric method, Light Detection And Ranging (LiDAR) or professional surveys. SfM photogrammetry is not only accurate, but it is also a relatively straightforward and accessible technology, with companies now offering online-based cloud computing services.

SfM photogrammetry utilises a series of regular digital photographs with significant overlap between images to generate a 3D model of a scene. The SfM photogrammetry software computes the geometry between the camera, its orientation and the common points in the photos, and solves these simultaneously with an iterative bundle adjustment procedure. With this, the software can assign the common points a location in 3D space. With the internal GPS receiver of the UAV adding a geo-tag to each image, the resulting model may also be approximately georeferenced when using a supporting software package. SfM surveys can be completed at a fraction of the cost of a LiDAR survey by in-house personnel and with relatively little investment.

There are a number of SfM photogrammetry software packages available, both commercial and open-source. Westoby et al. (2012) utilised SFMToolkit3, while Agisoft Photoscan (now Agisoft Metashape) was used in a number of studies (Casella, 2017; Sanz-Ablanedo, 2018). The Metashape platform allows the creation of 3D models from images that can be captured from any position through fully automated image alignment and 3D model reconstruction (Agisoft, 2019).

A 2016 study by Karl Forsman (Forsman, 2016) into the use of SfM photogrammetry for measuring the volume of log stockpiles in a sawmill yard determined that SfM was a viable technology for evaluating the volume of the stockpiles. The study found that the total modelled pile volumes ranged between 5% and 25% of the 'true' value, which was determined with terrestrial laser scanning.

The application of SfM photogrammetry has also been investigated for the purpose of modelling accumulations of large woody debris in fluvial systems (Spreitzer et al., 2020). The research focused on scale models of large wood accumulations in varying arrangements using PIX4DMapper photogrammetry software. The conclusion was that SfM photogrammetry was well suited to the application, and could be considered a valuable tool for quantifying volumes of large wood accumulations due to savings in both cost and time when compared to conventional surveying techniques.

With a need to plan for the accumulation and handling of residues on steepland sites, UAV imagery coupled with SfM photogrammetry is a relatively new and accessible tool that has the potential to measure complex residue piles. In this study, SfM photogrammetry software and methods have been investigated for their agreement with physical measures, comparison of results to the earlier geometric method, and also processing time on a desktop computer.

Methods

SfM is a photogrammetric process whereby it is possible to create 3D Point Clouds – similar to those obtainable through LiDAR sensing – from digital images taken by many common cameras. There are a number of software packages available at both the commercial and recreational levels, including Agisoft Metashape and PIX4D Cloud. The SfM process involves the identification of common points between images, for instance the end of a log. The software is then capable of determining that point's location in space, based on the geometry of the camera's lens and the other points that are visible.

The accuracy achieved with SfM photogrammetry is largely dependent on the overlap of the images collected, as the SfM process relies on the ability to identify common points between images. As such, the larger the number of common points between two photos, the higher the accuracy of the output model (Iglhaut, 2019).

The residue piles used in this study were selected on near-flat terrain for ease of estimating the ground surface level. A secondary criterion was for suitable access by foot on all sides for manual measurements. The residue piles used are generally representative of piles generated by ground-based harvest operations. They are generally located on the edge of the skid site, and shaped into a distinct pile by a machine with a clearly identifiable edge between the pile and ground. The piles used were not representative of cable extraction systems, or ground-based extraction on steepland sites, where residues are often located on the edge of the landing, draping over a curved ground surface.

Piles were surveyed in two forests over the course of several weeks. Digital still images of each residue pile were captured with DJI Mavic Pro UAV by the model's standard 12.35 megapixel camera. This was done flying first around the pile, capturing images at an oblique perspective at an elevation of 5–7 m, depending on the size of the pile, and then at an elevation of 20 m flying directly over the pile (see Figure 1). Images were captured on average every 1 m around the pile, and every 5 m when flying over the pile.

The imagery for each pile was input to Agisoft Metashape software, where a model was constructed. Default settings for aligning images and matching points were used; 40,000 and 4,000 on Key Points and Tie Points, respectively. The settings put upper limits on the number of matched points used to align the images.

After alignment, a low resolution model of the slash pile is created with the points that were identified during the alignment process. Using the points from the alignment, a 'dense cloud' is constructed (see Figure 2), with default settings for both quality and depth filtering. Generating the dense cloud consumes the most processing time of all the steps. The variation of processing time based on the number of input images was one of the questions of this study. To assess this, three different models of each pile were made with varying number of images (i.e. two models for each pile have significant numbers of images removed).

A Digital Elevation Model (DEM) is constructed from the dense cloud using Agisoft Metashape's default settings. DEM creation is the fastest of all the steps in Metashape, taking no more than 30 seconds to finish.

The DEM is used to measure the bulk volume of the pile using a built-in measurement tool. The soil-harvest residue boundary must be delineated and the volume is determined once the polygon is closed around the pile. Metashape creates a basic Triangular Area Network (TIN) using the nodes on the user-defined boundary as the estimate for the ground surface beneath the pile. The DEM, pile boundary and volume output can be seen in Figure 3.

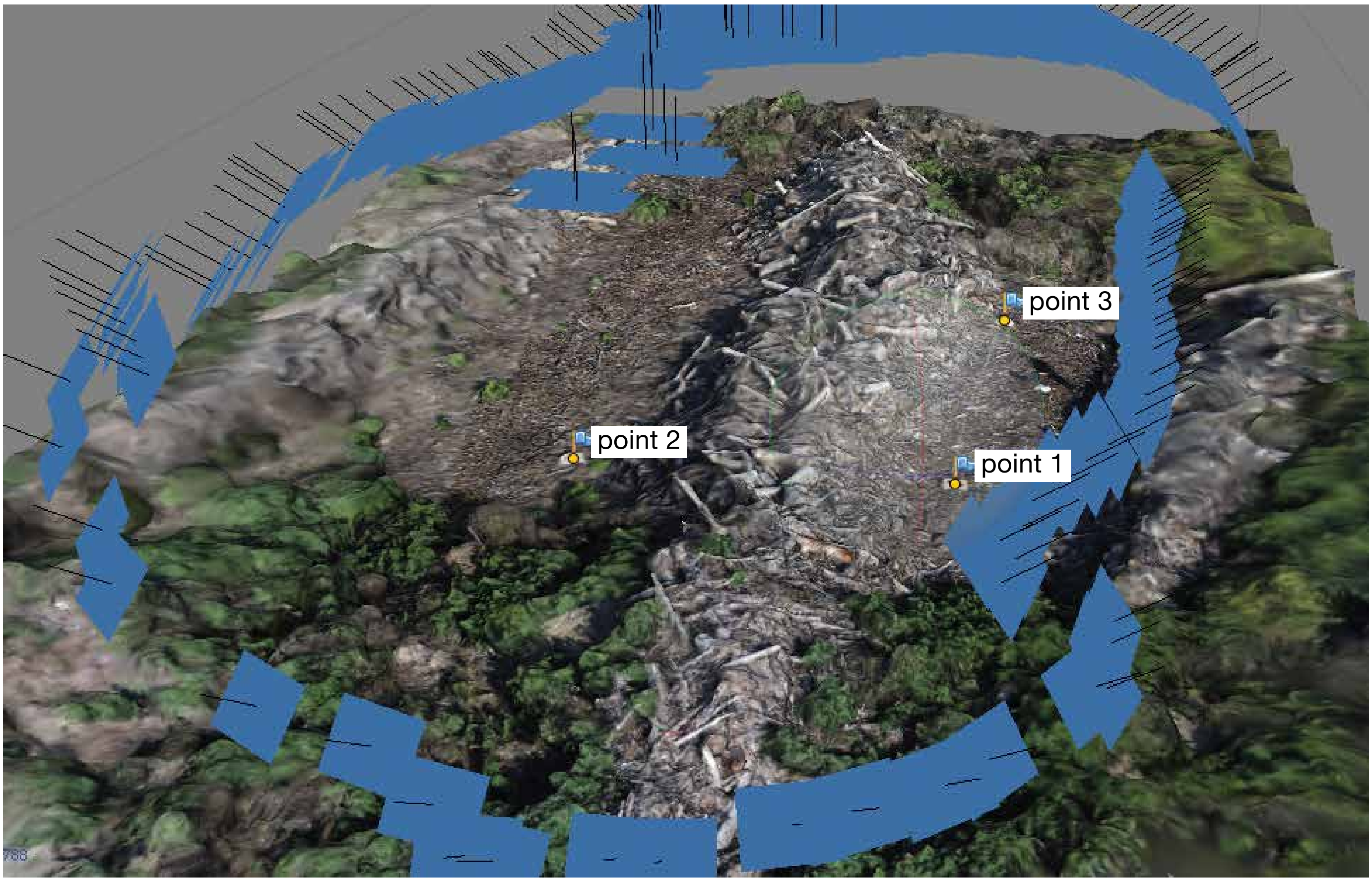


Figure 1: Orientation of imagery used in this study (blue rectangles) and the resulting model

Figure 2: Dense cloud output from Agisoft Metashape

The reliability of the volumes derived from the SfM process was assessed by comparing the volumes to those calculated by the geometric method. While the geometric method was expected to give volumes that were not accurate, the method is an accepted simplification without the aid of modern technology, given the complexity of residue pile shapes. The volumes obtained through the SfM process were expected to be generally lower than those derived through the geometric method.

Results

Nine harvest residue piles were imaged in total, with three models variants made of each pile. Of the 27 models, two failed to align the images (not enough matched points resulting in a failed model), and one model (using one-quarter of the total number of images captured for that pile) aligned in such a way that it was not possible to measure the volume. The remaining 24 models generated correctly, and all measurements were able to be collected from the models. Some

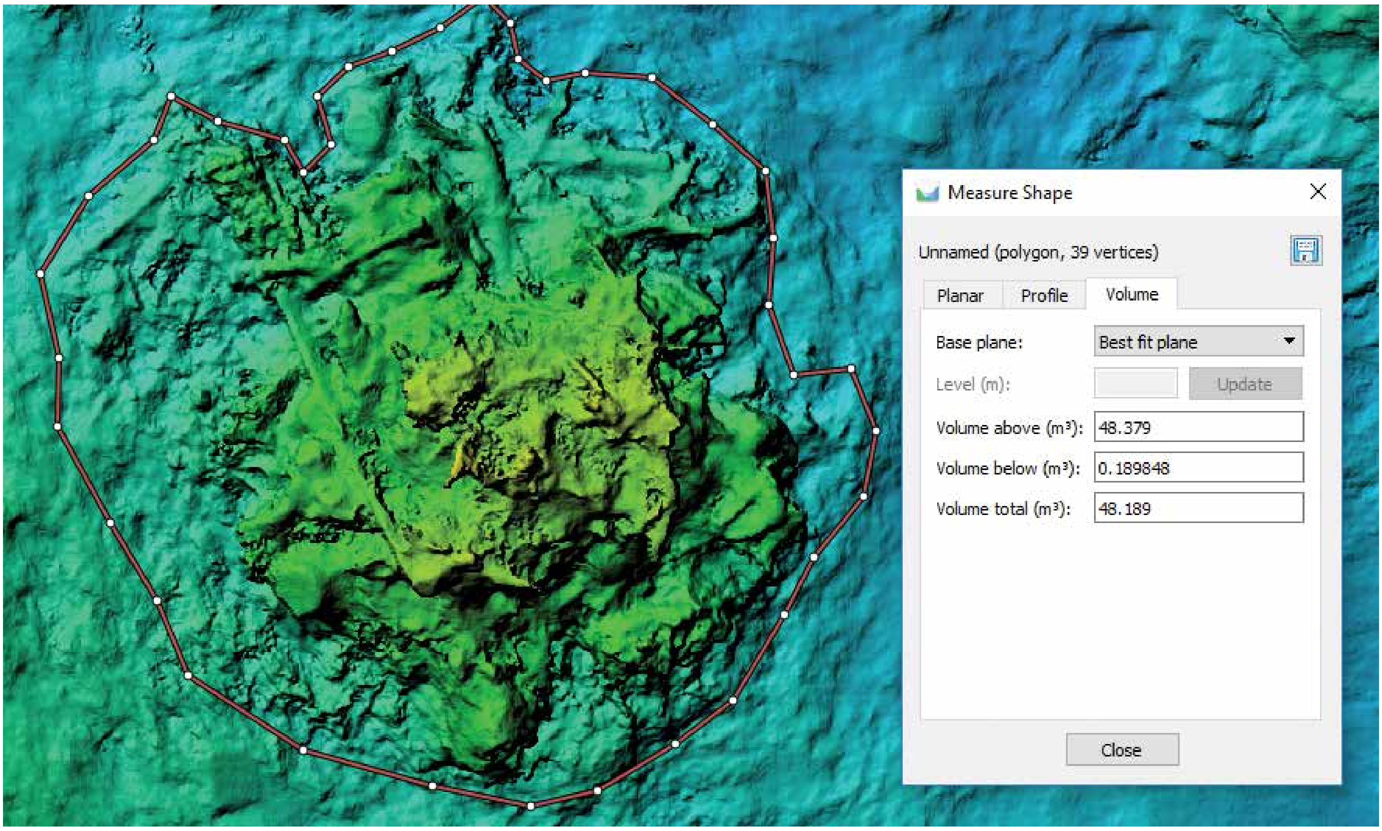


Figure 3: Volume measurement in Agisoft Metashape. The polygon outlining the pile is shown in red and the volume measurements are in the pop-up window to the right. 'Volume above' is taken as the volume of the pile

models, when created with one-quarter of the input images, returned error messages for images not aligned. However, this was only for one, two or three images in each case. These images were removed, and the alignment process was re-run, with the images aligning properly on the second attempt. Non-aligned images were typically of the very edge or the corner of a pile and tended to include more background than pile.

The piles were generally reproduced with reasonable quality. Many of the intricate features of the piles were captured, as evidenced in Figure 1. Individual logs on the surface of the pile can be clearly identified, with some even protruding from the pile, showing reasonable reconstruction of features. Details of length, width and height correlations, as well as the resolution of the DTMs, can be found in the original dissertation publication by the author (Riedinger, 2020).

Volumes obtained here have been through the geometric method or volume measurement from a SfM-derived DEM. The geometric method is generally not considered an accurate measure of pile volume, due to its approximation of the pile as a smooth solid. In this work, the geometric method was used as a basis volume measurement, to allow comparison. While it is not accurate, it provides a not-unreasonable estimate of volume and a 'common sense' method of checking the volume derived from the DEM.

Previous work by Long (2014) compared the geometric method to LiDAR-derived volume measurement. Figure 4 displays both Long's results and those obtained in this work. The graph also includes black lines indicating ±15% volume from the 1 to 1 line in the middle of the graph. This ±15% threshold was proposed by members of industry as to what might constitute a reasonable level of accuracy for volume measurements.

As the dimensions of the piles were preserved sufficiently well in the modelling process, it suggests that the application of the geometric method is the likely cause for the variation observed in the means of the differences. This is reasonable to assume, due to the difficulty encountered estimating the height of the piles for the application of the geometric method. All piles were approximated with shapes which require a height

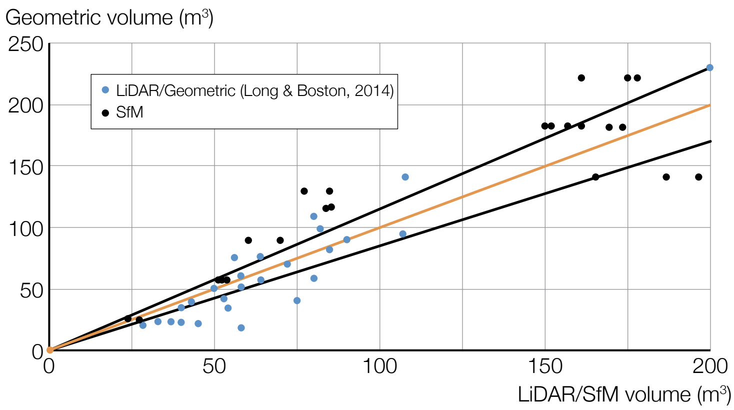


Figure 4: Pile volumes as determined by SfM (black) and LiDAR (blue) against the volume computed with the geometric method

measurement. This may have inflated the calculated volume of the piles, with a significant number of results appearing above the 1 to 1 line. This indicates a possible overestimation of volume from the geometric method, if the SfM volume is presumed to be more accurate. This was the case in 20 of 27 models, of which 24 volumes were measurable, resulting in 83% of geometric method volumes higher than the SfM volume.

The results obtained in this work are similar to those found by Long and Boston (2014) at low residue pile volumes. At large volumes, it is expected that the geometric method will produce inaccurate volumes that would tend to overestimate pile volume. This has been the case here, with three of the four large piles falling above the 1 to 1 line. Based on the good dimensional preservation, as discussed earlier, there is no reason to suspect that the increase in pile volume would lead to a decrease in the accuracy of the volume measurement. However, to fully check the validity of SfM derived volumes, it would be necessary to complete a high accuracy survey of the pile(s) and/or collect LiDAR data.

Processing time was also studied also as industry stakeholders were concerned about how much management time the processes might require. The total processing time required by Agisoft Metashape was recorded for each model and is presented in Figure 5 against the number of images used in the model. The computer used for the study ran a 64-bit version of Windows 10 Enterprise with an Intel Core i7-6700 processor and NVIDIA GeForce GTX1050 Ti graphics card. The total processing time is calculated as the total time taken to match/align the imagery, and generate the depth map and dense cloud. The time taken to generate the DEM was omitted, as it was less than 30 seconds in all cases.

Processing time is highly dependent on the number of images used. This is to be expected, as more images result in a larger number of Tie Points, which in turn creates a higher resolution dense Point Cloud compared to using fewer images.

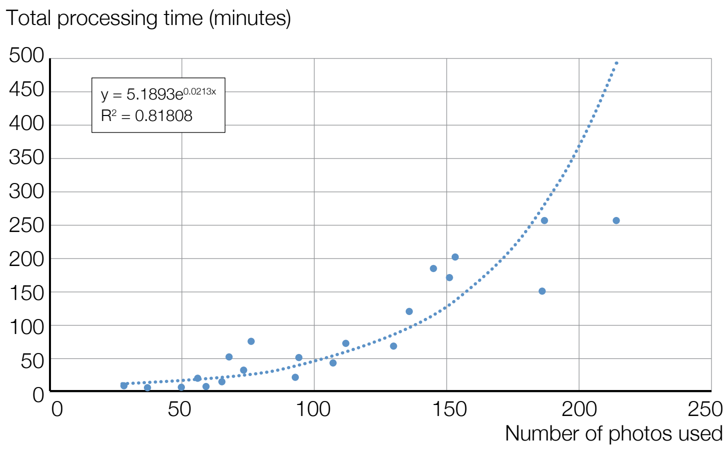


Figure 5: Effect of number of images used on the processing time required

Conclusions

This work has aimed to determine whether the SfM photogrammetry process, applied using basic methods, is a viable method for determining the volume of piled harvesting residues. Nine residue piles were surveyed, with three SfM models constructed of each pile to obtain 27 models. By measuring the length and width of the piles on-site with manual methods, and in the SfM model, it was concluded that the measurements of the piles were well preserved in the models.

SfM photogrammetry shows promise as being part of the solution for determining the bulk volume of harvest residue piles, especially where the pile shapes are complex. There is also potential for the SfM process to be used as a method for ongoing monitoring of harvest residue piles.

Using a similar process of modelling piles over time, even more accurate pile volumes may be measured using the original built landing surface as the datum surface. With enough pile volumes from harvest areas measured and compared against stand statistics, forest managers may be able to more reliably predict future pile volumes as a part of the harvest planning process.

The full process has several steps including image capture on-site, image retrieval, and model processing and measurement, which all require time. With the method employed in this study it would likely only be applied to high-risk residue piles or as a part of a focused residue volume study, due to the time required to obtain a model and a volume output. Cloud computing capabilities promise to cut down the time taken to build models, potentially only at the expense of freedom to adjust model parameters. Capital invested is not seen as a major concern as the UAV used is a consumer grade model and cloud computing services are available for building SfM models at a reasonable price.

References

Agisoft. 2019. *Agisoft Metashape User Manual: Professional Edition (1.5)*, 145. agisoft.com/pdf/metashape-pro_1_5_en.pdf

Bayne, K., Edwards, P. and Payn, T. 2019. Media Coverage of Recent New Zealand Storm Events. *New Zealand Journal of Forestry*, 64(1): 17.

Casella, E., Collin, A. and Harris, D. 2017. Mapping Coral Reefs Using Consumer-Grade Drones and Structure from Motion Photogrammetry Techniques. *Coral Reefs*, 36: 269–275. https://doi.org/10.1007/s00338-016-1522-0

Casella, E., Drechsel, J., Winter, C., Benninghoff, M. and Rovere, A. 2020. Accuracy of Sand Beach Topography Surveying by Drones and Photogrammetry. *Geo-Marine Letters*, 1–14.

Forsman, K. 2017. *Using Structure from Motion for Stockpile Inventory in the Forest Industry*. Second Cycle, A2E. Umeå: SLU, Dept. of Forest Resource Management.

Hall, P. 1993. Dismantling of Accumulations of Logging Residue Around Hauler Landings. *New Zealand Logging Industry Research Organisation Report*, 18: 6.

Hall, P. 1994. Waste Wood at Logging Landings. *New Zealand Logging Industry Research Organisation Report*, 19: 15.

Hall, P. 1998. Logging Residue at Landings. *New Zealand Journal of Forestry*, 43: 30–32.

Hall, P. 1999. Logging Residue Distribution. *New Zealand Logging Industry Research Organisation. Report*, 24: 9.

Hall, P. 2017. *Residual Biomass Fuel Projections for New Zealand – Indicative Availability by Region and Source*. Rotorua, NZ: Scion.

Hardy, C.C. 1996. *Guidelines for Estimating Volume, Biomass, and Smoke Production for Piled Slash*. Retrieved from: https://play.google.com/books/reader?id=zgGNPke5_JcC&hl=en&pg=GBS.PP1

Iglhaut, J., Cabo, C., Puliti, S., Piermattei, L., O'Connor, J. and Rosette, J. 2019. Structure From Motion Photogrammetry in Forestry: A Review. *Current Forestry Reports*, 5(3): 155–168.

Long, J.J. and Boston, K. 2014. An Evaluation of Alternative Measurement Techniques for Estimating the Volume of Logging Residues. *Forest Science*, 60(1): 200–204.

National Environmental Standards for Plantation Forestry. 2017. *Resource Management (National Environmental Standards for Plantation Forestry) Regulations 2017. LI 2017/174. M.f.P. Industries*. Online, New Zealand Parliamentary Counsel Office: 75.

NZ Forestry Owners Association (NZFOA). 2007. *New Zealand Environmental Code of Practice for Plantation Forestry (Vol. 1)*. Wellington, NZ: FITEC.

Sanz-Ablanedo, E., Chandler, J. H., Rodríguez-Pérez, J.R. and Ordóñez, C. 2018. Accuracy of Unmanned Aerial Vehicle (UAV) and SfM Photogrammetry Survey as a Function of the Number and Location of Ground Control Points Used. *Remote Sensing*, 10(10): 1606.

Spreitzer, G., Tunnicliffe, J. and Friedrich, H. 2020. Large Wood (LW) 3D Accumulation Mapping and Assessment Using Structure from Motion Photogrammetry in the Laboratory. *Journal of Hydrology*, 581: 124430.

Westoby, M.J., Brasington, J., Glasser, N.F., Hambrey, M. J. and Reynolds, J.M. 2012. 'Structure-from-Motion' Photogrammetry: A Low-Cost, Effective Tool for Geoscience Applications. *Geomorphology*, 179: 300–314.

Luke Riedinger was a final year Forest Engineering Honours student in 2020 and Campbell Harvey is a current PhD student at the School of Forestry, University of Canterbury in Christchurch. Corresponding author: lukeariedinger@gmail.com

The impact of recent climate on fire danger levels in New Zealand

Murray Dudfield, H. Grant Pearce and Geoff Cameron

Mt Cook Station – January 2008 fire

Abstract

Have changes in weather conditions impacted on the day-to-day management of fires in the New Zealand forest and rural landscape? The aim of this paper is to look at the impacts of climate over the past four to five decades and to use an assessment of past and present fire danger levels in New Zealand to assess what changes, if any, have occurred. The objective is to evaluate the question as to whether a change in the availability of fuel for combustion has taken place between the periods pre-2000 and 2000 to 2020. This study looked to analyse three key components of the daily outputs from the NZ Fire Danger Rating System (NZFDRS) for 15 representative fire weather stations located throughout New Zealand. These historical datasets range in length from 24 to 59 years. The results from this largely qualitative analysis show a trend that fuel availability for combustion prior to the year 2000 generally does not appear to have increased in the past 20 years. A general overall decrease in regional fire danger levels was seen for South Island stations, apart from a minimal increase for Queenstown. For the North Island, regional fire danger levels indicated no overall change, but a nominal increase for the Central North Island, Auckland, Whanganui and Northland. Despite these differences between regions and islands, this study shows that outputs from the NZFDRS indicate a marginal overall downward trend in fire danger levels across New Zealand for the past 20 years compared to the period prior to 2000.

Background

From a forest and rural fire standpoint, a fire danger rating system is the cornerstone for the day-to-day management of fire risk. These systems integrate the effects of weather and other fire environment factors, fuels and topography, to indicate the ease of ignition, rate of fire spread, difficulty of control and potential fire impact (Merrill & Alexander, 1987). Such systems provide a metric in the form of a fire danger rating or index(es) that can be used to support many daily operational decisions (such as suppression resource needs, alert levels, mobilisation and positioning), and longer-term strategic planning (e.g. defining burn prescriptions, justifying financial requirements, assessing future fire risk, etc). Fire danger rating is a mature science with almost a century of research, development and applications behind it.

All fire danger rating systems have the common objective of obtaining a relatively simple and comparable measure of fuel flammability from day-to-day (Chandler et al., 1983). In this study, the tool available to assist in providing the evidence to determine whether the levels of fuel availability for combustion in New Zealand have changed or not over the past 60 years is the NZ Fire Danger Rating System (NZFDRS) (Anderson, 2005; Alexander, 2008).

The NZFDRS is a New Zealand branded version of the Canadian Forest Fire Danger Rating System (CFFDRS) (Stocks et al., 1989). The CFFDRS, or at least its major subsystem (the Fire Weather Index (FWI) System), is extensively used both nationally and internationally to aid operational wildland fire decision-making (Taylor & Alexander, 2006). The CFFDRS has undergone considerable development since its introduction in Canada in 1971. Today it is one of the most comprehensive and scientifically-based rural fire land management decision support systems in the world. The CFFDRS enables fire managers to predict fire behaviour in most of their major fuel types and it is used extensively for fire protection planning and operations. The system is modular, computer and manually-based, and can be used in other countries by incorporating additional fuel types, provided the underpinning research is done to validate or extend the relationships between observed fuel moisture and the fire danger ratings (Wagner, 1988; Fogarty, et al., 1998; Anderson & Anderson, 2009). The FWI System was introduced into New Zealand in 1980 following a review of the main fire danger rating systems available around the world at that time (Valentine, 1978), and has undergone only minor modifications for change of latitude and season (Alexander, 1992; NRFA & NZFRI, 1993). This was followed by the adoption of the broader CFFDRS, including the empirical approach to developing a Fire Behavior Prediction (FBP) System using experimental burns (Anderson, 2005, 2009; Pearce et al., 2012). In the NZFDRS, this allows the fire danger indices from the FWI System (Figure 1) to be supported by fire danger classes for three fuel types, i.e. forest, grassland and scrubland (Anderson, 2005; Alexander, 2008).

Figure 1 illustrates that the components of the FWI subsystem of the NZFDRS. Calculation of the components is based on consecutive daily observations of temperature, relative humidity, wind speed and 24-hour rainfall (Van Wagner, 1987). The six standard components provide numerical ratings of relative potential for vegetation fires.

For the purposes of the fire climate trend analysis undertaken here, three components from the FWI System were chosen. The Build Up Index (BUI), Drought Code (DC) and Initial Spread Index (ISI) referred to in Figure 1 are defined as:

- The BUI is a numeric rating of the total amount of fuel available for combustion. It combines the Duff Moisture Code (DMC) and the DC
- The DC is a numeric rating of the average moisture content of deep, compact organic layers within the forest floor. This code is a useful indicator of seasonal drought effects on forest fuels and the amount of smouldering in deep duff layers and large logs
- The ISI is a numerical rating of the expected rate of fire spread. It combines the effects of wind and the Fine Fuel Moisture Code (FFMC) on rate of spread without the influence of variable quantities of fuel.

The ISI, BUI and FWI are each designed to represent some aspect of fire behaviour after ignition has taken place. The FFMC, DMC and DC, on the other hand, represent fuel moisture in different size classes of fuels and should therefore be related to the ease of ignition and availability for combustion. None of the FWI System components says anything about the presence or level of activity of fire-starting agents, in other words, fire ignition risk. Any comparison between actual fire occurrences and the FWI System combines both flammability (i.e. the relative ease with which a substance ignites and sustains combustion) and risk of ignition. The FWI System components can measure flammability but cannot account for ignition risk.

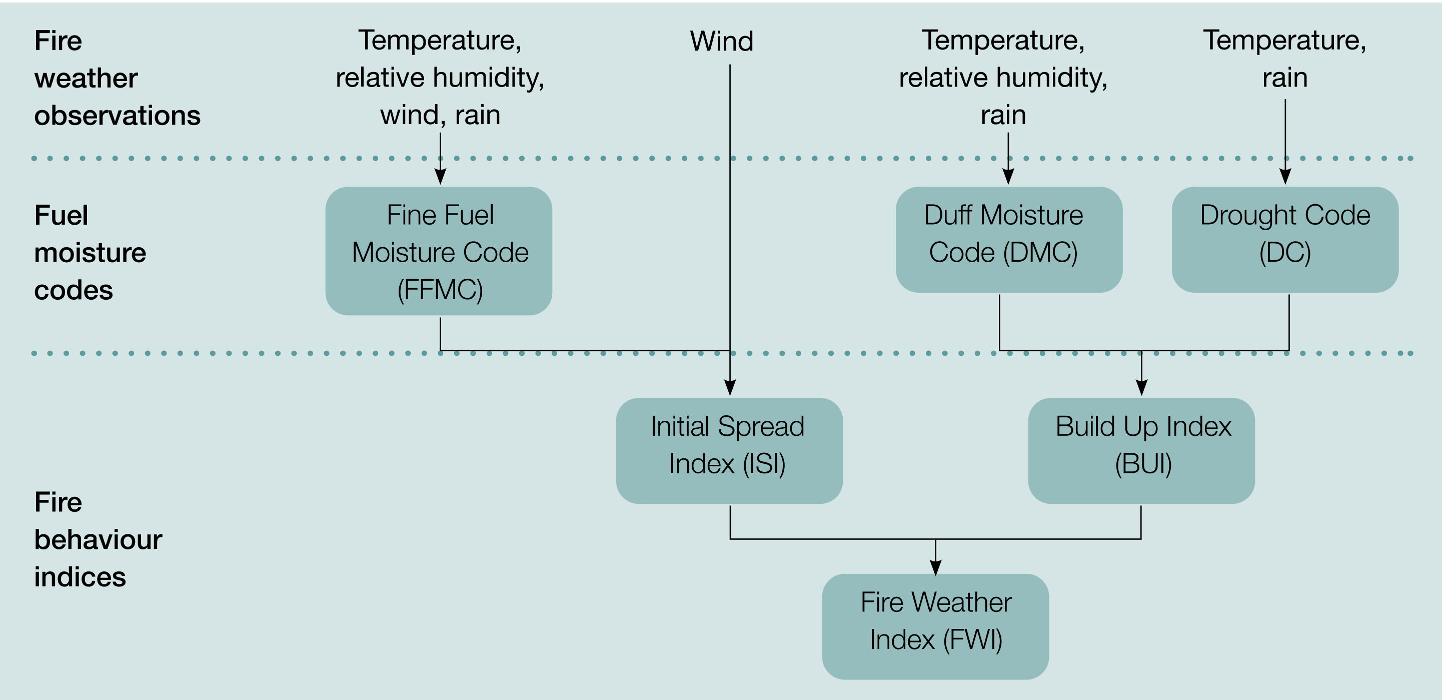


Figure 1: Inputs and outputs of the Fire Weather Index (FWI) System

Since a fire start depends most of all on the flammability of the fine surface fuel, the FFMC is the FWI System component most likely to compare well with vegetation fire occurrence. In addition, this paper has not considered whether there have been changes in fuel loadings in our forest and rural landscape over the past five decades.

The impacts of climate change on New Zealand and our environment is front and foremost in most people's minds. From a forest and rural fire perspective, is climate change already occurring, and has this had an impact on increasing periods of elevated fire danger, or is it leading to little change or even a reduction in fire danger levels for some parts of the country?

Fire danger level regional assessment methodology

This study uses daily climatology records from 15 weather stations located within different regions throughout New Zealand. Data was obtained from the Fire Weather System managed for Fire and Emergency New Zealand by the National Institute of Water and Atmospheric Research (NIWA), and records for discontinued Meteorological Service of NZ stations updated to June 2020 with synoptic data provided by MetService.

The study looked at two groups of fire danger indicators. These included:

- The monthly maximum BUI, DC and ISI values from historical datasets for the 15 weather stations ranging in length from 24 to 59 years. For stations with data available for more than 20 years prior to 2000, this was trended against the 20-year period following 2000. For those stations with historical indicators covering a 24-year period only, this data was split to compare two 12-year periods
- The number of days with DC greater than 300, BUI greater than 60 and ISI greater than 10 were identified, and a five-year rolling average was then applied to each station.

For the BUI and DC, most of the 15 weather stations selected took into account an extended length of available daily data, with 11 of the stations having daily data history ranging back more than 40 years. The analyses for each of the 15 weather stations involved nearly one million daily data records for the BUI, DC and ISI. The full datasets and detailed results for each station are available as supplementary data from both the NZ Institute of Forestry (www.nzif.org.nz) and Scion Rural Fire Research (www.scionresearch.com/rural-fire-research) websites. However the lack of ISI data history for the Napier, Masterton and Blenheim stations prior to 1996 meant the monthly maximum ISI data for this first part of the study covered only a period of 24 years.

The second part of the study took account of the number of days each year with values above recognised thresholds – for DC above 300, BUI above 60, and ISI above 10. For the 15 weather stations, the daily data history ranged from 24 to 59 years.

Mt Torlesse Station – research burn site in Canterbury 2008

To aid the simple assessment of overall changes from the historical trend period to current, one of five change categories was identified for each of the six indicators of change in fire danger values for each of the 15 stations:

- A notable increase in fire danger values
- A nominal increase
- No overall change
- A nominal decrease
- A notable decrease.

No formal statistical analysis was undertaken, and the difference between a 'notable' and 'nominal' change was based on a visual assessment of graphical comparisons of annual or monthly values for each station (e.g. see Figure 2 – Taupo and Figure 3 – Gisborne). For frequency of days above the identified threshold values, assessment of change was based on the slope of a line for the five-year moving average of annual frequency counts over each comparison period. For maximum values, assessment of change was based on the difference in maximum monthly values for each comparison period, with strength of change being based on the number of months values were above or below and the difference in maximum values.

Results

The high level-results of this assessment are outlined in Table 1. For the 90 fire danger indicators across the 15 weather stations, 68 (77%) of the indicators showed a no change to a nominal or notable decrease, versus 22 (23%) of the indicators showing a nominal to notable increase.

In fact, more stations showed decreases in fire dangers for the period since 2000 compared to the period prior to 2000, whether nominal or notable. Gisborne, Nelson, Blenheim and Christchurch mainly showed decreases, including many notable decreases, with Invercargill and Paraparaumu also showing no change or decreases. Only two stations (Taupo, Whanganui) showed notable increases, with significant increases for the number of days of DC >300 and maximum monthly BUI and DC values since 2000. The remaining stations showed more variable trends, with a mix of increases, decreases and/or no changes in fire danger indicators for the two comparison periods.

In general, increases occurred in the north (Kaitaia, Auckland) and central (Taupo, Whanganui) North Island, and also for Queenstown in the South Island. Decreases occurred on the East Coast of the North Island (Gisborne) and in the northern South Island (Nelson, Blenheim and Christchurch).

It should be noted, however, that even though Taupo and Whanganui showed notable increases for the number of days with BUI greater than 60 and DC greater than 300 during the period 1996–97 to 2019–20. Figure 4 shows that the annual number of days for Taupo and Whanganui do not regularly meet levels experienced at the Gisborne and Napier weather stations over that same 24-year period.

Discussion

A recent study by Meridian Energy (2019) could assist in understanding why there may have been a decrease in fuel availability to burn in the past 20 years compared to the period prior to 2000. If we look at the current and future impacts on fire weather in our forest and rural landscapes, especially in the South Island, a key component is annual rainfall trends. The Meridian Energy study has suggested that climate change may result in more rainfall impacting the West Coast and Southern Alps. In their May 2019 'Meridian Climate Change Impacts on NZ Renewable Electricity Generation to 2050' presentation to the Major Electricity User Group, they flagged that:

- An increase in air temperature of 1°C results in an 8% increase in the moisture carrying ability of the air
- Increasing wind speed (projected in coming decades) will enhance orographic uplift in the South Island in particular, enhancing both precipitation amounts and spillover over the Southern Alps and in the Waitaki, Clutha and Manapouri catchments (and likely others further north as well)
- For their modelling purposes, they estimated that each rain event would be 8% wetter by 2050.

The Ministry for the Environment (MfE, 2008) also previously stated that they expect annual mean rainfall out to 2040 to increase in the Tasman, West Coast, Otago, Southland and Chatham Islands regions. These areas are also likely to get more heavy downpours. Northeastern districts – Northland, Auckland, Gisborne and Hawke's Bay – are predicted to get less rain. Such an increase in rainfall, either as an increase in rain days or

Taupo Weather Station BUI

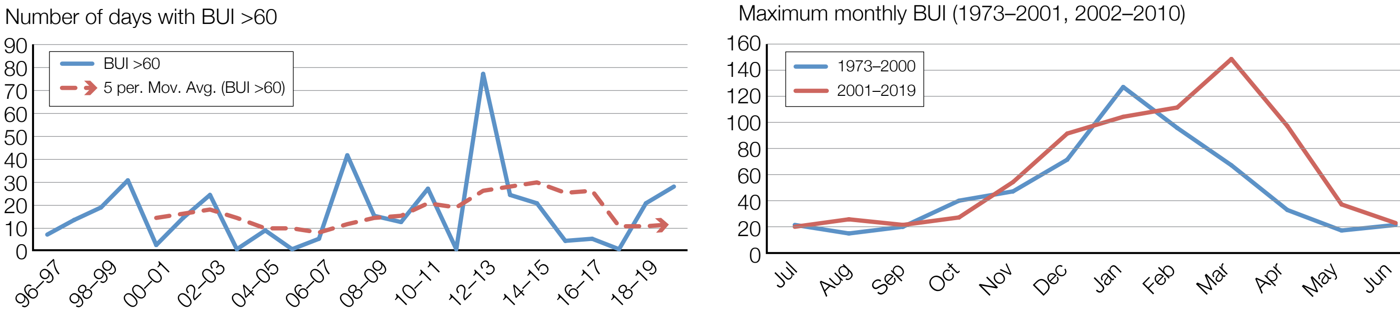


Figure 2: Example graphs for Build Up Index (BUI) from the Taupo weather station. Above left: Annual number of days with BUI values >60 for the period 1996–97 to 2019–20. Above right: Monthly maximum BUI values for the period 1973–2000 compared to 2001–2020. (In this case, the trends identified were 'No change' for days with BUI >60 and 'Notable increase' for monthly maximum BUI over the past 20 years when compared with the 27 years prior to 2000)

Gisborne Weather Station BUI

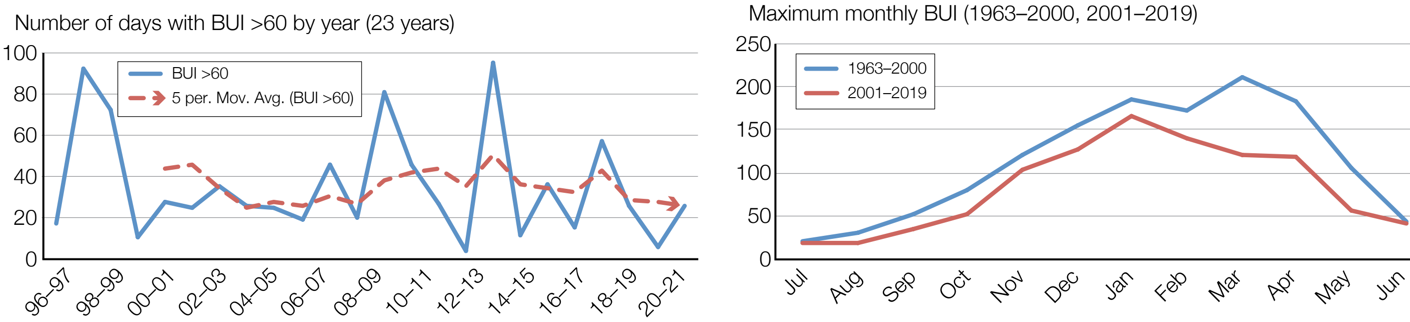


Figure 3: Example graphs for Build Up Index (BUI) from the Gisborne weather station. Above left: Annual number of days with BUI values >60 for the period 1996–97 to 2019–20. Above right: Monthly maximum BUI values for the period 1973–2000 compared to 2001–2020. (In this case, the trends identified were 'Nominal decrease' for days with BUI >60, and 'Notable decrease' for monthly maximum BUI over the past 20 years when compared with the 27 years prior to 2000)

in the amount associated with each rain event, would result in lower BUI and DC values in areas along and just east of the Southern Alps, such as seen here in this study for Nelson and Christchurch in the South Island. Predicted decreases in rainfall for northern areas would result in increased fire dangers, as also seen here for Kaitaia and Auckland. However, findings for Gisborne are at odds, with strongly decreased fire dangers shown here, compared to the increased levels expected under the MfE (2008) projections of reduced rainfall.

Similarly, a 2011 study by NIWA on 'Scenarios of Storminess and Regional Wind Extremes Under Climate Change' (Mullan et al., 2011) found that extreme winds are likely to increase over this century in almost all regions in winter, but decrease in summer, especially around Wellington and across the South Island. However, they also stated that the projected increase in wind speeds was not expected to be large, but just a few percent (i.e. <1 km/h) by the end of the century under a middle-of-the-range emissions scenario. The wind element has a strong impact on the daily ISI output value from the NZFDRS. The findings from this study are therefore supported by the NIWA predictions for similar or even reduced wind speeds for the first part of the century. This is because this study has shown that both the frequency of days with ISI above 10 and the maximum monthly ISI values over the past 20 years have not changed, and in fact in many cases have decreased compared with the period prior to the year 2000.

Short and longer-term climate drivers, such as sea-surface temperature changes around New Zealand and across the Pacific and Indian Oceans (including the Madden-Julian Oscillation, El Nino-Southern Oscillation (ENSO), Indian Ocean Dipole and Interdecadal Pacific Oscillation) also have a significant effect on atmospheric pressure patterns across the country (e.g. see NIWA, 2019), and therefore changes in weather and fire dangers. These changes over seasonal, interannual to decadal timescales are contributing to both increases and reductions in fire dangers in different parts of the

Table 1: Summary of changes in fire danger for 15 weather station locations across New Zealand

	Kaitaia	Auckl.	Gisbor.	Napier	Rotorua	Taupo	Whangan.	Parapar.	Mastert.	Nelson	Blenh.	Christch.	Queenst.	Dunedin	Invercar.
No. of years/ period:	59	54	24	24	24	24	24	24	24	24	24	24	41	55	58
Days of Build Up Index >60															
Days of Drought Code >300															
Days of Initial Spread Index >10															
No. of years/ period:	59	54	56	28	54	46	41	56	28	56	27	58	41	55	58
Maximum BUI by month for period															
Maximum DC by month for period															
Highest ISI per month for the period															

Key	Indicator spread
Notable increase	5
Nominal increase	17
Overall no change	34
Nominal decrease	16
Notable decrease	18
	90

Each colour generally shows the movement between the cluster of years prior to 1999 compared with the 2000 to 2020 cluster of years.

The BUI, DC and ISI referred to above are defined as:

1. The Build Up Index (BUI) is a numeric rating of the total amount of fuel available for combustion. It combines the Duff Moisture Code and the DC.
2. The Drought Code (DC) is a numeric rating of the average moisture content of deep, compact organic layers. This code is a useful indicator of seasonal drought effects on forest fuels and the amount of smouldering in deep duff layers and large logs.
3. Initial Spread Index (ISI) is a numerical rating of the expected rate of fire spread. It combines the effects of wind and FFMC on rate of spread without the influence of variable quantities of fuel.

country that may be masking increases in fire dangers due to the slower effects of climate change.

New Zealand's climate is also very diverse, with significant differences in fire climate severity due to microclimate effects associated with topography (Pearce & Clifford, 2008; Scion, 2011a, 2011b). Findings from this study are based on only a small subset of stations that have the long-term records required for such analyses. The analysis of trends in fire dangers is also based on a relatively simple, principally qualitative and non-statistical assessment only, and there is a need for more robust analyses of whether changes are occurring. To this end, work is currently underway to update long-term fire weather records (Pearce et al., 2003) for the wider set of weather stations across the country. This will provide a greater number of stations to undertake more formal statistical analyses of changes over time (e.g. Pearce & Whitmore, 2009), as well as comparisons between stations in the same regions (Pearce et al., 2011) and links to fire climate drivers such as ENSO and longer-term decadal variability (Heydenrych et al., 2001; Pearce et al., 2007), and fire occurrence data (Anderson et al., 2008).

Conclusions

The purpose of this study was to assess whether values of fire danger ratings that indicate the fuel availability to burn in forest and rural landscapes across New Zealand have increased over the past 20 years when compared with a similar period prior to 2000. The NZFDRS provides a sound scientific basis for answering this question, as well as supporting fire management decision-making. What has emerged is that the number of days with fuel available for combustion at an intense level – as indicated by elevated values of the BUI and DC components of the NZFDRS – has remained the same or actually reduced since 2000 for almost all of the weather station locations analysed. Similarly, indicators of increased fire spread potential (based on the ISI component of the NZFDRS) show even more widespread decreases. Along with the BUI and DC changes, this may be explained in part by changing wind patterns and associated increases in rainfall along the Southern Alps associated with natural seasonal climate variability, as well as longer-term climate change.

Based on this study, involving up to 60 years of weather data for a range of locations across the country, it will take a major swing in current weather patterns to suggest that the average annual frequency of elevated fire danger levels across New Zealand will increase dramatically over the next 20 to 40 years.

Acknowledgements

The authors would like to thank Fire and Emergency New Zealand for the use of data contained within the Fire Weather System. Provision of updated synoptic data from 2013 to 2020 for MetService stations by the Meteorological Service of NZ is also gratefully acknowledged.

References

Alexander, M.E. 1992. *Standard Specifications for Fire Weather Index System Computer Calculations*. Paper prepared for the 3rd Advisory Committee on Forest and Rural Fire Research held at the NZ Fire Service National Headquarters, Wellington, NZ, 21 October 1992.

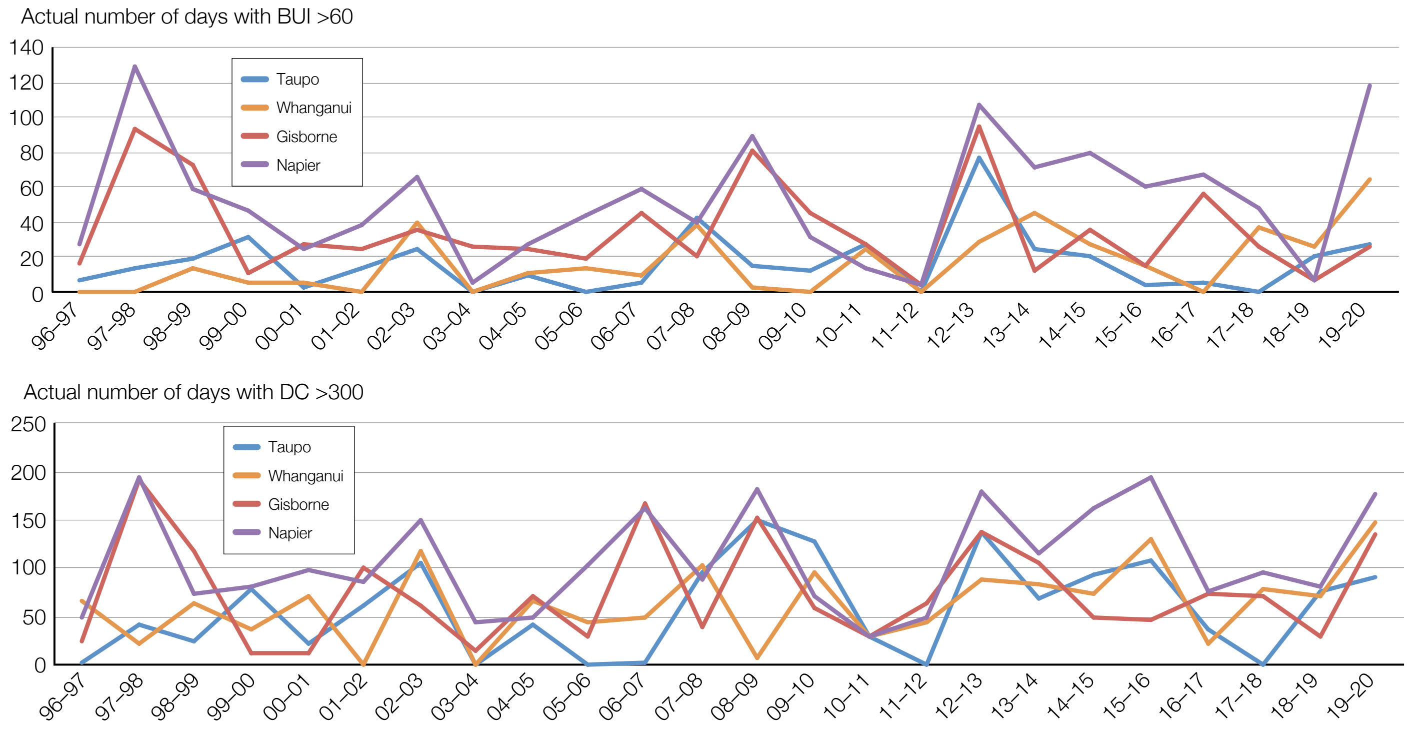


Figure 4: Comparison of annual number of days with BUI greater than 60 (top) and DC greater than 300 (bottom) for the Taupo, Whanganui, Gisborne and Napier stations

Alexander, M.E. 2008. *Proposed Revision of Fire Danger Class Criteria for Forest and Rural Areas in New Zealand* (2nd Ed.). National Rural Fire Authority, Wellington, NZ, in association with the Scion Rural Fire Research Group, Christchurch, NZ.

Anderson, S. 2005. Forest and Rural Fire Danger Rating in New Zealand. In Colley, M. (Ed.), *Forestry Handbook*. Christchurch, NZ: New Zealand Institute of Forestry.

Anderson, S.A.J. 2009. Future Options for Fire Behaviour Modelling and Fire Danger Rating in New Zealand. *Proceedings of the Royal Society of Queensland*, 115: 119–127.

Anderson, S.A.J. and Anderson, W.R. 2009. Predicting the Elevated Dead Fuel Moisture Content in Gorse (*Ulex europaeus L.*) Shrub Fuels. *Canadian Journal of Forest Research*, 39(12): 2355–2368.

Anderson, S.A.J., Doherty, J.J. and Pearce, H.G. 2008. Wildfires in New Zealand from 1991 to 2007. *New Zealand Journal of Forestry*, 53(3): 19–22.

Chandler, C.C., Cheney, P., Thomas, P., Trabaud, L. and Williams, P. 1983. *Fire in Forestry, Volume 1: Forest Fire Behavior and Effects*. New York, US: John Wiley and Sons.

Fogarty, L.G., Pearce, H.G., Catchpole, W.R. and Alexander, M.E. 1998. Adoption vs. Adaptation: Lessons from Applying the Canadian Forest Fire Danger Rating System in New Zealand. In Viegas, D.X. (Ed.), *Proceedings, 3rd International Conference on Forest Fire Research and 14th Fire and Forest Meteorology Conference*. Luso, Coimbra, Portugal, 16-20 November 1998.

Heydenrych, C., Salinger, J. and Renwick, J. 2001. Climate and Severe Fire Seasons: A Report on Climatic Factors Contributing to Severe Fire Seasons in New Zealand. *NZ Fire Service Commission Research Report No. 11*. Wellington, NZ: NZFSC.

Meridian Energy. 2019. *Meridian Climate Change Impacts on NZ Renewable Electricity Generation to 2050*. Presentation to the Major Electricity User Group, May 2019. Wellington, NZ: Meridian Energy.

Merrill, D.F., Alexander and M.E. (Eds.). 1987. Glossary of Forest Fire Management Terms (4th Ed.). *Publication NRCC No. 26516*. Ottawa: Ontario: National Research Council of Canada, Canadian Committee on Forest Fire Management.

Ministry for the Environment (MfE). 2008. *Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand* (2nd Ed.). Wellington, NZ: MfE.

Mullan, B., Carey-Smith, T., Griffith, G., and Sood, A. 2011. Scenarios of Storminess and Regional Wind Extremes Under Climate Change. *NIWA Client Report WLG2010-31*. Wellington, NZ: National Institute of Water and Atmospheric Research.

National Rural Fire Authority (NRFA) and New Zealand Forest Research Institute (NZFRI). 1993. *Fire Weather Index System Tables for New Zealand*. NRFA, Wellington, NZ, in association with NZFRI, Rotorua, NZ.

Pearce, H.G., Anderson, S.A.J. and Clifford, V.R. 2012. *A Manual for Predicting Fire Behaviour in New Zealand Fuels* (2nd Ed.). Christchurch, NZ: Scion Rural Fire Research Group.

Pearce, H.G. and Clifford, V. 2008. Fire Weather and Climate of New Zealand. *New Zealand Journal of Forestry*, 53(3): 13–18.

Pearce, H.G., Douglas, K.L. and Moore, J.R. 2003. A Fire Danger Climatology for New Zealand. *Fire Service Commission Research Report No. 39*. Wellington, NZ: NZFSC.

Pearce, H.G., Kerr, J., Clark, A., Mullan, B., Ackerley, D., Carey-Smith, T. and Yang, E. 2011. Improved Estimates of the Effect of Climate Change on NZ Fire Danger. *MAF Technical Paper No. 2011/13*. Wellington, NZ: Ministry of Agriculture & Forestry.

Pearce, H.G., Mullan, A.B., Salinger, M.J., Opperman, T.W., Woods, D. and Moore, J.R. 2005. Impact of Climate Change on Long-term Fire Danger. *NZ Fire Service Commission Research Report No. 50*. Wellington, NZ: NZFSC.

Pearce, H.G., Salinger, J. and Renwick, J. 2007. Impact of Climate Variability on Fire Danger. *NZ Fire Service Commission Research Report No. 72*. Wellington, NZ: NZFSC.

Pearce, H.G. and Whitmore, M.A. 2009. Analysis of Seasonal Trends in the Drought Code in New Zealand. *Scion Client Report No. 12788*. Christchurch, NZ: Scion Rural Fire Research Group.

Scion. 2011a. Future Fire Danger. *Rural Fire Research Update 9* (November 2011). Christchurch, NZ: Scion Rural Fire Research Group.

Scion. 2011b. *Fire Climate Severity. Rural Research Update 8 (July 2011)*. Christchurch, NZ: Scion Rural Fire Research Group.

Stocks, B.J., Alexander, M.E., Van Wagner, C.E., McAlpine, R.S., Lynham, T.J. and Dube, D.E. 1989. The Canadian Forest Fire Danger Rating System: An Overview. *Forestry Chronicle*, 65: 450–457.

Taylor, S.W. and Alexander, M.E. 2006. Science, Technology and Human Factors in Fire Danger Rating: The Canadian Experience. *International Journal of Wildland Fire*, 15(1): 121–135.

Valentine, J.M. 1978. Fire Danger Rating in New Zealand: Review and Evaluation. *Forest Establishment Report No. 123*. Rotorua, NZ: New Zealand Forest Service, Forest Research Institute.

Van Wagner, C.E. 1987. Development and Structure of the Canadian Forest Fire Weather Index System. *Forestry Technical Report 35*. Ottawa, Ontario: Canadian Forestry Service.

Van Wagner, C.E. 1988. *Note on the Use of the Canadian Forest Fire Weather Index System in Other Countries*. Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ontario. Unpublished filenote, April 1988.

Murray Dudfield is a Forest Fire Advisor and Chair of the NZIF Forest Fire Committee, H. Grant Pearce is with the Scion Rural Fire Research Group, and Geoff Cameron is a Forester and on the NZIF Forest Fire Committee. Corresponding author: murrayd@supermail.co.nz

Identifying post-harvest soil disturbance using satellite imagery

Jim Walsh and Rien Visser

Abstract

Minimising the overall level of soil disturbance during forest operations is a cornerstone of sustainable forest operations. Soil disturbance assessments are generally carried out using plots or line transects that are both labour-intensive and time-consuming, and hence currently rarely done except for research purposes. The increasing availability of higher resolution satellite imagery and improved image classification tools means there may be an opportunity to efficiently estimate soil disturbance as part of a performance assessment tool.

Seven harvest sites in the South Island were used to assess the accuracy of using satellite images for measuring soil disturbance. Satellite images obtained through *PlanetScope* were collected for each site (3 x 3 m resolution). The images were processed in ArcMap using two supervised classification tools: Maximum Likelihood Equation (MLE) and Support Machine Vector (SVM). Ground-truthing was carried out creating two lines of 15 points at 10 m intervals where land cover type was determined by visual inspection (e.g. bare soil, slash or vegetation).

The accuracy assessment compared classification methods and techniques. The supervised classification techniques were able to easily identify large disturbances (such as roads and skid sites), but struggled to pick up smaller disturbances due to the effects of 'mixed' pixels, where the pixels contain more than a single land cover class. The average overall agreement for MLE and SVM with the ground-truth measures was 64% and 65%, respectively. For best case scenarios, average overall agreement for MLE and SVM was 68% and 72%, respectively, confirming that the SVM classifier outperforms the MLE.

This project highlights that it is feasible to achieve realistic measures of soil disturbance from satellite images. Higher resolution imagery from daily satellite images, or drones and fixed-wing aircraft, presents an opportunity to increase the accuracy of the classifications.

Introduction

It is well known that vegetation, and in particular trees, improve slope stability and reduce erosion (Norris et al., 2008). Tree roots reinforce soil, making it stronger, and tree canopy keeps soil drier through interception and transpiration which also increases soil strength (Phillips et al., 2015). However, after harvest the loss of canopy cover exposes the soil to direct rainfall impact, increasing the amount of fluvial erosion. Exposed soil from forestry practices (such as earth works, movement of harvesting equipment, dragging logs across slopes and mechanical land preparation) have the potential to create erosion and sedimentation issues that do not meet the National Environmental Standards for Plantation Forestry (NES-PF) regulations.

Determining soil disturbance at forestry sites has been carried out using ground-based methods, including the Point Transect (PT) method, Line Transect (LT) method and Grid Point Intercept (GPI) method (McMahon, 1995). These are tried and tested methods that are well known and provide consistent results. Firth et al. (1984) combined aerial photographs with ground reconnaissance to assess site disturbance and found this method had several advantages over the ground-based methods (such as rapidly assessing large areas for deep disturbance). However, identifying less severe disturbance (and disturbance without a distinct colour difference) was difficult.

With soil disturbance from infrastructure, Petherick (2014) looked at the amount of long-term unproductive land as a proportion of the total harvest area. This unproductive area was classed as landings and permanent forestry roads (roads used for accessing skids, not skid trails) and the unproductive area averaged 4.8% of the total harvest area. This unproductive area was determined using satellite images and ArcGIS to measure the area of the skids and lengths of roads within the harvest area. The road lengths were then multiplied by a width, depending on the type of road, to get a total sum of unproductive area for skids and roads. A similar approach was used by Allum (Personal communication, 2020) to successfully ascertain the infrastructure levels in New Zealand woodlots. However, this direct measure method was not found to be suited to measuring soil disturbance in the cut-over.

Satellite imagery is a readily available resource, with around 95% of New Zealand being mapped and accessible through Land Information New Zealand (LINZ, 2020). While platforms such as Google Earth provide free satellite imagery, more detailed imagery can be obtained using drones, fixed-wing aircraft or satellites to help provide more current and/or higher resolution images. These images have many uses (such as determining land cover type or looking at land use change over time).

Images can be processed using a range of software programs, and the image classification is a very useful tool for determining the land cover type over large areas. Three of the main types of image classification are supervised, unsupervised and object-based image analysis (OBIA). Supervised classification uses training samples to classify the image, while the unsupervised classification finds spectral classes without the analyst's intervention. OBIA groups pixels into representative shapes with size and geometry. When using low spatial resolution, supervised classification outperforms unsupervised resolution. For high spatial resolution, OBIA is considered superior to traditional pixel-based classification (GISGeography, 2014).

The goal of this project is to investigate the opportunity of identifying soil disturbance using readily available satellite imagery for post-harvest assessments, and compare its accuracy against in-field classification of land cover.

Methods

The satellite constellation used for this study was *PlanetScope*, providing a pixel size of 3 x 3 m (from Planet.com). The multispectral sensors aboard the satellites collect information from different wavelengths. Unlike digital cameras, which are limited by visible wavelengths, it detects a much broader range of wavelengths not visible to the human eye (such as infrared and thermal). Information from each wavelength is stored as a separate image, commonly called a 'band' (Horning, 2004).

PlanetScope has four bands, which include red, blue and green (RGB), and a near infrared band (NIR). These bands when viewed alone are like a black and white photograph, and a user can combine the images from different wavelengths to create the desired colour image. The combination of bands can be used to highlight certain features within an image (such as vegetation, water or soil). The following list provides information on the first four bands (from Horning, 2004) and provides a generalised wavelength range and common uses for each band:

- **Band 1 (0.45–0.52 µm, blue-green):**
  This short wavelength penetrates better and is often used for aquatic ecosystems. It is used to monitor sediment in water, mapping coral reefs, and water depth. However, short wavelength blue light is scattered more than the other bands
- **Band 2 (0.52–0.60 µm, green):**
  Has similar qualities to band 1 but not as extreme, and was selected because it matches the wavelength for the green we see when looking at vegetation
- **Band 3 (0.63–0.69 µm, red):**
  Since vegetation absorbs nearly all red light (it is

Figure 1: Location of three harvest sites near Nelson

sometimes called the chlorophyll absorption band), this band can be useful for monitoring vegetation health, but also for distinguishing between vegetation and soil

- **Band 4 (0.76–0.90 µm, near infrared):** Since water absorbs nearly all light at this wavelength, water bodies appear very dark. This contrasts with bright reflectance for soil and vegetation, so it is a good band for defining the water/land interface.

A total of seven sites were analysed for this study. Three sites were from the Golden Downs area near Nelson and are managed by OneFortyOne (Figure 1) and ranged from 71 ha to 330 ha. All had been recently harvested, with some areas having undergone mechanical site preparation. Four Canterbury sites managed by Laurie Forestry, ranging in size from 2 ha to 10 ha, were also used. These four sites have all been mechanically prepped and recently planted.

The satellite images for each site were uploaded into ArcMap 10.7.1 and projected using the WGS84 coordinate system. Using the polygon tool on ArcMap, the harvest boundary of the harvest area was outlined. This allows for only the pixels within the harvest boundary to be processed.

Each harvest area was visited to create ground-truth plots using two separate lines of 15 points at 10 m spacing. The ground-truth plots were differentially corrected using the known location of a base station, individually correcting each point at the same time that point was created. At each point a visual inspection determined the major land cover type to be either bare soil or slash/vegetation for a 3 m radius around the point (Figure 2).

Slash was further broken down into five sub-classes: 1 being Light slash cover and 5 being Heavy slash cover. Figure 3 provides an example for some of the possible land cover types, and it shows a Light and Heavy slash example (1 and 5 on the scale range, respectively), as well as a Bare soil and a Vegetation example. The Light slash, Heavy slash and Vegetation are all classified as ‘Slash’, while the Bare soil is the only one classified as ‘Bare soil’.

Selecting appropriate training samples is the most important step in the image classification process as they are used to train the algorithms in the software. Training samples can be created for the two classes – either bare soil or slash and vegetation. This is done by zooming into sections of the image where each class can be easily identified (Figure 4). The training sample collection process is a matter of manual interpretation between the two classes where the location and size of the training sample comes down to the analyst’s interpretation.

When selecting training samples, they should be evenly spread over the site, aiming to cover the entire

Figure 2: Using GPS ground-truth land cover assessment

Figure 3: Example of land cover types used in this study

Figure 4: Comparison of training sample sets

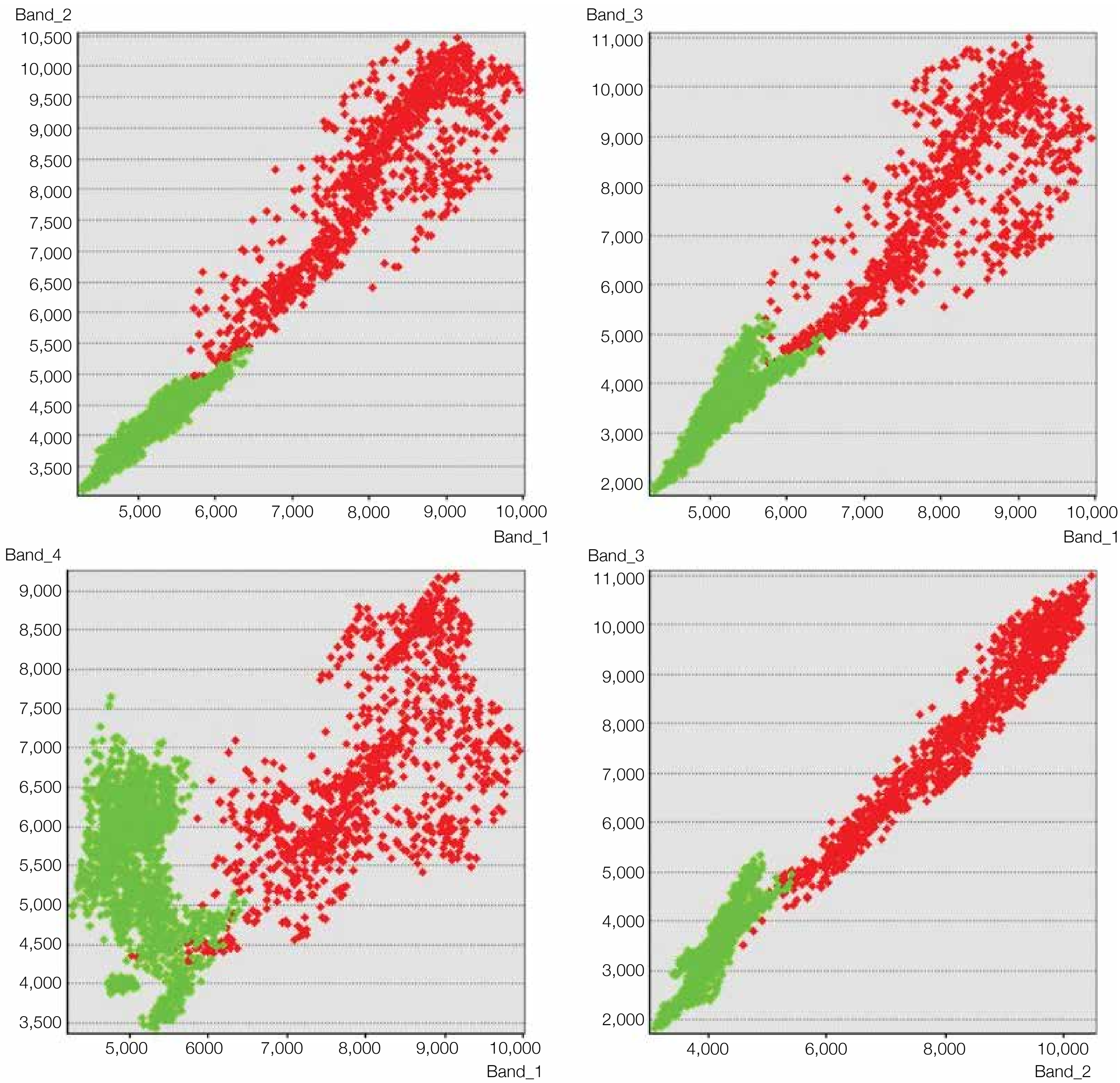


Figure 5: Scatter plots showing band range for bare soil (red) and slash (green)

spectral range and variability for each class. Training samples should not include pixels where the ground-truthing was carried out, as these points are later used to assess the accuracy of the classification tool.

Once the training samples have been created, they are evaluated to ensure they provide an accurate classification. This is done by displaying histograms, scatter plots and the statistics for the band ranges within the group of training samples (Figure 5). Each should be examined so that there is minimal overlap between classes. If there is overlap, this means some training samples need to be removed or re-done. This is an iterative process and is repeated until the user is happy with the training sample set.

Once a good set of training samples is attained, they are saved as a signature file. This signature file is then be used to create both an SVM classifier file and an MLE classifier file, and also to create the final classification for that set of training samples.

A confusion matrix was computed for each site, training sample size and classification method to help analyse the results. Each matrix includes errors of commission and omission, overall accuracy, and derives a Kappa index of agreement between the classified image and the ground-truth data. The Kappa index shows the level of accuracy relative to the simple random probability of getting it right. The errors of commission, known as the user's accuracy or type 1 error, are false positives where pixels are incorrectly classified. For example, the classified image identifies the pixel as bare soil when the ground-truth identifies it as slash.

The errors of omission known as the producer's accuracy, or type 2 error, are false negatives where pixels of a known class are classified as something else. For example, the classified image identifies a pixel as slash, but it should be bare soil. The overall accuracy of the classification is the total number of pixels that agree for all classes in the classification.

Results

Figure 6 provides an illustration of both the original image (left) and the SVM processed image (right). While roads and landings are readily identified, skid tracks and cut-over areas with higher levels of disturbance are also visible on the processed image. However, shading on the image can readily lead to errors of commission, as is readily visible on the south-west facing slopes on the eastern side of the site. These slopes are shown on the processed image as having high levels of exposed soil, yet on the original image no soil disturbance is visible.

Table 1 shows an example set of results when using the SMV classifier for the overall agreement and the Kappa index for the varying sample size. The numbers highlighted in yellow show the best results for each site, for each classifier, and at which training sample size it occurred.

For the larger Nelson sites, as the number of training samples increased so did the accuracy of the classification, while the smaller sites around Christchurch have the best results when only using five or 10 training samples. With the larger sites there is a higher chance that there will be more variability throughout the site, which will require more training samples. While the smaller sites required less samples to cover the variability throughout the site, more training samples increases the chance of mixed pixels being included when training the classifier.

Taking the average results for both overall agreement and Kappa index for all training sample sizes returns an overall agreement of 64% and Kappa index of 0.19 for the MLE classifier, and an overall agreement of 65% and Kappa index of 0.18 for the SVM classifier. The SVM classifier provides

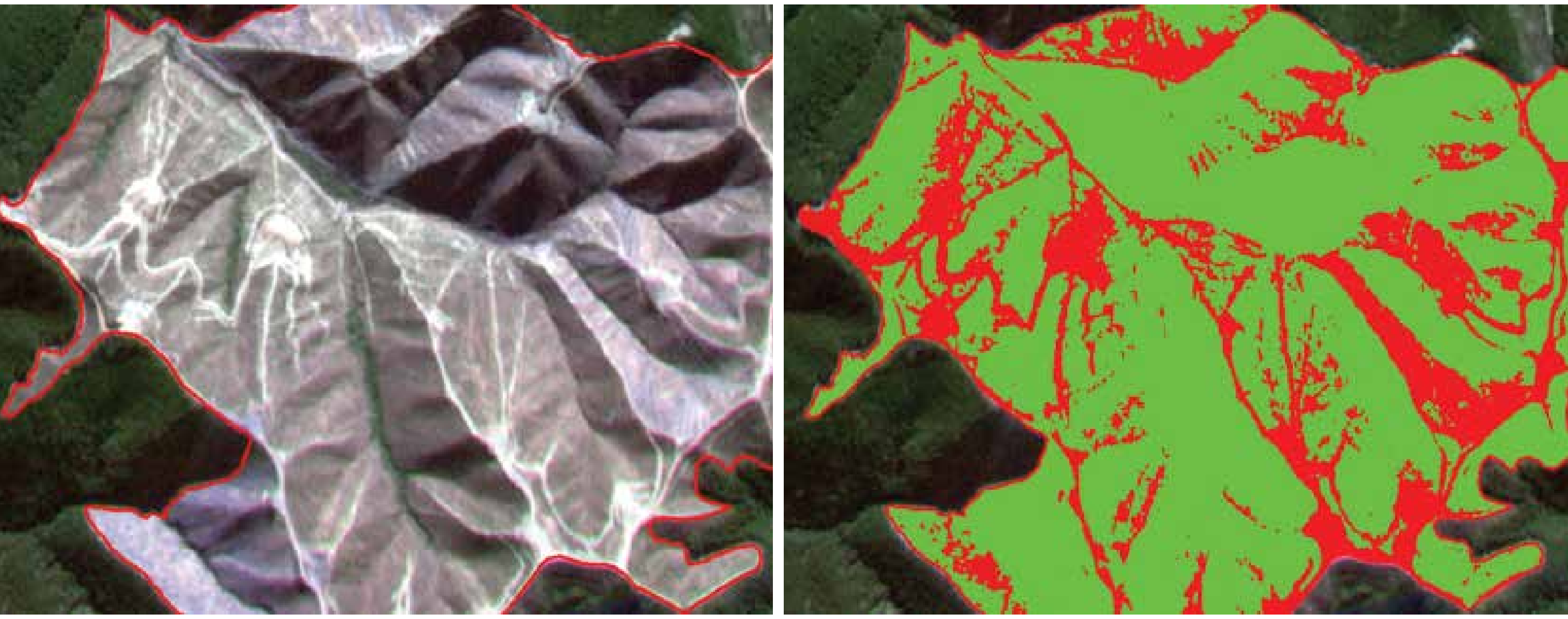


Figure 6: An original satellite image of a harvest site (on the left) and a classified satellite image using the SVM classifier (on the right)

Table 1: Overall accuracy level and Kappa index for SMV classification

		5 Samples		10 Samples		15 Samples		20 Samples	
SVM		**Overall**	**Kappa**	**Overall**	**Kappa**	**Overall**	**Kappa**	**Overall**	**Kappa**
Christchurch	Site 1	0.77	0.43	0.5	−0.03	0.67	0.25	0.57	0.11
	Site 2	0.77	0.44	0.73	0.39	0.77	0.39	0.77	0.39
	Site 3	0.57	0.18	0.6	0.23	0.57	0.2	0.53	0.15
	Site 4	0.53	−0.3	0.57	−0.15	0.57	−0.15	0.57	−0.27
Nelson	Site 1	0.57	0.18	0.53	0.06	0.37	−0.21	0.3	−0.34
	Site 2	0.57	0.02	0.87	0.27	0.97	0.65	0.97	0.65
	Site 3	0.73	−0.11	0.73	−0.11	0.77	0.1	0.63	−0.08

a more accurate classification than the MLE classifier in terms of overall accuracy and Kappa index when looking at the best case scenarios. It is also clear that the Christchurch sites are most accurate with smaller training sample sets compared to the larger Nelson sites.

Conclusion

This study aimed to determine if satellite images could be used in conjunction with supervised image classification to accurately identify bare soil on harvested sites. Overall, the two classification methods both have relatively high overall agreement with the ground-truth data. Both classification techniques easily pick up large disturbances (such as skids sites and roads), but struggle with smaller lighter disturbances where pixels contain some of both classes. For example, the pixel may be mainly disturbed, but also contain some heavy slash, which is called a 'mixed' pixel and can be difficult to classify, reducing the accuracy of the classification. Another factor affecting the accuracy of the classifications is shaded areas, as the shade changes the reflectance of the ground, resulting in the misclassification of pixels.

As higher resolution images become more readily available, it will make classifications more accurate by decreasing the pixel size. It will also increase the number of 'pure' pixels (pixels that contain only one class) and reduce the area of mixed pixels at the boundaries between classes.

Acknowledgements

We would like to thank Campbell Harvey and Stephan Hoffmann for their support, and special thanks to Mark Forward and Reihana Fisher for taking the time to assist with data collection. Also note that this project was completed by Jim Walsh within the scope of his final year dissertation at the School of Forestry. The full report can be downloaded from: https://forestengineering.org

References

Allum, 2020. Personal communication.

Firth, J., Van Dijk, W.A.J. and Murphy, G. 1985. *A Preliminary Study of Techniques for Estimating Harvesting-Related Soil Disturbances from Aerial Photographs*. Rotorua, NZ: Forest Research Institute, New Zealand Forest Service.

GISGeography. 2014. *Image Classification Techniques in Remote Sensing*. Retrieved from: https://gisgeography.com/image-classification-techniques-remote-sensing/

Horning, N. 2004. *Selecting the Appropriate Band Combination for an RGB Image Using Landsat Imagery Version 1.0*. American Museum of Natural History, Center for Biodiversity and Conservation. Retrieved from: http://biodiversityinformatics.amnh.org

Land Information NZ (LINZ). 2020. *Aerial Imagery*. Retrieved from: www.linz.govt.nz/data/linz-data/aerial-imagery

McMahon, S. 1995. Accuracy of Two Ground Survey Methods for Assessing Site Disturbance. *Journal of Forest Engineering*, 6(2): 27–33.

Norris, J.E., Stokes, A., Mickovski, S.B., Cammeraat, E., Van Beek, R., Nicoll, B.C. and Achim, A. (Eds.). 2008. *Slope Stability and Erosion Control: Ecotechnological Solutions*. Springer Science & Business Media.

Petherick, K. 2014. *Assessing the Level of Unproductive Area in Production Forestry Sites in the South Island of New Zealand*. Christchurch, NZ: Honours Dissertation, University of Canterbury.

Phillips, C., Marden, M. and Basher, L. 2015. Forests and Erosion Protection: Getting to the Root of the Matter. *New Zealand Journal of Forestry*, 60(2): 11–15.

Planet. 2020. *Planet Imagery Product Specifications*. Retrieved from: https://assets.planet.com/docs/Planet_Combined_Imagery_Product_Specs_letter_screen.pdf

Jim Walsh was a final year Forest Engineering Honours student in 2020 and Professor Rien Visser is Director of the Forest Engineering programme at the School of Forestry, University of Canterbury, Christchurch. Corresponding author: jwa214@uclive.ac.nz

Preliminary estimation of catchment capacity to develop debris flows and their runout distances using high resolution Digital Elevation Models (DEMs)

Mark Bloomberg and David Palmer

Abstract

Given recent occurrences of debris flow landslides from harvested forests in New Zealand, it is important to investigate the likelihood of debris flows from these sites. In this study, we examine simple methods for 1) identifying catchments where debris flows can initiate, and for those catchments 2) estimating the length of the debris flow runout zone. To do this, we use Ligar Bay (located on the north coast of the South Island, New Zealand) as a study area. In December 2011, Ligar Bay was subjected to a severe rainfall event, which led to devastating debris flows and associated debris floods. The effects of these debris flows were documented by GNS Science and their report is compared with the results of our analysis.

Introduction

A debris flow is a type of landslide that includes a combination of loose soil, rock, organic matter, air and water, all of which are mobilised and transported as a rapidly-moving slurry. On forestry clearfell sites, debris flows can mobilise not only rocks and soil, but also slash (harvesting residue) on slopes and in channels. These materials can 'run out' for long distances onto lowland environments, including river flood plains and the coast, where they end up on beaches (Phillips et al., 2016).

Through inundation and/or direct impact, debris flows can be a risk to both built and natural environments, as well as potentially causing injuries and loss of human life. Given the risks of debris flows from harvested forest sites it is important to investigate the likelihood of debris flows from these sites. In this study we examine 'desktop' methods for identifying catchments where debris flows can initiate, and for those catchments estimating the length of the runout of the debris flow.

To do this, we use Ligar Bay (located on the north coast of the South Island, New Zealand) as a study area. In December 2011, Ligar Bay was subjected to a severe rainfall event, which led to several devastating debris flows and associated debris floods. The effects of these debris flows were documented by GNS Science (Page et al., 2012) and their report provides a good baseline with which to compare the results of our analysis.

Background

Debris flows require a sufficiently large source of material (landslide debris), a source of water to saturate that debris, and a flow path that is steep enough to sustain the flow of saturated debris material (Kailey, 2013). Debris flow occurrence is therefore related to frequency and severity of landslides, which can be increased by predisposing factors such as deforestation.

The role of deforestation has specific relevance to New Zealand plantation forests, where forest canopy cover is completely removed by clearfelling on a 30-year cycle, as part of normal forest management. As a consequence, during the period after harvest when forest canopies and roots no longer provide protection from landslides, their occurrence increases substantially.

Debris floods ('hyperconcentrated flows') can also occur during debris flow events, or in other storm events where debris flows do not occur. Both debris flows and debris floods differ from normal flood flows in streams by having very high concentrations of suspended fine sediment (approximately 30% by weight; Davies, 1988), but only debris flows carry large boulders (Welsh & Davies, 2010). Peak flow rates of debris flows can be up to 50 times greater than ordinary flood flows (Page et al., 2012) because debris flows travel in surges, whereas debris floods do not surge but have peak flows two times greater than floods under equivalent conditions. These greater peak flows, and the much higher density of the debris flows/floods compared with ordinary floods, makes them more hazardous than ordinary floods under the same conditions.

Relevance of debris flows to NZ plantation forestry

Plantation forestry is an extensive land use, which profitably utilises land with limitations to agriculture in

A small debris flow originating from a clearfelling site in the Marlborough Sounds. Note that the debris flow has been able to transport debris originating from a mid-slope landslide right down to the coast and into the sea. Photo courtesy of Steve Urlich

terms of productivity, soil properties and topography. An important category of such limitations is soil erosion, and about 25% of New Zealand plantation forests are located on land that is highly susceptible to erosion.

For most of the forest rotation, the plantation forest mitigates landsliding on highly erosion-susceptible land, but after clearfell harvesting storm-triggered, post-harvest shallow landslides are likely to occur on such erosion-susceptible land. Where three factors (sufficient landslide debris, a source of water to saturate the debris, and a steep flow path) permit, debris flows may occur.

It is therefore essential for sustainable management of New Zealand plantation forests to identify catchments from which debris flows can initiate. In this study, we examine 'desktop' methods for identifying such catchments and estimating the potential length of the debris flow runout zone. This will allow forest managers and regulatory authorities to identify downslope fans and alluvial/coastal areas that are vulnerable to debris flows and floods.

Methods

Ideally, debris flow hazard would be inferred from detailed geomorphological data, coupled with mathematical modelling (Davies & McSaveney, 2008). However, this approach is costly in terms of time and money. In New Zealand, this cost precludes the wide use of such a detailed approach to investigating potential debris flow hazards in plantation forests.

Alternatively, the first step is to decide whether a specific catchment has the potential to initiate debris flows, but if it does not then no costly detailed investigations are needed. Where a catchment is identified as potentially able to initiate debris flows, the second step is to estimate 'runout' (i.e. how far a debris flow would travel downslope or downstream from the catchment). If the debris flow can travel beyond the steepland catchment where it originates and inundate lowland environments, then there is a clear need for more detailed investigations of the debris flow hazard. This is particularly so where high-value environments and/or human safety may be impacted.

Here we describe two simple methods for 1) estimating catchment capacity for debris flow initiation and 2) estimating debris flow runout distance. Rather than using detailed data or complex models, our methods are based on analysis of a Digital Elevation Model (DEM) using a Geographical Information System (GIS). The use of GIS means that catchments can be rapidly and cheaply classified on a desktop basis using existing DEMs.

Estimating catchment capability for debris flow initiation

Davies and Welsh (2010) developed a method for routine preliminary identification of potential debris flow catchments in New Zealand. The method uses the Melton ratio (R) and watershed length (WL) defined as:

$R = H_b/A_b^{0.5}$, where H_b is catchment relief (maximum minus minimum altitude in the catchment) and Ab is catchment area (Melton, 1965)

WL is the straight line distance between the points of maximum and minimum altitude in the catchment based on the model proposed by Wilford et al. (2004).

R and WL are indices of catchment steepness and size, two of the key factors identified by Welsh and Davies (2010) as predisposing debris flow occurrence. They classified Melton ratio values as follows:

$R \leq 0.30$	– the threshold below which conventional fluvial processes are generally dominant in a watershed
$0.30 < R < 0.60$	– the range for watersheds that are prone to debris floods
$R \geq 0.60$	– the threshold above which watersheds are prone to debris flows.

In addition, threshold classes were also defined for values of WL following Wilford et al. (2004):

WL≤2.7 km	– debris flows can occur in the watershed
WL>2.7 km	– conventional fluvial processes and/or debris floods are the dominant processes in the watershed.

Both R and WL can be calculated from existing DEMs, thus providing adequate discrimination of catchments that have the capacity to develop debris flows.

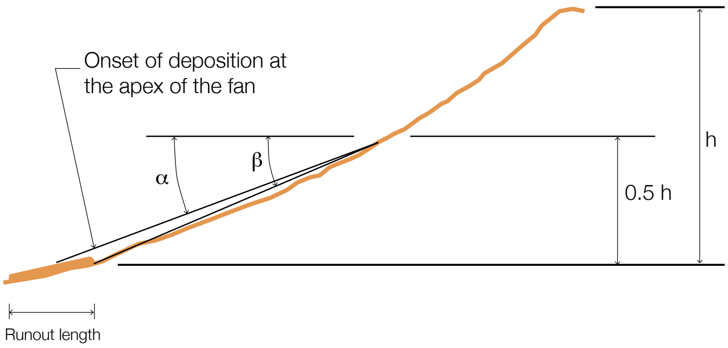


Figure 1: Angle of reach for a debris flow and its relationship to catchment profile. Source: Reprinted from Prochaska et al. (2008) with permission from Elsevier

Estimating debris flow runout distance onto fans

In this study, we used a simple method developed by Prochaska et al. (2008), which predicts the runout distance of a debris flow onto a fan, based on the angle (angle β in Figure 1) connecting the apex of a fan and the elevation half-way between this point and the drainage divide of the basin above it (= 0.5 h in Figure 1). The angle of reach (α) for the maximum extent of the debris flow runout beyond the fan apex was estimated as $\alpha = 0.88\beta$. A straight line projected downslope from 0.5 h at an angle α would intersect the fan surface at the point of maximum runout distance.

Although it seems simplistic, the method was tested and worked well for a variety of unobstructed, moderate-sized, non-volcanic debris flows in western North America over a range of ground covers and lithologies (Prochaska et al., 2008; Kailey, 2013). As with the Melton ratio, this method has the advantage that debris flow runout distances can be estimated directly from a DEM with no fieldwork or additional data requirements.

The study area

This study analysed debris flow occurrence and runout distances for a 1026 ha area between Tata Beach and Ligar Bay, northeast of Takaka township in the Tasman District (40° 49′ 13.3″S 172° 55′ 18.5″E) (Figure 2).

In December 2011, this study area was severely impacted by a high-intensity rainfall event that delivered 454 mm of rainfall over a 24-hour period (Page et al., 2012). The rainfall triggered severe landsliding and, in some catchments, debris flows and debris floods that caused about $10 million of property damage and posed a serious risk to human safety.

The upper catchments in the study area are underlain by Separation Point Granites (SPGs) (Page et al., 2012). SPGs are recognised as erodible and have a history of erosion and landsliding during high-intensity rainfall events, which occur frequently in Golden Bay and the adjoining Motueka Catchment.

The upper catchments in the study area comprise moderately steep (21–25°) and steep (26–35°) terrain. Altitude ranges from 20 m to 665 m above sea level (ASL). Below the steep hillslopes are gently sloping fans formed by the deposition of eroded sands, gravels and boulders transported from the steeper land upstream. These fans extend to the coastline over distances of 200–1000 m. The fans are traversed by a main public road and power reticulation. There are settlements scattered along the public road, and some parts of the fans have been developed for high-density housing.

After the December 2011 event, a detailed survey was made by GNS Science of landslide and debris flows triggered by the event, as well as the impacts on the downslope environment (Page et al., 2012). According to the GNS Science report, debris flows and/or debris floods occurred in eight catchments. However, in only three catchments did debris flows extend well beyond the apex of the upper fans and therefore pose a risk to human life and property downslope.

Geospatial analysis

In this study, Melton ratios and debris flow runouts were calculated for each catchment using a GIS to extract catchment morphological metrics from a DEM representing catchment terrain. Two DEMs were available from the LINZ Data Service:

- A 1 m cell size resolution DEM was accessed from the Tasman-Abel Tasman and Golden Bay LiDAR (Light Detection And Ranging) 1 m DEM (2016) – https://data.linz.govt.nz/layer/95578-tasman-abel-tasman-and-golden-bay-lidar-1m-dem-2016/

  LiDAR was captured for Tasman District Council by AAM New Zealand in December 2016. The datasets were generated by AAM New Zealand and their subcontractors.

- A second 8 m cell size resolution DEM was accessed from the New Zealand 8 m DEM (2012) – https://data.linz.govt.nz/layer/51768-nz-8m-digital-elevation-model-2012/

  This 8 m DEM was originally created by Geographx (http://geographx.co.nz) and was primarily derived from January 2012 LINZ Topo50 20 m contours (https://data.linz.govt.nz/layer/768).

There are advantages and disadvantages to using either DEM. GIS analysis of a 1 m cell size resolution DEM is computationally heavy (slow), and 1 m cell size resolution data is not available nationally but must be created from specially commissioned aerial LiDAR surveys.

Conversely, the 8 m cell size resolution is available nationally and is computationally easier to work with. However, the 8 m cell size resolution DEM was developed from 20 m contours, and therefore may only be representing the landscape at that resolution and at the time that the contour maps were photogrammetrically surveyed.

The coarser 8 m cell size resolution may not be critical when analysing steep catchments where the absolute error in the vertical plane and accuracy in relative gradient (slope) are less important. Therefore, the use of the 8 m cell size resolution DEM might be adequate for calculating the Melton ratio (R) for the steep upper catchments. However, in this study we also sought to measure debris flow runout distances on low-angle fans, where small errors in the estimation of slope could result in large errors in estimated runout distance. It should also be noted that the LINZ Data Service cautions that this 8 m cell size layer is 'suitable for cartographic visualisation only. It was created by the interpolation of 20 m contours with post-processing and filtering. It is not suitable for terrain analysis.'

For this reason, the analysis was performed using the 1 m cell size resolution DEM over most of the study area. Because the 1 m raster did not completely cover the upper terrain across the study area, the 8 m resolution data was resampled and merged with the 1 m raster to complete a small area in the southwest of the study area. Using GIS analysis of the 1 m cell size resolution DEM, we calculated Melton ratios and debris flow runout distances for all catchments to compare with observed occurrence of debris flows and floods in the December 2011 event.

First, the DEM rasters were masked to the catchment areas of interest, and an algorithm used to fill sinks, depressions and pits, resulting in a hydrologically sound DEM (i.e. water flows across the landscape from cell to cell without impediment).

The second step of the watershed and fan model was to develop a hydrologically sound catchment for each watershed. Stream and river channels across the entire fan and watershed surface were developed using the flow direction and flow accumulation commands and by setting an upper catchment threshold beyond which the stream stops. The filled DEM and the 'watershed' command in ArcGIS were used to develop each of the catchments across the area of interest, resulting in 23 catchments.

The third step was to develop the fan apex locations. This was achieved by intersecting the stream channel, the watershed and the fan, to provide the location at which the watershed opens out to the fan along the stream channel flow path.

Finally, for each of the 1 m cells along the flow path, elevation and the Euclidean distance from the fan apex (developed during the watershed delineation) were extracted. This provides us with both the watershed and the fan metrics from which we can calculate the Melton ratio and the runout length (as shown in Figure 2).

The GIS analysis was done using a Python script, which automatically calculates the Melton ratio and runout distances for each watershed and then outputs the results to a .csv file format.

Results

Figure 2 shows the catchment boundaries within the study area, delineated using the GIS analysis.

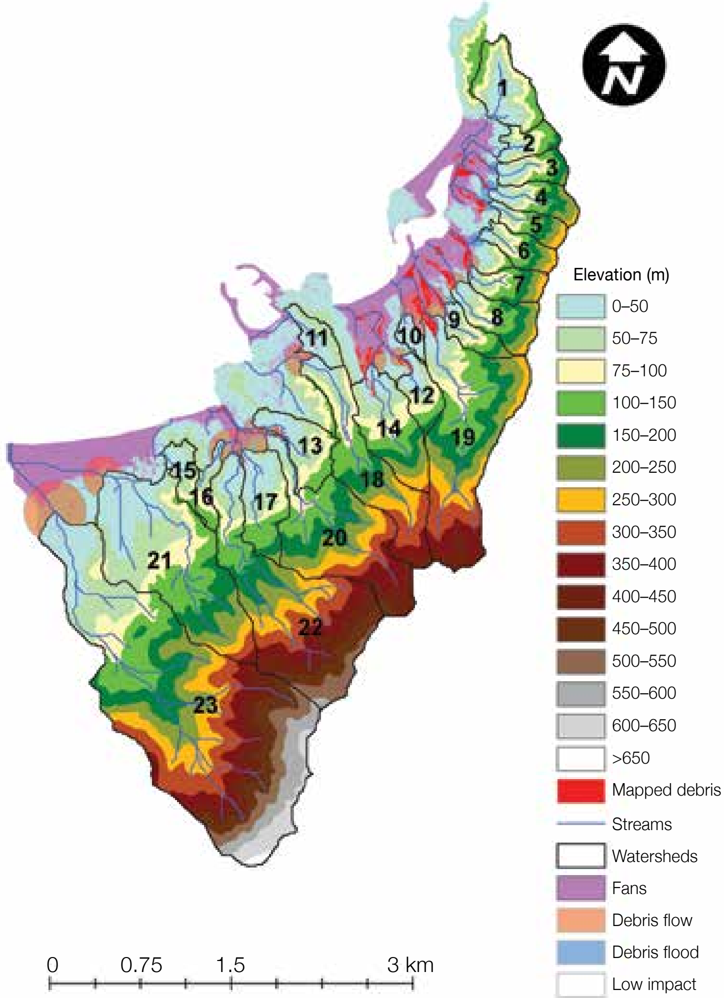


Figure 2: Catchment boundaries and mapped and estimated debris flow runout zones for the study area

Catchment sizes varied from small catchments (Catchments 1–17, areas ranging from 5–38 ha) in the northern end of the study area, to larger catchments in the southern end (Catchments 18–23, areas ranging from 56–276 ha).

Figure 2 also shows estimated debris flow runout distance for each catchment as the radius of a brown semi-circular arc from the fan apex. The GNS Science-mapped extent of debris deposition (debris flows and debris floods) is marked in bright red. Deposition in Catchments 1–9 resulted from debris floods. Debris flow/flood deposition in Catchment 19, which had the most significant impacts, is clearly shown.

Table 1 summarises catchment characteristics for the study area. Estimated Melton ratio (R) and runout distance were calculated using the methods described in this paper. The right-hand column shows the actual occurrence of debris flows ('Dflow') and debris floods ('Dflood') as reported by Page et al. (2012).

Discussion

While occurrences of debris flows and floods in 2011 were clearly related to R and WL, occurrence was not completely consistent with the thresholds proposed by Welsh and Davies (2010), as follows:

1. Welsh and Davies (2010) identify R>0.6 and 0.3<R<0.6 as thresholds for debris flow and debris flood occurrence, respectively. However, debris flows occurred at R~0.4 and above in the study area. In contrast, debris floods did not occur for catchments in the range 0.3<R<0.6, but were identified only in steeper but smaller catchments, with R = 0.6–0.77.
2. Wilford et al. (2004) and Welsh and Davies (2010) state that debris flows are unlikely in catchments longer than 2.7 km, although there are examples of longer catchments that have generated debris flows (e.g. Illgraben DF research catchment in Switzerland is 4.5 km long). In this study, most of the catchments were smaller than 2.7 km, but one of them (Catchment 23) was 3.38 km in length yet generated a significant debris flow in 2011.
3. At the same time, small catchments (<1,000 m in length and <30 ha in area) showed a distinct break at R = 0.5, with no debris flows or debris floods occurring below this threshold. This is not to say that these catchments are not capable of generating debris flows or floods. For debris flows and floods to occur, there needs to be a minimum volume of landslide debris. It may be that in the 2011 event, landslide volume was insufficient to generate debris flows in these smaller catchments, even though the catchment morphology (R) would have allowed a flow to initiate, given a sufficiently large volume of debris.
4. Also of interest was the occurrence of debris floods where R>0.6. One possible explanation is that these debris floods were associated with debris flows, but these were small and did not run out onto a downslope fan. Therefore, evidence that debris flows occurred may have been missed, since the associated debris floods would have reached further downstream.

Estimating runout distance

Unfortunately, specific runout distances for debris flow catchments were not mapped by GNS Science. Thus, it was not possible to compare estimated runout distances using the Prochaska method with observed runout distances.

However, catchments were classified into those where debris flows and/or debris floods occurred and those where none occurred. Those catchments that had debris flows in 2011 also had markedly longer estimated debris flow runout distances, while those that had debris floods had very small estimated runout distances. Interestingly, while most catchments that had no debris flows or debris floods had relatively low values for estimated runout, there were a few with estimated runout distances greater than 50 m – a longer distance than estimated for the catchments that generated debris floods. This reinforces the earlier point that smaller catchments did not generate debris flows or floods, even though they were steep enough to do so. Thus, the observed lack of debris flows and floods in one event (2011) may not reflect the potential of small catchments to periodically generate debris flows.

Assessment of debris flow hazard

Page et al. (2012) assess the annual exceedance probability of at least one debris flow occurring downslope of the study area as 0.5% or 10% over 20 years and describe this as ‘unacceptably high.’ An approximate hierarchy of catchments for debris flow hazards was proposed (catchment numbers as in Figure 2):

- Most hazardous – Catchment 19
- Hazardous – Catchments 7, 8
- Least hazardous – Catchments 3–6, Catchment 9.

This hazard assessment can be compared with the R values and calculated runouts in this study. Catchment 19 is clearly hazardous. While its calculated R was only 0.4, its estimated runout distance is 200 m, extending well into an intensively developed fan.

Table 1: Catchment characteristics for the study area

Catchment no.	Area (ha)	WL (m)	Max. elevation (m)	R	Estimated runout (m)	Dflow/ Dflood
1	27.1	700	151	0.27	53	None
2	10.8	575	180	0.50	70	None
3	12.8	604	233	0.60	46	Dflood
4	16.2	763	281	0.65	56	Dflood
5	11.7	704	289	0.77	55	Dflood
6	13.9	684	289	0.73	49	Dflood
7	15.0	655	284	0.68	46	Dflow
8	22.2	832	282	0.55	70	Dflow
9	11.7	792	282	0.77	59	Dflood
10	5.0	464	74	0.30	24	None
11	11.1	650	81	0.23	45	No data
12	14.3	761	224	0.54	66	Dflow
13	22.6	728	155	0.29	79	None
14	38.2	1200	327	0.50	104	Dflow
15	10.4	712	129	0.37	85	None
16	8.1	740	129	0.41	35	None
17	28.6	1003	244	0.42	103	None
18	56.0	2005	425	0.53	126	Dflow
19	103.4	2175	425	0.40	200	Dflow
20	79.6	1907	484	0.52	157	Dflow
21	111.8	2021	426	0.39	160	Dflow
22	118.7	2271	567	0.50	177	Dflow
23	276.4	3385	665	0.39	249	Dflow

The hazards associated with Catchments 3–9 are less clear. While all catchments have a high R (0.6–0.77), they are small and estimated runout distances are short (46–70 m). In December 2011, all these catchments developed debris floods rather than debris flows.

The hazards for the large catchments in the southern part of the study area (Catchments 12, 14, 17–23) appear to be far more significant. These large catchments do not have particularly high R values (0.39–0.54), but all except one developed debris flows in 2011. Because of the size of the catchments, estimated runout lengths from the fan apex range from 103–249 m. Although many of the fans below these catchments are not intensively developed, this study suggests a serious hazard to the built and natural environments within the estimated runout distances.

Effect of DEM resolution

The geospatial models for this study were developed using a high resolution 1 m DEM, as we saw a need for accuracy in estimating slopes and therefore runout distances on fans. The studies by Welsh and Davies (2010) and Prochaska et al. (2008) used spatial information at a coarser resolution. Welsh and Davies (2010) used a 25 m DEM to estimate R for their study catchments. Prochaska et al. (2008) used topographic maps ranging in scale from 1:24,000–1:50,000 to analyse the morphology of their study catchments. Further work is needed to compare the estimates of R and debris flow runouts for catchments gained from analysing high resolution versus coarse resolution DEMs.

Conclusions

The study area has been a useful location to evaluate catchment capacity to develop debris flows and estimate their runout distances. The results of the 2012 GNS Science study were a good baseline to compare with estimated Melton ratios and calculated runout distances. However, debris flow runouts were not mapped after the December 2011 event, so that estimated runout distances cannot be compared with observed values. To truly test the use of the Melton ratio and Prochaska method as a screening tool for catchments with debris flow hazards, they need to be tested using data from studies where runout distances of debris flows were measured.

The study confirmed the practicality of processing high resolution DEMs to automatically generate R, WL and debris flow runout estimates. Since these automated estimates were generally consistent with the findings of the 2012 GNS Science report it is worth continuing the development of these geospatial methods. As high resolution DEMs become available widely on a regional basis, it will be possible to identify potential debris flow hazards with much greater accuracy and generate region-wide maps of potential debris flow hazard. Such maps would allow forest managers and regulatory authorities to focus further detailed studies and management effort on the areas where debris flow risks are greatest.

Acknowledgements

We gratefully acknowledge the contributions and support of Tim Davies (University of Canterbury), Steve Urlich (Lincoln University), Matt Oliver (Marlborough District Council), and Glenn Stevens and the late Bernard Simmonds (Tasman District Council). We also wish to acknowledge our extensive use of the data from the 2012 report on the Ligar Bay event, written by Mike Page and his colleagues at GNS Science.

References

Davies, T.R.H. 1988. *Debris Flow Surges – A Laboratory Investigation*. Mitteilung Nr 96, VAW, ETH-Zurich, Switzerland, 122.

Davies, T.R.H. and McSaveney, M.J. 2008. Principles of Sustainable Development on Fans. *Journal of Hydrology New Zealand*, 47: 43–65.

Kailey, P. 2013. *Debris Flows in New Zealand Alpine Catchments*. Christchurch, NZ: University of Canterbury.

Melton, M.A. 1965. The Geomorphic and Paleoclimatic Significance of Alluvial Deposits in Southern Arizona. *Journal of Geology*, 73: 1–38.

Page, M.J., Langridge, R.M., Stevens, G.J. and Jones, K.E. 2012. *The December 2011 Debris Flows in the Pohara-Ligar Bay Area, Golden Bay: Causes, Distribution, Future Risks and Mitigation Options*. GNS Science Consultancy Report, 305.

Phillips, C., Marden, M., Basher, L. and Spencer, N. 2016. *Storm-Initiated Debris Flows and Plantation Forestry: Protocols for Monitoring and Post-Storm Data Capture*. Landcare Research report for Gisborne District Council LC 2607. Lincoln, NZ: Manaaki Whenua Landcare Research.

Prochaska, A.B., Santi, P.M., Higgins, J.D. and Cannon, S.H. 2008. Debris-Flow Runout Predictions Based on the Average Channel Slope (ACS). *Engineering Geology*, 98(1–2): 29–40.

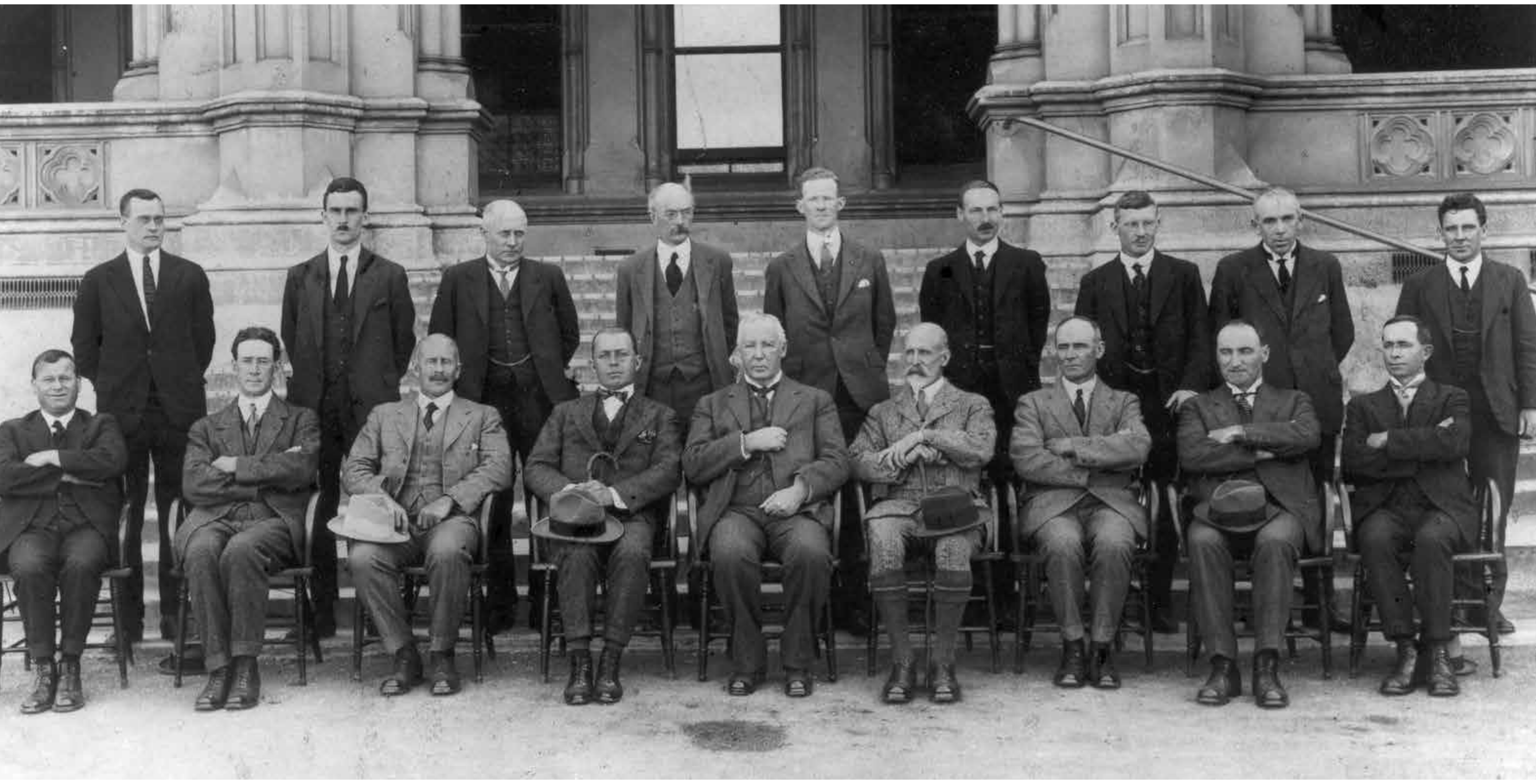
Welsh, A. and Davies, T. 2010. Identification of Alluvial Fans Susceptible to Debris-Flow Hazards. *Landslides*, 8(2): 183–94.

Wilford, D.J., Sakal, M.E., Innes, J.L., Sidle, R.C. and Bergerud, W.A. 2004. Recognition of Debris Flow, Debris-Flood and Flood Hazard Through Watershed Morphometrics. *Landslides*, 1: 61–66.

Mark Bloomberg is Adjunct Senior Fellow at Te Kura Ngahere | The School of Forestry, University of Canterbury and David Palmer is Spatial Scientist at Scion Research based in Christchurch. Corresponding author: mark.bloomberg@canterbury.ac.nz

2021 – another New Zealand forestry centenary

Michael Roche



Sir Francis Bell, front centre, flanked by Ellis (left) and Phillips Turner (right) and the officers of the State Forest Service in 1921

Choose your anniversary

On 24 September 2019, the 100th anniversary of the establishment of the New Zealand Forest Service was marked at Parliament with speeches and presentations (Golding, 2019). A year before (in 2018) Te Uru Rākau Forestry New Zealand was established to 'strengthen and grow the forestry sector in New Zealand.' This in itself signals that the existence of state forestry agencies has not been unbroken, nor has their purpose been unchanging. Consider also the disestablishment of the New Zealand Forest Service in 1987 to make way for a Ministry of Forestry, a Department of Conservation and a Forestry Corporation (of which only the Department of Conservation remains in 2021).

In many ways 2019 was a good year to celebrate the 100th anniversary of forestry in New Zealand. It marks the point at which forestry was administratively separated from the Lands Department, with Edward Phillips Turner appointed as Chief Officer. In his first and only annual report he indicated that the position of Director of Forests had been advertised in North America and the UK and that the 1908 Forest Act remained deficient in many ways. By 1920, the Director's position had been filled and by 1921–22 a new Forests Act was in place.

Under this legislation a State Forest Service, replacing the short-lived Forest Department, came into being. Thus 2021, if rather hard on the heels of 2019, is another year in which the forestry sector can celebrate a centenary. Indeed, I would argue that in some ways 2021 marks a richer anniversary date. Whereas 1919 might be regarded as marking a beginning, 2021 coincides with the passage of a new Forestry Act, one that established the State Forest Service. Furthermore, it is the State Forest Service that managed the new tender system for standing indigenous forests and planned and implemented the 300,000 acre exotic afforestation boom in the mid-1920s. Many elements of state forestry in New Zealand carried on by the New Zealand Forest Service after 1949 can be sheeted back to the State Forest Service of 1921.

Origins of the State Forest Service

There were short-lived efforts to establish a Forestry Department in New Zealand in the 1870s and 1880s, but it was not until 1897 that a more enduring Forestry Branch of the Lands Department was set up in response to timber famine concerns raised at the 1896 Timber Conference. Despite its name, the branch was entirely concerned with afforestation activities, including some experiments with indigenous species. Official reports on the timber industry in 1905 and 1907 further raised the specter of a timber famine, which a Royal Commission on Forestry in 1913 put at 30 years hence, and they recommended (among other things) reserving forest land and expanding exotic afforestation efforts. WWI slowed progress, although Sir David Hutchins, a distinguished Imperial forester who reported on Australian forestry prior to being invited to New Zealand in 1915 to undertake similar investigations, kept forestry matters before officials and the public.

Phillips Turner was a surveyor by training, formerly Inspector of Scenic Reserves, an accomplished forest botanist, and effectively the sole self-taught advocate for scientific state forestry in the higher echelons of the public service. He had a powerful behind the scenes supporter in Sir James Wilson of Bulls, an influential farmer politician, and more publicly in Sir Francis Bell, a prominent lawyer, member of the Legislative Council and Prime Minister William Massey's senior ally. However, the scope of Bell's forestry concerns was originally limited to price and export controls. From 1918 to 1920, he had ministerial responsibility as the Commissioner of State Forests and ushered in the administrative independence of forestry from the Lands Department, laid out a new forest policy, and via the designation of provisional state forests moved large areas from Lands Department into Forest Service control.

Edward Phillips Turner, Secretary of Forests 1921–1928 and Director of Forests 1928–1932

A Director of Forests – Leon McIntosh Ellis

Among the recommendations of the Royal Commission on Forestry in 1913 was the appointment of a professionally qualified forester to head a new Forests Branch, then to be within the Lands Department. This measure was supported behind the scenes by Phillips Turner who also, having observed Hutchins at work in New Zealand, privately expressed the view that the appointee come from Australia or North America and not the British tropical forest services. There were 19 applicants.

The successful candidate was Leon McIntosh Ellis. Born in Canada in 1887, he had graduated in forestry from the University of Toronto, after which he worked in the forestry section of Canadian Pacific Railways. From 1916, he served in the Canadian forces, mostly with the Canadian Forestry Corps, rising to the rank of Captain (McKelvey, 1989). He remained in the UK post-war and was employed by the Board of Agriculture and the Forestry Commission. Ellis was interviewed in London for the Director's position by a panel comprised of Lord Lovat (chair), R.L. (Roy) Robinson (an Australian Rhodes Scholar and Oxford forestry graduate), both later to chair the British Forestry Commission, and A.G. Herbert (New Zealand High Commission). The other shortlisted candidate, A.A. Dunbar Brander, was unable to delay his return to India so withdrew at the last minute. He had a solid if unspectacular professional career in India, but it is difficult to imagine that he would have had Ellis' impact in New Zealand.

The Forest Service was in many ways fortunate to secure Ellis as its first Director. He possessed great energy and enthusiasm and fully believed in the forestry principles he had been taught by Bernhard Fernow in Toronto, which was reinforced by his time in France and more limited forestry experience in Britain. He was also only 33 when he arrived in New Zealand to head a new department, but this was not exceptional. The Dominions of the British Empire were generally slow to embrace forestry and qualified candidates were all comparatively young. Owen Jones arrived as chair of the

Victorian Forestry Commission in 1920 aged 32 with seven years' experience in Ceylon, and 31-year-old C.E. Lane Poole, with 10 years' experience in South Africa and Sierra Leone, took up the position of Conservator of Forests in Western Australia in 1916. However, Ellis was coming to a public service where there was limited appreciation of forestry and professional qualifications were often subordinated to 'seniority'.

Ellis' 1920 report on forest conditions in NZ

Arriving in 19 March 1920 and working quickly Ellis inspected the forests of the Dominion and prepared a report for Bell as Commissioner of State Forests, which provided a summary of the 'forest conditions' and also laid out a 'forest policy'. In this Ellis proposed:

1. An effective Forest Act
2. A Forest Service
3. A fund for forest development and demarcation
4. The administration and management of all the Crown forests and forest lands by the Forest Service
5. A progressive timber sale policy
6. Facilities for technical forestry education
7. State co-operation in private tree-growing
8. Administration and management of all scenic reserves, national parks, forest reserves, forested national and educational endowments, and forested Native lands by the Forest Service
9. A Forest Products Laboratory for research
10. A survey and inventory of the forests, forest resources, and soils
11. An economic survey of the timber industry, and
12. The administration and protection of the fish, bird and game resources by the Forest Service.

Of these, 8) and 12) proved unachievable, 3) and 7) were problematic, and 6) proved surprisingly vexed. Some of his recommendations reflected his previous experience in Canada and Great Britain, for example, 8) and 12). Of interest a century on are the organisational models he proposed for the new State Forest Service.

Ellis identified these three organisational models:

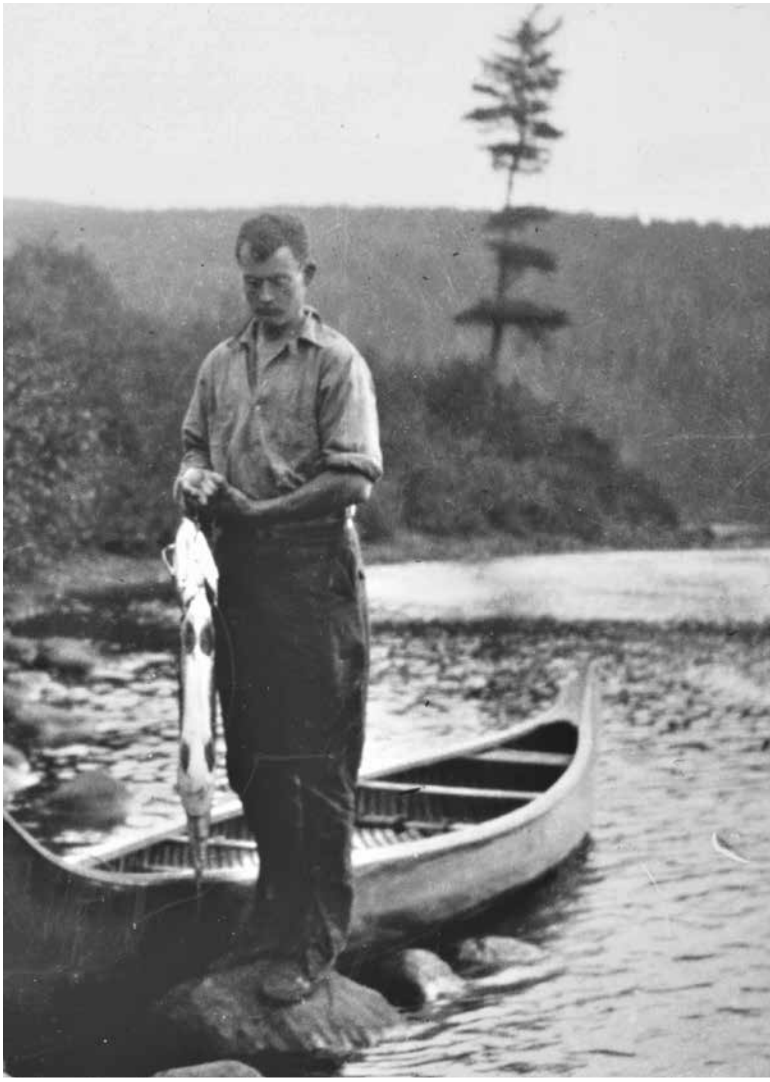
- The first model had four tiers. The Director was responsible to the Minister in Charge. Under the Director was an Advisory Forest Board and a Secretary (records, fiscal, office administration), below that and directly responsible to the Director was the Chief Inspector, and underneath that seven 'conservation regions' each had their own staff
- The second model involved the creation of a forestry commission to 'control and administer the execution of forest policy', manage state forests and function as the 'competent forest authority' (AJHR C3A, 1920, 26). The commission would comprise of the Minister, Director, Secretary of Forestry and representatives of the forest industry (he probably meant timber industry), consumers and labour. The Director would retain charge of all operations, with a Chief Inspector reporting directly to him and the Secretary retaining the administrative functions, as for the first model. Under these would be seven 'conservation regions' with their own staff
- The third model, adapted from that recommended by the Royal Commission on Forestry of 1913 was for an executive officer 'to be in complete control' (AJHR C3A, 1920, 26), but with an Advisory Board of experts, at least four in number.

Ellis' third model derived from the 1913 Royal Commission he included, perhaps strategically, to give a broader set of options, but there are subtle clues in his wording that he never entertained it as a serious alternative: 'an executive officer of approved administrative and financial ability to be in complete control' (AJHR C3A, 1920, 26). He himself did not meet these criteria, being unproven in the higher levels of public service administration. Besides, under this model forestry expertise was rendered almost incidental.

There is an echo here of the circumstances surrounding the restricted membership of the Royal Commission which included no foresters. Their Advisory Board proposal made some sense where there were enthusiasts but no experts, except for Sir Francis Bell, so it potentially represented a dilution of ministerial responsibility and control. Sir William Schlich, the doyen of Imperial forestry and Professor of Forestry at Oxford University, had earlier been critical of the Royal Commission's plan of an executive officer and an Advisory Board of experts. This opinion was available to local decision-makers, having been republished in the *New Zealand Journal of Science and Technology* in 1918:

> *This putting the cart before the horse; the arrangement should be the reverse. If justice is to be done to the work the executive head of the branch must be a high-class forestry expert, to be associated with an Advisory Board of, say, two officers of approved administrative ability. The board should be called together at stated times so as to bring the action of the executive officer into harmony with the general policy of the Lands Department*
>
> (Schlich, 1918, 203).

This left only two real options as far as Ellis was concerned. The forestry commission model, he observed, 'is working successfully in Great Britain, New Brunswick, several States of the United States, in Australia' (AJHR C3A, 1920, 26). Ellis himself had had some limited experience of the commission model in operation in Britain. In 1920, a forestry commission was set up in Victoria, chaired by Owen Jones, an Oxford trained forester. Suffice to say that Jones became disillusioned with the opposition that the commission faced from other government departments seeking to open land for settlement, with



Above left: Ellis, Kaingaroa c 1925. Right: Hansson studied forestry in his native Norway before working for Canadian pulp and paper companies, and completed a Master of Forestry degree at Yale before becoming Chief Inspector of Forests in the NZ State Forest Service in 1921

political criticism, and with the limited appreciation of the precepts and principles of scientific state forestry. So much so that in 1925 he came to New Zealand as forestry superintendent for New Zealand Perpetual Forests, the forerunner of New Zealand Forest Products. A case could be made that there would have been similar difficulties with a forestry commission model in New Zealand.

Ellis' first organisational plan was one that he observed had 'proven most successful' in France, Germany, Canada (including the Provinces of British Columbia and Quebec) and the US (AJHR C3A, 1920, 26). The Canadian scene would have been known to Ellis who also served in France in WWI. Further weight came from noting that Sir William Schlich had suggested a similar administrative structure for New Zealand. The point to note is that while Ellis may have later acted very boldly on afforestation, his recommendations for the organisation of the service were quite orthodox.

Ellis' recommendation was for the first model, not the forestry commission model, as in his view it secured 'a direct line of authority and responsibility from the Minister through the Director, right down to the forest guard' (AJHR C3A, 1920, 27). Furthermore, in his view, it assured '*unity of control, direction, inspiration, and responsibility*' [italics in original] (AJHR C3A, 1920, 27). By implication, none of these might have prevailed under the commission model.

The model put forward by Ellis was accepted by Bell. It enabled him to combine Ellis' expertise with Phillips Turner's public service experience in a way that minimised any longer-term risk. Entrican (1996, 46), presented Bell and Ellis as complementing each other: Bell was 'a dour personality who spoke and acted with a grim conviction, Ellis was a colourful personality with great public appeal'; Bell was orthodox, Ellis unorthodox. There is something to this and Entrican was one of Ellis' first appointments in 1921, but Bell had relinquished his ministerial responsibilities for forestry in 1920 so the two did not work in tandem for long.

Perhaps more important is Bell's preference that Phillips Turner take the position of Secretary of Forestry, with Ellis being appointed directly by Cabinet on a three-year renewable contract. Phillips Turner was the most senior permanent officer in the service.

Essentially, he managed the administrative matters and day-to-day finances while Ellis was to develop and implement a forestry programme, with Arnold Hansson (as Chief Inspector) providing specialist technical assistance. This interlocking division of responsibilities was somewhat complicated. In practice, Hansson and Phillips Turner both saw themselves as second only to Ellis, but Bell specifically approved the plan.

Staffing

A new Forest Act came into law in 1921, which was another achievement for Ellis. Not that it was passed into law unaltered – clauses that would have designated unrevoked provisional state forests as permanent state forests were removed. The Act also provided for the establishment of a Forest Advisory Board to be comprised of State Forest Service and timber industry representatives and chaired by the Director of Forests. Ellis successfully delayed its establishment during his directorship – it would have made the implementation of controls over the timber industry more difficult and after 1928 there was little political will to invoke the clause.

In his first annual report dated 31 March 1921, Ellis laid out what had been accomplished. The State Forest Service now had 97 staff, 24 of these were at the Head Office in Wellington (of whom 12 had clerical responsibilities), and the rest were spread across seven 'forest conservation regions'. Of the latter, Rotorua (with 20 staff) and Canterbury-Otago (with 18) were the largest. Forest Ranger appointments were made for all regions, but financial difficulties delayed the appointment of Conservators to Wellington and Nelson-Marlborough. Ellis, and his Chief Inspector Arnold Hansson, possessed forestry qualifications. There were other specialist appointments such as Alex Entrican, a future Director of Forests (1939–1961) as Engineer in Forest Products, and Camille Malfroy as a milling expert.

Ellis also reported success in having the gradings and renumeration increased, but warned 'the state must be prepared – if it expects to have this high level [of performance] maintained – to pay for their devotion, loyalty, and efficiency just as commercial organizations must pay for it' (AJHR, 1921, C3, 3). This view was somewhat out of step with the ethos of the times. Ultimately, salary issues would be part of the reason why Ellis departed from the Director's position for the private sector in Australia in 1928.

Conclusion

Ellis' report on 'Forest Conditions in New Zealand' regularly employed italics for emphasis. For example, in discussing his 12-point plan of action he stated that the '*adoption of the principles involved should result in immediate increased forest revenue to the State*' (AJHR, 1920 C3A, 2). On the one hand, this shows his conviction, but on the other it was overly exuberant and not the dispassionate language of other government reports of the time. Newspaper reportage about Ellis' 1920 report was largely factual, but generally supportive, but one wonders if the heads of other government departments may have been a little dismissive of him – possibly to their cost.

Some elements of Ellis' original vision for state forestry were never to be achieved. National parks and scenic reserves remained beyond State Forest Service control. Bell himself considered that it was impossible to hold the ministerial responsibility for both scenery preservation and state forestry. Wildlife also remained with Internal Affairs, although deer culling would for a time be part of the Forest Service portfolio. Some of Ellis' other concerns about forest grazing and forest fires did not translate that closely into the New Zealand setting.

In retrospect, it is clear that backed by effective legislation, and with an appropriate organisational structure and high quality appointees (even if few in number but with vision and energy) and bolstered by technical expertise, the State Forest Service was still able to achieve much in a short span of years. The Great Depression was not the trigger for an expanded afforestation programme, although this belief remains in the popular domain. Today's circumstances may be different and more pressing, but the early decades of the State Forest Service are a reminder that challenges can be met. Te Uru Rākau Forestry New Zealand could do worse than also mark this anniversary in 2021.

References

Entrican, A.R. 1996. McIntosh Ellis Had Great Influence on New Zealand Forest Policy. *New Zealand Journal of Forestry*, 41(2): 46–47.

Golding, C. 2019. The New Zealand Forest Service 100-year Anniversary. *New Zealand Journal of Forestry*, 64(3): 43.

McKelvey, P. 1989. L. MacIntosh Ellis in France. *New Zealand Journal of Forestry*, 34(2): 15–18.

Report on Forest Conditions in New Zealand and Proposals for a New Zealand Forest Policy. 1920. *Appendices to the Journals the House of Representatives* C3A.

Schlich, W. 1918. Forestry in the Dominion of New Zealand. *New Zealand Journal of Science and Technology*, 1(4): 201–210.

State Forest Service Report for the Year ended 31st March 1921. 1921. *Appendices to the Journals the House of Representatives* C3.

Professor Michael Roche is based at the School of People, Environment and Planning at Massey University in Palmerston North. Email: m.m.roche@massey.ac.nz

School of Forestry update

Bruce Manley

School of Forestry numbers

We had another good enrolment of first-year students in 2020 with 33 first-year forestry science students and 15 first professional year forest engineering students. There were 32, 20 and 20 BForSc students in years 2, 3 and 4, respectively, and 12 and nine BE students in second and third Pro, respectively.

Graduating students have been finding plenty of jobs available in the post-COVID recovery, with both the domestic and export markets finishing the year strongly.

School of Forestry 50th anniversary

The School of Forestry 50th Anniversary Conference and Reunion, planned for 16–17 April 2020, had to be postponed. A decision on when to reschedule the event will be made once there is a clearer way forward. We are hoping to hold it at a time when the significant number of internationals who registered for it will be able to attend.

Meanwhile, FORSOC took the opportunity to present the School with a tōtara tree and a plaque to commemorate the occasion. In the words of Gracie Perkins, FORSOC committee member, the tree was planted to 'acknowledge how far as a school we have come, what we have done as professionals and students collectively to contribute to the forestry industry, and the future generations who shall reap the harvests or walk through our future forests.'

FORSOC president Erica Weblin presents to Head of School Professor Bruce Manley a plaque with the inscription: '*This plaque and a tōtara tree planted outside have been presented by FORSOC to the New Zealand School of Forestry | Te Kura Ngahere to commemorate 50 years of forestry education from 1970 to 2020*'

New staff member Dr Steve Pawson

Dr Stephen Pawson joined the School of Forestry in May 2020 as a Senior Lecturer in Forest Health and Biosecurity. He teaches a variety of courses both within the School, and more broadly at the university, with topics ranging from forest and insect biology to biosecurity. As UC's only specialist entomologist Steve is assisting other departments with ongoing projects in the School of Biological Sciences, Computer Science, and the Wireless Research Centre.

As part of his role within the School of Forestry, Steve has responsibility for the forest health component of the NZ Dryland Forest Initiative (NZDFI), and is currently supervising Leslie Mann who continues her work on the resistance and tolerance of various naturally durable eucalyptus species to defoliation by paropsine beetles. Identifying breeding lines of those that are least impacted by these serious defoliators is an important component of maximising the productivity of these alternative species.

Steve is currently advertising for a second PhD position that will investigate options to reduce paropsine beetle populations by creating landscapes favourable to existing predators, (e.g. the cleobora ladybird beetle). This exciting project is a collaboration with Dr Toni Withers from Scion who has extensive experience in biological control of eucalyptus defoliators.

In addition to the NZDFI programme, Steve is keen to develop a broader research programme at the interface of biosecurity and the natural and production forests of New Zealand. As part of this he has pulled together 30 academics from across the five colleges at UC to start a new transdisciplinary research cluster with a focus on biosecurity. This is an exciting initiative that you will no doubt hear more about in the future, but in essence it brings together different knowledge domains and disciplines from throughout the university to work on difficult biosecurity problems, including those related to forestry. As such, if you have a problem that is related to biosecurity (either at the risk assessment or pest management ends of the spectrum) he would love to hear from you.

Tōtara being planted outside the School of Forestry to commemorate the 50th anniversary. FORSOC president Erica Weblin is planting the tree while FORSOC committee member Gracie Perkins looks on

Ongoing Restoration Ambassador funding

Te Kura Ngahere | School of Forestry (through Professor David Norton) received funding from the Te Uru Rākau One Billion Trees Fund to establish the Restoration Ambassador programme in 2019–2020. This allowed us to employ Dr Adam Forbes, a PhD graduate from Te Kura Ngahere, to provide free and independent advice to farmers, iwi and others in rural Aotearoa New Zealand on how to do good ecological restoration and assistance with preparing applications to the One Billion Trees Fund to help fund this work. The focus of the first year's work was the Gisborne and Hawke's Bay Regions, where there is limited access to good restoration information, but Adam also provided advice to landowners from Whangaroa in Northland to Banks Peninsula in Canterbury, and the Chatham Islands.

The first year was very successful and Te Uru Rākau have now funded the School of Forestry for a second year (2020–2021), which is allowing us to continue to employ Adam on a part-time basis as well as a new full-time assistant Restoration Ambassador position. This additional funding will allow us to continue with the great work that Adam has started and also to expand our coverage in the South Island as well. The South Island-based role has been filled by UC School of Forestry Masters graduate Josh Foster. There has been huge interest from farmers needing advice on how to establish native forests on their land. Having two people in the role will mean more free and independent advice can be provided to farmers, iwi and others in rural New Zealand on how to carry out good quality, planned ecological restoration. This project continues the strong link between Te Kura Ngahere | School of Forestry and Te Uru Rākau.

Final year forestry class marae visit

One of the two capstone courses in the final year of the BForSc degree is Environmental Forestry (FORE447). This course provides an overview of the broader environmental and cultural issues associated with plantation forestry in Aotearoa New Zealand using the framework of the ecosystem services provided by plantation forestry. The course focuses on biodiversity conservation, soil and water conservation, and cultural services, as well as the policy frameworks within which ecosystem services are managed. A particular emphasis is placed on bicultural competence and confidence, as Māori are key players in Aotearoa New Zealand forestry as landowners, as managers and as a people to whom forests are an essential part of life.

As part of this course, we try and organise a marae visit each year and this year we were fortunate to be able to visit Ōnuku Marae during Te Wiki o te Reo Māori (Māori Language Week). This marae is in

Restoration Ambassadors Adam Forbes (right) and Josh Foster (left) advise a farmer on native forest restoration

First-year forestry students help Nick Ledgard in the battle against wilding conifers

Final year BForSc students with Professor David Norton at Ōnuku Marae

a beautiful location on the shores of Akaroa Harbour and the manaakitanga (hospitality) we received was outstanding. The visit was a great opportunity for the class to discuss and reflect on a wide range of issues around Te Ao Māori (the Māori worldview of interconnectedness and interrelationship of all living and non-living things) and how these might relate to their future careers in forestry. We benefited greatly from the expert guidance of Carbon Te Aika (Kaiārahi Māori, Office of the AVC Māori, University of Canterbury) over the two days. On the way back to Christchurch we also visited Ōnawe Peninsula and had the chance to talk about some of the tragic events that happened there in the 19th century.

First-year field trip

In a normal year, all four year groups of forestry students go on a field trip during the April mid-semester break. In 2020, these had to be cancelled. As a partial substitute, a field trip to Craigieburn Basin was organised for first-year students by Associate Professor Justin Morgenroth. The field trip included:

- Case study of harvesting Douglas-fir on Mt Bruce with helicopter extraction
- Cass field station
- Craigieburn forest park – conservation and recreation value
- The impact of wilding conifers. Under Nick Ledgard's guidance, students pulled out hundreds of Douglas-fir and contorta pine seedlings.

Bruce Manley is Head of School and Professor of Forest Management at the School of Forestry at the University of Canterbury in Christchurch. Email: bruce.manley@canterbury.ac.nz

FISC update

Fiona Ewing

Ellis Silviculture Contracting crew in their 'office' at Autawa, Stratford, with Mt Taranaki in the background. Photo courtesy of Richard Stringfellow, Safetree Toroawhi

An extraordinary year

2020 was an extraordinary year. Many people might be happy to forget about it. But for forestry there were lessons learnt in 2020 that should be remembered and incorporated into how we work in 2021 and beyond.

Last year showed us that the risks to forestry posed by COVID-19 were not limited to the risk of people getting sick from the virus. The lockdowns and various COVID-19 alert levels had an economic impact that affected forestry companies, contractors, the industry's extended supply chain, and workers and their families.

One positive note during that period was the extraordinary way the sector got behind efforts by FISC to create all-of-industry guidance for working at various COVID-19 alert levels. That guidance was endorsed by WorkSafe and supported the industry to get back on its feet as quickly as possible when the alert levels began to drop, and in a way that helped protect business and people.

It was a great example of how health and safety can provide 'neutral ground' where people working in a highly competitive industry can work together on issues that affect the wellbeing of people, and ultimately of businesses.

While the market for New Zealand logs has recovered to pre-COVID levels, FISC is determined to remember and to draw on lessons learnt during COVID-19 for how we can support the industry in 2021 (and beyond).

In particular, FISC will be focusing on three areas that we believe can help forestry build safer, more resilient and profitable businesses. These areas are building capability (certification), strengthening engagement (our Toroawhi pilot), and developing leadership (the Forestry Charter and frontline leadership courses).

Building capability – contractor and worker certification

Our Contractor Certification programme is now almost three years old. So, we are reviewing it in 2021 to look at how we can improve it. The review will particularly focus on costs, improving the software that supports the programme, and the quality of customer service. It will also look at how we can add a 'stretch' element to certification for contractors who want to continuously improve their performance.

By the end of 2020, 250 contractors had become Safetree Certified, including 35 silviculture businesses. An additional 173 contractors are in the process of becoming certified.

Crew members attending a Safetree Leadership Course

The aim of the certification scheme is to promote ownership and leadership of health and safety in contracting businesses and to recognise the professionalism of these businesses:

- For contractors, certification demonstrates their professionalism to clients. It provides a benchmark that their health and safety systems can be assessed against and means everyone is held to the same standards
- For forest owners and managers, using certified contractors provides an assurance that the companies they have hired are competent to do the job
- For workers, the scheme will lead to improved health and safety and employment conditions.

The scheme was designed in consultation with the regulator, WorkSafe, and with extensive input from the industry. Certified contractors are added to a searchable register on the Safetree website.

During 2020 new certification modules were developed in response to feedback from contractors and FICA. An environmental module is now available to those being recertified. There are also health and business capability modules that will be developed further (along with any other suggestions) following a workshop we are holding in 2021 as part of the review of certification.

The health module recognises the legal requirement to protect both the health and safety of workers, and that healthy workers are less likely to be involved in incidents. This module is strongly linked to another FISC project, where we are working with Dr Tom Mulholland and his health and wellbeing KYND app. This project includes easy-to-understand health tailgate cards, which can be downloaded from the Safetree website.

The environment and business capability modules, while not strictly about health and safety, recognise that good business performance supports good health and safety.

Following requests from management companies, we also began testing a way for forest management companies to become certified. The first companies to go through this process were the Forest Management Group, for its three independent companies Forest Management (FML), Tasman Forest Management (TFM) and Forest Management North Island (FMNI), along with Logic Forest Solutions Ltd. NZ Forestry Ltd are close to completing the process.

By the end of 2020, 379 workers had become Safetree Certified: 316 tree fallers and 63 breaker outs. During the year we did a benchmarking exercise to look at improving the consistency of the application of the Safetree worker certification methodology across the industry, and developed electronic data collection.

This was further explored at a Certification Workshop in early 2021, with the goal to ensure we have a single, universally applied approach to certification used across the industry.

Strengthening engagement – Toroawhi pilot

WorkSafe has agreed to extend the pilot of Safetree's Toroawhi/worker engagement champions initiative for a further six months, to the end of June 2021. This extension was a welcome endorsement of the work our Toroawhi have done since they were appointed at the start of 2020, despite the challenges presented by COVID-19.

We know from experience that workplaces are safer, healthier and more productive when workers are involved in health and safety decisions. Our Toroawhi – Richard Stringfellow and Wade Brunt – were brought on board to support improved engagement. They are working with crews, forestry companies, communities and iwi. Richard is based in Taupo and covers the Central North Island, while Wade is based in Gisborne covering the Gisborne/Tairāwhiti region.

An independent assessment of their work in the first half of the year showed that despite the COVID-19 lockdown, Richard and Wade have managed to engage with a diverse group of stakeholders. Feedback is

250 – certification hit a new milestone at the end of 2020 when Inta-Wood Forestry Ltd became the 250th Safetree Certified Contractor and the 35th silviculture contractor to become certified

More crew members attending a Safetree Leadership Course

that these stakeholders appreciate the Toroawhi's independence, extensive industry knowledge, and ability to work with people at all levels, including new and young workers, and Māori. They enable a safe environment for people to open up and discuss sensitive issues.

The assessment suggested focus areas for the second part of the pilot, including more work with silviculture crews, more sharing of insights, and more engagement with iwi. These findings are encouraging and helpful, and we are looking forward to seeing what else our Toroawhi can achieve over the coming months of this pilot.

Developing leadership – leadership courses and safety charter

FISC has been working to develop frontline leadership through our Frontline Leadership and Team Up training.

Twelve of these frontline leadership courses, originally developed by The Learning Wave, have been run since July 2020 involving more than 120 workers. This brings the total number of workers who have been through this training to more than 500.

Course dates are being set for 2021 and details are available on the Safetree website. Locations will be confirmed based on expressions of interest.

These courses encourage people to look at health and safety differently – not as a 'tick box' exercise but as a way to develop leadership capability. They were created specifically for the forestry industry. The courses are very hands-on and help attendees learn how to:

- Lead a high-performance team focused on key results, including safety
- Effectively communicate with people who are different from themselves
- Get workers involved in solving problems and making good safety decisions
- Hold people to account without bullying
- Focus their teams on learning from things going right – not just waiting for things to go wrong.

During 2021, the existing FISC safety charter will also be reviewed.

The revised charter will seek a commitment from the industry to extend support for existing FISC work. There will also be a focus across the supply chain looking at contracts, employment standards and safety-in-design aspects. We would welcome any expressions of interest to be involved in this work.

Get in touch

FISC's success depends on the support of the industry and uptake by the industry of our initiatives. We appreciate the strong support the industry has shown to date and look forward to that continuing in 2021.

If you would like to get involved in our activities please get in touch:

- About the review of contractor certification, safety charter, or for more information on the leadership courses: info@safetree.nz
- With our Toroawhi: richard@safetree.nz (Central North Island region); wade@safetree.nz (Gisborne/Tairāwhiti region)

Fiona Ewing is National Safety Director of the Forest Industry Safety Council (FISC) based in Wellington. Email: fiona.ewing@fisc.org.nz

The dangers of invisibility

Jeremy Fleming

It has been my privilege to have worked in the forestry and seafood industries, two of our great primary industries. Combined they generate $8 billion in export earnings and employ 52,000 people in primary production and processing. Plantation forests are ubiquitous in our rural landscapes, most of us live in houses built from plantation grown timbers, an increasing number of us enjoy recreation in plantation forests, most of us have seen inshore fishing boats leaving and entering harbours around the country, and almost all of us enjoy fish and chips and seafood from the supermarket.

Why then are these two great industries largely invisible in our media unless things go wrong. Does invisibility matter? It is not as if this a new phenomenon or unique to forestry and commercial fishing.

Prima facie, decades of unbalanced, incorrect and deliberately misleading media (mainstream and social) coverage has had limited direct impact on the growth of both sectors. The pressure on legislators and industry generated by the cumulative impact of informed and uninformed commentary has, however, seen very significant changes in the way we operate. Examples that spring to mind include the almost complete cessation of all indigenous timber production since the passing of the Forests (West Coast Accord) Act 2020, the NZ Forest Accord of August 1991 that brought an end to conversion of indigenous forest to plantations, and the Fisheries Act 1996 which established New Zealand's world-leading fisheries management regime. More recent examples include the sweeping changes to environmental law described by Fowler and Buddle in issue 65(3): 2020 of this journal, and the introduction of a wide range of new electronic reporting and monitoring requirements for commercial fishers (see the *Digital Monitoring of Commercial Fishing* page of the Ministry for Primary Industries website).

By and large, changes in operating rules represent negotiated compromises arrived at either directly between interested parties or through our legislative processes. Successful negotiation, and hence liveable compromises, depend on good information and shared understanding of issues. Successful compromises cannot be built on misinformation or irreconcilable worldviews (the demise of industry-owned fisheries research partnership Trident Systems LP is a case in point).

Markets are often the arbitrator between differing views on the most appropriate use of resources. Market forces have, at different times, resulted in large areas of grazing land being converted to plantations and of plantations and sheep and beef farms being converted to dairy. Markets are not perfect. The availability of grants and tax write-offs encouraged conversion to plantations in the 1980s, and the right to discharge nitrogen and abstract water at no cost has had a strong bearing on dairy conversions.

Ecosystem services models are an attempt to bring rigour to valuing the benefits and costs generated by ecosystems and the production systems they support (see issue 61(4): 2017 of this journal for three excellent papers on the topic). In an ideal world all ecosystem services would be valued and the costs and benefits of service consumption imputed into land value to promote optimal land use, given the value society places on the services an ecosystem produces. The paper by Monge, Parker and Pizzirani identifying complementarities for the dairy and forest industries in the Central North Island in issue 61(4): 2017 of this journal is an example. Even if the practical problems of monetising ecosystem services could be addressed, the recent coverage of farmer objections to the conversion of sheep and beef farms to trees demonstrates how hard it is to overcome the urge to legislate when the monetisation of a previously free ecosystem service produces an answer we do not like.

In the absence of fully informed markets, we will continue to rely on regulation to resolve competition for access to resources and the services that ecosystems generate. Regulations should be based on well-informed compromise and not favour the loudest voice in the room. Persistent communication of facts and the continued development of tools such as ecosystem services models will help keep the debates balanced. Harnett and Payn in issue 65(3): 2020 of this journal has an excellent discussion of the communication challenge in a post-fact world. Most important of all, however, is that what we actually do on the ground and at sea that matters. No amount of good communication or sophisticated modelling will offset the damage done when we breach our own rules, standards and undertakings.

Email: jeremy.fleming@xtra.co.nz

NZIF FOUNDATION

Appeal for Funds



Please help us to help NZ Forestry?

The NZIF Foundation was established in 2011 to support forestry education, research and training through the provision of grants, scholarships and prizes, promoting the acquisition, development and dissemination of forestry-related knowledge and information, and other activities.

The Foundation's capital has come from donations by the NZ Institute of Forestry and NZIF members. With this, the Board has been able to offer three student scholarships and a travel award each year. It has also offered prizes for student poster competitions at NZIF conferences.

To make a real difference to New Zealand forestry, including being able to offer more and bigger scholarships and grants, the Board needs to grow the Foundation's funds. Consequently it is appealing for donations, large and small, from individuals, companies and organisations.

The Board will consider donations tagged for a specific purpose that meets the charitable requirements of the trust deed. A recent example has seen funds raised to create an award in memory of Jon Dey who was known to many in New Zealand forestry. Donations for that award are still being sought.

The Foundation is a registered charity (CC47691) and donations to it are eligible for tax credits.

To make a donation, to discuss proposals for a targeted award or for further information, please email foundation@nzif.org.nz or phone +64 4 974 8421.

Make a donation today.