Long-term management of streams in planted forest steeplands

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Abstract

Stream systems in steepland forests typically produce high water quality for most of the forest rotation. Highest potential risks to these freshwater resources are associated with harvesting activities, flooding and debris flows resulting from intense rainfall events. A range of research initiatives aimed at reducing the potential risks to steepland forest's freshwater resources are underway. Here we draw attention to these initiatives and other opportunities to assist in achieving this outcome.

Background

There are an estimated 24,220 km of streams running through New Zealand's planted forest estate. For most of the forest rotation these streams provide a source of high water quality to downstream users (Baillie & Neary 2015). Steepland forests, which make up approximately one-third of New Zealand's planted forest estate (Basher et al., 2015), contain a higher density of stream networks than forests located on flatter topography. These stream networks extend into the steep upper reaches of headwater catchments, which are frequently characterised by highly erodible soils and geologies. In addition, these areas are often subject to intense rainfall events that can result in flooding and generation of debris flows (Phillips et al., 2012). Regulatory requirements such as the National Policy Statement (NPS) for freshwater management, the draft National Environment Standards (NES) for Plantation Forests, forest certification requirements, council rules and guidelines, and adverse public attention around debris flows originating from planted forests, all place increasing scrutiny on the performance of planted forests and the management of their freshwater resources.

Ground-based harvesting along a waterway in a central North Island planted forest

What we know

When it comes to maintaining freshwater resources in steepland forests, the harvesting component of the forestry cycle is the most challenging (Baillie & Neary, 2015). Ground-based harvesting systems used on flatter terrain enable a higher degree of control on the harvesting and extraction of timber around waterways, minimising soil and vegetation disturbance in the streamside management zone (see first photo) and the amount of logging slash that ends up in waterways (Baillie et al., 1999). Where an intact vegetated riparian zone is retained during the harvesting phase, many of the pre-harvest physical and biological characteristics of water quality and stream integrity remain intact or are subject to minimal disturbance (Graynoth, 1979; Rowe et al., 2002; Boothroyd et al., 2004; Quinn et al., 2004).

In steepland forests, the challenge of trying to optimise what can frequently be conflicting logistical, environmental and economic constraints around roading and landing infrastructure often results in timber being harvested and extracted across the stream channel. This method provides the ability to harvest areas which otherwise would not be accessible. However, hauling across waterways and associated riparian areas in steep headwater streams has been shown to impact water quality, physical habitat, aquatic biota and a range of other physical and biological processes (Baillie et al., 2015; photos A–C).

In particular, sediment inputs to waterways typically increase following harvesting in steepland forests (Phillips et al., 2005; Fahey & Marden, 2006; Basher et al., 2011), and in some headwater streams this sediment is locked into the system by logging slash and the in-stream vegetation regrowth following harvest (Baillie, 2006; photo C). This material can contribute to debris flows that originate upslope and have sufficient impetus to reach the stream channel (Phillips et al., 2012; photo D). While some aspects of waterway recovery to pre-harvest conditions can occur within one to two years of harvesting (photo C), the degree of impact and recovery time varies depending on site

Riparian vegetation and woody debris in a small headwater stream: A – before harvest; B – immediately after harvest; C – approximately one year after harvest; D – the same stream channel after a debris flow resulting from an estimated one-in-100-year rainfall event, approximately one year after the site was harvested

conditions, harvest method, post-harvest management techniques and the scale of operations (Reid et al., 2010; Baillie & Neary, 2015).

Hauling back from waterways reduces the degree of disturbance in both the riparian and stream environments in steepland forests. However, it needs to be assessed against the cost of additional roads and landings and the risk of infrastructure failure, resulting in mass movement of sediment from roads, tracks and landings into receiving waterways, particularly during high-intensity rainfall events (Fransen et al., 2001; Pearce & Hodgkiss, 1987). These concerns aside, the risk of sediment generation from landslides reaching waterways may be of even greater concern (Marden et al., 2006; Phillips, et al., 2012).

Once past the harvest and post-harvest period of the forestry cycle, site establishment and silvicultural activities that enhance site productivity and maintain forest health, such as fertiliser and pesticide use, also have the potential to affect water quality (Baillie & Neary, 2015). Some initial research on herbicide application in planted forests to control weed growth shows that if best management practices are applied during these operations the potential risk to receiving water bodies is very low (Baillie et al., 2015). Highest risks were associated with aerial application of herbicides in steepland forests where the broken terrain and dense stream networks limited the ability to fly parallel to the stream edge.

Our research has shown that the highest concentrations of herbicides in the water following operational application occurred on the day of spraying, and after rainfall in the following month. These amounts were rapidly diluted (within 100 m) downstream and remained at low concentrations for the remainder of the monitoring period (Figure 1) (Baillie et al., 2015). Despite data that supports low risk of herbicide contamination of waterways, the increasing national and international concern around pesticide impacts on both humans and the environment is raising the pressure on forest managers to either reduce or eliminate pesticide use (Rolando et al., 2013). This is a key component of the Forest Stewardship Council (FSC) pesticide use strategy with forest managers facing ever-changing constraints on the pesticides they can use in their forests, some of which are critical to the viability of the forest crop (Rolando et al., 2013).

What are we doing?

The Scion-led Growing Confidence in Forestry's Future (GCFF) research programme aims to increase the productivity of New Zealand's planted forests while ensuring that intensification management strategies are within sustainable and environmental limits (http://gcff.nz). In particular, Research Aim 3 (RA3) 'Sustainability under intensified regimes' aims to assess the effects of any key interventions on soil, water and biodiversity over multiple rotations.

Some of this research is focusing on methods to mitigate steepland harvesting impacts on site productivity and also methods to reduce the risk of erosion. For example, the use of willows inter-planted with *Pinus radiata* to fast-track root re-establishment after harvest is being investigated together with validation of the SoSlope model to simulate the effects of the spatial and temporal variability of root reinforcement on the stability of a slope in the planted forest environment. This work will inherently benefit waterways in the process. In conjunction with this work, Scion is undertaking research to provide quantitative data on the recovery rate of steepland headwater stream and riparian ecosystems following exposure to an extreme weather event (estimated one-in-100 year rainfall event) (photos A–D).

Scion also has a programme that has been assessing the impacts to water quality of herbicide use in forest management, particularly in the receiving environment (Rolando et al., 2013; Baillie et al., 2015). Because of the high risk of surface flooding and erosion in steepland forests, some of this work has been conducted in steepland terrain. This research underpins the sector's aspiration to ensure that herbicide use within the plantation environment is environmentally safe with no long-term negative impacts to aquatic fauna and flora. Data collected on the fate of two key herbicides over two years in pumice soil is contributing to the development of a catchment scale model to determine the cumulative effects of herbicide use in planted forest waterways. This research will assist in identifying the sustainable limits of herbicide use in planted forests and will play a key role in supporting the forest industry's licence to operate as certified by the FSC.

The FSC is an environmental certification body that provides assurance to customers that wood, and wood products, come from sustainably managed forests. Increasingly, certification systems provide access to premium markets for wood products.

What we need to know

In steepland forests, the harvest and immediate post-harvest phase of the forest rotation poses the highest risk to freshwater resources and has the potential to impact on the forest industry's social and environmental licence to operate. Advances in harvesting systems that reduce riparian disturbance, minimise excess logging slash and reduce sediment discharge to waterways will provide the greatest gains in improving the quality of freshwater resources from steepland forests. The steepland harvesting programme is undertaking research work on mechanisation on steep terrain and is documenting recent advances in the use of steep slope feller bunchers. These machines show promise in improving long-term productivity off this type of terrain (Amishev & Evanson, 2010; Reza et al., 2012), and would benefit from further research to evaluate their performance in reducing harvesting impacts on riparian areas and waterways.

The forest industry needs more robust empirical data on the water quality, water quantity and biodiversity of the freshwater resources originating from steepland forests. Currently this information is variable and sparse and planted forests are under-represented in the national water quality monitoring network (Baillie & Heaphy, 2011). It is difficult to effectively manage the freshwater resources in steepland forests without baseline knowledge on the characteristics of the resource.

While the current re-assessment of the national water quality monitoring network may provide some additional planted forest sites, this outcome is uncertain and the forest industry would benefit from working with their local councils to improve planted forest representation in regional water quality networks. Any water quality monitoring sites installed by forest managers should be in locations that maximise their value in filling in the information gaps. Long-term data sets would improve the forest industry's ability to identify high-value and at-risk water resources, and also understand the impacts and effectiveness of any management interventions.

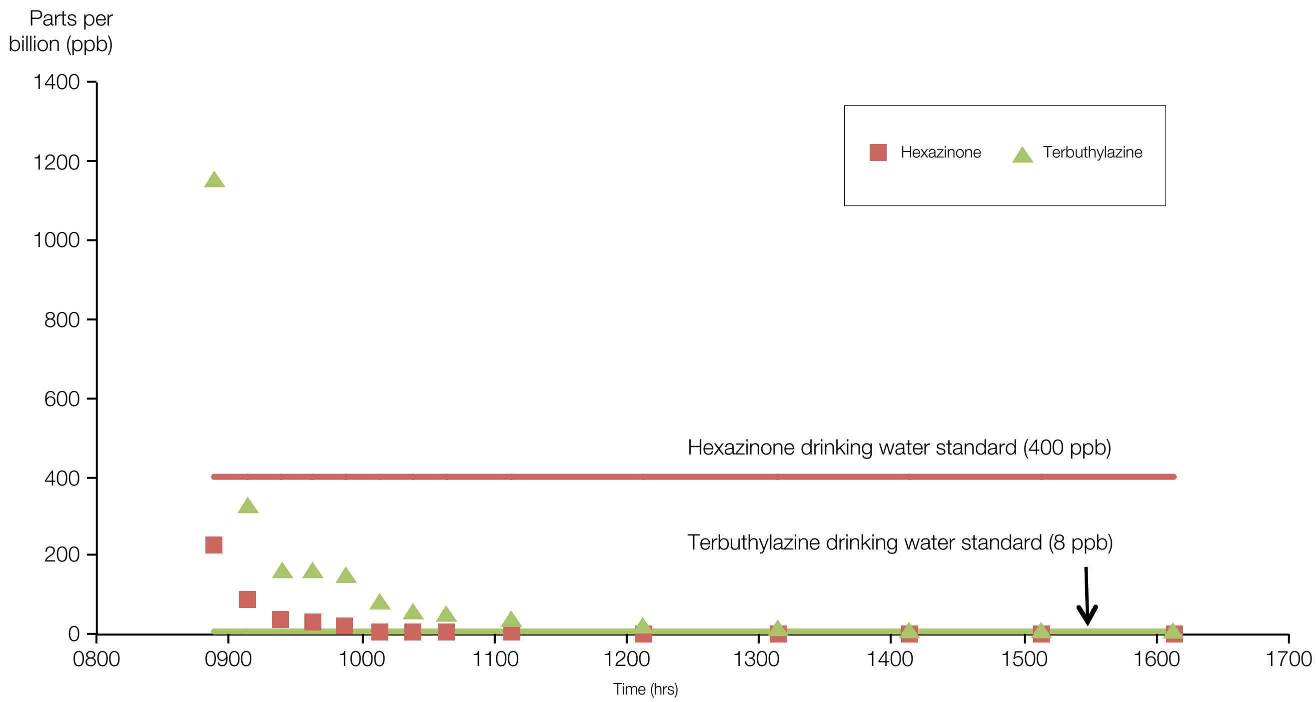

Figure 1: Concentrations of hexazinone and terbuthylazine recorded in a small headwater stream immediately following aerial application (Baillie et al., 2015)

Implications for inter-rotational management

Other authors (Basher et al., 2015) have highlighted the need for continual improvement in identifying and mapping at risk areas for erosion and debris flows. An additional information gap is the ability to predict the quantities of logging slash likely to end up in streams, and the risk of off-site movement of logging slash into downstream receiving environments. This information, along with better information on the freshwater values present at each site, would assist in management of woody debris in streams that takes into consideration both the risk and the ecological benefits.

The ability to model future harvesting scenarios and the effects of different intervention strategies to improve timber production, such as varying rates and combinations of fertiliser and herbicide applied at varying points throughout the forest rotation, on water quality and biodiversity would identify at-risk locations in the temporal and spatial landscape. This would assist in maximising productivity gains while minimising risks to freshwater environments. The aim to improve NuBalM (Garrett et al., 2015) to enhance the ability of the model to identify areas at risk from nitrogen leaching is one such example. These types of tools will ultimately benefit the management of waterways in steepland forests.

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