Debris flows

New Zealand planted forests environmental facts.

There are some 1.7 million hectares of planted forests in New Zealand, and about a third of these are on erodible steepland terrain. Many of these forests were originally planted as erosion control forests and are now being harvested.

There is increasing concern and media attention about the environmental effects of steepland planted forestry. These centre on the post-harvest landscape response, including the increasing occurrence of woody debris in rivers and on beaches following intense rainstorms that generate landslides, and debris flows that entrain wood and sediment.

The challenge for New Zealand's steepland planted forests is to minimise these impacts within and beyond the forest boundary for improved environmental, social, and economic outcomes.

The process

Debris flows are not new. They are a natural mass movement process that occurs in all steepland regions throughout the world and can occur in any type of forest. Debris flows happen where there is a combination of steep slopes, intense rainstorms and high sediment supply. There is a risk of their occurrence whenever forests are harvested from such terrain. In New Zealand, the North Island and the top of South Island are susceptible.

Defining debris flows. A debris flow is a 'very rapid to extremely rapid surging flow of saturated debris in a steep channel'. Their distinguishing feature is that they have very high sediment concentrations by weight, about 80%, and are much more powerful and destructive than water alone. Strong entrainment of sediment and water from the flow path enables debris flows to 'grow' and they often move in surges. They may or may not contain woody material from forests (i.e. they can be sediment-only). Debris avalanches or shallow landslides can transform into debris flows once they become confined to a channel.

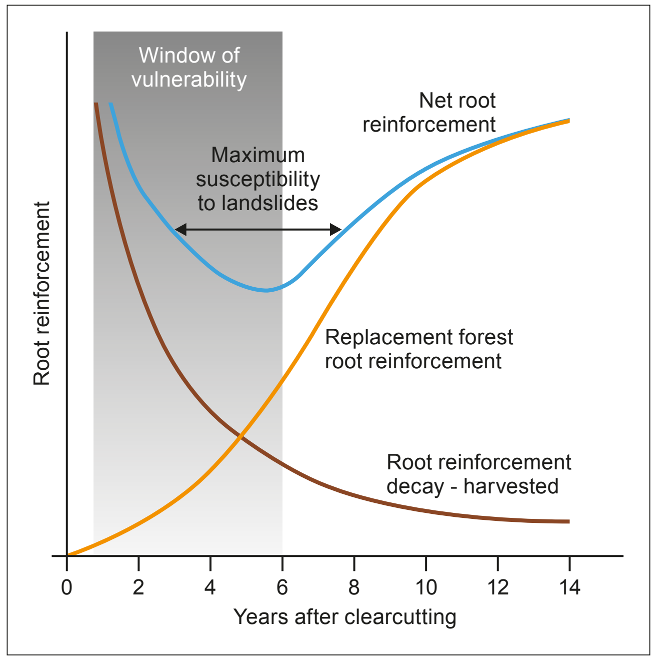
Rainfall and runoff on their own will not result in the movement of logging slash off slopes. Runoff into a stream channel will also not generally move large woody debris. Debris flows rarely occur if there is no slope failure. The primary cause of debris flows is the generation of sediment by mass movement into a channel.

Debris flows are very erosive within stream channels. They tend to erode vertically into the channel bed rather than laterally. As a rule, they only cease moving once the gradient changes or the flow depth reduces, such as on a fan or where a steep stream exits onto a flood plain.

Minimising debris flow risk

There are two primary factors that can be used to assess the risk of a debris flow.

Window of vulnerability describes the elevated risk of landslides after a forest has been harvested and before the next crop reaches canopy closure and root site occupancy. The window is about 5-6 years but depends on factors such as stocking density, interval between harvesting and planting, geology, slope and terrain. It is during this period that debris flows are most likely.



An example of typical changes in forest vegetation root strength or root reinforcement after timber harvesting showing the 'window of vulnerability' (see Phillips et al. 2012 for more details).

Hazard zoning and risk assessment. Debris flows typically occur during intense rainstorms where slopes are steep and the landscape is susceptible to mass failure, providing large amounts of sediment.

There are three components to identifying risk: erosion susceptibility; storm event frequency and magnitude; and down-stream consequences of an erosion/debris flow event.

Records of past events can help to broadly understand the conditions that trigger debris flows. Predictive tools (e.g. topographic indices) to help identify where debris flows could occur and hence are likely to occur again, are improving. However, predicting the exact conditions under which a debris flow will occur, is challenging.

Improving understanding of past debris flow occurrences and development of predictive tools, coupled with an understanding of the likely down-stream consequences of debris flows (e.g. to infrastructure, communities) can help to develop effective risk assessment and hazard zoning.

Mitigation

What can we do about it? As landslides and debris flows are natural processes, it is not feasible to stop them completely. These events have helped shape the New Zealand landscape. Currently, science is not yet able to determine the storm threshold conditions for which these events could be managed, however, we can try to minimise their impacts. To do so needs a combination of mitigations.

Hazard avoidance. Identify areas where debris flows are unlikely to occur, and site roads, bridges and other infrastructures in these places.

Narrowing the window of vulnerability. Rapid replanting, and replanting at a higher stocking density to shorten the time it takes for the new crop to close canopy, is a practical and easy option. Other options in the long term could be planting coppicing species that maintain live roots after harvest, though this is as yet unproven.

Concrete and steel structures. Where the risk to life or infrastructure is high because the hazard cannot be avoided, engineered structures (e.g. driven railway irons and slash racks, various types of in-channel or deflection structures) may help mitigate the risk by trapping or storing debris, which can then be extracted in a controlled manner.

Riparian management zones. Evidence from New Zealand and overseas suggests that planting trees in riparian zones may be either positive or negative in terms of trapping woody residue and debris flows. Channel gradient and confinement needs to be considered before planting in riparian zones to avoid the risk of the debris flow entraining these plantings and making their impact larger. These plantings are best placed on the lower parts of slopes, especially on fans or where steep channels reduce gradient as they become unconfined on fans or flood plains.

Longer rotation crops or retirement into permanent forest cover. If an area is recognised as having a very high risk of debris flows then a planned change to rotation length or conversion to permanent forest cover may be options to manage future risk. This will require an assessment of the area most at risk to landslides and debris flows from past events, e.g. hindcasting to identify where those places are.

Improved risk models. There is inadequate data to effectively assess risk and mitigation options for forest management, including retirement. Collection of standardised data on size, frequency and impact of debris flows as a part of routine forest monitoring operations will enable us to improve risk models, and manage and mitigate the impacts of debris flows more effectively.

Key references

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