Forests for soil and water conservation - what does the science say?

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New Zealand has a considerable history of research into the effects of tall vegetation management on water quantity and quality. In any area of biophysical science it is difficult to say that we have enough experimental evidence for definitive answers to land use effects questions. However, in the area related to how vegetation affects water there are broad trends that we can recognise. When these are refined through study within the geographical area of concern it allows us to answer some of the questions with a reasonable level of certainty.

This paper presents evidence on the affect of tall vegetation and forestry practices on water and sediment yields. For ease of presentation water quantity is separated from quality although there is considerable interaction between the two, most commonly in sediment related issues.

Water Quantity

Forests have an influence on the water balance of a catchment through evaporation of intercepted rainfall, thereby reducing the amount of water available for runoff and streamflow. Generally trees have a high capability for interception due to a large leaf area and high aerodynamic roughness above the canopy. The same can be said for any tall vegetation, whether it is scrub and weed species, indigenous or exotic forests. Experimental studies in New Zealand show reductions in annual water yield of between 30-80% following afforestation of pasture. These figures are lower where afforestation has replaced scrub species (Davie and Fahey, 2005). The effect of afforestation on peak flows is considerable, particularly for small flood events although there is some evidence that storms with long return periods may also be substantially reduced following afforestation. There is considerable debate whether these effects can be seen at a large catchment scale; the one study on large–scale effects in New Zealand (Tarawera catchment; Dons, 1986) suggests that the same effects can be recognised at a larger scale. The effect of afforestation on low flows is less well studied. Low flows are reduced following afforestation but it appears that in some cases low flows are affected to a lesser extent than annual yield (Davie and Fahey, 2005).

It is worth noting that there is no evidence to uphold the widely held belief in forests acting as sponges for water. The "sponge theory" suggests that catchments covered in forests absorb water that is then available for slow release at a later date, thereby dampening out extremes in the hydrological regime. Forested soils generally have higher organic matter content and infiltration rates than for pastoral areas, suggesting they can absorb more water. However these positive impacts are outweighed by reduced amount of water reaching the soil following interception loss from the vegetation canopy.

Water Quality

Almost all the scientific evidence suggests that forestry is extremely good for general water quality. In a recent nationwide review of water quality streams in New Zealand rivers where snowmelt is not a significant part of hydrological regime, Larned *et al.* (2004) clearly show that forestry as a land use is beneficial to water quality. They were not able to detect any difference between plantation forestry and native forest catchments and in many cases plantation forestry showed the best water quality standards. When compared with pastoral and urban land cover, dissolved reactive phosphorus (DRP), oxidised nitrogen (i.e. nitrate and nitrite), ammonium, and E. Coli concentrations were "2-7 times higher" in the pastoral and urban classes compared to native and plantation forest classes. Larned *et al.* (2004) confirm numerous small scale studies highlighting the beneficial role that forestry has in removing animals from water courses, reducing nutrient inputs and providing positive shading and bank stability functions.

Larned *et al.* (2003) looked at water quality over a long time period however Fahey *et al.* (2004) provide evidence that forestry practices can have a short-term effect on water quality parameters. At Porokohukohu, in the central North Island, the total phosphorus and nitrogen loads showed a marked increase in the year following harvesting, however the values soon dropped to below pre-logging levels in the following years.

Suspended sediment is part of the overall water quality picture although the review of Larned *et al.* (2004) did not specifically include it. Water clarity was considered, which has a relationship with suspended sediment amongst other things. In this paper suspended sediment has been separated out in order to describe soil erosion processes as well as sediment yield.

Soil erosion and sediment yield

It is important in any review of sediment and forestry to differentiate between sediment generation (soil erosion) and sediment yield. Soil erosion is the first step in the sedimentation process that consists of erosion, transportation and deposition of sediment. A fraction of eroded soil passes through a channel system contributing to sediment yield at the catchment mouth. Some of it stays close to where it was eroded and some of it gets deposited

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in stream channels. The ratio of erosion to sediment yield is the sediment delivery ratio.

Forests have an important role in soil conservation through reduction in landsliding and slope wash processes. The landsliding element is well illustrated by Dymond *et al.* (2006) for the Manawatu storm of February 2004. In validating a landslide susceptibility model Dymond *et al.* (2006) show that forest cover (irrespective of indigenous or exotic) reduces landslide susceptibility by 90% and that scrub cover reduces it by 80%. Forests affect slope stability through a mixture of an alteration of soil moisture and pore water pressures and mechanical reinforcement of the slope through rooting structure (O'Loughlin, 2005).

Reduced slope wash under forest cover comes from improved soil structure under forests and the canopy reducing raindrop impact. However, areas of bare soil (e.g. land sites, haul lines and roads) are susceptible to slope wash and require cautious management to ensure limited delivery of fine sediment to stream channels. Studies show that the majority of suspended sediment generated in commercial forestry areas is from roads, tracks and landings (O'Loughlin, 2005).

The most vulnerable period for soil erosion and potentially increased sediment yield is immediately following harvest. Good engineering design of roads etc. and the rapid establishment of vegetation cover are critical for ensuring low sediment yields in this period. In terms of total sediment yield a comparison of sediment yield from pasture and commercial forestry in the Hawke's Bay shows that total yield from forestry over a full rotation cycle is less than those from the pasture over the same period (Fahey *et al.* 2003). This raises questions over whether aquatic ecosystems are better able to handle a steady drip of sediment or single pulse (the Hawke's Bay study showed that sediment yield returned to lower levels than pasture within 3 years of harvest).

In summary it can be said that forests have a positive benefit in terms of peak flow reduction, a lessening of landslide risk and high levels of water quality. Forests have a negative effect on low flows although it appears to be not as severe as the effect on overall water yield. Sediment yield during harvesting is a problem that requires careful management, something that latest guidelines are taking into account. Any consideration of the role of forestry in the landscape needs to be integrated in approach, considering the positive aspects in conjunction with any negatives.

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