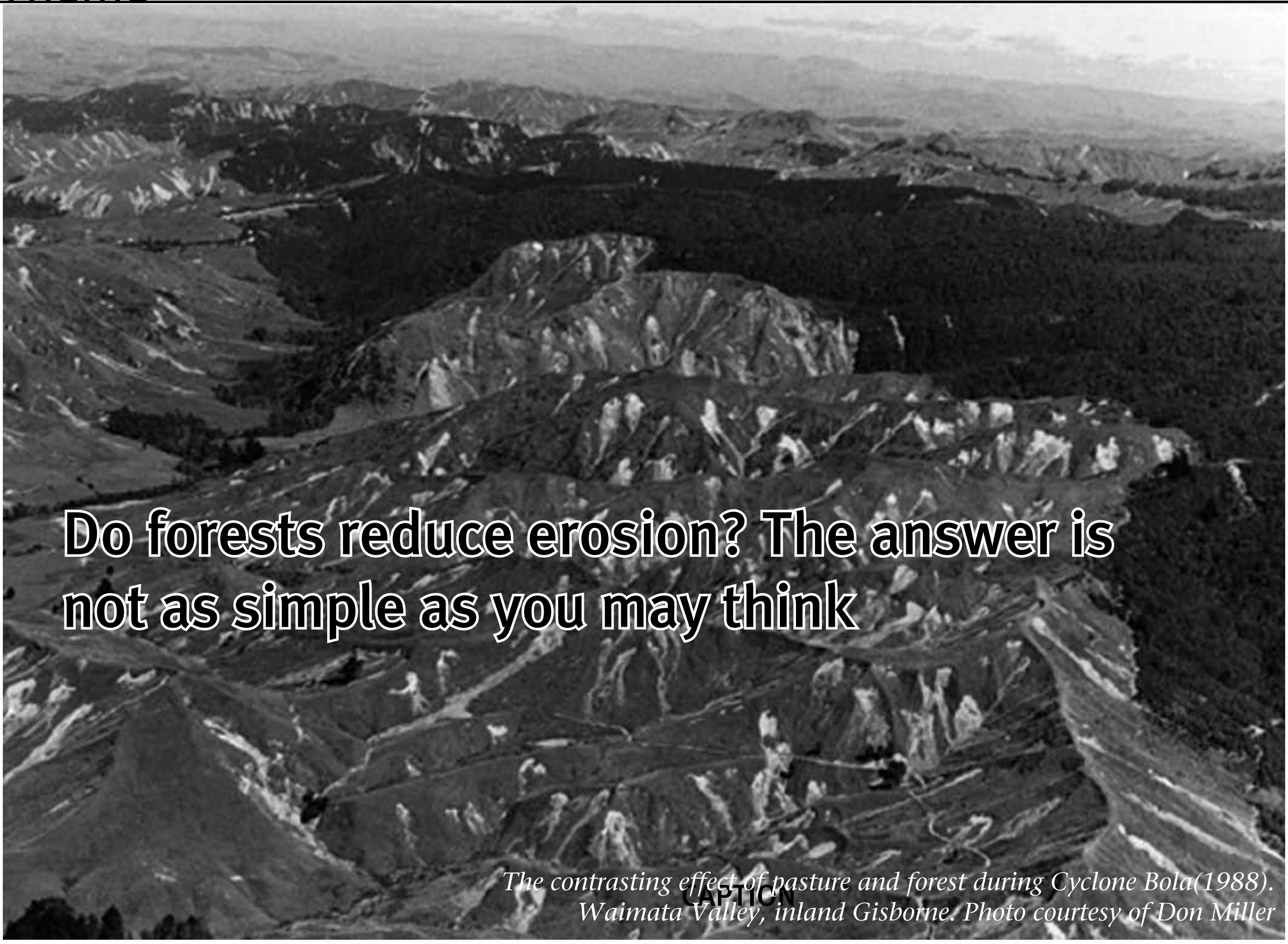

The contrasting effect of pasture and forest during Cyclone Bola(1988). Waimata Valley, inland Gisborne. Photo courtesy of Don Miller

Do forests reduce erosion? The answer is not as simple as you may think

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Introduction

In this article we attempt to reconcile two different perspectives of soil erosion in relation to land cover. From a land-use perspective, there is ample evidence that planting trees reduces erosion; from a geological perspective, however, land-use is irrelevant to long-term erosion rates which are controlled by tectonic uplift and denudation. We show that aspects of the geological viewpoint are indeed relevant to the land-use perspective.

Human experience of erosion in NZ

The interaction between forests and soil erosion has featured in New Zealand history from the beginning of human settlement. Deforestation by Māori settlers, mostly achieved by fire, reduced the forested area in New Zealand by about half (McGlone 1989). There is evidence that this deforestation triggered erosion, with tree charcoal preserved in hollows buried by downslope movement of soil and debris (McGlone 1989). Harmsworth and Raynor (2004) state that Māori were intimately involved with the physical environment and managed natural resources (including forests) within the domain of *ritenga*—customs and laws regulating behaviour in relation to both people and the environment. King et al. (2007) document Māori environmental knowledge in relation to natural hazards, but the only landslides mentioned are those triggered by volcanic activity. Neither report a specific Māori focus on conserving forests as a means to combat soil erosion.

European settlers arrived in significant numbers from the mid-19th Century onwards. Their initial focus was on conversion of remaining lowland native forests to short pasture, with scant awareness of the implications for land stability. However, there was early recognition of the role of native forests in reducing erosion in the mountainlands, eventually leading to the gazettal of much of New Zealand's montane and subalpine forests as catchment protection forest. By the mid-20th century, it was apparent that conversion of otherwise fertile and productive lowland hill country from indigenous forest to pasture had

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triggered severe soil erosion in many parts of New Zealand. From the onset of a nationally-based soil conservation programme in the 1940's, reforestation of pastoral land with exotic tree species has been a preferred method for control of erosion. This policy has resulted in significant areas of plantation forests in NZ located on land with high or very high erosion susceptibility (Bloomberg et al. 2011).

Erosion science; two views

The way in which forests affect soil erosion has been well documented in the literature, with many papers on this topic published in the New Zealand Journal of Forestry (see for example Davie 2006; O'Loughlin 2005; Hicks 1991, as well as the paper by Chris Phillips, Mike Marden and Les Basher in this issue). Forests retard erosion principally through mechanical reinforcement of the soil by their extensive strong woody root systems; and also through the hydrological influence of their rough canopies with large leaf areas. These intercept rainfall more effectively than the canopies of non-forest vegetation, therefore reducing the degree to which soils beneath the canopy become saturated (and therefore less stable) during moderate rainfall events.

However, as with any important scientific issue, there are differences in viewpoint on the effectiveness of trees in reducing soil erosion. In a recent paper, Davies and McSaveney (2011) contend that in the long term, rates of erosion are controlled by geological uplift, with climate regime, rock weathering and lithology as important modifiers. Forested and deforested catchments sharing the same geological, geomorphological and climatic characteristics will therefore have the same long-term rate of erosion. Davies and McSaveney (2011) illustrate this point with an example of "accelerated" erosion of deforested hill country. After forest clearance and establishment of pasture, the soil erodes (deflates) to a shallower equilibrium depth corresponding to the hydrological and root reinforcement properties of pasture vegetation; however once that new equilibrium soil depth is reached, soil deflation ceases and the net erosion rate reduces to match the uplift rate (which is not affected by vegetation). Conversely, reforesting pastures will result in reduced erosion while soil depth builds up to a new equilibrium depth following tree root development, but once this process eventually reaches equilibrium the net erosion rate will increase to again match weathering and uplift.

From this viewpoint the terms "natural" and "accelerated" erosion are therefore problematic, because human activity has no bearing on the underlying geologically-controlled rate of erosion. Any effects of human activities such as deforestation and reforestation are temporary (McConchie, 2008). From an erosion management perspective, however, the rates at which landscapes adjust to land-use changes, and the time-scales on which these changes occur, are crucial. Scale is important when considering any natural process and we need to consider how the Davies and McSaveney model plays out in the shorter-term context of soil erosion relevant to human land-use.

In the earlier example described by Davies and McSaveney we can regard a forest soil as a deep reservoir of soil material, in contrast to the shallower soils found under short pasture or other non-forest vegetation. This deep reservoir of soil material is maintained even though long-term erosion rates under forests are the same as for non-forest vegetation. When forests are converted to non-forest vegetation some of the reservoir of soil material is released. While a new equilibrium of the whole catchment-stream system will eventually be reached, in the short term streams may be unable to efficiently sort and transport this released material, which is additional to sediment arising from underlying geologically-controlled erosion. If the rate of additional sediment supply from the deflating forest soil is significant, streams will respond accordingly, probably by aggradation—with detrimental consequences for downstream communities. Conversely, riverbed aggradation can be reversed by reforesting eroding areas currently under non-forest vegetation, and allowing the reservoir of soil material on the hillslope to build up again. The resulting reduction in sediment supply may reverse the aggradation caused by deforestation and lead to downcutting in riverbeds; however once the soil again reaches its equilibrium depth, sediment supply will achieve long-term rates, and the catchment and stream system will again come into (dynamic) equilibrium.

This example is not merely hypothetical. In the Waipaoa and Waiapu catchments of the Poverty Bay/East Coast region of the North Island, widespread conversion of native forest to pasture from 1890-1920 resulted in a rapid increase in rates of landsliding and gully erosion. Consequent aggradation of riverbeds resulted in burial of alluvial flats, roads, bridges and buildings, and an increase in flood hazard for downstream townships within a period of decades (Allsop, 1973). Fortunately, targeted reforestation with exotic plantations in the Waipaoa catchment has now "shut down" many of the gullies supplying sediment to the catchment on a similar timescale (Marden et al. 2011; Reid and Page 2003). Progress with reforestation in the Waiapu catchment has been less rapid, and unless there is successful reforestation of active gullies, aggradation of the Waiapu riverbed will continue (Marden et al. 2011).

Pinnacles Gullies, inland Tokomaru Bay. Under a pastoral regime both gullies doubled in size over a 40-year period before being planted in 1998. Photo courtesy of Ministry of Forestry

Is the geological perspective important for human land-use?

As noted by Davies & McSaveney (2011), the soil reservoir refilling and depletion time "...will be shorter in an active than in a less-active landscape." Given that NZ landscapes are some of the most active on Earth, the geological viewpoint is more likely to be significant here than almost anywhere else. Unfortunately, data to quantify these time-scales appear to be sparse, though the plentiful information from the Waipaoa catchment referred to above should be able to be used for the deforestation component; i.e. how long does it take for erosion under pasture converted from forest to (a) increase and (b) reduce again to background levels?.

The geological perspective indicates that reforestation is no guarantee against the consequences of extreme storm events, because erosion can and will occur under forests. Therefore detritus from large-volume landslide and gully erosion may temporarily overwhelm a catchment's ability to sort and transport sediment, regardless of the vegetation cover in the catchment. There is even conjecture that in such extreme events the volume of erosion under forest may be greater than that under non-forest vegetation due to the greater depth of soils under forest and the exacerbating effect of woody debris on erosivity of landslide detritus (Davies and McSaveney, 2011; McConchie, 2008).

News from overseas frequently shows large slips in forests causing serious effects on communities, as did the recent (14th-15th December 2011) Nelson rainstorm. On the other hand, storm damage assessments after major events such as Cyclone Bola (1988), and the February 2004 storms that affected the lower North Island, suggest that on lowland sites intact forests were effective in reducing erosion severity (Blaschke et al. 2008; Hancox and Wright 2004; Hicks, 1991).

One difficulty in estimating the effect of reforestation is the spatial heterogeneity of erosion events under forest. This appears to be at least an order of magnitude greater than that under pasture so that under forest, individual landslides are larger and less frequent than under pasture— but magnitude-frequency data for planning are not available, meaning

Pinnacles Gullies under pine cover. Using models to predict how long it will take for gullies to stabilise under a forest regime, there is a 50% chance that the smaller gully will stabilise within one rotation of pine while the larger gully will show a 50% reduction in size but will take ~30-years to stabilise fully. Photo courtesy of Ministry of Forestry

that very long-duration and extensive monitoring will be required to quantify erosion rates and soil depths under forests.

Effects on life-sustaining capacity of soils

So far, this discussion has focussed on forests and their effects on sediment supply to catchments (off-site effects). A further implication of the geological scenario is that agriculture on deforested pasture soils is using a depleting – but perhaps not yet fully depleted – resource (an on-site effect). In contrast to agriculture, on land with high erosion susceptibility forests are able to maintain deeper and more developed soils than non-forest vegetation and therefore support a higher level of primary productivity.

While the off-site effects of erosion receive considerable attention from regulatory agencies, the on-site effects do not receive the attention they deserve—strangely so, when "safeguarding the life-supporting capacity of the soil" is set out at the beginning of the Resource Management Act 1991 (RMA) as a purpose of the Act. There seems to be an implicit attitude in New Zealand society that freehold ownership of soil confers the same rights as ownership of any capital item, including the right to "run it into the ground." For example, evidence given by a consortium of farmers' groups in an appeal against soil conservation rules for highly erodible land (HEL) in the Horizons Regional Council's "One Plan" states: "Farm production across these areas has risen significantly despite limited erosion. The farms are still profitable. This would suggest that current land management and decision-making by the farmers are sustainable" (McConchie, 2008). Yet the adverse effects of soil slip erosion on productivity of North Island hill country soils have been well documented (Rosser and Ross 2011; Trustrum and de Rose, 1988). For significant areas of HEL, the underlying life-sustaining capacity of the soil is being reduced as soil profiles deflate down to the equilibrium depth that can be sustained under pasture. If productivity has been maintained, it is likely to be because of compensating improvements in terms of weed control, and stock and pasture management. The key question is; for how long can the present land-use and productivity be sustained?

Conclusions

In the long term, rates of erosion are controlled by geological uplift, as modified by the climate regime and lithology. Forested and deforested catchments sharing the same geomorphological characteristics will have the same long term rate of erosion. In this context, forest soils can be regarded as a reservoir of weathered material compared with soils under short pasture or other non-forest vegetation. Much of this reservoir of weathered material is released when forests are converted to non-forest vegetation. "Short-term" (in terms of geological time-scales) aggradation of riverbeds may result, but note we are not able to quantify what "short-term" really means.

This process of "short-term" aggradation can be reversed by reforesting eroding areas currently under non-forest vegetation. Reforestation however is no guarantee against the consequences of extreme storm events where detritus from severe landslide and gully erosion may temporarily overwhelm a catchment's ability to transport sediment, regardless of the vegetation cover in the catchment.

On land with high erosion susceptibility, forests are able to maintain deeper and more developed soils than non-forest vegetation and therefore support a higher level of primary productivity. A key purpose of the Resource Management Act is to safeguard the life-supporting capacity of soils and reforestation of erosion-susceptible land is one way to achieve this purpose.

The two perspectives on erosion – geological and land-use – are certainly compatible, and the geological perspective has some value in developing land-use strategies, but crucial information on the time-scales of erosion response to land-use changes is not yet available.

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