Erosion Management in NZ

Management of erosion is one of the key objectives of the measures that come under the umbrella of *Soil Conservation*. Erosion has a direct influence on the productivity (in its widest sense of beneficial as well as economic use). It may deny access or destroy infrastructures associated with recreational uses of land. High sediment loadings may drastically impact on freshwater fisheries and therefore the tourist industry. In agricultural or horticultural terms, erosion may cause the following:

- loss of soil, leading to shallow soils in which plants suffer poor root development and water stress
- topsoil losses leading to low organic matter and deterioration of soil structure, manifesting in poor cultivation characteristics, loss of soil water holding capacity and infiltration of water
- subsoils may be exposed that have poor plant growth medium characteristics
- lost topsoil carries with it much of the plant nutrients in soil (e.g. phosphorus and nitrogen) that end up in waterways and lakes where they contribute to eutrophication, resulting in phenomena such as algal blooms
- gullying may hinder being able to move stock or access areas of land in farming operations
- farm infrastructure (buildings, fences tracks) may be damaged
- accelerated sedimentation raises the levels of affected river beds, causing increased flooding risk in adjacent areas

The amounts of material transported in our river systems gives some indication of the rates of erosion today. For example, the Manawatu River at average flow moves a 5 tonne truckload of sediment under the bridge at Palmerston North every 13 seconds. This equates to a lowering of the catchment by an average of 1 mm every year. In an annual average flood this rate goes up to one truckload per second and in an 8-year flood, two truckloads per second. During cyclone Bola the Waipaoa River, near Gisborne, had a discharge rate of 5,300 m^3s^{-1} and a suspended sediment discharge of about 400 m^3s^{-1}. Some 600,000 tonnes of sediment were discharged by the river in this storm event.

East Coast Hill and Steepland

The Hawkes Bay hill is part of a long belt of similar country extending from East Cape to eastern Marlborough. There are close similarities in climate, landscape and soil parent material through the entire region that contrast markedly with the hill country of Taranaki and Manawatu.

If you examine a map you will observe that the mountain ranges and chains of hills on the eastern side of North Island are aligned predominantly northeast-southwest, roughly parallel to the coast and the rocks and fault lines are distributed along a similar trend. The explanation is found in a branch of geology called "plate tectonics" which recognises that the surface of the earth is made up of a number of semi-rigid plates moving relative to one another.

Hikurangi Trench (Figure 1) marks the position where the Pacific Plate collides with the Indian-Australian Plate. The Pacific Plate is composed of dense basaltic rocks so it slides beneath the lighter continental crust of the Australian Plate (whether we like it or not, the North Island and the west of the South Island are already part of Australia!).

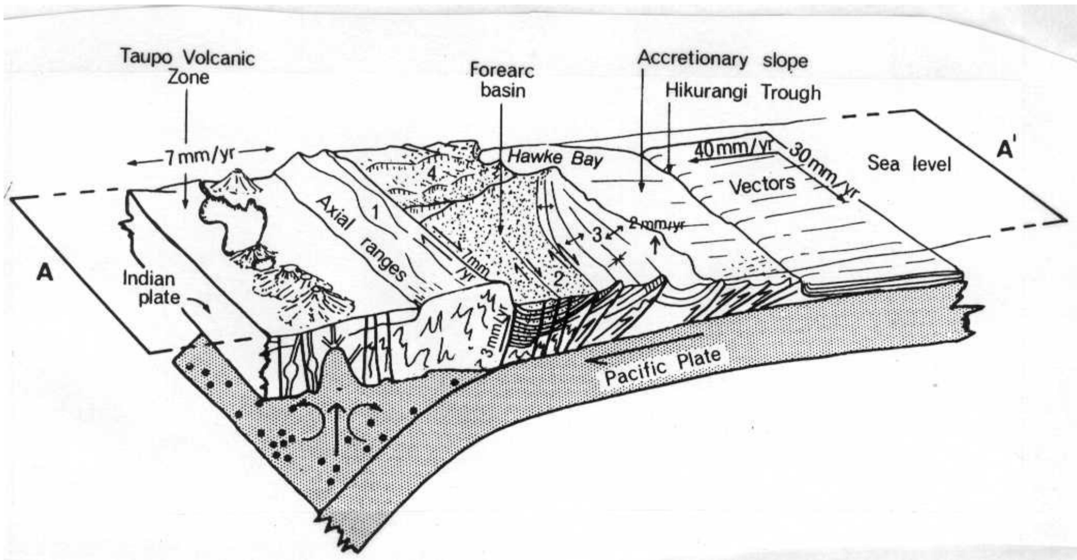

Figure 1. **A block diagram of the convergence of the Pacific Plate with the Australian Plate**

Rates of earth movement in this region are therefore rapid, often with disastrous consequences for humans. It is envisaged by scientists that earthquakes are generated by the friction between the descending Pacific Plate and the Australian Plate and by stresses accumulated in the Australian Plate above. Figure 1 shows that shallow (and potentially destructive) earthquakes may be expected quite frequently in eastern Hawkes Bay as strain builds up. Earthquake epicentres become deeper towards the west.

The nature of the parent rocks has also strongly influenced the development of landscapes and soils. The high axial ranges are composed of Mesozoic (a period of time - 60 million years ago), greywacke and argillite rocks. In contrast, the coastal ranges are a complex mixture of slivers of younger Cretaceous and Tertiary rocks (120 - 60 million and 60 - 2.5 million years ago respectively). These rocks vary from harder limestones and sandstones which tend to form ridges with steep faultbounded east facing slopes and more gentle west facing slopes, to soft mudstones and siltstones. Numerous active faults (Figure 1) have crushed, uplifted and strongly tilted these rocks rendering them very susceptible to erosion. The intervening plains and valleys receive the eroded material from the axial ranges and coastal hills, and are built up from aggradation gravels and sands to form terraces, fans and floodplains.

Climate is also a factor in predisposing the country to erosion. By consulting the New Zealand Atlas you will see that the region receives most of its rainfall in winter and that in summer droughts are to be expected more often than not. The result is that soils dry, shrink and crack in summer. In winter the soils become wet and clay particles are forced farther apart by water and may expand slightly. They then have reduced strength, and the weight of water is often enough to push the soil particles apart and send the whole soil layer cascading downslope in a muddy slurry, called a slip. In other situations the underlying rock may also be destabilised by the weight of water and a more deep seated slump may result. Erosion is usually particularly evident after the occasional high intensity rainstorms that affect the region, for example Cyclone Bola which struck in early March 1988.

Erosion in the hill country causes the streams and rivers struggling to remove the debris to aggrade. Since the original forests and regenerating shrubby forests were removed at the turn of the century and into the 1930s, some rivers and tributaries have built up their beds by more than 10 metres. All rivers have been affected by this aggradation which then predisposes the lower terraces on either side to flooding. Clearly what happens in the hill country affects the lowlands

The soils that form the flood-deposited silty or sandy alluvium are some of the most fertile in New Zealand. this is because the hill country rocks are usually calcareous (contain lime) and also micaceous (contain potassium). Because of the presence of abundant base cations (calcium, potassium, sodium, and magnesium), the pH of the soils is high which in turn stimulates an active and diverse array of soil organisms.

Although many of the eroding parent rocks are fertile in terms of plant nutrients, when they lose the soil layer it takes some time to regenerate organic matter and become fully productive again. On some rock types pastoral production is back to 100% after 40-50 years but on other rock types it is over 100 years. The problem now is that erosion is of such magnitude that large areas of hill country in some districts are losing productivity at an alarming rate. Studies by Landcare Research NZ Ltd on some hill country in Wairarapa show that since forest clearance, over 40% of the original soil has eroded. After 5 years the eroded areas were back to only 20% production. Even after 20 years the soils are not back to full production. One of the serious side affects is the reduced plant available moisture holding capacity of the new soil. Not only does this predispose the hillsides to drought, but also leads to increased runoff in winter storms, further increasing the propensity for erosion.

Serious flooding in the first half of the century led to massive flood protection works on the lower reaches of major rivers in Poverty Bay, Hawkes Bay, Wairarapa and Marlborough in the 1950's and 60's. For the most part these have been successful and now offer at least partial protection to productive pastoral and horticultural land and the towns that service them. Protection work carried out in the hill country has largely been through planting exotic forests and gully stabilisation. Some large forests have been planted on particularly susceptible land; for example Mangatu forest was established in the headwaters of the Waipaoa River to try and control the Tarndale slip and protect the surrounding land on similar crushed argillite rocks.

All these possibilities exist to produce periods of erosion and deposition that some scientists believe occurred at the same time down the entire East Coast. Soils on slightly higher and older terraces are flooded less often and develop deep dark topsoils. Soil mapping has identified these soils which then become most sought after for productive use. The slightly older soils also have the advantage of having weathered to develop brown earth colours and more stable structures. Use of the soils on slightly lower and more flood prone areas is always going to be a risky venture, particularly where capital costs of development are high.

Manawatu-Taranaki Hill Country

During the Tertiary, the area from Manawatu to Taranaki and including the Rangitikei River valley lay beneath the sea in what has been called the Wanganui Basin. It was an area of rapid sedimentary accumulation. Pleistocene glaciation influenced global sea levels and the region was alternately a coastal plain undergoing erosion; and submerged, receiving further sediment. In deeper water, especially when the sea level was high during interglacials, mudstones were deposited. During colder glacial intervals, sea level was lower and sandstones and conglomerates were deposited offshore while erosion took place on land. Gradually, though, the Wanganui Basin was elevated at a rate of about 0.5 mmlyr and the coastline retreated to the south. The southern coastal strip is thus younger and dominated by marine terraces. Moving inland, we cannot fail to notice the progressive dissection with altitude (and age) until marine terraces are no longer recognisable.

Rainfall increases inland from 1000 mm for hill country near the coast to 3000 mm in the King Country. Polynesian people had little impact on the vegetation of the region. European settlers encountered dense lowland broad leaf-pod ocarp rainforest. The main species were tawa *(Beilschmedia tawa)*, kamahi (*Weinmannia racemosa)* and rimu (*Dacrydium cupressinum).* Clearance began in about 1847 and was mostly complete by 1920. The method of felling and burning did not lend itself to preservation of forests for parkland or reserves. In the 1930s large areas of steeper and poorer land reverted to scrub and regenerating forest which was later cleared once more in the days of subsidies.

Following forest removal scientists are easily able to document increased soil erosion. The soil mantle that once existed under forest is removed by successive erosion events as the binding effect of the tree roots is gradually lost. The idea behind conservation planting of poplars, alders and willows is to replace some of these binding agents in the soil.

The valley sides are produced by soil creep, slips, slumps and debris flows. A characteristic of mudstone as it weathers is that the upper metre or so becomes loose and friable with a sharp distinct contact between soil and underlying rock. Soils become cracked and dry in summer, and supersaturated during storms in winter and spring when rapid runoff also occurs. These are ideal conditions for erosion. All the while, streams in the valley floors either aggrade when the supply of eroded detritus is high, or cut down, undercutting the valley sides and causing further erosion. Particularly severe periods of erosion probably relate to high intensity rainstorms such as Cyclone Bola and may affect whole regions. Some scientists believe that long term variations in storminess cause periods of erosion that may affect the whole country. Other causes of instability are: earthquakes, volcanic eruptions where vegetation has been adversely affected by ash-fall, and clearance and burning first by Polynesians (c. 600-800 years ago) and latterly by European foresters and farmers.

Erosion in this landscape has occurred in a relatively stable tectonic setting, where the rocks are only gently tilted, and uplift rates increase only slowly inland. The Quaternary rocks magnificently exposed in this region are one of the thickest and finest sequences of this age in the world. Consequently New Zealand and overseas scientists have made detailed studies of the rocks and fossils they contain to shed light on the climatic history of the world over the last 5 million years.

Erosion of the original forest soil results in thin soils with reduced water storage capacity. Not only are pastures then more susceptible to summer drought, but winter rains quickly exceed the storage capacity of the soil allowing more runoff and erosion. It is not surprising that pasture production is adversely affected, and will continue to decline. More and more hill country will become uneconomic for farming, particularly when product prices are low. The problem is accentuated when farmers cannot afford to put fertiliser on the land, leading to reversion to poor grass species, scrub and fern.

Exotic forestry is becoming a common land use, and agroforestry (spaced planting of exotic trees to allow less intensive grazing between) is becoming a more attractive option.

SOIL CONSERVATION TECHNIQUES

Erosion is largely caused by the action of water and wind. Soil conservation measures are therefore based on practices which control those actions. These include; reducing the velocity of runoff and streamflow, improving soil stability, increasing soil infiltration and protecting the soil from raindrop impact. Management of erosion can be conveniently described under three headings; tillage techniques, vegetation techniques and construction of artificial structures.

TILLAGE TECHNIQUES

Conservation tillage is a method of cultivation that leaves a protective cover of crop residue, together with a roughened surface, both of which reduce raindrop impact and maintaining or improving the physical properties of the surface layer of the soil. *Direct drilling*, a technology developed at Massey University, is an aid to minimum tillage practice.

Sheet and rill erosion can be controlled by *contour ploughing* and *strip cropping*, where the furrows are aligned along the contour.

VEGETATION TECHNIQUES

These techniques involve the planting of trees to control erosion or its products. Trees have a twofold effect, they hold the soil together with their roots and the transpire water, maintaining the capacity of the soil to store water during rainfall events. They also intercept rainfall and lessen its impact on the ground and help maintain high rates of infiltration. All of this slows down the movement of water through the system, reducing flood risk in all but the more severe rainfall events. Poplars and willows are the most common species used because they can tolerate a wide range of conditions, transpire large amounts of water in their growing seasons and are easily established from poles or cuttings.

Agroforestry is one technique that can reduce erosion and at the same time add to land productivity. The more traditional techniques include:

- **Space planting:** Trees are planted at wide intervals across erosion-prone surfaces where mass movement such as earthflows, soil slip and slumping occurs.
- **Pair planting:** A technique used to control gully erosion. Trees (willows) are planted in pairs at 3 – 5 m intervals along opposite sides of small gullies or eroding streambanks. The root systems of the pair meet in the streambed and reduce the scouring effects of streamflow.
- **Riparian zones:** These are established along streambanks to as buffer zones to filter out sediments and nutrients otherwise carried into waterways by runoff.
- **Gully planting:** Planting up of eroding gullies to stop headward erosion.
- **Retirement:** Actively eroding areas are planted up and retired from productive use.
- **Shelter Belts:** These are often species other than poplar or willow and are used to reduce the impact of high winds.