Soil and forest pattern of saltwater forest

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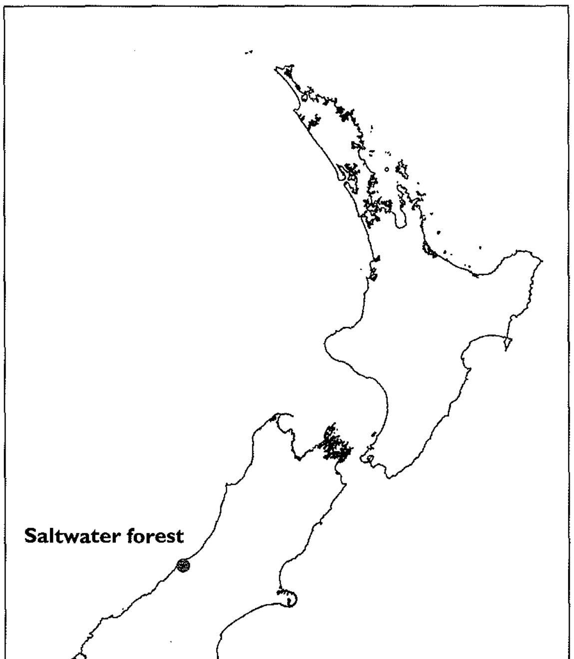
We are familiar with effects of soil type on forest composition, particularly in natural forests. Species organise themselves in the landscape in part according to their competitiveness in different conditions of soil fertility and drainage. Variations of species composition in plantation forests are usually imposed by forest managers but soil variation still expresses itself by way of differences in mortality and growth rates.

In this article we are going to delve into the interaction between soils and the natural rimu dominated podocarp forest of Saltwater Forest in South Westland. We will find familiar forest compositional changes caused by differences in soil fertility, but we will also see more subtle patterns of structural and compositional change related to how forest disturbance regime varies on different soil types.



In an earlier *Indigena* article in August 2008, the history of a soil found on a glacial outwash terrace in Saltwater Forest was discussed. This soil type is one of a family of strongly leached, low fertility soils or Podzols, found on glacial landforms dating from between 40,000 and 19,000 years ago. These landforms were constructed by glaciers that extended out of their alpine valleys in the Southern Alps during the last glaciation, and include moraines and outwash terraces.

Moraines are piles of glacial debris dumped from the margins of the glaciers themselves, whereas outwash terraces are simply old floodplains formed by glacier meltwater rivers. Three kinds of moraines are recognisable in Saltwater Forest and illustrations of these are on the outside back cover of this issue of *Indigena*. Lateral moraines are high, steep-sided ridges formed on the sides of the Poerua and Whataroa glaciers. Terminal moraines are the broader, gentler, rolling topography formed at the former terminal face of the Whataroa glacier. Ablation moraines are basin-like areas littered with small, isolated piles of glacial debris in areas formerly occupied by glacial ice.

Along with the moraines, three different outwash terraces are recognised according to their age. The oldest, Terrace 1, is about 40,000 years old and exists as small terrace remnants. The loess soil described in the earlier article is found on this terrace. The two younger terraces, Terraces 2 and 3, are more extensive, have no loess cover, and are about 23,000 and 19,000 years old, respectively.

The coastal part of Saltwater Forest is made up of post-glacial floodplains, bogs and sand dunes. Apart from the minor areas of sand dunes the soils are all poorly drained Gley soils, or organic soils. The organic soils are so poorly drained they are covered by bog vegetation communities rather than forest. The gley soils, being much younger than the soils of the glacial landforms, are of much higher fertility.

Forest compositional variation

The broad subdivision of Saltwater Forest into glacial and post-glacial landforms is reflected in a clear compositional change in the forest. The post-glacial floodplains, covered by moderately fertile gley soils, have kahikatea as the dominant canopy podocarp. Moving from terraces close to the Poerua River, where kahikatea is the sole canopy species, to older parts of the floodplain near Saltwater Lagoon, kahikatea's dominance begins to be challenged by rimu. The increase in abundance of rimu is a reflection of declining soil fertility as soils increase in age and become more leached and nutrient depleted.

Shifting to the glacial age landforms, kahikatea becomes uncompetitive on the low fertility soils, and the conquest of the landscape by rimu is complete. However, this is not to say the forest is monotonous. Within the rimu-dominated forest, at least two broad types can be recognised.

The first is exemplified by the forest on steep lateral moraines where relatively sparse, very large rimu trees emerge over a canopy made up mostly of kamahi and quintinia. In the second type, found on the flat terraces, rimu forms a closed canopy with a subcanopy of angiosperms beneath. These two types of forest reflect the relative competitiveness of the angiosperms on the well drained lateral moraines compared to the poorly drained terraces. Well drained soils allow angiosperms to establish and crowd out the podocarps so that only few are able to emerge above the canopy and exploit the light above.

Forest composition

This broad distinction of hill and terrace forest in Westland's rimu forests is clear for all who have made even the most cursory examination. Less obvious are the more subtle changes in forest structure in what is lumped into the terrace forest-type across the flat terraces, the flat to hummocky ablation moraines and the gently rolling terminal moraines.

On these landforms, forest varies between dense stands of rimu and silver pine poles, to less-dense stands of larger rimu trees forming a 30 metre high, closed canopy over subdominant miro, to stands with a more open canopy and large mature or stag-headed rimu trees over a subcanopy of angiosperms. These stands vary in size from less than 0.2 hectares to 20 hectares and have been interpreted as representing different stages in stand development following some disturbance event that wiped out an earlier generation of trees. Therefore, Westland terrace forest is generally accepted as being a mosaic of even-age forest patches. Early studies identified wind as the major disturbance agent, especially effective on the wet soils characteristic of these landforms.

Variation

The spatial pattern of the different stand types is, however, more interesting, and less random than wind disturbance would seem to imply. In the area of glacial landforms of Saltwater Forest, a forest survey was conducted in the 1980s by NZ Forest Service to determine the variability of forest composition and structure. Canopy podocarp species were identified within 0.2 hectare circular plots, and allotted to one of 11 diameter classes. The plot data was then analysed using a numerical classification procedure which identified four different structural types as shown on the back cover.

The first three structural types 1, 2, 3 recognise the variation in stand structures described for the terrace forest above. In other words successively fewer but larger rimu trees from structural type 1 to 3. Silver pine is an important component only in structural type 1, while miro reaches maximum importance in structural type 3. Structural type 4 recognises sparse very large rimu amongst dense angiosperms characteristic of hill forest. An interesting feature of these structural types is that they all show a humped distribution of tree sizes – the smallest trees saplings and poles less than 20 cm diameter are not the most common trees. Rather, the most common trees are in some larger size class, and the diameter size-class that is most common increases from structural type 1 to 4.

The most common size class for each of the structural types is 20 to 29.9 cm for structural type 1, 40 to 49.9 cm for structural type 2, 50 to 59.9 cm for structural type 3 and 70 to 79.9 cm for structural type 4. This kind of distribution supports the interpretation that Westland rimu forest is a mosaic of even-age patches. Most trees were established sometime in the past following a disturbance with very little recruitment of younger trees.

The spatial distribution of the four structural types across the landscape is far from random. Structural type 1 is most common on the oldest terrace, terrace 1, which is dominated by deep extremely poorly drained organic soils. Structural type 2 is most common on terrace 2, which has a much higher abundance of mineral perch-gley podzols and less organic soils. Structural type 3 is most common on terrace 3, and on the terminal moraines. Terrace 3 has a lot of perch-gley podzols and very small areas of organic soils, while the terminal moraines are dominated by perch-gley and better drained podzols. Structural type 4 is found almost exclusively on the steep-sided lateral moraines and terminal moraines where well drained brown soils and podzols are common. The ablation moraines have a mix of topography from flat peat-filled basins to small protruding hillocks. The range in structural types reflects the variety in terrain.

The general pattern of forest structural types across landforms suggests that dense stands of young trees are associated with landforms with wet, weak, poorly drained soils, whereas stands of older trees are more commonly found on better drained landforms: This finding suggests soil conditions influence forest disturbance frequency, which in turn has a large bearing on forest structure. Moreover, some landforms may be so intrinsically unstable that the likelihood of trees ever reaching senescence is very low.

A more detailed analysis

This interpretation, of course, relies on a strong correlation between tree diameter and tree age. If the explanation given above is valid, then one would expect to see some correspondence between tree age and soil type. Measuring tree age is a very laborious process. However one transect in Saltwater Forest, along which tree ages have been measured by increment boring, shows an even-aged group of young trees, averaging about 200 years old, to correspond with an area of wet, deep organic soils.

In contrast, the adjacent forest growing on less poorly drained, and, importantly, mineral perch-gley podzols, has older trees. The tree age data clearly shows that while an earlier patch of trees on the organic soils was destroyed sometime before 260 years ago, the age of the oldest trees in the cohort, much of the surrounding forest was left undamaged.

Recently, forest ecology and paleoseismic studies have suggested an alternative disturbance mechanism to wind. Westland lies at the foot of the Southern Alps, which are being uplifted along a major fault line, the Alpine fault. This fault accommodates the motion between two of the Earth's tectonic plates, the Australian Plate and the Pacific Plate. Despite the lateral motion between the plates being about 25 mm a year, no motion at the fault has been recorded in historical times. Evidence from ages of forest, and wood beneath landslides and river terraces formed after earthquakes suggests movement occurs abruptly, producing earthquakes on irregular but approximately centennial timescales.

The last three earthquakes, all thought to be close to magnitude 8, occurred in about 1717, 1625 and 1460. Shaking during these earthquakes may be an equally or even more important cause of forest disturbance than wind in Westland's lowland forest, especially where soils are wet and vulnerable to liquefaction. Allowing 30 years for rimu to establish and grow to 1.4 metres height, most trees in this cohort would have established between 1730 and 1820.

Summary

If Saltwater Forest is a reasonable microcosm of Westland lowland forest, it demonstrates three important soil-forest interactions. Firstly, soil fertility determines the major forest compositional changes. Secondly, soil drainage interacts with forest disturbance to determine the frequency of forest turnover and forest age and size structure. Lastly, soil drainage determines the competitiveness of different species establishing in disturbance gaps, which affects composition – podocarp versus angiosperm components – and structure.

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Ages of rimu trees as measured from increment bores at 1.4 m height, and land surface elevation along a 600 metre long transect in Saltwater Forest. Cohorts of trees are identified and numbered.