The Important Role of Trees in Combating Coastal Erosion, Wind and Salt Spray – A New Zealand Case Study

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Summary

In their technical papers on aspects of tree development in coastal areas Prasetya (2006) and Takle et al (2006) discuss a number of important factors that determine how best to use trees and forests to combat coastal erosion, wind and the debilitating effects of salt spray. The principles and techniques they describe can be used to determine not only the most effective methods for establishing and using trees, but are also important pointers to the species most likely to survive and do well in such situations.

This paper describes an example from New Zealand of severe coastal erosion arising from inappropriate land use, leading to the wide-scale release of partially consolidated coastal sand-dunes during settlement of the country. Adopting many of the principles and techniques described by Takle and Prasetya has led to the problem largely being over come.

Although in this case it is likely that careless landuse created much of the problem, it could equally have arisen as a consequence of vegetation removal via extreme drought, fire, tsunami, or earthquake and the consequences would have been the same.

An important feature of the New Zealand programme is that much of the erosion involved tribally owned lands, and through direct involvement in the restoration and subsequent commercial forest harvesting activities local people have gainful employment and social and community development has occurred.

Introduction

New Zealand is a geologically young country, and both degradation and aggradation of its coastline is a common occurrence at different points around its perimeter. A combination of high mountains made up of a relatively high component of erodible sedimentary rocks, steep slopes and high rainfall mean that the country's many rivers are constantly contributing silt and sandy debris to its beaches.

The country is also long and relatively narrow – lying across the prevailing westerly wind belt between 34 and 47 degrees south of the equator, and constant onshore winds and occasional gales from a westerly quarter are a fact of life.

A consequence of these two factors is that on parts of the west coast of the North Island around Himitangi, it has been estimated that over the last 20 000 years the coastal shoreline has extended out to sea by between 10-20km and the average elevation has increased by 3-5m as a consequence of the deposition of sand on the beaches and its subsequent wind assisted drift inland. Similar situations exist in many other areas along the western side of the country with some hundreds of kilometers of sandy coastline typically existing.

Photo 1 - Typical west coast dune system, 1960s – 90 Mile Beach, New Zealand

When European settlement commenced in the early 1800s most of these areas were stabilized by native grasses and shrubs, although early journals of explorers such as the naturalist Sir Joseph Banks (1769), who accompanied Captain James Cook in his great voyage of discovery, reported seeing tall dunes of bare sand in the north of the country. At this time the country had already been occupied for possibly 800 years by the indigenous Polynesian people, the Maori, whose food gathering and cropping activities included land clearance and use of fire and it is likely that at least some of the dunes had been open up in this manner. However it is also clear that as European settlement proceeded land clearance for agricultural purposes involving careless use of fire, other inappropriate vegetation removal, and grazing of livestock led to even greater disturbance of the sand areas and wide scale drifting soon recommenced.

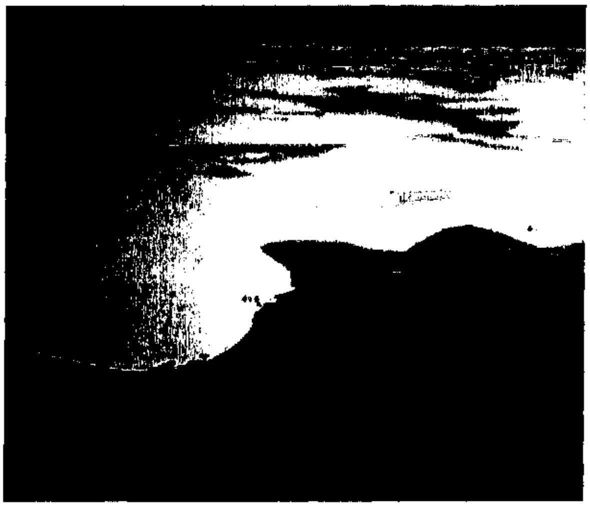

Photo 2 – Drifting sand quickly covered productive farmland, lakes and forests. In this case over grazing and poor farming practices released the sand but it could have been fire, storms or even tsunami.

Estimates suggest that by the early 1900s up to 150 000 ha of drifting sand dunes were creating major problems, including loss of valuable productive farm land, and potential closure of important north – south road and rail links. Areas of native forest and tall forest shelter established to provide protection against the salt-spray laden wind were also overwhelmed. Wendelken in a paper published in 1974 reports that "dunes as high as 200m were recorded....extending for many miles along an unbroken front", in this case backing onto the locality known as Ninety Mile Beach (which is a coastal complex of dunes extending N - S for 140 km).

Photo 2 – Tall pine trees overwhelmed and killed by drifting sand.

In 1903 the government passed legislation encouraging action to control sand drift by local authorities, but otherwise took little notice of the problem. A more comprehensive review of the situation by renowned botanist Dr L. Cockayne led to more aggressive efforts to challenge the problem, including a series of trials designed to replicate some of the European experience with drifting sand such as that at Gascony.
In 1919 the Government set up the NZ State Forest Service and from that point on virtually all of the effort to contain the drifting sand and most of the supporting research work was undertaken by that department although the Public Works Department also had a role for a number of years.

Important Considerations

A number of issues required consideration in the early years of the NZ sand stabilization programme;-

1. The drift of sand is continually replenished off the beaches and during windy periods sand quickly accumulates around and over any obstacles.
2. The drifting sands are driven by relatively strong westerly winds, which has a strong influence on what plants can be grown at different stages in the revegetation process;-
    a. Wind may seriously dry-out and desiccate plants trying to establish on the dunes. The sand has little ability to retain water for any length of time, although regular rainfall in winter does permit vegetation to establish and grow.
    b. Vegetation established on the dunes in the initial phases of the revegetation process is exposed to abrasive windblown sand.
    c. High levels of salinity in both the air and in the soil due to the proximity of the sea and relatively heavy surf along NZ's west coast limits plant species that may be grown.
    d. During periods of intense sunlight sand surface temperatures rise well above levels most plants can tolerate.
3. The sand has low nutrient status, being largely composed of small particles of river and sea washed rock and shell.
4. Scale is very important – small trials exposed to attack on every quarter are difficult to protect from constant drift, which is best stopped at or near its source.
5. Much of the land subject to the worst drift problems was tribally-owned (Maori or customary land), with attendant problems of multiple ownership in decision making and approval processes.

Many of the processes that have evolved to address these matters are the same processes that Takle and Prasetya (loc cite) also address in their papers on the use of trees to control coastal erosion and provide protection against wind and salt spray.

Coastal Processes and Erosion Control

The natural vegetation in the NZ coastal sand-dune setting includes a number of species which are well adapted to life in what is often a fairly hostile environment. Immediately above the beach plants able to tolerate abrasive sand, high wind and salt exposure include a native grass (*Spinifex hirsutus*) and a species of sedge (*Desmoschoenus spiralis*), which grow at more or less the rate of sand accumulation and help shape the high beach-front sand ridge or foredune. This frontal dune in turn protects more inland areas from the full force of the wind and salt spray while its vegetation traps sand blowing off the beach. Over time new dunes develop around driftwood and other debris left on the beach, leading to a seaward migration of the shore line, while the vegetation on the old foredune in turn consolidates in the shelter provided by the new rising dune in front of it. Vegetation in the more sheltered setting is also somewhat wind and salt tolerant but is able to grow taller and tends to be more luxuriant.

Damage to the vegetation of the foredune can quickly lead to a collapse of this system (known as a "blow-out") – foredune sand is able to quickly run inland covering existing more stable vegetation and creating an opening for the full force of salt-laden winds to also do further damage. Blow outs of this nature may run inland for 100s of metres. Repairs are undertaken by building artificial barriers across the gaps caused by blow-outs, usually of semi-permeable materials which slow the wind and result in sand being deposited on their lee side.

Early barriers or fences used a thicket of twigs or thatch but more recently plastic mesh has proven most effective and much simpler to erect. As the sand covers the first fence another is raised above and behind it until a significant barrier is once again recreated. This is then planted with sand binding plants, however the native species have not been widely used as they are more susceptible to trampling, relatively difficult to transplant and slow growing (the preferred species has been marram grass *Ammophilla arenaria* which was introduced into NZ from Europe and is relatively fast-growing in these circumstances). In many cases the initial extent of the coastal sand erosion problem was so great that many kilometers of fences were required, and little other work could be undertaken until the problem of containing the rush of sand off the beach was underway.

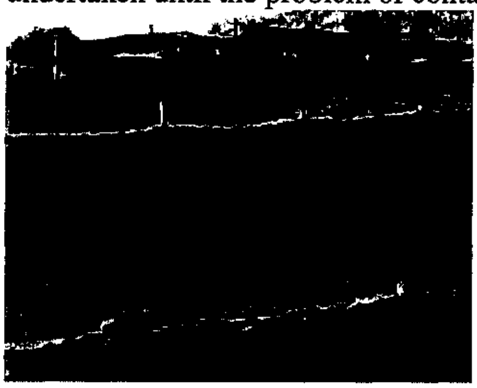

Photo 4 – Fences erected to catch the drifting sand and rebuild the foredune, preventing the deposition of sand over more inland sites.

Photo 5 – Revegetation of new foredune to stabilise it against further drift and to provide permanent protection of inland sites

Further inland drifting dunes also needed to be halted, and after some trial and error practical techniques were developed which enabled broad areas to be quickly fixed. In brief the stages in the process are;-

- Planting with marram grass – large nurseries of marram grass are established on flat, open sandy areas from where it is harvested using an under-cutting technique. Bundles of the grass gathered in this manner retained part of the rhizome and rootlets and planted at relatively close spacing (1-2m rectangular spacing) in winter quickly root and as it grows and spreads it slows surface sand movement and provides shelter for other plants.

Photo 6 – A 6-Man marram planting machine capable of planting 20 ha of marram grass per day.

- A year or so after planting marram grass yellow tree lupin (*Lupinus arboreus*) is established, initially by direct surface seeding but later trials found that improved results could be obtained where the seed was drilled into the sand. Lupin is a legume and typically adds significant quantities of nitrogen into the growing plant biomass. It is also salt and wind tolerant and relatively deep rooting so it makes an important contribution to consolidation of the dunes and provides further shelter to other herbs and shrubs as these develop (a fungus of the genus *Coletotrichum* developed to more or less epidemic proportions in the 1980s and largely eliminated yellow tree lupin from NZ's coastal areas, and a range of other leguminous species have been used in its place although it has made something of a recovery in more recent times).

- The established thicket of lupin and other species is planted through with the coastal pine species (*Pinus radiata*) about two years after lupin has been planted. Radiata pine is relatively salt and wind tolerant and grows rapidly once established, with roots reaching more than 20m in some cases in search of both nutrients and moisture. However in the most exposed coastal sites growth is slower and the tree is usually very deformed and stunted, but the shelter offered by those in the most coast-ward areas allows others further inland to grow to more or less their full potential, providing a commercial wood source over tens of thousands of hectares on a 30 year rotation.

Discussion

The inadvertent release of the massive sand drifts of the west coast of New Zealand by land clearance and grazing could have as easily been triggered by vegetation removal through natural phenomenon such as prolonged drought, fire, prolonged wind or tsunami and the consequences would have been the same.

The critical factors are;-

- The continued re-supply of sand off the beaches. In New Zealand's case the beaches of the west coast are aggrading as additional debris is supplied by a number of major rivers and harbours which exit along this coastline. The prevailing wind carries sand off the beaches and up onto the foredune in significant quantities especially during storms. The vegetation growing on this area needs to be resistant to desiccating winds; salt spray and the abrasive effects of wind carried sand, and be able to continue to grow at least at the rate of sand accumulation while ignoring the fact that much of its lower parts may quickly become submerged in sand. In bright sunshine temperatures at the sand surface can also be extremely high. A small number of grasses and sedges exist well in these circumstances, most having high silica content or hairs, etc to resist abrasion. Leaves are usually thickened and rolled to protect the stomata and reduce transpiration while root systems are very extensive tapping moisture from considerable depths. Marram grass has been used widely because of its ease of propagation and relatively rapid growth.
- Low nutrient status of recently eroded and deposited sand. Recently deposited coastal sand dunes have no organic content, no soil structure and high salinity/very low inherent nutrient status. Accordingly while quickly establishing a cover crop may be the top priority high tolerance to these difficult conditions is a key issue. As noted above marram grass will establish well and quickly if planted into these conditions, however planting is still undertaken during the wet season (winter in NZ) to ensure best chance of initial survival. Following planting

the marram grass is fertilized with a surface application of ammonium nitrate or urea (not regularly used because of volatilization problems) and responds well to application rates as low as 20kg N per ha. This is also critical to the plant's survival – without N the plants start to die out with 6-8 months.

- Long term nutrient status and soil development. Although the marram grass can be kept alive and growing reasonably well by regularly adding fertilizer it has little ability to encourage colonization by other plants. Accordingly lupin is planted after 12 months and rapidly develops in the shelter of the marram. As a colonizing plant it quickly develops to occupy most of the site, while it's thick hairy leaves provide protection from the wind and low moisture levels. It is again a deep rooting species and its leguminous habit quickly adds significant quantities of N into the system. Other wild herbs and shrubs establish in its cover and within two years a good litter layer and root mat is usually formed while the lupin plants are 1-2 metres in height and provide good side shelter and shade.
- Tree planting and salt tolerance. About 3 years after the initial marram planting radiata pine trees may be planted through the lupin cover. Trees about 50cm tall are planted with up to half of the tree being placed into the ground (to maximize access to water). The lupin provides good shade and shelter while the tree becomes established but may need to be removed (by spraying or cutting back) as the tree grows. Radiata pine is moderately tolerant of salt spray and wind but is badly burned and desiccated nearer the coast and may be killed by full exposure to these conditions. A number of other species have been tested in the most exposed localities with quite mixed results – several species have the necessary salt and wind tolerance but are unable to adapt to the wide soil moisture fluctuations and difficult nutrient conditions. These include a number of native species (*Metrosideros excelsa, Olearia traversii*), well known coastal species from other countries (Norfolk Island pine *Araucaria excelsa*, the Australian *Tamarix* and she-oak, *Casuarina equisetifolia, Pinus pinaster* from the Mediterranean, Jackpine or *Pinus thunbergii* from Japan all of which grow in relatively hostile marine environments. Monterey cypress (*Cupressus macrocarpa*) from the Monterey peninsula region of California has been found to have most of the preferred characteristics and is planted as a two row shelter along the coastal stand edge. Radiata pine is planted behind this shelter once it is established allowing the development of a commercial crop from 100m or so behind the foredune.

Photo 7 – Coastal stand edges are badly damaged by salt wind but where shelter in the form of a higher foredune, or resistant species are planted, commercial tree crops can be grown.

The synergistic relationship between the pine trees and lupin established during the sand stabilization phase is important. It has been found that the N contributed by the legume is equivalent to 200-250 kg per ha which would otherwise need to be added via artificial fertilizers. As the crop of pine trees develops it shades out the lupin however lupin seed is viable in the soil for several decades when the pines are thinned the soil disturbance and extra light result in a fresh crop of lupin appearing – providing the equivalent of a further dose of fertilizer. Similarly a heavy regrowth of lupin may follow harvesting of the forest crop.

- Commercial enterprises and Community development. Radiata pine established on the dunes in this manner grows progressively better moving inland from the coast, although where reasonably sheltered will usually produce at least a commercial crop of logs, firewood, etc. As noted earlier much of the eroding area was on tribal land and the stabilization provided work programmes for hundreds of people – initially working in the nurseries and on the planting and sowing machines, etc.

Photo 8 – Thinned and pruned 8 year old radiate pine growing on recently stabilized sand-dunes. Forest operations provides employment opportunities on tribal lands.

- Later the developing forests required attention as thinning and pruning operations commenced, and today sustainable harvesting operations are proceeding in several locations supplying world scale wood processing and export operations. Pastoral farming, horticulture and cropping activities occur as a matter of course on the agricultural land once threatened by the drifting sands – the shelter provided by the tall forest provides an ideal microclimate. Meanwhile activities such as ecotourism based around the forests, and the improved access via forest roads onto the beaches have provided both better recreational and employment opportunities for local people.

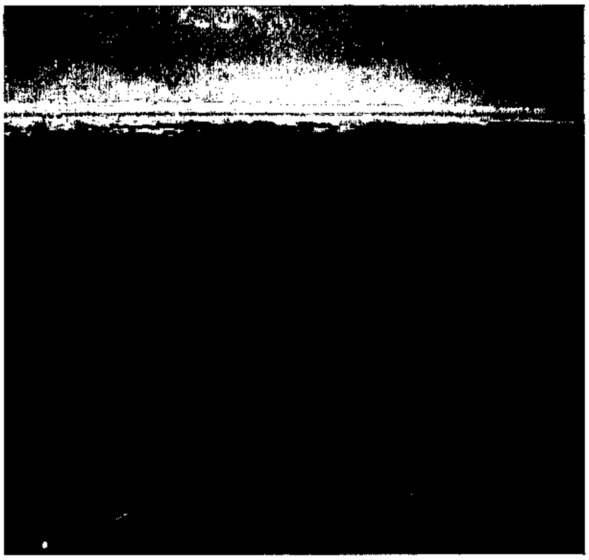

Photo 9 – Mature forest on coastal sand-dunes provides commercial enterprise and protects inland agricultural land.

Conclusions

In this New Zealand case study into the use of trees to combat the effects of coastal erosion, wind and salt spray, the benefits of adopting soundly based techniques such as are discussed by Takle and Prasetya (loc cite) are well demonstrated. Issues such as wind speed and run and the use of permeable barriers to cause deposition of wind carried sand, use of species with high inherent salt tolerance and development of shelter are addressed. The product of the sand stabilization process has been development of a successful commercial forestry enterprise providing permanent employment for local people, while simultaneously high quality agricultural land has been returned to production and other facilities including coastal settlements, railways and roads are also protected.

Photo 10 - A rebuilt foredune providing protection of a coastal settlement against future storms or similar events.

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