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New Zealand Experience in Stabilization and Afforestation of Coastal Sands

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INTRODUCTION

New Zealand is geologically a young country, and over two-thirds of its coastline is backed by steep cliffs. When European settlement began in the 1840s only about 180,000 ha (0.4% of the total land area) had sand as a soil, all located at or near the sea coast. Most of it was stabilized by native grasses and shrubs, although there were exceptions in places where coast formation was active at river mouths and estuaries and also in places where sands of almost-pure silica, unsuitable for plant growth, were constantly supplied by marine currents and were encroaching on the land. Various Polynesian groups, known as Maoris, which had already occupied the country for some 1,000 years prior to the Europeans had not appreciably affected the natural balance, even though most of their habitations were near the coast, in particular near open beaches and estuaries that provided a suitable environment for their basically food-gathering way of life. The activities of the European settlers in burning to clear land for development and in grazing farm livestock led to the disturbance and depletion of the natural cover of the sand areas, and drifting was not long in becoming apparent.

The earliest official mention of the need to retain the sandy wastes was in 1877, when the first conservator of forests, I. Campbell Walker, drew attention to their threat to valuable farmlands and at the same time pointed out their potential for utilisation as forest land. However, despite the fact that within 3 years of these recommendations the area of drifting sands was about 40,000 ha, it was not until 1903 that Government passed legislation to deal with the problem, enabling action to be taken. By this time coastal farmers had for a number of years been experiencing difficulties with sand blowing on to their lands, and on some parts of the North Island west coast migratory dunes, large enough to engulf tall coastal scrub or forest, highlighted the need for counter measures.

THE MAJOR SAND AREAS

GENERAL.- New Zealand is long and narrow, with an area of 26.5 mill ha lying between 34 and 47° of latitude south and exposed to predominantly strong westerly winds. The most extensive areas of coastal sand, and also those posing the greatest threat of encroachment, are concentrated in three main localities in the North Island. They are Manawatu, Auckland, and Ninety Mile Beach (Fig. 1) and together make up most of the 115,000 ha of unconsolidated or recent sand country in the North Island. In the South Island areas of sand generally pose no difficulties: those in the west are not large; and although the east has some fairly extensive sand beaches their limited exposure to off-sea winds and the limited

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in the far north forming a compact hilly area. During Pleistocene times successive warping and downfaulting of the land, combined with fluctuations in sea level, brought about a series of marine, estuarine, and littoral sand deposits, and these extended over what is now the whole area of this northern narrow peninsula.

Overall, the sands are whitish in colour, being composed mainly of quartz and/or feldspar, and localised patches are of such purity that they are mined for glass-making and other special industrial uses. Some deposits are so inert that plant growth is naturally impeded, and probably they never carried much vegetation. Sir Joseph Banks, when exploring the New Zealand coast with Captain James Cook in 1769, recorded in his journal seeing large areas of dazzling white sand on the east coast of the northern tip on which no kind of plant life was to be seen. He was reporting on the Parengarenga sand fascies. They are characterised by a very high silica content normally in excess of 95% and an iron oxide content of less than 0.1% (Schofield, 1969).

The extensive bare sand areas along the western coast of this northern tip had a long history of warfare between Maori tribes and this, coupled with the generally youthful stages of vegetation development, the paucity of essential plant minerals, high summer temperatures, and periodic droughts, led to frequent large fires. The name given to the northernmost Maori tribe (Aupouri) means "Big Smoke", recording the frequency of fires in these people's territory. Early European settlement further depleted the coastal scrub and poor grass cover that had managed to survive, especially on the most recent sands.

A continuous supply of fresh sand is available from the shallow littoral areas where frequent strong gales bring sand to the storm high water level. Dunes as high as 200 m were recorded in the early days of settlement, extending for many miles along an unbroken front. Inland, climax associations of kauri (AGATHIS AUSTRALIS) and pohutukawa (METROSIDEROS EXCELSA) clothed the older volcanic remnants and, together with the many shrub species associated with them, invaded and colonised the older sand dunes as they became consolidated during periods between major conflagrations.

More recently, attempts to develop the older sand fascies into permanent pastoral farms brought realisation that the western areas of raw sand threatened farming and in turn the very existence of the Maori communities relying predominantly on this for their livelihood.

CLIMATE.- Rainfall along the North Island west coast is generally adequate for plant growth, rarely falling below 750 mm and usually lying between 900 and 1.500 mm annually. The rainfall pattern is however generally even and typical of a temperate maritime climate and is not a limiting factor in consolidating sand areas.

Although strong winds, principally from the western quarter, are frequent they are not of serious consequence once a stable foredune has been constructed.

Frosts occur in the late winter months, even in the far north, but do not affect survival of the main native sand-binding plants or of most of the specialised plants adapted to these conditions from other countries and now naturalised in New Zealand. Overall, climatic factors are neither so harsh nor so extreme as to prevent use of a variety of plants capable of effectively stabilising loose raw sand.

NATURAL VEGETATION.- The natural vegetation of the sand areas was relatively simple, when compared with other indigenous associations, but, nevertheless, partly because of plant specialisation and partly because of the absence of browsing animals (as was the case before European settlement), there were a considerable number of plants adapted to micro-sites in the sand and dune complexes. Few of these are amenable to propagation in artificial establishment of vegetation on bare sand country. The endemic grass pingao (DESMOSCHOENUS SPIRALIS) is common but rarely gregarious, being found either close to the foredune or capping

remnant dune crests. Also common along foredunes is the silver sand grass (SPINIFEX HIRSUTUS), native to New Zealand and Australia. It has a long rhizome which grows rapidly and extends over sand surfaces, rooting at the nodes. Its usefulness in revegetation work is limited because of the long internodes and open nature of its leaves. Nevertheless, SPINIFEX is a particularly useful grass for protecting the seaward edge of foredunes.

Given some stability at the sand surface many native plants effectively colonise sand areas, and in the absence of fires and grazing a permanent woody plant complex develops, leading eventually to specialised coastal forest types containing a number of climax species. Notable among these pioneering species are members of the Compositae and Rubiaceae, such as OLEARIA SOLANDRI, PIMELEA ARENARIA, CASSINIA LEPTOPHYLLA and C. RETORTA, RAOULIA HOOKERI, and COPROSMA ACEROSA, but none are very effective pioneers of bare sand. Other plants appear as stabilisation and colonisation continues with the establishment of flaxes (PHORMIUM TENAX and P. COOKIANUM), manuka (LEPTOSPERMUM SCOPARIUM), and a variety of almost leafless shrubs such as DISCARIA TOUMATOU, CARMICHAELIA FLAGELLIFORMIS, and COROKIA COTONEASTER, which are associated with several creeping plants such as MUEHLENBECKIA COMPLEXA, PARSONIA HETEROPHYLLA, CALYSTEGIA SOLDANELLA, and DISPHYMA AUSTRALE, all contributing to the development of a complete cover (Moore and Adams, 1963). This natural process is slow, susceptible to disturbance by animals, and cannot be economically adapted to use in large-scale stabilisation work where other land values are threatened.

ADMINISTRATIVE CONTROLS

The essential feature of legislation introduced in 1903 to control sand areas was that by petition of local authorities by two or more people the Government could declare by proclamation that certain provisions would come into force over a specified area. The Government would then prepare a scheme to control the sand drift and to prevent further encroachment on to adjoining lands, apportioning the costs of the various operations among owners of land within the proclaimed area. The responsibility for the work might be delegated to local authorities or to the Government department concerned with stabilisation work (at that time the Department of Lands and Survey).

Unfortunately many of the worst problem areas lay in the lee of large natural sand dunes that were held in multiple ownerships by the native Maori peoples. These people had no resources to pay for their share of any work. The legislative measures were effective in areas of close farm settlement but failed to be effective in the large sparsely settled sand areas in the north of the North Island.

This early legislation was followed by a comprehensive report by Dr L. Cockayne (1909), tabled for Government consideration. Reference was made to work already done in western Europe, beginning with experience in 1780 on the dunes of Gascogny. The report provided a good base from which to plan work and the methods to be followed in fixing moving sands.

In 1915 the Forestry Branch of the Department of Lands and Survey began small-scale trials in several areas in North Auckland. These trials were exploratory in use of both native and introduced sand-binding plants to hasten consolidation and experimented with various introduced coniferous tree species to assess their ability to survive and grow on the range of sites found in the sand areas, i.e. a range from exposed coastal sites to sheltered inland ones, varying from bare to stable sands. Larger scale trials began when the Forestry Branch became the Forest Service in 1919 (Goudie, 1921).

About 1931 the Forest Service, because of economic factors arising from a world-wide depression, ceased its role in sand work - temporarily, as it turned

Aircraft have been used but distribution proved to be irregular and the slightly increased cost with topdressing machines was preferable as an even growth of marram grass resulted.

MARRAM GRASS NURSERIES.- Early attempts to provide special marram grass nurseries were abandoned in favour of lifting tillers from previous plantings or obtaining additional supplies from naturally colonised areas. With the ready availability of artificial nitrogenous manures about 1920 the technique of accelerating rhizome growth and culm formation by heavy applications of fertiliser to selected planted areas for use as temporary nurseries became standard practice.

Marram grass 'nurseries' are now selected in level sheltered areas which were planted (as a routine in stabilising operations) some 15 months previously. They vary in size from about 1 to 5 ha, depending on terrain. In addition to the standard applications of nitrogenous fertiliser made after planting, nursery areas receive 250 kg/ha when selected and sets are lifted in the following winter months, i.e. at about age 22 to 26 months. These nursery areas provide some 17,000 to 18,000 kg/ha of marram for one crop; subsequently they are sown with lupin seed at 11 kg/ha and left to regenerate.

LUPIN SOWING.- Lupin not only helps develop a better protective vegetation but also adds important nitrogen to the soil. Planted marram grass and other areas where lupin is absent receive a broadcast of 10-11 kg/ha of lupin seed at the time of the second fertiliser application in autumn. Recent investigations indicate that less seed need be used if it is sown about 2 to 3 cm deep rather than being broadcast. For this purpose agricultural seed and fertiliser drills have been modified to sow lupin seed, and trials are now under way to test the feasibility of introducing lupin seed at the time marram grass is planted. Early results at Woodhill Forest (Auckland sand area) suggest that the time needed for stabilisation of sand drifts and dunes may be shortened from 5 years to 3-4 years when lupin seed is subsurface sown.

OTHER METHODS OF STABILIZATION.- Various trials to stabilise bare sand have been made using emulsions derived from petroleum, bitumen, or rubber (to avoid the 5-year fixation period using marram grass). Each compound tried has shown some advantage but supply problems and high costs have prevented large-scale use. Little purpose would be served in describing the materials and techniques experimented with because in each case proven overseas experience has been followed to test applicability under New Zealand conditions.

AFFORESTATION

GENERAL.- Tree planting begins after the preliminary stabilisation is complete. In the early exploratory years, before commercial afforestation became the final goal in stabilisation work, tree species were selected on the basis of overseas experience (principally western European), and more emphasis appeared to be given to their ability to grow and form a dense windbreak or closed stand than to their potential for producing useful wood. Those tried in the early years included PINUS PINASTER, P. NIGRA, P. AUSTRIACA, P. BANKSIANA, P. ECHINATA, P. TORREYANA, P. THUNBERGII, P. DENSIFLORA, ALNUS GLUTINOSA, CUPRESSUS MACROCARPA, and CHAMAECYPARIS LAWSONIANA. In 1921 progress was reviewed and it was then thought that P. DENSIFLORA and P. THUNBERGII would be well suited for sand afforestation (Goudie, 1921).

EMERGENCE OF PINUS RADIATA.- Towards the end of the decade 1920-1930 the superiority of P. RADIATA and the general utility of P. PINASTER and P. MURICATA were recognised, these becoming the main species used for afforestation, with radiata pine being used most commonly. Because of severe stunting and scorching of foliage at the coastal edges of stands, CUPRESSUS MACROCARPA, together with P. PINASTER and P. MURICATA, was selected to develop a coastal

shelter zone behind which the faster growing radiata pine could grow in a more upright timber-tree form. However, radiata's ability to withstand exposure as well as the more typical shelter species has led to its adoption for all tree planting from the exposed coastal zone to the inland margins of sand forests.

As the Forest Service continued to develop sand stabilisation and afforestation techniques, improve operational practices, and man permanently the main sand forest areas (principally in Manawatu and Auckland regions at this time) into the 1950 decade, almost complete reliance was placed on radiata pine. It was now known to be one of the species most resistant to exposure to salt-laden winds and also had fast growth rates and the ability to produce useful wood in good log form. It showed the greatest promise of being the most economical species to use on sand country, capable of supplying industry with an acceptable timber having general utility and hence demand (Kear, 1964).

TREE PLANTING.- Tree planting can begin after some 3 to 5 years of lupin growth, by which time it has been calculated that a lupin-dominated stand has accumulated a total of up to 446 kg/ha of nitrogen (Gadgil, 1969). By using conventional tree planting machines some 2.5-3.0 ha can be planted in an 8-h working day by each machine. The tree planting machines are drawn behind a crawler tractor of about D4 capacity, i.e. 70 horsepower, so that the coulter and plough run directly in the crushed vegetation lying behind one set of tracks. Currently, trials are being conducted with tree planting machines mounted directly by hydraulic linkage on to a tractor, thus dispensing with the front wheel support of the planting machine.

Planting stock is open-rooted radiata pine aged between 15 and 18 months and some 45 cm tall ($1\frac{1}{2}/0$ stock), i.e. tree seed is sown in tree nurseries about January and lifted in the winter months of the following year after having been wrenched several times in the nursery bed. Trees are conveyed to planting sites in plastic bags or in cartons, with care being taken at all times to ensure the bags are not compressed and are not exposed to direct sunlight.

ESPACEMENT.- Until recently spacement of trees was traditionally 1.8 m along rows and 2.4 m between rows, and planting took place directly into the dense mat of grasses and creeping plants developed among and along with the marram grass (which by this stage is frequently suppressed) and lupin established a few years previously.

After several trials with espacement of trees, and after timber cut from trees grown at various spacings had been analysed for grade production, it became clear that trees could be spaced much wider at planting. Whiteside (1964) described the quality of timber from untended stands of radiata pine grown on sand and found it was significantly superior to that from untended stands grown on inland pumice and clay soils. Superiority existed in board and framing grades, and in general the density of timber - and hence its strength - was higher. Depending on site productivity, assessed partly by an estimate of exposure and position in relation to the coast and partly by experience based on the vigour of native vegetation developed since stabilisation was completed, it is now practice to widen spacing to 2.4 m between trees in the rows and to some 3 to 3.2 m between the rows.

COMPETING VEGETATION.- Where lupin and other vegetation is vigorous it is necessary to release the trees. Frequently two releasings are required in the first year after planting and one in the following year. Agricultural discs drawn by wheeled tractors have been modified to chop and crush vegetation on either side of the rows of trees. The discs have a cut-away section in the centre so that when mounted on the three-point linkage of a tractor they straddle a row of trees. A narrow strip of uncut vegetation is left on either side of trees. This is able to provide some shelter to the planted stock, yet is not sufficiently dense to suppress its growth.

PRODUCTION OF USABLE WOOD FROM SAND DUNE FORESTS

Sizable forest-based industries have now been developed relying on the sand forests adjacent to Auckland. In the Manawatu local sawmillers and post and pole manufacturers use logs from the smaller sand forests, which thus help to meet the local demand for forest produce. Because terrain is usually easy and good roads are readily established by spreading layers of sandy clay at about 1 m^3 per 5 m^2 of running surface, early harvesting by thinning is adopted to maximise wood yields. Where pruning of branches is carried out over the lower stem, usually to some 6 m height, a careful balance is needed between striving for early returns from thinnings and waiting until piece sizes produced from thinnings are sufficiently large to enhance the economics of handling them. Undue delay in thinning following completion of pruning, which may be a two or three stage process, is to be avoided as fast growth of clear wood over the pruned branch stubs must be maintained if the investment in pruning and the overall economies of growing quality wood are to be maintained.

OTHER ROLES FOR SAND DUNE FORESTS

New Zealand has a relatively low density population, some 2.8 million people occupying 26.5 million ha, i.e. more than 9 ha per person. Distribution is heavily concentrated in urban areas throughout New Zealand (77%), and this is especially so towards the northern part of the North Island near Auckland.

Within an area of 550,000 ha - the Central Auckland statistical area - 674,000 people reside, i.e. more than 1 person/ha, an increase of 22% since 1966. Heavy pressure falls on all recreational areas and facilities, and as New Zealanders are active in outdoor pursuits, especially swimming, surfing, fishing, boating, and others associated with the sea, every available beach is under demand for recreational use.

Local authorities have a statutory obligation under the Town and Country Planning Act 1953 to prepare and operate a district scheme aimed at developing an area in such a way as will 'most effectively tend to promote and safeguard the health, safety and convenience, and the economic and general welfare of its inhabitants, and the amenities of every part of its area.'

It has been indicated that much of New Zealand's coastline is rocky. Frequently a complex of bluffs, promontories, inlets and sandy bays extends for many miles offering a variety of attractive sites ideally suited for coast-oriented recreational use. Where long exposed coastlines having some depth of marine derived sands exist, as has been discussed in this paper, recreational use may not be so intense as in small bays, but nevertheless in localities adjacent to large urban centres such as Auckland city heavy use is frequently made of them. Active management and maintenance primarily for protective purposes is necessary in order to provide initially the stabilising cover and to maintain it in the face of heavy trampling and the threat from fires.

Recreational use is becoming an increasingly important aspect of management of coastal sand dune forests, with more attention now being paid to planning for heavy public use of access roads and attractive localities within the forest and adjacent to and along the beach. Experience in this field has been limited until recently, but pressures to use forests for recreation are building up rapidly. Small areas of State forest adjacent to local body domains and recreation reserves have been handed over for intensive development once the sand has been stabilised by a permanent vegetative cover; e.g. to extend a golf course or a picnic area shown to be too limited in extent to meet recreational demands.

Local body expertise in managing the vegetation on the one hand to maintain a satisfactory protective cover, and in controlling people and their activities on the other to prevent undue damage, has been shown to be less effective than is desired. The Forest Service and foresters now generally believe that control of other activities, secondary to protective functions of sand stabilising forestry, must remain in the hands of the forest manager. Eventually such questions as whether or not the user should pay must be answered, but in the meantime it is confidently felt that with the ability of a managed radiata pine crop to provide a good financial return on an investment primarily made for protection purposes, secondary recreational functions can be permitted as a service to the public at no extra cost. It is anticipated that more intensive development of access paths to beaches may be required, with corduroy routes, timber steps, bitumenised surfaces, and a number of other techniques likely to be used where large numbers of people tend to congregate or pass.

REFERENCES

BANKS, J. (1796) : The Endeavour Journal of Joseph Banks (1768-1771). Edited by J.C.Beaglehole, 1962. Trustees of the Public Library of New South Wales in association with Angus and Robertson.

CAMPBELL WALKER, I. (1877): Report of the Conservator of State Forests. Wellington, Government Printer. 59 pp.

COCKAYNE, L. (1909) : Report on the Sand Dunes of New Zealand: The Geology and Botany, with Their Economic Bearing. Wellington. Government Printer, 30 pp.

CONWAY, M.J. (1956) : Mechanisation in sand dune afforestation. Empire Forestry Rev., 35: 143-148.

ESLER, A.E. (1969) : Manawatu Sand Plain Vegetation. N.Z. Ecol.Soc. Proc. No 16, 32-35.

GADGIL, Ruth L. (1969) : Nitrogen in the Ecosystem during Dune Stabilisation at Woodhill State Forest: I. The Pre-Radiata Phase. N.Z. Forest Service, Forest Research Institute, Soils and Nutrition Report No 3. 13 p (Unpublished.)

GADGIL, Ruth L. (1971a): Lupin Productivity in Pinus radiata Stands at Woodhill. N.Z. Forest Service, Forest Research Institute, Soils and Site Productivity Report No 26. (Unpublished.)

GADGIL, Ruth L. (1971b): The Nutritional Role of LUPINUS ARBOREUS in Coastal Sand Dune Country. Plant Soil No 34, 357-367 and 575-593.

GOUDIE, H.A. (1921) : Sand Dune Reclamation; Activities of the State Forest Service. N.Z. J.Agric.

KEAR, David (1964) : Coastal Sand Deposits; North-Western North Island. N.Z. J.Forest., 9: 139-145.

LEWIS, E.R. (1954) : Yield of Unthinned PINUS RADIATA in New Zealand. N.Z. Forest Service, Forest Research Institute, Forest Research Notes 1(10). 19 p.

LEVY, E.B. (1948) : Report of the Research and Afforestation Committee on Sand Dune Country in the Manawatu Catchment District. Palmerston North, New Zealand, Manawatu Catchment Board Publication No 1.

MEAD, D.J., GADGIL, R.L., RENNIE, P.J. and WILL, G.M. (1968): Response of Pinus radiata to Thinning and the Presence of Lupins. N.Z. Forest Service, Forest Research Institute, Silviculture Report No 119. (Unpublished.)

MOORE, Lucy B. and ADAMS, Nancy M. (1963): Plants of the New Zealand Coast. Pauls Book Arcade, Auckland and Hamilton.

NEW ZEALAND FOREST SERVICE (1950): Annual Report of the Director of Forestry for the Year Ending 31 March 1950. Wellington, Government Printer.