AERIAL SEEDING OF PINES FOR PROTECTION AFFORESTATION: KAWEKA FOREST, HAWKE'S BAY

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SYNOPSIS

Establishment of pines, principally Pinus contorta, *by aerial seeding in Kaweka Forest, Hawke's Bay, was commenced in 1965 in an attempt to reduce erosion surfaces and to supplement alternative more costly methods of revegetation. Results indicate that, after five years, a satisfactory stocking of 620 to 740 s.p.ha can be achieved up to an altitude of 1,220 m. Stocking is affected by sowing rates, surface conditions, degree of slope, density of existing vegetation, altitude and exposure, and sites have been classified on the basis of these factors. The comparison of this technique with hand planting and mechanical seeding methods of revegetation is discussed.*

INTRODUCTION

Since 1948 the N.Z. Forest Service has been striving to contain erosion damage in the southern and eastern portion of Kaweka Forest, some 20,000 ha in extent, where the vegetative cover is mainly manuka and subalpine scrub, interspersed with extensive eroded surfaces. The dominant land feature is the north to south massif of the Kaweka Range, rising to over 1,500 m, with steep easterly slopes up to 40°. Flanking this area, to the east, are the Black Birch and Don Juan Ranges (rising to 1,070 and 1,000 m, respectively) and, to the south, the fault blocks of the Kaikimata, Burns and Glen Ross Ranges.

The major rock types are strongly folded and shattered greywackes; consequently much of the area is highly susceptible to erosion once the surface cover of vegetation and overlying mantle of soil have been destroyed. Soils are derived from volcanic ash showers of varying depth and are of low fertility. Their lightness makes them susceptible to frost, rain and wind erosion when the vegetation is removed. The extent of active erosion, thought to exceed 4,000 ha in the headwaters of the Tutaekuri and Ngaruroro Rivers, suggests that a large amount of detritus is being carried into the main river courses. The vegetation associations of the Tutaekuri and Ngaruroro catchments have been described in detail by Cunningham (1968) and Wallis (1966), respectively.

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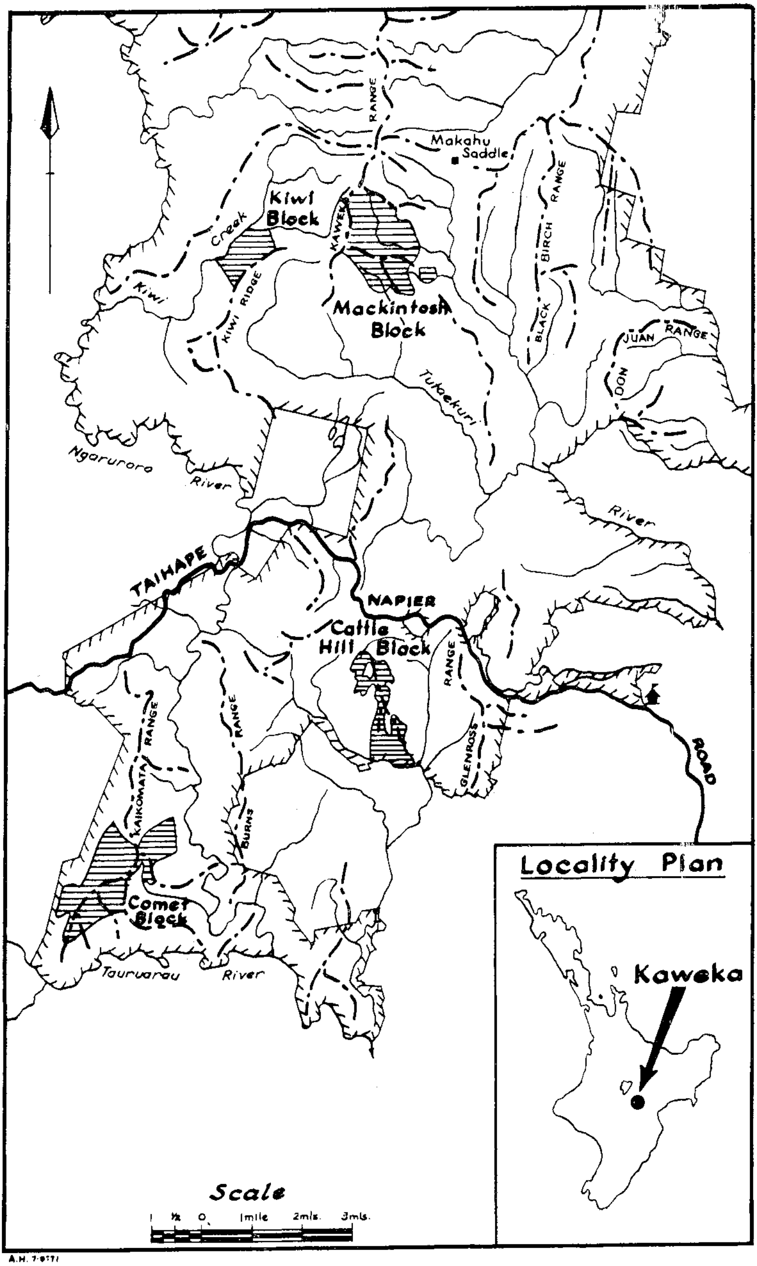

FIG. 1: *Aerial seeding areas, Kaweka State Forest.*

Rainfall varies from about 1,520 to 3,300 mm a year depending on altitude. Temperatures are often very low; average monthly minimum is −1°C. (Cunningham and Gannaway, 1970.) Snow is common in winter but falls usually average no more than 15 to 25 cm. Winds are persistent and strong — the prevailing direction is from the north-west but the most damaging winds are from the south-east.

Early work in revegetation, between 1948 and 1958, involved trial plantings of pines on eroding areas near the Napier-Taihape road — an area now well-established and being managed for production of timber. During the late 1950s, planting was extended to more remote areas, and in the early 1960s consisted of planting *Pinus contorta* and *P. mugo* in contour lines at 15 m intervals. This work was costly, and as a result the Forest Service began trials of direct seeding in 1965. The objectives of the direct seeding trials were to:

(1) Revegetate a large sample area of eroding surfaces.

(2) Test different seeding techniques and determine the minimum quantity of seed for effective tree cover.

(3) Establish trees able to regenerate naturally in the area.

(4) Study development of forest stand behaviour on exposed sites.

(5) Observe the effects on ground stability as the proportion of vegetation cover increased.

(6) Determine the problems of managing large areas of uneven-aged stands established by direct seeding.

INITIAL SMALL-SCALE TRIALS

Methods

In 1965-6, 14 initial seeding trials, totalling 9.7 ha, were established on the north-west slopes of Kiwi Range on partially eroding subalpine scrubland. Slopes ranged from 0 to 35°, and altitude was from 1,160 to 1,310 m. The purpose of the work carried out here was to:

(1) Compare various direct-seeding methods — hand broadcasting on the ground, hand broadcasting from a helicopter, and spot sowing with a manually operated seeder.*

(2) Study suitable rates of seed application of between 0.45 and 1.57 kg/ha.

(3) Compare the results of using stratified and unstratified seed.

(4) Compare the establishment of *Pinus contorta* and *P. mugo*.

*The seeder used (Wright) was basically a 5 cm diameter pipe about 1.2 m long with a polished cruciform tip at one end and a plunger handle at the other. The plunger releases the seed from the pipe when the implement is pressed into the ground. There is an adjustment to control the number of seeds released.

(5) Compare the results of direct-seeding methods with hand-planted 3/0 seedlings.

In 1966 there were two further investigations:

(6) A study of the effect of seed stratification at 1 to 3° C for 60 days.

(7) A study to determine the value of adding mycorrhiza and fertilizers to seed of contorta pine. Mycorrhiza was introduced in nursery soil and in duff from beneath a contorta pine stand. Fertilizers were (a) compound "Magamp K" added at rates of 0.3 to 1.0 kg per kg of seed; and (b) a 2% solution of seaweed fertilizer ("Maxi-crop") in which seed was soaked for 12 hours. Latex and methyl cellulose in aqeous solution were used as sticking agents, and mixing was done in a concrete mixer. The resulting mixture was dried into pellets containing approximately one to five seeds and hand broadcast at 0.45 kg/ha.

Results

1. *Comparison of hand planting with seeding of contorta pine*

An area of 0.8 ha, planted with 3/0 contorta pine, was surveyed annually for mortality and measured for height growth. Mortality after the first growing season was only 5%, and each successive year there has been a slight decrease in the number of surviving trees. After five growing seasons, 80% of the number established still survive. The main damage to the planted stock has been from hares and deer, the latter causing 40% leader mortality by antler-rubbing. However, there is a strong degree of recovery by growth of lower shoots. After five growing seasons, annual height growth had reached 12.5 cm per annum — this compares with 2.5 to 7.5 cm per annum for seedlings originating from direct seeding.

2. *Aerial seeding of* P. mugo *compared with contorta pine*

Only a small trial was undertaken because of the difficulties in obtaining seed. Stockings up to 12,000 seedlings per ha at a sowing rate of 1.1 kg/ha have been obtained. It appears that this species can be established as successfully as contorta pine.

3. *Comparison of seed treatments of contorta pine*

In 1966, samples of seed taken from areas sown with "mycorrhizal-coated seed" and untreated controls were checked for the presence of mycorrhiza on the rootlets. As untreated seedlings had several more mycorrhizal rootlets, and the "inoculation" had no apparent effect on germination or vigour, the treatment was discontinued.

The use of "Magamp K" as a seed coating was examined by G. W. Hedderwick at the Forest Research Institute. It resulted in a considerable reduction in the germinative capacity and energy of the seed. This may have been partly a result of the thickness of the latex coating. It is also felt that the small quantity of fertilizer added by this coating probably provided no significant benefit to the seedlings.

Soaking the seed in a 2% solution of "Maxi-crop" appeared to have little effect on the vigour of the seedlings. More concentrated solutions produced a reduction in germinative capacity and the speed of germination (C. Bassett, pers. comm.).

Seed stratification tests carried out in 1965 gave inconclusive results owing to the small area treated and the lack of replication to eliminate site differences. After 1965, seed stratification was not rigidly adhered to because of the difficulty of treating large seed lots and the danger of premature germination in the event of delays in sowing.

4. *Determination of suitable sowing rates*

Variations in the amount of seed applied per hectare, up to 1.5 kg, indicated that a mature tree cover of 250 to 500 stems per hectare (s.p.ha) could be achieved from sowing rates between 0.45 and 0.67 kg/ha; these stocking rates are considered adequate. As a result of this, all blocks direct seeded after 1966 were at a rate of 0.45 to 0.67 kg/ha (49,000 to 99,000 viable seeds per hectare).

LARGE-SCALE OPERATIONAL TRIALS

Details of Operations

After the initial hand-broadcast seeding on Kiwi Ridge in 1965-6, large-scale operations were undertaken in the south and east of Kaweka Forest. The bulk of sowing was carried out by helicopter with a rotating conical seeder slung beneath it. The seeder could hold 90 kg of seed and could spread a swath of 20 to 27 m. Recurrent blockages at the base of the seeder, and difficulties in determining when the seeder was empty, resulted in a shift to fixed-wing aircraft, fitted with an Easton air-flow fertilizer spreader. This was calibrated to sow 0.45 to 0.67 kg/ha. At a flying speed of 150 to 180 km/hr, and at an altitude of 25 m, the seeder was capable of sowing in a swath 18 to 20 m wide. Direct seeding by fixed-wing aircraft enabled more extensive areas to be sown at a slightly lower cost per hectare. Sowing was generally carried out in September or October, and seeding blocks were demarcated on the ground by white calico. Details of operations are given in Table 1

Assessment Methods

On each seeding block, 30 to 40 plots were established on grid lines in the late summer after sowing. These were used for the first and subsequent annual assessments. Each plot was 0.004 ha, being 1 m wide and 40 m in length along the contour. An endeavour was made to sample extremes of slope, altitude and vegetative cover. At each plot the following were recorded: seedling numbers, height and comparative vigour; slope, aspect and altitude; percentage of existing vegetative cover, and surface conditions.

TABLE 1: DETAILS OF SEEDING OPERATIONS

Seeding Block	*Year Seeded*	*Aircraft*	*Area (ha)*	*Sowing Rate (kg/ha)*
Kiwi 1	1966	Helicopter	39.7	0.45
Kiwi 2	1966	Helicopter	49.4	0.45
Comet 1	1966	Helicopter	182.9	0.45
Comet 2	1967	Helicopter	243.6	0.21
Comet 3	1967	Helicopter	120.2	0.37
Comet 4	1970	Fixed wing	108.5	0.71
Cattle Hill	1968	Helicopter	313.6	0.29
Mackintosh 1	1969	Fixed wing	466.2	0.67
Mackintosh 2	1969	Fixed wing	29.9	0.67
Studholme*	1970	Fixed wing	142.4	0.71
		Total area	1,696.4 ha	

*An area adjacent to Mackintosh Block.

Description of Surface Conditions

The type of surface or erosion condition was assessed on the proportion of mobile rock (scree) to fine soil material present. The sampled areas ranged from 760 to 1,520 m in altitude and surface conditions are mainly influenced by physiographic and climatic factors. As a result, six common erosion types were clearly recognized from the sampling undertaken. These are described below.

1. *Scree with fines* (26% of plots). This occurs mainly in the mid-altitude range from 760 to 1,220 m, on slopes of 20 to 40°. Fine particles are thoroughly mixed and can be readily observed between the scree component. Chip size is small and the scree tends to be mobile on the steeper slopes.
2. *Scree over ash* (22% of plots). This covers a wide range of altitude and slopes, but is more common between 910 and 1,220 m, with slopes between 20 and 30°. A layer of angular greywacke rock fragments from 2.5 to 37.5 cm deep overlies a compact yellowish-brown silt-loam recognized by Cunningham (1968) as "undifferentiated brown ash".
3. *Rock and scree* (12% of plots). This occurs commonly at the upper altitudes above 1,070 m on steep slopes, often associated with rock outcrops; it contains little fine material.
4. *Vegetation-covered sites* (13% of plots). These are generally found at altitudes below 1,070 m where the soil sequence has been largely retained owing to the presence of vegetation.
5. *Bare silty pans* (12% of plots). These consist of bare surfaces predominantly of compact undifferentiated brown ash, directly overlying the greywacke bedrock, and are found between 910 and 1,070 m. These sites are sensitive to frost-heave and rain-wash, and have low nutrient levels.
6. *Erosion pavement* (15% of plots). This is commonly found on flattish terrain, but can be on slopes of up to 20°; it is generally very exposed. The ash has been eroded away, leaving large angular rocks with smaller stones and fines between them.

FACTORS INFLUENCING STOCKING

Effect of Time on Survival

Survivals after six months are generally less than 5% of the stocking theoretically possible. However, slight increases in average stocking over the succeeding two years appear to occur, presumably because of delayed germination. Although thought to be common on most sites, the reason is difficult to determine precisely. In the third year, stocking is reduced and this may indicate unsatisfactory nutritional levels on certain sites. The influence of erosion surface, slope, altitude and cover on seedling survival are all closely interrelated and affect stocking with time.

TABLE 2: STOCKING BY GROUND SURFACE TYPES

		Scree with Fines	*Scree over Ash*	*Rock and Scree*	*Vegetation Covered*	*Bare Silty Pans*	*Erosion Pavement*
Frequency %		26.1	21.8	15.4	12.5	12.0	12.2
% plots with seedlings		54	38	29	48	35	23
Mean no. of seedlings per plot	Year 1	3.1	3.8	0.7	6.9	7.2	8.5
	Year 2	3.5	2.2	5.7	0.6	9.2	5.5
	Year 3	15.0	2.1	2.8	0.8	5.6	4.5
	Year 4	4.0	1.7	1.0	1.2	2.6	0.8
% change, yrs 1-4		+ 29	— 55	— 43	— 82	— 64	— 90

Effects of Surface Conditions

From Table 2 it is seen that "scree with fines" and "vegetation-covered" sites have the best initial distribution of seedlings. Although large numbers of seedlings were initially recorded per plot on some surface types, ensuing mortality has resulted in considerable changes over the four assessments except for "scree with fines" which maintained a more uniform stocking. This is thought to be due to the retention of moisture, the presence of fine material, and the shelter offered by scree fragments. Water is thought to be generally deeper within the scree and therefore does not affect small seedlings in their early stages of growth.

Unfortunately, the assessment techniques were not sufficiently refined to take cognisance of small changes of surface types within any plot, so that seedling counts can be boosted by surfaces of higher grade material traversed by the line plot. This is exemplified by the results from the "bare silty pan" sites, where seedlings frequently occur around the lower edge of the slopes where fine material collects, and where there is often shelter from nearby vegetation. It appears that frost heave, rain-wash and exposure take a severe toll of seedlings on "erosion pavement" and "bare silty pans". On "rock and scree", considered to be one of the most difficult surface conditions on which to establish seedlings, the reduction in average stocking per plot (82%) would be more realistic if taken from year 2 to year 4.

Effect of Slope

Generally there is a common progression of surface types with increases in both slope and altitude. The order with increasing slope is: vegetation-covered sites, erosion pavement, bare silty pans, scree over ash, scree with fines, and rock and scree. Hence, changes in slope often reflect changes in the surface condition as well as being directly proportional to altitude. It must be remembered, when discussing slope, that several factors affecting stocking are involved.

TABLE 3: AVERAGE STOCKING PER PLOT (0.004 ha) WITH CHANGES IN SLOPE

	Degree of Slope								
	0-5	*6-10*	*11-15*	*16-20*	*21-25*	*26-30*	*31-35*	*36-40*	*40 +*
Year 1*	13.6	12.1	1.6	7.2	4.2	2.0	7.0	3.0	0.8
Year 2	1.3	17.2	10.3	1.9	3.4	0.7	4.9	0.6	1.2
Year 3	3.2	11.8	7.6	3.7	1.1	1.8	6.2	1.5	1.8
Year 4	2.6	4.2	8.0	5.3	2.2	1.5	1.0	0.5	1.0
Average over 4 yr	5.2	11.3	6.9	4.5	2.7	1.5	3.6	1.4	1.2
% frequency of plots	20.0	8.4	6.5	7.3	12.7	12.7	12.7	8.4	11.3

*First year after planting, etc.

Survival, measured in terms of average seedling counts per plot at 5° slope intervals, shows a general decrease with increases in slope (see Table 3). The low numbers in the 0 to 5° class result from the effects of frost. Over 25° there appears to be a greater decrease in successful stocking, although there is a slight improvement in the 31 to 35° class, probably because of the presence of "scree with fines" at the higher altitudes. Over the last four assessment periods, slopes in excess of 30° were recorded over 30% of the plots. The lower variation in stocking over the steep slopes suggests that, once initial establishment is successful, seedlings have a good chance of survival.

Influence of Vegetative Cover

Low manuka is common on over 50% of the plots, giving way to subalpine species at higher altitudes. Above 1,220 m, tussock begins to dominate. By comparing each unstocked plot with its proportion of vegetation cover, it can be deduced that fewer bare plots occur where there is 20 to 60% vegetative cover. The number of trees on these plots varies from a stocking of 500 to 1,000 s.p.ha. Establishment is much less successful (below 500 s.p.ha.) where there is less than

20% cover — normally at higher elevations above 1,070 m. Although there were few plots in areas with more than 80% cover, there is some indication of a slight fall-off under these conditions; presumably there is more competition for light, nutrients and growing space. Major fluctuations in stocking counts are attributed to delayed germination, and to easier location of seedlings in later assessments because of increased seedling height.

Adequate cover for successful establishment (740 to 900 s.p.ha.) becomes increasingly important with increase in altitude as the effects of frost, wind and rain-wash become more severe and reduce the number of surviving seedlings. Most of the seriously eroded surfaces, making up 60% of the area sown, and generally at higher elevations above 1,220 m, are almost completely bare of vegetation. Average stocking four years after sowing, in the 1,250 to 1,520 m altitudinal range, was 120 s.p.ha. But at the lower elevations, below 1,070 m, sites with only a minimum vegetative cover (less than 20%) have been successfully revegetated (up to 740 s.p.ha.).

Altitude and Exposure

The importance of altitude to stocking has been touched on in the preceding section. Initial assessment of the operational trials in the 600 to 1,220 altitudinal range (which includes 85% of the seeded areas) revealed an initial germination of 1,230 to 1,980 s.p.ha. In four years this was reduced to 620 to 740 s.p.ha. Above 1,220 m, the initial germination survivals of 250 s.p.ha have been reduced to 120.

From experience during assessment periods, and from data collected at Makahu Saddle by the Forest and Range Experiment Station, it appears that the south-east winds are the most damaging — very cold, of high velocity and high frequency (13%). Forty per cent. of all plots recorded without seedlings in their first assessment are situated in the north-east to south-east sector. Winds from the north-west are of the highest frequency (21%; P. A. Gannaway, pers. comm.), and cause continual buffeting and loss of soil about the seedlings.

CONCLUSIONS AND RECOMMENDATIONS

Results to date indicate that, by using unstratified seed of contorta pine, sown from the air at a cost of $8.50 to $11.00 per ha, the main areas of eroding and erosion-prone surfaces up to 1,220 m in Kaweka Forest can be successfully revegetated. Five years after sowing, a stocking of 620 to 740 s.p.ha has been achieved, but above 1,220 m stocking is only 50 s.p.ha and supplementary planting may be necessary. Although there is annual mortality, it is believed that sufficient stems will remain to cast viable seed, beginning at age seven or eight years, and gradually revegetate much of the area. The writers would be satisfied with a stocking of 75 to 200 s.p.ha at age 10 years.

It is now possible to classify sites and to assess the likelihood of success from seeding with some degree of certainty. This classification, coupled with the use of helicopters for seeding, could enable the selective application of seed to those areas most likely to result in successful establishment.

Alternatives to aerial seeding have been used. A mechanical hand-seeder is suited to the treatment of small areas where labour is available. Costs range from $17 to $25 per ha. Hand planting of seedlings is considerably more expensive; for contour terracing and hand planting, costs can exceed $250 per ha. Labour for such work is difficult to find and accommodation must be provided.

Attempts should be made to refine the technique developed in these trials, particularly the rate of sowing, the calibration and operation of the seeder, and ground control.

Still to be tried is the application of grass, clover and fertilizer to provide initial stabilization, pioneered by the Forest and Range Experiment Station (McCracken, 1969). A management-scale trial of this technique should be implemented in the near future.

It is also important that emphasis be given to photo-interpretation and mapping of this and other critical erosion areas, so that sites requiring different treatments can be demarcated and a balanced programme formulated.

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