PAST AND PROJECTED USE OF FERTILISERS IN NEW ZEALAND FORESTS

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ABSTRACT

In 1975, 15 915 ha of forests were fertilised during routine management operations. Of this 4 617 ha were newly planted land, 7 875 ha were in established stands of exotic species, 2 852 ha were in protection forestry zones and 571 ha were in nurseries and seed orchards. Between 1954 and 1976, 54 529 ha of production forests were fertilised, over 90% of which was in **Pinus radiata**.

Quantities of N, P, K, Mg and B used in 1975 were 560, 515, 36, 22 and 28 tonnes respectively. Most of the N, P and B was applied to production forests while most of the K and Mg was used in nurseries. The principal fertiliser sources of N, P, K, Mg and B were urea, superphosphate, NPK compound fertilisers, dolomite and dehydrated sodium borates respectively.

Based on an assumption of fertiliser use on all responsive sites, forestry use in 1985 was projected to be (tonnes):

N	P	K	Mg	B
14 000	3 000	70	30	130

INTRODUCTION

Commercial applications of fertilisers to exotic forests in New Zealand started in the Auckland region during the late 1950s when large areas of severely P-deficient radiata pine (*Pinus radiata* D. Don) stands were aerially topdressed with superphosphate (Conway, 1962). The success of these early commercial operations stimulated considerable interest in the use of fertilisers as a means of increasing the productivity of exotic pine plantations. Research during the 1960s showed many soils in New Zealand to be deficient in N, P or B for optimum growth of exotic pines (Will, 1978) and by the 1970s fertilisation with these elements had become accepted practice in many of New Zealand's exotic forests.

Because of the expansion of forest fertilisation operations planners in government departments and the fertiliser manufacturing industry became interested in obtaining statistics on forest industry fertiliser consumption. As a consequence surveys of fertiliser use by state and private forestry organisations were undertaken in June of 1975 and 1976. In the 1976 survey respondents were asked to estimate their fertiliser use to the end of 1976. Detailed results of these two surveys have been reported (Ballard and Will, 1975; Ballard, 1977). This paper presents a summary of these surveys together with a projection of possible fertiliser consumption by the forest industry in 1985. Emphasis will be placed on 1975 statistics as these are more reliable than those for 1976.

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AREAS FERTILISED

Areas fertilised by both state and private forestry organisations during 1975 in the seven forestry regions (corresponding to the NZ Forest Service Conservancies) are given in Table 1. A graphical summary, by forest operations, of areas fertilised between 1954 and 1976 is shown in Fig. 1.

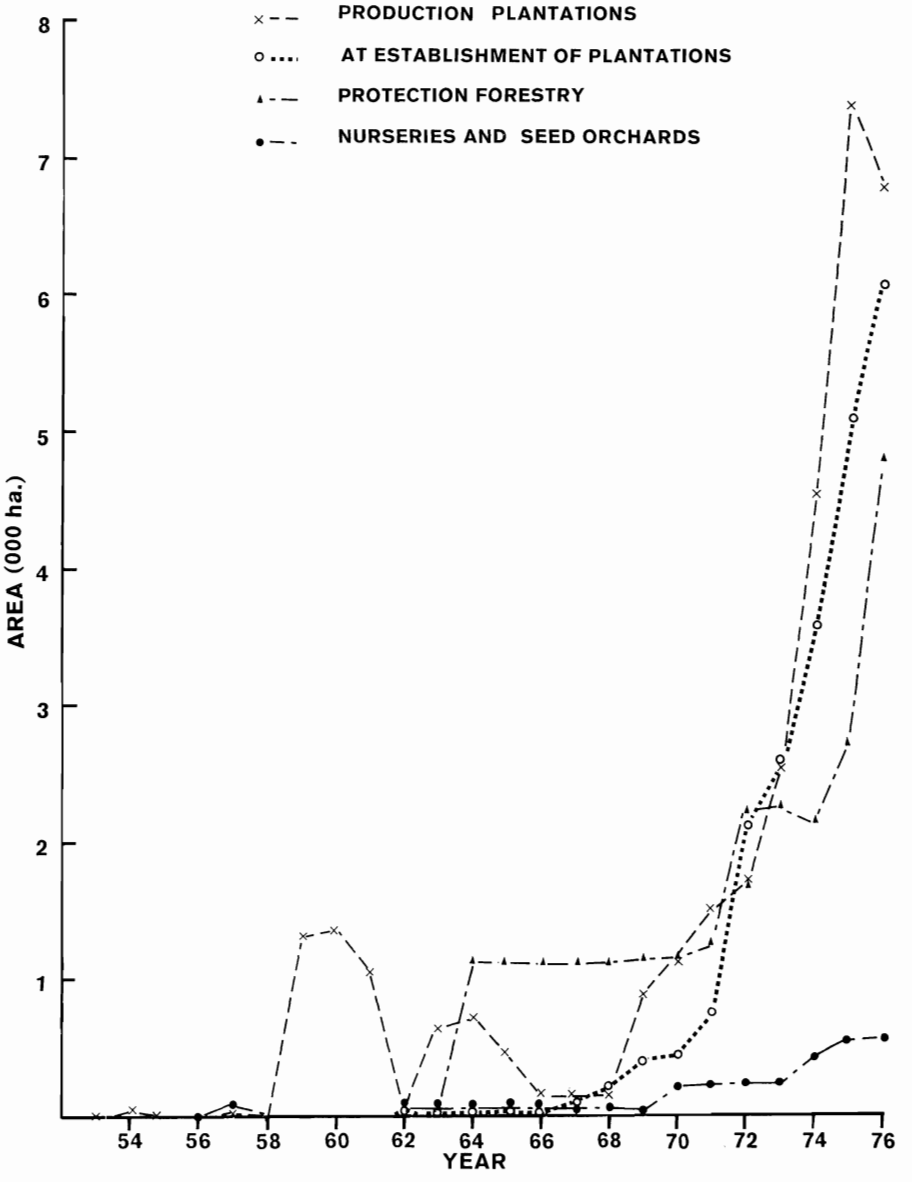

FIG. 1—Forest areas fertilised in New Zealand (1954-1976).

Production Plantations

Commercial fertilisation of established stands started in 1958/59 with the aerial topdressing of P-deficient stands on weathered clay soils in the Auckland region. Approximately 6 000 ha of P-deficient stands were topdressed during the period 1958/66.

The down-turn in fertilisation during 1966/68 corresponded with an economic depression. Agricultural use showed a similar down-turn during this period. It is interesting however that the 1975 depression which had a pronounced depressing effect on agricultural use (Durrant and Bryant, 1975) had no noticeable effect on use by the forest industry. This is probably a reflection of a greater acceptance by forest managers of the value of fertilisation, particularly relative to other silvicultural operations, and the importance of the timing of the infrequent applications used in forestry. The marked up-swing in areas of production forests fertilised as from 1970 corresponded with the initiation and expansion of commercial operations to correct deficiencies of N, N + P + B and B in the Rotorua, Nelson and Canterbury regions respectively. During 1975 in excess of 2 000 ha of established stands were fertilised in each of the Auckland, Rotorua and Nelson regions (Table 1).

At Establishment

Significant areas of new plantings were not fertilised until the late 1960s when trials confirmed the value of establishment applications on poor sites in the Auckland (Ballard, 1969) and Nelson regions (Jacks, 1970).

The rapid expansion of areas fertilised in the 1970s corresponded with the introduction of a soil testing service for predicting the need for P fertilisers at planting (Ballard, 1971) and the initiation of a fairly large programme of applying N to *Eucalyptus* species in the Rotorua region.

TABLE 1—Forest areas (ha) fertilised in New Zealand (1975)

Region	At establ.	Prodn. forests	Nurseries	Seed orchards	Protectn. forestry	Total
1. NORTH ISLAND						
Auckland	2 788	2 128	103	—	1 462	6 481
Rotorua	805	2 464	142	84	—	3 495
Wellington	—	—	57	87	452	596
Total	3 593	4 592	302	171	1 914	10 572
2. SOUTH ISLAND						
Nelson	836	2 199	20	—	290	3 345
Westland	16	—	9	—	—	25
Canterbury	112	1 002	25	—	—	1 139
Southland	60	82	44	—	648	834
Total	1 024	3 283	98	—	938	5 343
Overall Total	4 617	7 875	400	171	2 852	15 915

Over the last 3 years 80-90% of all new plantings in forests on clay soils in the Auckland region have been fertilised with P. Elsewhere the only programmes of any size are those applying N to eucalypts in the Rotorua region and P + B to radiata pine in Nelson. Otherwise most applications at establishment are restricted to amenity plantings and skid sites where topsoil has been removed.

Protection Forestry

Fertilisers are used in two distinctive protection forestry operations; the establishment of marram grass on shifting sand dunes (Eyre, 1974) and the revegetation of eroded zones in mountainous areas (Ledgard, 1976).

Areas of marram grass fertilised in the sand dune stabilisation programme, which is principally restricted to the Auckland region, have remained at between 1 000 and 1 500 ha/year since 1964 except for a large increase to 3 424 ha in 1976.

The rise in fertiliser use in protection forestry operations as from 1972 corresponded with the large scale use of fertilisers in the high-country revegetation programmes in the Southland, Nelson and Wellington regions. In 1976 around 1 400 ha were fertilised in these programmes.

Nurseries and Seed Orchards

Nursery areas fertilised have been increasing slowly in line with the growth in size of the exotic forest estate. The increase in area fertilised over the 1974/75 period was mainly due to the introduction of a programme of fertilising seed orchards. Although in terms of area fertilised nurseries and seed orchards are insignificant compared to other forestry operations, because of their intensive use of fertiliser they contribute significantly to the quantities used (Table 2).

Up to the end of 1976 some 50 000 ha of exotic plantations had been fertilised, with over half of this in the Auckland region (Table 6). This constitutes close to 8% of the total exotic forest area in New Zealand. In 1976 about 12% of all new plantings in exotic forests were fertilised at or close to planting time.

TABLE 2—Proportion (%) of fertiliser elements used in different forestry operations (1970 and 75)

Element	Year	At establ.	Prodn. forests	Nurseries	Seed orchards	Protectn. forestry
N	1970	3.7	8.1	22.8	0.0	65.4
	1975	6.5	73.0	5.3	4.6	10.5
P	1970	10.3	71.6	17.5	0.0	0.6
	1975	11.8	67.4	5.2	1.8	13.8
K	1970	0.0	0.0	99.6	0.0	0.4
	1975	2.8	0.0	83.8	0.3	13.1
Mg	1970	0.0	0.0	95.4	0.0	4.6
	1975	3.7	0.0	58.4	13.2	14.7
B	1970	23.9	76.1	0.0	0.0	0.0
	1975	10.8	88.2	0.0	0.0	1.1

QUANTITIES OF FERTILISER USED

The quantities of N, P, K, Mg and B used by the forest industry each year since 1954 are shown in Fig. 2. The regional breakdown of these statistics for 1975 is given in Table 3. Detailed statistics for earlier years can be found in Ballard and Will (1975). The proportion of fertiliser elements used in different forestry operations in 1970 and 1975 is given in Table 2.

Nitrogen

Up to and including 1970 the major applications of N were in protection forestry operations and nurseries. Most of this was in the sand stabilisation programme in the Auckland region. By 1975 the proportion of N used in different operations had changed dramatically from that in 1970 (Table 2); by far the greatest use was in established stands—the result of a major expansion by private companies of the N fertilisation programme in the Rotorua and Nelson regions. While consumption in nurseries and

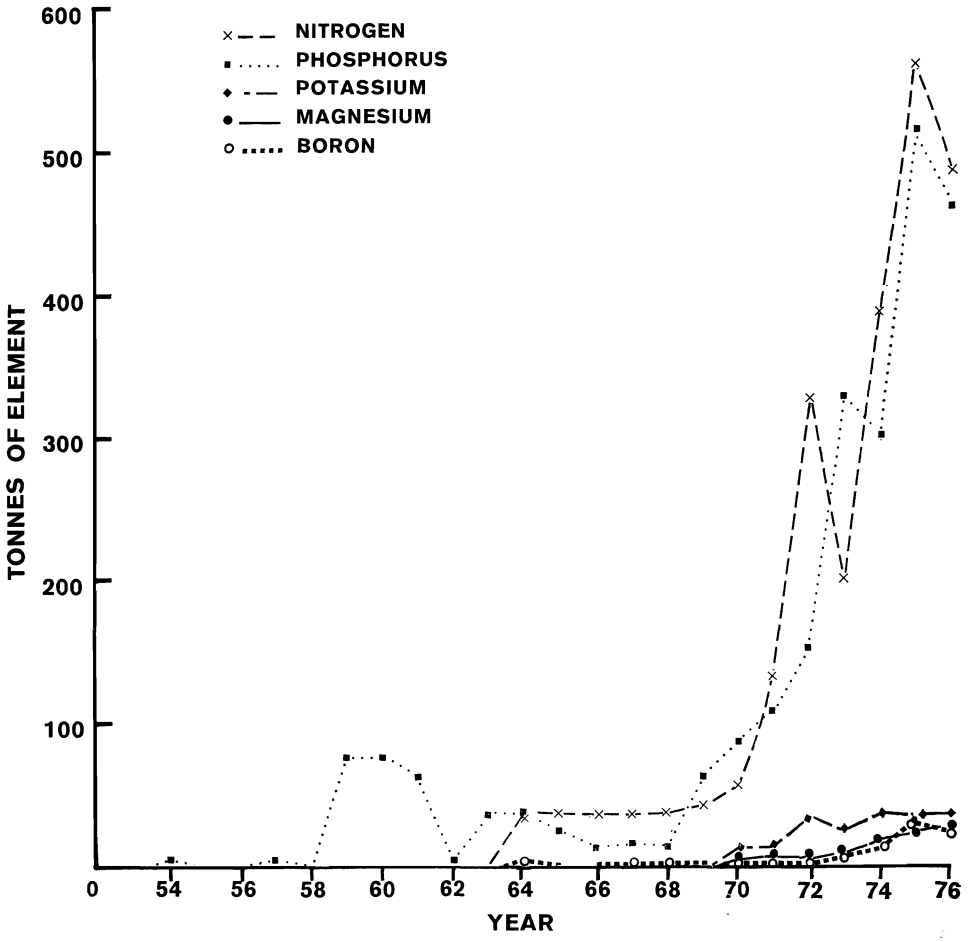

FIG. 2—Quantities of fertiliser elements used in New Zealand forestry (1954-1976).

TABLE 3—Use of fertiliser elements (tonnes) in forestry (1975)

Region	Element N	P	K	Mg	B	Other
1. NORTH ISLAND						
Auckland	47.3	333.1	10.5	3.3	—	—
Rotorua	414.2	14.1	11.8	11.8	—	—
Wellington	26.7	25.6	2.7	—	—	Mo
Total	488.2	372.8	25.0	15.1	—	
2. SOUTH ISLAND						
Nelson	51.7	89.7	6.0	5.7	18.7	—
Westland	0.8	1.1	1.8	1.0	—	—
Canterbury	0.2	5.5	—	—	9.1	lime
Southland	18.6	45.6	3.1	0.1	0.1	Mo
Total	71.3	141.9	10.9	6.8	27.9	
Overall Total	559.5	514.7	35.9	21.9	27.9	

protection forestry operations increased over this period, that by other operations increased to a greater extent. Of particular note was the major quantities of N applied to seed orchards.

Phosphorus

Before 1970 almost 100% of the P used was applied to established stands in the Auckland region. In 1970 most P was still applied to established stands, mainly in the Auckland region with some in the Nelson region but significant quantities were also applied at establishment and in nurseries. Over the period 1970/75 consumption of P in all operations increased dramatically (Fig. 2). The proportions used in production forestry operations remained fairly constant but a pronounced increase occurred in protection forestry use—reflecting the expansion of the high-country revegetation programme.

Potassium

Up to and including 1970, K was used almost solely in nurseries. Nursery consumption increased over the period 1970/75 but by 1975 small amounts of K were also being used in the high-country revegetation programmes and to assist establishment of radiata pine on Mg rich soils in the Nelson region.

Magnesium

As was K, the use of Mg was restricted to nurseries up to 1970. By 1975 nurseries were still the major users of Mg, but significant quantities were also being used in seed orchards (Rotorua region) and protection forestry operations (Nelson). Small quantities were also applied at establishment through use of serpentine superphosphate and to production forests in Westland during 1974.

Boron

Up to and including 1970 only small quantities of B were used, nearly all in the Nelson region. By 1975 relatively large quantities of B were being applied to production forests in both the Nelson and Canterbury regions, and smaller quantities in Westland.

The dramatic increase in fertiliser use by the forest industry over the last decade has paralleled that in many overseas countries (Baule, 1973). Despite the impressive-looking increases (Fig. 2), the actual quantities of the various elements used are very small in relation to total New Zealand consumption (Table 4).

TABLE 4—Fertiliser use by forestry as a percentage of total New Zealand consumption

	Element				
Year	N	P	K	Mg	B
1970	0.4	0.05	0.01	0.09	0.4
1975	2.0	0.30	0.03	0.3	7.0

Total N.Z. consumption based on data provided by the Economics Division of the Ministry of Agriculture and Fisheries.

FERTILISER SOURCES

A summary of the fertiliser sources used in 1975 is given in Table 5.

Nitrogen

Urea was the major N source used in 1975, and has been since 1970. It is practically the only N source used in the fertilisation of production forests and seed orchards, and is likely to continue to be the major source in the future.

Diammonium phosphate (DAP) is used in nurseries, in the high-country revegetation programme and in the establishment of seedlings on N + P deficient sites in the Auckland region and "skid sites" in the Rotorua region. Use of this source will probably increase in the future as combined N and P responses are likely to become more common in areas currently fertilised with either N or P.

Calcium ammonium nitrate (CAN), which prior to 1970 was the major N source, is used exclusively in the establishment of marram grass in the sand-dune stabilisation programme. Evidence indicates that urea could, and in the future probably will, replace CAN in this programme (Eyre, 1974).

NPK compound fertilisers (sold under trade names such as Top Crop, Rustica, Complesal and Ammophos) provide most of the N used in nurseries.

Phosphorus

Superphosphate is, and always has been, the major P source used in forestry. Although molybdenum (Mo) is not required for pines, most of the super used in high-country revegetation programmes is Mo-enriched to encourage growth of legumes. Boron-enriched superphosphate (4—6% fertiliser borate) is used when planting young stock in the Nelson region.

TABLE 5—Fertiliser sources used in New Zealand forestry (1975) as percentage of total element used

N		P		K		Mg		B	
Source	%	Source	%	Source	%	Source	%	Source	%
Urea	81.8	Superphosphate	72.5	NPK Compound	46.0	Dolomite	51.1	Dehybor	51.4
DAP	6.9	Molybdic super	8.5	Muriate of potash	35.9	Serpentine super	22.0	Colemanite	30.0
CAN	6.4	DAP	8.4	Sulphate of potash	12.3	NPKMg compound	12.3	Pyrobor	8.6
NPK compound	3.8	Boron super	5.4	Potassic super	5.8	Serpentine	6.4	Boron super	8.2
Blood and bone	0.5	NPK compound	2.6			Magnesite	5.9	Borospray	1.8
$(NH_4)_2SO_4$	0.4	Serpentine super	1.1			Kieserite	2.3		
Other	0.2	Sulphur super	0.7						
		Blood and bone	0.5						
		B. serp. super	0.2						

CAN, calcium ammonium nitrate (NH_4NO_3 + $CaCO_3$; 26% N); borospray, sodium pentaborate decahydrate (18.3% B). For other trade names see text.

Serpentine superphosphate is used in nurseries, in some protection forestry operations, and recently, by one major private company, in the fertilisation of pines at establishment.

Potassium

Prior to 1975 muriate of potash (KCl) was the major source of K used in forestry operations. Since there is no established need for sulphur in nurseries (principal users of K fertiliser) there is little demand for the more expensive K_2SO_4 with a lower K content.

Since 1975 there has been a swing in nursery management from the use of single nutrient fertiliser sources to compound sources providing N, P and K (and in some cases Mg).

Magnesium

Dolomite and serpentine superphosphate were the major sources of Mg in 1975 and have been in previous years. Dolomite is used in nurseries and seed orchards while serpentine super is used in protection forestry operations (Nelson region), in nurseries and at establishment of radiata pine seedlings.

Boron

Anhydrous borax ($Na_2B_4O_7$), previously sold as FB65 and now as Dehybor or Pyrobor, is the major source of B used in forestry. Because of fluctuations in supply of the preferred sodium borates other sources such as colemanite (a calcium borate) have been heavily relied on in some programmes — viz. Canterbury in 1974 and 1975.

Species Fertilised

As expected because of the emphasis on *P. radiata* in exotic forests, 95% of the area fertilised was in this species (Table 6). Most of the remaining area fertilised was in *Eucalyptus* species.

The data in Table 6 excludes species fertilised in nurseries, seed orchards and protection forestry operations. However in both nurseries and seed orchards *P. radiata* is the main species involved. Most areas fertilised in protection forestry operations are in grasses or grass-clover mixes although some of the areas fertilised have contained *P. mugo* and *P. contorta,* two species used in high-country revegetation programmes.

TABLE 6—Total area of various species fertilised in production forest up to the end of 1976

Species	Region						
	Auckland	Rotorua	Nelson	Canterbury	Southland	Westland	Total
	ha						
P. radiata	29 079	11 047	7 233	4 016	155	297	51 827
Eucalyptus spp.	27	1 808	67	—	108	—	2 010
P. elliottii	224	—	—	—	—	—	224
P. taeda	41	—	—	—	—	—	41
P. radiata/P. elliottii	107	—	—	—	—	—	107
P. radiata/P. taeda	28	—	—	—	—	—	28
P. elliottii/Eucalyptus spp.	61	—	—	—	—	—	61
Pseudotsuga menziesii	—	—	58	—	18	—	76
Other	54	3	16	82	—	—	155
TOTAL	29 621	12 858	7 374	4 098	281	297	54 529

Methods and Rates of Application

Methods of application are fairly standard for the various forestry operations and can be summarised:

Nurseries:	Tractor — broadcast, drilled
Seed Orchards:	Truck or tractor — broadcast
At establishment:	Manual — individual seedling basis
Production forests:	Air — broadcast (limited amount tractor — broadcast in thinned stands on easy terrain)
Protection forestry:	Air — broadcast (high country)
	Tractor — broadcast (sand-dune)

Rates of application are not as standardised and will not be covered in this paper as they have been presented and discussed in recent reviews on fertiliser use in nurseries (Knight, 1978), in protection forestry (Nordmeyer, 1977), at establishment (Ballard, 1978), and in production forests (Mead, 1977).

ESTIMATED USE OF FERTILISERS IN 1985

To satisfy the anticipated demands for wood products within New Zealand and to provide the raw material for an expanded export trade, New Zealand's afforestation programme is expected to increase and reach a rate of about 55 000 ha/yr. This planting target was proposed at the 1975 Forestry Development Conference.

It is difficult to forecast how these new plantings will be distributed throughout the country, but a reasonable assumption is that they will be roughly in proportion to the existing forests. Based on this assumption, annual planting rates and total areas planted by 1985 will be as given in Table 7.

TABLE 7—Projected annual planting rates and total areas (ha) of pine forests in New Zealand conservancies in 1985

Region	New planting	Replanting*	Total stocked area
Auckland	11 000	800	160 000
Rotorua	15 000	2 000	460 000
Wellington	10 000	1 000	105 000
Nelson	8 000	1 500	140 000
Westland	2 000	200	30 000
Canterbury	2 000	400	50 000
Southland	8 000	700	125 000

* Based on areas planted in 1960.

Based on our present knowledge of tree growth responses, the fertiliser application rates given in Table 8 are those likely to be necessary to achieve optimum production. The figures for P and B are more certain than those for N; it is only in the last few years that trials with N fertilisers have been established on a range of soils and in stands of different ages. The 8 and 16 yrs in Table 8 are only an indication of the age when the fertiliser will be applied. Some stands may need an application of P 4-6 yrs after planting, and another at age 14; in the case of N, applications should coincide with thinning rather than be tied to a set age. The rates of N application may seem high when little N is used at present, but current trials indicate that responses to N are likely to be widespread in the country (Woollons and Will, 1975; Mead, 1976). An increase in N fertiliser use to the rates in Table 8 would be no more dramatic than that which took place in Sweden in the 1960s.

Using the figures in Tables 7 and 8, and assuming a 25-yr rotation, total quantities of fertilisers that will be used per annum have been calculated and are given in Table 9. In addition to these figures allowances should be made for use in nurseries, protection forestry operations, etc. At least a doubling of present use in these operations can be expected by 1985, which would bring total use of approximately tonnes):

N	P	K	Mg	B
14 000	3 000	70	30	130

It must be appreciated that these projections are based on maximum potential use — to apply fertiliser wherever and whenever a significant response can be achieved —

TABLE 8—Projected fertiliser application rates (kg/ha as the element) in New Zealand forests in 1985

Region	Soil	At planting	Age 8	Age 16
Auckland	Sands	—	100 N	100 N
	Clays	34 P	100 N	100 N
			100 P	100 P
Rotorua		—	200 N	200 N
Wellington	Sands	—	100 N	100 N
	Others	—	200 N	200 N
			100 P*	
Nelson		34 N	200 N	200 N
		34 P	100 P	50 P
		1.5 B	8 B	8 B
Westland		34 N†	200 N	200 N
		34 P†	100 P	
Canterbury		—	200 N	200 N
			8 B*	
Southland		—	200 N	200 N
			100 P	
			8 B‡	

* Applied to 1/2 of the forest area.
† Applied to 1/3 of the forest area.
‡ Applied to 1/4 of the forest area.

TABLE 9—Estimated use of fertilisers (as tonnes of element) in New Zealand state and private exotic forests in 1985

					Totals		
Region	Soil	At Planting	Age 8	Age 16	N	P	B
Auckland	Sands	—	240 N	240 N	480		
	Clays	340 P	400 P	400 P		1 140	
			400 N	400 N	800		
Rotorua		—	3 600 N	3 600 N	7 200		
Wellington	Sands	—	60 N	60 N	120		
	Other	—	180 P			180	
Nelson		300 N	1 120 N	1 120 N	2 540		
		300 P	560 P	280 P		1 140	
		15 B	50 B	50 B			115
Westland		10 N	240 N	240 N	490		
		10 P	120 P			130	
Canterbury		—	400 N	400 N	800		
			8 B				
			8 B				8
Southland		—	800 N	800 N	1 600		
			400 P			400	
			8 B				8
					14 030	2 990	131

without regard to economic considerations. The extent to which these projections are realised will be determined to a large extent by the supply and price of fertilisers (particularly N) in relation to the demand for, and value of, wood products.

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