CONTRIBUTED PAPERS

EFFECTS OF THE 1969-70 DROUGHT ON TWO REMNANTS OF INDIGENOUS LOWLAND FOREST IN THE MANAWATU DISTRICT

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SUMMARY: The effects of the 1969-70 drought were studied in two forest remnants near Palmerston North: Bledisloe Park and Keeble's Bush. Mortality occurred among more than 40 percent of the species of trees and shrubs examined. In Bledisloe Park, where mahoe, ngaio, titoki and tawa are the main components, the short-term effect of the drought is considered to be an increase in the cover of titoki and ngaio with reductions in mahoe and tawa. The forest of the terrace examined in Keeble's Bush consists of podocarp/tawa and podocarp/titoki stands and the short-term effect of the drought has been to reduce podocarp density and to favour an increase in the cover of titoki. In the long term, however, increased establishment of podocarps is possible. Keeble's Bush is a particularly valuable stand of lowland forest from a scientific point of view because of its position in a rainfall of 1000mm, near the climatic limit of rimu, and because it has escaped major modification.

INTRODUCTION

Over the 1969-70 growing season the Manawatu district experienced the most severe drought since rainfall recording began in 1928. The drought occurred over large parts of the country (Finkelstein 1971) and its synoptic aspects have been discussed by Hill (1971). At the D.S.I.R. Grasslands Division meteorological station, Palmerston North, where the mean annual rainfall is 998mm, the total rainfall measured during the period 1 September 1969 to 30 April 1970 was 341mm. The 30 year average for this period is 644mm and the previous lowest rainfall for the same period was 460mm in 1949-50.

Not only was rainfall extremely low, but wind was greater than average in every month of this period and sunshine hours were greater over the summer. Maximum monthly air temperatures between November 1969 and April 1971 were all higher than average. These factors would increase evaporation. Total pan evaporation for the September to April period was 854mm, a figure only once exceeded (871mm in 1961-62). As an index of the severity of the drought, monthly rainfalls were subtracted from monthly evaporation figures to give potential moisture deficits. The total deficit for the same eight-month period was 511mm compared with 332mm in the September 1961-April 1962 period. The average deficit over the 20 years for which evaporation data are available is 68mm. Usually, however, a moisture deficit occurs only during the months November to March and the 20 year average for this five-month period is 133mm.

The severity of the 1969-70 drought was probably accentuated by the low rainfall of the previous winter. For the six-month period of March to August 1969 the total rainfall was 365mm (30 year average: 503 mm). Thus water-tables are likely to have been abnormally low at the beginning of the 1969-70 growing season.

Our objectives were firstly to record and contrast the effects of the drought on plant species in two forest remnants close to Palmerston North, and secondly to determine what effects, if any, the drought was likely to have on the trend of forest succession. Primary observations were made during March 1970 with checks in subsequent months.

METHODS AND DESCRIPTION OF STUDY AREAS

The two forest remnants selected were Bledisloe Park (22 acres) at the northern border of the Massey University grounds opposite the D.S.I.R. campus (New Zealand Map Series 1 reference N149: 110 320) and Keeble's Bush (30 acres), 1.5 miles south-west of the D.S.I.R. campus along the Palmerston North-Shannon road (N149: 091 295).

The site chosen in Bledisloe Park is a moderately steep terrace escarpment facing south-west and mapped by Cowie *et al* (in prep.) as Halcombe hill soils, a weakly leached moderately gleyed yellow-grey earth from loess. A point analysis of crown cover in the forest canopy, using a method similar to that of Druce (1966), showed that the main canopy trees (Table 1) were mahoe (*Melicytus ramiflorus*), titoki (*Alectryon excelsus*) and ngaio (*Myoporum laetum*). Podocarps were present originally but these have been logged. The canopy is uneven in contour but is mostly between 10 and 12 metres high. In the understorey, kawakawa (*Macropiper excelsum*), rangiora (*Brachyglottis repanda*), hangehange (*Geniostoma ligustrifolium*), mahoe and mapou (*Myrsine australis*) are the commonest woody plants. Severe frosts apparently do not occur on this slope. Moisture stress among the plants appeared greatest towards the top of the escarpment face. (An area of seepage from a drain here was avoided). The forest on the adjacent alluvial flat was not sampled since soil moisture did not reach particularly low levels there.

TABLE 1. *Canopy composition of forest examined in Bledisloe Park*

Species	Crown-cover percentages (n=50) and sampling errors (1 sigma)
Alectryon excelsus	12 ± 4.6
Beilschmiedia tawa	6 ± 3.4
Cyathea dealbata	2 ± 2.0
C. medullaris	4 ± 2.8
Elaeocarpus dentatus	4 ± 2.8
Hedycarya arborea	4 ± 2.8
Hoheria sextylosa	2 ± 2.0
Laurelia novae-zelandiae	2 ± 2.0
Melicytus ramiflorus	38 ± 6.9
Muehlenbeckia australis	2 ± 2.0
Myoporum laetum	14 ± 4.9
Pittosporum tenuifolium	2 ± 2.0
Pseudopanax crassifolium	2 ± 2.0
Ripogonum scandens	2 ± 2.0
Gaps in canopy	4 ± 2.8
Total	100

The Keeble's Bush site is a low-level terrace above and south of the small flood plain of the Maungatungaroa stream which meanders through the remnant. The soil was mapped by Cowie *et al* as Ohakea silt loam, a weakly leached, strongly gleyed yellow-grey earth. The forest canopy, 12 to 30 metres in height, is markedly two-layered with the upper emergent layer formed by rimu (*Dacrydium cupressinum*), kahikatea (*Podocarpus dacrydioides*), matai (*Podocarpus spicatus*) and a few totara (*Podocarpus totara*). The second layer is dominated by tawa (*Beilschmiedia tawa*) and titoki. In the understorey, mahoe, titoki, kawakawa and small-leaved milk tree (*Streblus heterophyllus*) are common.

Floristic details of both these forests have been given by Esler (1962) who described Keeble's Bush as the finest of the lowland remnants in the Manawatu. It may be regarded as a modified remnant of a type formerly widespread on terraces in the Manawatu.

Drought effects were recorded using the size classes and drought-damage classes listed in Table 2. Concave moister parts of the escarpment in Bledisloe Park have been separated as 'concave slopes' thus indicating that certain species are confined to the moister part of the slope. The method used was to record each individual of the species according to its size and signs of moisture stress along a predetermined route. However, a number of species were only represented by one individual and these are not included in the tables. Drought effects were not recorded on all species in Bledisloe Park because of time limitations, and in Keeble's Bush only the larger trees and shrubs were studied.

TABLE 2. *Effects of 1969-70 drought on some indigenous plants in the Bledisloe Park forest, Palmerston North*

Key to size classes of trees

1	short sapling: 0.3-2m ht
2	tall sapling: 2m ht-10cm d.b.h.
3	small-diameter tree: 10-30cm d.b.h.
4	medium-diameter tree: 30-50cm d.b.h.
5	large-diameter tree: > 50cm d.b.h.

Key to drought-damage classes

U	plant apparently unaffected
D	many leaves drooping or affected in some other way by drought
W	all leaves wilted but green foliage still present; with trees and shrubs, death of branches was sufficient to alter shape of crown
X	no green foliage, plant apparently dead
(X)	placed in the W or D columns indicates that a proportion of the plants recorded as W or D have since died.

Species	Site	Size Class	Effects of Drought			
Trees and Shrubs			U	D	W	X
Alectryon excelsus	Slope	1	15	5		
	Slope	2	8	4		
	Slope	3	2	1		
Aristotelia serrata	Slope	2			1	1
	Slope	3		1		
Beilschmiedia tawa	Concave slope	1		1	1	1
	Concave slope	2			3	
	Concave slope	3		6	8	1
Brachyglottis repanda	Slope	1		13	11(X)	1
	Slope	2		5	3(X)	1
Coprosma areolata	Slope	1	1	3	1	
C. australis	Slope	1 and 2		5	3	
C. robusta	Slope	1 and 2	2	5		
Cordyline australis	Slope	1	4	3		
	Slope	2 and 3	8			
Corynocarpus laevigatus	Concave slope	2	2			
	Concave slope	3	1			
Elaeocarpus dentatus	Slope	2	1	1		
	Slope	3	1	1		
	Slope	5			1	
Geniostoma ligustrifolium	Slope	1 and 2			18	2
Griselinia lucida (terrestrial)	Slope	2		3		
	Slope	3		1		
Hebe stricta	Slope	1	9	2		
	Slope	2		3		
Hedycarya arborea	Slope	2		9	6	1
	Slope	3		2	1	1
Hoheria sextylosa	Slope	1		2		
	Slope	2		4		
	Slope	3		1		1
Knightia excelsa	Slope	1	1			
	Slope	2	1			
	Slope	3	3			
Leptospermum ericoides	Slope	3	3			

			U	D	W	X
Species	Site	Size Class		Effects of Drought		
Macropiper excelsum	Slope	1 and 2		12	12	1
Melicope simplex	Slope	1	6	1		
	Slope	3	1			1
Melicytus ramiflorus	Slope	1		7	1	
	Slope	2	6	5	6	3
	Slope	3			5	1
Metrosideros robusta (terrestrial)	Slope	3	3			
Myoporum laetum	Slope	1		6		
	Slope	2		4		
	Slope	3	3			
Myrsine australis	Slope	1	9			
	Slope	2	10			
	Slope	3	1			
Pennantia corymbosa	Slope	2		1		
	Slope	3	4	3		
Pittosporum eugenioides	Slope	2 and 3	3	5		1
P. tenuifolium	Slope	2	6	5		1
	Slope	3	2			
Podocarpus spicatus	Slope	2	1			
	Slope	3	1			
P. totara	Slope	1	3			
	Slope	2	1			
Pseudopanax arboreum	Slope	2	5	2	2	1
	Slope	3	2			
P. crassifolium	Slope	2	3			
	Slope	3	8			
Schefflera digitata	Concave slope	2 and 3		2	1	1
Sophora microphylla	Slope	3	5			
Streblus heterophyllus	Slope	1		1		1
(*Paratrophis microphylla*)	Slope	2	2	2		
	Slope	3	2			
Woody Climbers:						
Clematis paniculata	Slope		1	1		
Freycinetia banksii	Slope		2			2
Metrosideros colensoi	Concave slope				1	1
M. diffusa	Concave slope		3	2	1	
M. perforata	Slope			2	1	
Muehlenbeckia australis	Slope		3	1	1	
Parsonsia capsularis	Slope			2		
P. heterophylla	Slope		1	4	1	
Ripogonum scandens	Concave slope		1		3	
Ferns:						
Adiantum cunninghamii	Slope		1	3	4	3
Asplenium bulbiferum	Concave slope			5	7	1
A. lucidum	Slope			2	17	1
Blechnum sp. (*B. capense* agg. "lowland" species)	Concave slope					2

Species	Site	Effects of Drought			
		U	D	W	X
B. aggregatum (*B. lanceolatum*)	Concave slope		1	1	3
B. membranaceum	Concave slope			1	2
Cyathea dealbata	Concave slope	1	9	5	5
C. medullaris	Concave slope		10(X)		
Lastreopsis glabella	Slope	3	2	19	1
L. velutina	Slope		11		
Pellaea rotundifolia	Slope	1	6	13	
Phymatodes diversifolium	Slope	1	5		3
P. scandens	Slope		1	1	
Polystichum richardii	Slope	2	4		1
Pyrrosia serpens	Slope		6		
Other Herbaceous Plants:					
Dianella nigra	Slope		2		
Gahnia setifolia	Slope		5		
Microlaena avenacea	Slope	2	6	3	

RESULTS

Bledisloe Park (Table 2)

Of 33 species of trees and shrubs represented by more than one individual, 14 (42 percent) showed some mortality as a result of the drought. Of the major forest trees mahoe and tawa were much more affected than either titoki or ngaio. At least six tawa are known to have died (not all encountered in the sample); almost all of them were trees with large spreading crowns. Most of the tawa remaining have lost major portions of their crowns. Rata (*Metrosideros robusta*), rewarewa (*Knightia excelsa*), kowhai (*Sophora microphylla*), lancewood (*Pseudopanax crassifolium*), mapou, matai and totara showed no effects, but in other bush remnants of the Manawatu district mature rewarewa died during the drought. Epiphytic plants of *Collospermum hastatum*, common in the park, were unaffected.

Of the 15 species of ferns examined quantitatively, 10 showed mortality. There was also widespread mortality of the climbing fern *Blechnum filiforme*, not recorded quantitatively. Bracken (*Pteridium aquilinum* var *esculentum*), growing on upper convex slopes, showed complete die-back of all fronds but these were replaced in the following spring.

A few species, represented only by single individuals, are worthy of comment. A small tree of black maire (*Nestegis cunninghamii*) and a tall sapling of white maire (*N. lanceolata*) were unaffected. A large tree of pukatea (*Laurelia novae-zelandiae*), growing in a concave site adjacent to tawa trees that either died or lost most of their crowns, lost a few leaves and then recovered completely. A large sprawling specimen of *Metrosideros fulgens* lost about three-quarters of its leaves (including all the older leaves) and many twigs, but it survived. A planted specimen of kauri (*Agathis australis*), 3.76m high in 1969, died.

Delayed effects of the drought may have caused death of adult kohuhu (*Pittosporum tenuifolium*) and reduced vigour of tawa but in neither case is there certainty.

Keeble's Bush

Results for trees and shrubs are given in Table 3 which shows that of the 17 species examined, there was mortality in seven. Among the larger trees rimu, kahikatea and tawa were the most affected by the drought and totara* and black maire the least affected. There was widespread mortality of kawakawa, not recorded quantitatively. The common epiphyte *Collospermum hastatum* again showed no effects.

* In the Otaki district south of the Manawatu, some totara growing on stony alluvial soils died during the drought.

TABLE 3. *Effects of 1969-70 Drought on some Indigenous Trees in Keeble's Bush, Manawatu District* (*key to symbols given in Table 2*)

Species	Size Class	Effects of Drought			
		U	D	W	X
Alectryon excelsus	2	12			
	3	7	4		
	4		1		
Beilschmiedia tawa	2			2	
	3		1	5	8
	4		1		7
Cordyline australis	2	1	4		
	3	2	1		
Cyathea dealbata	2	1	1		6
	3	2	1		3
Dacrydium cupressinum	2		1		
	3		2	1	1
	4		4	2	3
	5 (50-70cm)*	2	2	7	3
	5 (70-90cm)*				1
Elaeocarpus dentatus	3	1	2		
	4			1	
E. hookerianus	3		3		
	4		2		
	5 (50-70cm)*	1			
Hoheria sextylosa	2	1	5	1	2
	3		1	1	
Knightia excelsa	2	4			
	3	1	1	1	1
Melicytus ramiflorus	2		4	2	
	3		2	2	
Myrsine australis	1		1		
	2	1			
	3	1	2		
Nestegis cunninghamii	2	1			
	3	1			
N. lanceolata	2	1			
	3	2	1		
	4	1			
Podocarpus dacrydioides	1		1	1	
	2		1		
	3		3		
	4		1	1	
	5 (50-70cm)*		1	3	3
	5 (90-110cm)*				1
P. spicatus	1	1			
	2	1	1		
	3	2	3		
	4	1			

Species	Size Class	Effects of Drought U	D	W	X
P. spicatus	5 (50-70cm)*	1			
	5 (90-110cm)*	1			
P. totara	2	1			
	3	1			
	5 (50-70cm)*	1			
	5 (70-90cm)*	1			
Pseudopanax crassifolium	1				1
	2			1	
	3	1	1		

* Diameter of trunk at breast height (1.4m).

Where larger individuals of tawa, rimu and kahikatea had died or lost considerable parts of their crowns, it was possible to assess the immediate short-term effects on the adjacent trees in the stand. Two main effects appeared to be operative. Death of a tall podocarp among a group of podocarps is likely to reduce root competition with the remaining podocarps thus making them less prone to future droughts. Reduction in crown size that occurred in many trees also makes them less prone to future droughts. Secondly, death of a podocarp or tawa in a stand of dicotylous trees has not only reduced root competition but has increased the light reaching young trees in the understorey.

Observations of these effects accompanying tree mortality were made at 25 stations. Positive effects on the growth of dicotylous trees could be predicted at 15 stations whereas growth of the remaining podocarps appeared likely to benefit at eight stations. At two stations, the growth of both podocarps and dicotylous trees appeared likely to benefit. Increase in the cover of titoki was apparently favoured at 10 stations and reduced root competition for the surviving rimu occurred at seven stations.

DISCUSSION

In comparing the behaviour of plant species during the drought, it has to be remembered that their distribution is already partly determined by the history of earlier droughts. Thus the data given cannot be used to arrange species in order of drought tolerance. Furthermore, the response of a particular species is very much dependent on soil conditions as, for example, the contrasting behaviour of kahikatea in Keeble's Bush and Himatangi mentioned below.

Pukatea in both forest remnants was little affected by the drought and on the high water-table dune flats at Himatangi Bush, near Foxton, it was noted that pukatea, kahikatea and *Eugenia maire* were all unaffected by the drought. Tawa and rewarewa growing alongside these species died. The first three species, being capable of developing roots in poorly oxygenated, waterlogged soils, probably had deep root systems which allowed them to survive. Tawa and rewarewa are likely to have shallow root systems in soils of high water-table and are thus more vulnerable to droughts.

The mortality of trees and shrubs in the total sample can be compared between size-classes (Table 4) and this indicates greatest mortality among the larger plants in Keeble's Bush but no significant differences between size-classes in Bledisloe Park. Trees with larger crowns and leaf surface areas can be expected to be more vulnerable to moisture loss and this may explain the greater mortality of the larger sizes of tawa. The difference between the two forest remnants is possibly related to the emergent and therefore more exposed positions of podocarp crowns in the forest canopy of Keeble's Bush. In killing canopy trees here without having equal effects on understorey

TABLE 4. *Mortality of trees and shrubs according to size classes*

	Short saplings 0.3-2m ht.	Tall saplings 2m ht.-10cm d.b.h.	Small-diameter trees 10-30cm d.b.h.	Medium-diameter trees 30-50cm d.b.h.	Statistical significance of difference between classes
Bledisloe Park	4.3%	6.7%	6.9%		N.S.
Keeble's Bush		4.4%	15%	40%	**

trees, the drought has increased the rate of forest development.

Concerning trends of succession, the short-term effect of the drought in Bledisloe Park has been to favour titoki and ngaio while reducing the crown cover of mahoe and tawa. In the understorey, mortality of rangiora and hangehange was greater than indicated by the counts. However, the increased light has allowed many rangiora seedlings to establish so that the density of this species will probably be greater than before the drought. Many hangehange with 'W' ratings have resprouted from the base but the drought has favoured kawakawa more than hangehange since the percentage mortality of kawakawa was very small.

In Keeble's Bush the composition of the forest on the terrace examined varies between podocarp/tawa and podocarp/titoki with rimu the most abundant podocarp. The immediate net effect of mortality of rimu, kahikatea and tawa in these stands seems likely to be that of swinging the succession towards podocarp/titoki stands in which there is a reduced density of podocarps.

The effects of the drought in damaging the crowns of the podocarps demonstrates one mechanism by which the asymmetrical 'stag-headed' growth form of podocarps can develop. This form is common in many parts of the country. Upstanding dead crowns and branches following a major drought in a podocarp/dicotylous forest of similar structure to Keeble's Bush would make it vulnerable to lightning-induced fires. It may be these conditions which led to some of the pre-Polynesian fires known to have occurred in forests of the Canterbury Plains (Cox and Mead 1963).

The long-term effect of the drought on succession in Keeble's Bush is not clear. Saplings and small-diameter trees of all four podocarp species were found, some of which have been established since the forest became an isolated stand at the time of tree-felling in the 1880's. It is certainly possible that the increased light or altered root environment following the drought will allow further establishment of podocarps.

The situation with rimu is of particular interest because the size-class distribution of the 29 trees counted (Table 3) shows that regeneration has occurred, at least periodically. The numbers of "pole-size" trees, 10-30cm d.b.h., (4) are unusually high for a stand of primary podocarp/dicotylous forest in the lowlands and may reflect seasonally wet soil conditions. In the Wairarapa and Hawke's Bay districts, rimu is generally not found in areas where annual rainfall is less than 1000mm. Stumps of decaying rimu in Keeble's Bush indicate past mortality and possibly some of this was a result of earlier droughts. Many podocarps were lost also during the 1936 storm (Mr A. E. Esler, pers. comm.) so that at the time of settlement, the terraces of Keeble's Bush were occupied by a comparatively dense stand of podocarps.

The drought effects studied here, in which titoki has apparently gained more than any other species, are an example of only one type of weather extreme that can influence the composition of vegetation. The Ohakea soils are often gleyed (Cowie 1964) indicating high water-tables in winter. It is conceivable that a sequence of unusually wet summers and winters could, by raising the water-table, adversely affect the growth of titoki in the future.

Conversion of the land surrounding Keeble's Bush to pasture last century has increased the exposure of tree crowns in the remaining forest and thus almost certainly accentuated mortality during droughts. Nevertheless, although Keeble's Bush is not particularly unusual in floristic composition, a strong case can be made for its use as a scientific reserve. It is in a much less modified condition than any other remnant in the Manawatu lowlands and its climatic position near the rainfall limit of rimu makes it an ideal area for study of the dynamics of podocarps and dicotylous trees.

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