Another method of application used
th the seed in combination with other
is placed well down, there appears
g seedlings, through the tender roots
tration of copper sulphate.
from broadcast dressings is a residual
he residual effects of copper sulphate
many other workers similarly claim
an effect in the area under discussion
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s that year, a heavier crop of very
ained in the 1948-49 season with no

LEDGMENTS

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Thanks are due to Dr. M. M. Burns
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r the trial.

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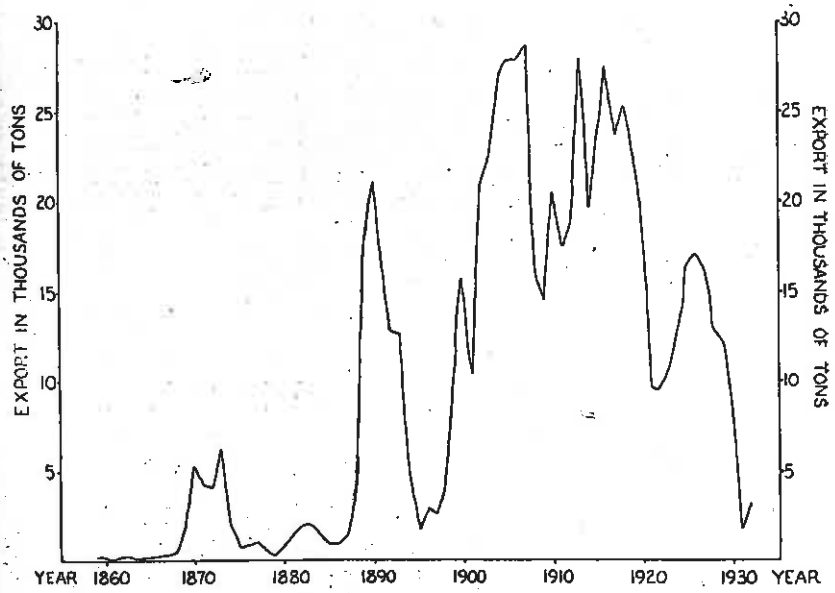
STUDIES OF PHORMIUM MANAGEMENT, MOUTOA ESTATE, FOXTON

By A. L. POOLE and W. R. BOYCE

HISTORY LEADING TO THE GOVERNMENT PURCHASE OF MOUTOA

THE Phormium industry in New Zealand, from its origin in the early years of the nineteenth century until 1930, was built largely on an export trade to cordage fibre markets overseas. This trade between 1900 and 1920 maintained an average export of approximately 20,000 tons of line fibre per year which represented an annual harvest of about 200,000 tons of green leaf. It was marked, however, by excessive fluctuations from year to year with a rapid decline from 1925 until exports ceased after 1933. These movements are shown graphically in Fig. 1. A small internal market for a few thousand tons of fibre existed, but its importance was overshadowed by the recurrent opportunities of the export market until the latter collapsed finally in 1933. It was only



ANNUAL EXPORT OF PHORMIUM LINE FIBRE

Fig. 1

then that the future of the industry was seen to lie in the potentialities of New Zealand's own fibre requirements. With the present world fibre shortage these requirements have been estimated at a minimum of 10,000 tons of unscutched fibre per year. Because of the shortage of green leaf the local industry cannot provide more than 35,000 to 45,000 tons per year which is equivalent to 4,000 to 5,000 tons of unscutched fibre.

What then has been the relation of the industry to its supplies of raw material? In the era of the export trade the use and development of supplies of leaf has been considered by A. H. Cockayne (Department of Agriculture Reports) and others to fall into three periods: the first up to 1900, when leaf was obtained from naturally occurring stands which were widely distributed over the North and South Islands; the second from 1900 to 1920, which marked the rise of indigenous induced areas (this term is explained in Section 2), of which those bordering the Manawatu River were the most extensive; and a third period after 1920 marked by a rapid decline of indigenous induced areas and an attempt to replace them by plantations.

The closing of the export era further hastened the decline of the indigenous induced areas, and rendered abortive, with few exceptions, efforts to establish plantations. It also frustrated a promising movement marked by the work of J. S. Yeates (D.S.I.R. Reports) and to a lesser extent that of Seifert, Walls and Wood to improve by selection and breeding the qualities of the plant.

Reasons for the fluctuating fortunes and failure of *Phormium* on the world cordage fibre market were:—

1. It was available only in comparatively small quantities—a maximum of 28,000 tons in a world hard fibre demand approaching 400,000 tons.

2. As a cordage fibre its quality was more variable and tended to be inferior to manila and sisal. These defects were due in part to (a) variations of plants occurring in the natural and induced areas, (b) difficulties in separating the fibre from the leaf, and (c) the number of small mills operating and a large element of opportunism which attended the working of some of them.

3. After 1930 the increased quantities of sisal from East Africa and the economic depression in the ensuing years dealt a death blow to the industry.

Strenuous efforts were made at various times to retrieve the position by improving machinery, instituting a grading system, and later by research work on plant breeding and fibre processing. However, this did not avert the final collapse.

There remained local requirements to support an industry. These included fibre for cordage, lashings, baling and binder twine, plasterer's tow, upholsterer's tow, matting and woolpacks, the last being the most substantial requirement. New Zealand uses some 800,000 packs each year to bale its wool clip, for which a total of 4,000 tons of unscutched fibre would be needed. Although classed as a hard fibre, *Phormium* occupies an intermediate position in fibre quality between typical hard fibres such as sisal and manila and soft fibres such as jute, and can cover a range of uses in both groups in cordage and textile work. Hence, whereas in overseas cordage markets *Phormium* was at a disadvantage, it has because of its wide range of uses marked advantages for the local market.

In 1933 an attempt was made to establish in Foxton, New Zealand, an industry for manufacturing woolpacks from the tow scutched out in producing line fibre for export. Previously this tow had been a by-product for which little economic use existed. However, such was the state of decline of the industry in this and following years that insufficient tow was produced to maintain production, and many difficulties were encountered when line fibre had to be treated on machinery not designed for the purpose. This period also marked the passing of most of the remaining indigenous induced areas from *Phormium* production to other agricultural purposes, and brought to an end many attempts to establish plantations. The year 1935 marked a crucial point in the development of the industry. A decision was made by the executives of the private company which had commenced manufacturing woolpacks that only with government assistance to ensure their supplies of leaf and to enable the factory to be re-equipped with machinery suitable for handling line fibre could they continue production. This assistance was given. In 1938 the government took over, for development and research, the Moutoa estate, the last large area of *Phormium* remaining in the Manawatu.

The industry has thus been stabilized temporarily but its future which depends on adequate supplies of green leaf is not yet assured. Such supplies must come from both naturally occurring and indigenous induced areas. The problems of managing and maintaining these in economic production tend to become increasingly difficult. Some will be replaced by managed plantations with their improved working conditions, higher yield of fibre per acre and more even quality of leaf, while other areas will have to be maintained in production. In the latter task research will be necessary to enable the requirements of the industry to be adjusted to the ecological requirements of the plant.

ECOLOGY OF INDUCED PHORMIUM COMMUNITIES

To date, by far the greater part of green leaf for the fibre trade has come from what Cockayne (1928) termed "indigenous induced" swamps. This term was applied by that author to areas in which the vegetation was dominated by indigenous plant species, but in which the structure of the vegetation was altered considerably by interference. One cannot do better than quote Cockayne's description of such indigenous induced *Phormium* communities, "In various parts of New Zealand proper, especially where large rivers overflow their banks, there are extensive areas of ground, perhaps extremely wet in winter, but quite dry in summer, occupied by bushes (tussocks) growing closely of *Phormium tenax,* making apparently a pure association. To one unversed in this class of vegetation, it would unhesitatingly be considered primitive, yet *it has arisen solely through draining the Typha-phormium swamp described in Part II.* Nor would it remain stable for long were it not that various invading species are removed by the owners of the 'flax-swamps,' so called:

"As has been explained, the primitive swamp is wet at all seasons and contains abundance of *Typha angustifolia* (in a wide sense), but, as with *Phormium,* it only occurs more or less stunted here and there in the shallowest water or fringing the margin of the swamp. Into the latter deep drains are cut, its water-content is greatly lessened, and in a year or two the *Phormium* present attains its full dimensions; then

the substratum becoming drier the *Typha* will languish and young *Phormium* plants come up thickly all over the drained ground. In a few years such attain their full dimensions and the former swamp will be almost pure *Phormium* 3.6 m. high, under favourable conditions."

It will be seen from Cockayne's description that the underlying cause bringing about the vegetation changes was the effect of altered water table conditions on the zonation of communities in a swamp.

The Moutoa *Phormium* area at the time of purchase in 1938 was typical—apart from a somewhat excessive encroachment of introduced weed species—of such an indigenous induced swamp. It was indeed the last of any size remaining of the once-extensive area along the Manawatu River banks from about Palmerston North to Foxton.

Various causes led to the failure of these Manawatu swamps for the production of *Phormium*: overdrainage, stopbanking, insect damage and weed invasion, the disease known as "yellow leaf," the cause of which is as yet not diagnosed, and the greater value of the land for other agricultural purposes. But from the information available the main cause underlying the disappearance of these *Phormium* areas appears to have been either the failure to recognize or the inability to provide, the ecological requirements for induced *Phormium* under periodic cutting. The narrow belt which *Phormium* occupied in the primitive community indicates that its requirements are exacting and vary within small limits. (To what extent these factors are determined by special physiological requirements of the plant or by the interaction of factors outside the plant is a subject for future research.) This belt lies between swamp forest and scrub on the dryer side, and *Typha angustifolia* and sedges on the wetter side.

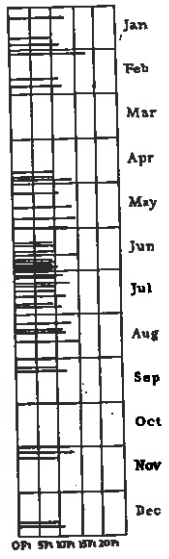
The development and decline of these areas can be traced briefly as follows: Initial drainage led to the spread of *Phormium* from its original narrow belt to occupy the *Typha* and sedge zones. This spread of *Phormium* and its increased growth was followed by cutting operations. Further exploitation of the areas required more extensive drainage and stopbanking to give flood protection. Then followed a characteristic decline marked by insect damage, weed invasion and yellow leaf disease. Secondary causes such as fires, stocking and poor cutting practices aggravated the rate of decline in particular cases. Miller (1917) has described the sequence of events for the Makerua area (one of the Manawatu swamps) in relation to insect damage; it was drained in the 1890's and milling commenced in 1900. More intensive development followed and the first incidence of grub attack was reported in 1902. Later reports show that diseases of the yellow leaf type were first reported about 1908, while serious losses from this disease were reported by L. Cockayne (1920). Miller refers also to the contrast provided by the Moutoa area which at the time of his investigations remained free from the troubles affecting other areas.

That the soil moisture conditions can readily be upset by drainage is apparent; that the prevention of silt laden floods from covering the areas removes one of the conditions for optimum growth is also evident. Because of free flooding and restricted drainage, the Moutoa alone of all the once extensive Manawatu areas remained in *Phormium*. Under similar conditions *Phormium* stands along the lower reaches of the Ruamahanga River flowing into Lake Wairarapa have also yielded heavy crops of healthy leaf for a long period of time.

THE MOUTOA AREA

HISTORY AND GENERAL DESCRIPTION

The Moutoa Phormium Development Area purchased by the Government in 1940 covers some 5,000 acres on the north bank of the Manawatu River, about five miles from its mouth. It is part of a very shallow semi-basin with contours ranging from about 6 ft. to 20 ft.* above mean sea-level, with about two-thirds of the area lying between the 6 ft. and 9 ft. contours. The highest contours are along the river where continual flooding and deposition of sand has formed a low levee, while the lowest contours are to the north of the area, roughly parallel with the general flow of the river. Prior to purchase, flooding occurred on an average of four times per year. The size and distribution of these floods is shown in Fig. 2.



Summary

HEIGHT-DISCHARGE RELATIONSHIP

9 on gauge board	=	23,000 cusecs.
10 "		28,000 "
11 "		33,000 "
12 "		39,000 "
13 "		45,000 "
14 "		51,000 "
15 "		58,000 "
16 "		67,000 "
17 "		76,000 "

NUMBER OF FLOODS PER YEAR

1929	4
1930	3
1931	5
1932	4
1933	2
1934	2
1935	6
1936	5
1937	–
1938	9
1939	5
1940	1

Total number of floods = 46
Average number of floods per year = 4·18
Greatest number of floods in one year = 9
Least number of floods in one year = –
Greatest flood month is June = 10 floods
Least flood month is March = no floods

FIG. 2.—FLOODING OF MANAWATU RIVER
COMPOSITE GRAPH OF FLOODING FOR ELEVEN YEARS ENDING 31 MARCH, 1940
Height of River on Gauge Board at Fitzherbert bridge, Palmerston North. Floods occur at nine feet or over.

Recent sediments deposited by the Manawatu River, together with peaty phases in the lower-lying parts, form the soils. The sedimentary deposits range from sands and sandy silts on the river banks to silts and clay loams on the lower ground away from the banks. All these recent sedimentary deposits are underlain at depths of from 18 in. to 12 ft. by a more consolidated bluish clay loam in which are the stumps of an old forest. Where peaty phases or even shallow silt phases have

* River Levels: All levels are to datum of Manawatu-Oroua River Board. Zero is Low Water Spring Tide at Manawatu Head. To this datum mean sea level is reduced level 4. Therefore if 4 ft. is subtracted from all levels it will give the amount of such levels above mean sea level.

shrunk through drainage, these stumps appear above the surface. All soil types are fertile as far as plant food requirements are concerned and are less acid than is usual for meadow soils.

What now roughly constitutes the area was purchased in 1870 in London, for the purpose of clearing and developing farmlands. Draining commenced within a short time and the dry river banks were soon cleared of forests and were farmed. As draining proceeded into the interior of the area, burning was commenced but never succeeded in killing the swamp vegetation. About this time the *Phormium* fibre industry had become well established and in the year 1887 the cutting of green leaf commenced on the area. Nevertheless, further attempts were made to clear by burning up to about 1900. Commencing with a change of ownership in 1902, the area was thereafter managed for *Phormium* leaf production. Drains were maintained, weeds were dealt with in the best *Phormium* stands, and a certain amount of planting of *Phormium* and thickening up of natural stands was done.

VEGETATION SURVEY

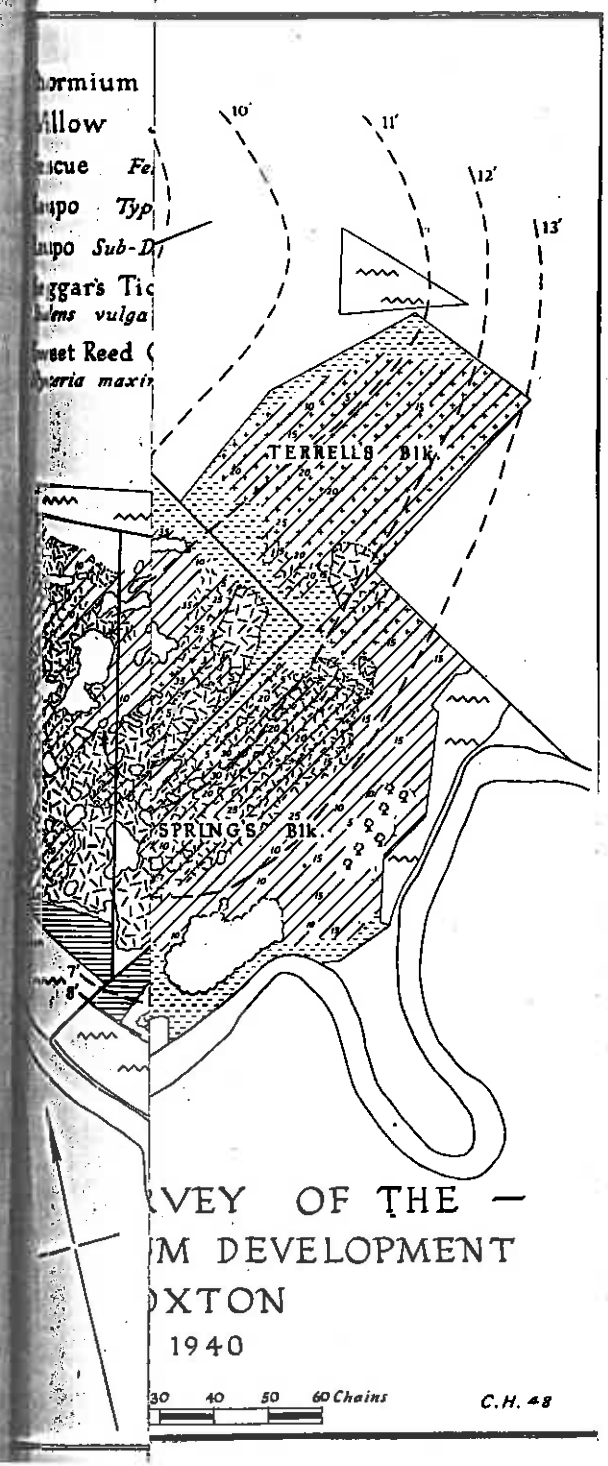
Just prior to purchase in 1940 a 100 per cent vegetation survey, combined with an estimate of the total *Phormium* green leaf crop, was made (Poole, 1946). There follows a detailed description of this survey, since from it can be reconstructed the approximate boundaries of the original plant communities and the alterations following drainage. Upon this information depended the formulation of any plans for the future management of the area. A knowledge of the position *Phormium* occupied in the vegetation zonation and of the conditions under which optimum stands could be stabilized was basic.

METHODS OF SURVEY

The base line of the survey was a cut inspection line running east and west through the whole length of the area. At right angles from this, and at ten-chain intervals, offset lines were cut to the river and to the northern boundary; thus the area was covered by parallel cut lines at ten-chain intervals. Along these lines two chainmen and two mappers cruised. Each mapper recorded in field note books all the vegetation by communities on one side of the line, and where *Phormium* was present assessed the stand in tons of green leaf per acre as at maturity. The information thus obtained was transferred to a base map of five chains to an inch. From this, all basic data such as the total *Phormium* stand, the area and distribution of the plant communities, etc., was obtained. Fig. 3 is a reproduction of the vegetation map showing plant communities and the *Phormium* stands.

The determination of the important plant communities was obtained by studying aerial photographs combined with field inspections. The communities selected were named after the dominant plants, as follows:

Phormium	(*Phormium tenax*)
Raupo	(*Typha angustifolia*)
Tall fescue	(*Festuca arundinacea*)
Beggar's ticks	(*Bidens vulgata*)
Reed sweet grass ..	(*Glyceria maxima*)
Crack willow	(*Salix fragilis*)
Remnant kahikatea forest	(*Podocarpus dacrydioides*)
Miscellaneous weeds and sown pasture.	



Each of these communities will be described, and at the same time notes which can be followed on Fig. 3, made concerning their distribution. This map was drawn with particular reference to the commercial crop of *Phormium*. Stands of about 20 tons of green leaf per acre were dominated by *Phormium* and were considered as *Phormium* communities. When the stand dropped below 20 tons per acre associated plants were becoming dominant and *Phormium* sub-dominant. This must be borne in mind when reading the map. The lowest commercial stand of *Phormium* was one that yielded about five tons per acre of green leaf.

Relevant statistics of leaf tonnages and areas covered by different communities are given in Tables I and II.

The Phormium Community

Phormium is a perennial plant with short, much branched rhizomes. The ends of the branches are semi-erect, terminating in a fan bearing six to ten leaves. New leaves appear on alternate sides in the centre of the fan, live for eighteen months, and then die off from the outside of the fan as they are displaced by succeeding younger leaves.

A fan, about its fourth or fifth year, reaches a stage of equilibrium at which the number of new leaves produced is balanced by the number dying off. The fan then bears from six to ten harvestable leaves and is considered mature for cutting. A complete cut is made in which all leaves of a fan and all fans of a plant are cut six to nine inches above ground level. The life of a fan and its leaf production is terminated by flowering which may take place any time after its third year of growth. It is then replaced by shoots from the base of the fan which develop into young fans branching from the old rhizome. In this way a *Phormium* bush spreads outwards from its initial position with young fans on the periphery. In time, older fans in the centre flower and die out, leaving a ring of younger fans, which in turn may break up into isolated clumps with nothing but the old rhizome traces to show a connection with the origin of the bush. It is this method of growth which gives the random distribution of small clumps of fans, typical of the best induced stands. As little regeneration from seed appears to take place in dominant *Phormium* stands, it is possible that plants growing to-day had their origin in the first induced stands, and have since continued by vegetative growth. Another characteristic of the growth habit is that young rhizomes arise at progressively higher levels, as a result of which the bush tends to rise above the surrounding soil surface. Where flooding and silting takes place old leaves and decaying vegetation are incorporated with silt in a loose friable mulch round the base of the plant. By this means the soil level keeps apace with the production of new plants, and optimum conditions for growth are provided. On the other hand, in the absence of flooding and silting, and where drainage tends to compact the surface soil, younger fans may be well above the soil level. Roots then become exposed and subjected to damage by desiccation and insect attack. Insect populations may build up quickly in the absence of flooding and greatly increased damage to aerial and subterranean portions of the plant results.

In the optimum facies of the *Phormium* community *Phormium* grew gregariously, producing a maximum weight of about forty tons of green leaf per acre (see Fig. 5). In these gregarious stands, other plants

TABLE I. MOUTOA ESTATE VEGETATION SURVEY
AREA IN ACRES OF VARIOUS TYPES OF VEGETATION. AREA IN ACRES SHOWN THUS :— DOMINANT 23, SUBDOMINANT (23)
Compiled by P.W.D. from basic Vegetation Survey Map

	Terrell's.	Springs.	Oldfield's	Kari.	Toss'.	No. 18.	No. 10.	Paiaka.	No. 17.	Huia.	Nye's.	Pukeko.	Total.	Per cent of Total
Phormium	149	66 247	256	147	88	49	209	299	137	437	155	74	2313	49·4
Willow	—	36	70	84	17	57	55	75	66	251	150	30	891	19·0
Fescue	43	59(145)	38(24)	50(76)	64(88)	17(40)	11(43)	1(47)	9(31)	38(34)	(20)	22(32)	352(580)	7·5(12·2)
Raupo	6(9)	4(121)	44(59)	18(55)	—	2	17(81)	3(69)	12(53)	103(84)	169(40)	2(30)	380(801)	8·1(17·1)
Beggar's ticks	—	—(30)	—	—(3)	—	—	20(30)	—(22)	—(33)	9(126)	25(149)	—	54(390)	1·2(8·3)
Reed sweet grass	—	—	—	—	2	—	2	—	—	12	22(5)	27(9)	65(14)	1·4(0·3)
Miscellaneous	—	—	—	—	—	—	62(3)	—	6	78(34)	64(25)	24	234(62)	5·0(1·3)
Forest	—	12	—	—	—	—	—	10	17	—	—	—	39	0·8
Pasture, etc.	18	45	26	—	—	37	—	51	86	41	20	32	356	7·6
Blackberry	—(140)	—(48)	—(125)	—	—	—	—	—	—	—	—	—	—(313)	—(6·7)
Total	216	469	434	299	171	162	376	439	333	969	605	211	4684	100·0

NOTES: Phormium areas include only those yelding 5 Tons per acre or over.
Willow areas exclude clumps smaller than 1 square chain.

Kari Kari Road

Langley's Drain

Diagonal Drain

TABLE II. PHORMIUM CROP
SCHEDULE OF ACRES CARRYING VARIOUS WEIGHTS PER ACRE — AND GROSS TONNAGES
Compiled by P.W.D. from basic vegetation survey map

Tons per acre.	Terrell's.	Springs.	Oldfield's	Kari.	Toss'.	No. 18.	No. 10.	Paiaka.	No. 17.	Huia.	Nye's.	Pukeko.	Totals.	Per cent of total area.	Tons.
No flax or less than 5 tons	67	156	178	152	83	113	167	140	196	532	450	137	2371	50·6	
5 - 10	41	59	18	45	27	—	50	—	—	59	81	31	411	8·8	3,100
10 - 20	79	126	20	72	61	—	61	20	16	120	64	42	681	14·6	9,900
20 - 30	29	46	70	10	—	12	66	39	28	192	10	1	503	10·7	12,500
30 - 40	—	16	98	20	—	37	32	220	86	63	—	—	572	12·2	19,700
40	—	66	50	—	—	—	—	20	7	3	—	—	80 (66)	1·7 1·4	3,200
Totals in acres	216	469	434	299	171	162	376	439	333	969	605	211	4684	100	
Gross weight of Flax in tons	2,200	4,000	7,600	2,300	800	1,500	4,000	9,800	4,200	9,300	1,800	900			48,000
Tons/acre on Gross Area	11·1	9·9	17·5	7·7	4·7	9·3	10·6	22·3	12·6	9·6	3·0	4·3			10·4
Tons/acre on Flax Area	14·7	16·2	30·0	15·6	9·1	30·6	19·1	32·7	30·5	21·1	11·6	12·2			21·5

40	Tons/acre	gives	6·5	per cent of crop for	1·7 per cent of area
30	„ or over/acre	„	47·0	„ „ „ „ „	13·9 „ „ „ „
20	„ „ „ „	„	73·0	„ „ „ „ „	24·6 „ „ „ „
10	„ „ „ „	„	93·5	„ „ „ „ „	39·2 „ „ „ „
5	„ „ „ „	„	100·0	„ „ „ „ „	48·0 „ „ „ „

were not present in any quantity. Quadrat counts showed that the number of fans per acre was fairly constant varying from 20-25,000. A typical quadrat is shown in Fig. 4, and the position of plants recharted seven years later shows the movement which has taken place. The leaves in such a stand reached a height of eight to ten feet and through touching and interlacing excluded sunlight from the floor, thus making it unsuitable for colonization by other plants. A few managed to exist and scattered *Blechnum procerum, Carex ternaria, C. secta, Agrostis tenuis* and *Typha angustifolia* were most commonly present. Occasional shrubs, as high as or somewhat higher than *Phormium*, were also present. The species were *Coprosma propinqua, C. robusta* and hybrids between these two, *C. areolata, Muehlenbeckia australis* and *M. complexa*, often scrambling over other shrubs, and *Pittosporum tenuifolium*. The shrubs must have been much more plentiful at one time, but many were probably cleared with each cutting of the *Phormium* leaf. Rising about three times the height of the *Phormium* were scattered cabbage trees (*Cordyline australis*).

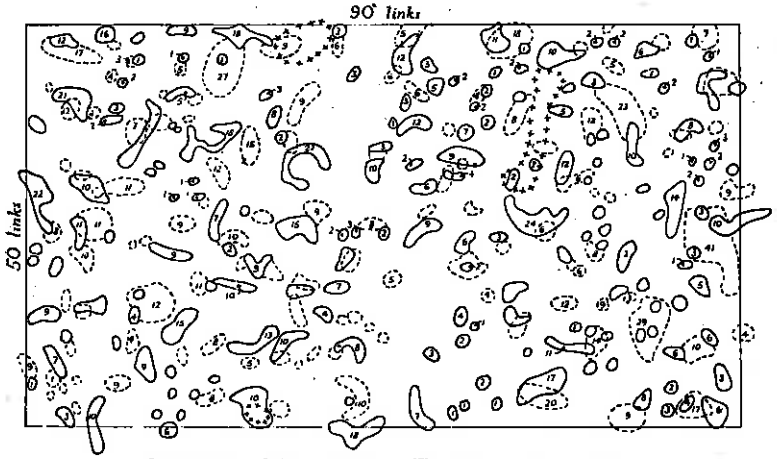


FIG. 4.—Basal areas of *Phormium* bushes in an optimum *Phormium* stand.

Over the whole Moutoa Estate, *Phormium* stands of above twenty tons per acre covered 1,140 ac., or approximately one-quarter of the total; while stands below this amount covered 1,040 ac. Gregarious stands occurred in areas up to 150 ac. in extent. They were situated away from the river banks, mainly between the seven to twelve-foot contours (Oldfield and Paiaka Blks.), and had a decided relationship to the drainage and the history of the drainage.

Under conditions both drier and wetter than those which favoured the optimum facies, *Phormium* became more widely spaced and other plants more plentiful. On the dry side, *Phormium* bushes became scattered, though individually larger. Old isolated plants had an outwardly spreading ring of fans. Shrubs, mainly *Coprosma* spp., *Muehlenbeckia australis*, and *Cordyline australis* increased greatly in the open *Phormium* stand. This type of community was common as the optimum *Phormium* stands approached the river bank.

FIG. 5.—A good stand of *Phormium*, Oldfield's Blk.

A common sub-dominant plant on the dry side was blackberry, *Rubus laciniatus* and *R. ulmifolius*, and it sometimes also entered optimum stands. The main area in which it occurred was towards the eastern part of the estate within approximately the 10-13 ft. contours.

The most common sub-dominant to *Phormium*, which gradually passed into a dominant as conditions became drier, was tall fescue (*Festuca arundinacea*). This facies occurred near drains mainly in the eastern half of the estate or in proximity to the river bank. In the latter area it was invariably accompanied by goat's rue (*Galega officinalis*), and bindweed (*Calystegia sepium*). Tall fescue is a prolific seeder in these districts, and where conditions suit it, has the ability to invade the base of *Phormium* bushes or the tops of *Carex secta* clumps. By itself, it forms dense tussocks which in the second season will grow as much as 2 ft. above the ground level. Inundation of about one week is sufficient to kill tall fescue.

Carex ternaria which was present throughout all *Phormium* stands sometimes increased over small areas to form the dominant plant.

On the wet side of the optimum *Phormium* facies raupo (*Typha angustifolia*) was the most common sub-dominant. As conditions became wetter the more scattered and stunted in growth became the *Phormium*, finally giving way to raupo entirely. The delicate balance between these two plants was the best indication of optimum conditions for *Phormium*. In places beggar's ticks (*Bidens vulgata*) came in with raupo.

Raupo Community

In the optimum facies of this community raupo occurred gregariously with a dense layer of rhizomes about 6 in. under the surface, giving other plants no opportunity to invade. It had a marked seasonal varia-

tion as the leaves were killed by the first heavy frosts and young shoots did not appear again until October. It occurred most commonly in the low-lying western parts where it occupied extensive areas. In the central portion (Paiaka and the surrounding blocks), it was in delicate balance with *Phormium* (see Fig. 6). Within a short distance of twenty yards or so, there could be a transition from dominant *Phormium* to dominant raupo and back again (see Fig. 7). In other words, a large part of the area consisted of a mosaic of these two communities and transitional stages between them.

FIG. 6.—*Phormium*—raupo balance, Diagonal Blk.

FIG. 7.—A stand of sweet reed-grass; *Phormium* and willow in the background.

The transitional facies from *Phormium* to raupo have been described under the *Phormium* community. As conditions became wetter than suited raupo, this plant gave way to reed sweet grass (*Glyceria maxima*), beggar's ticks and *Carex secta*. The junction between the first plant and raupo was abrupt because of the habit of reed sweet grass of creeping over the ground to the exclusion of all else. Beggar's ticks, being an annual, was an ephemeral plant. Its germination and persistence seemed to depend upon surface water conditions.

Reed Sweet Grass Community

This naturalized species frequently accompanied by another naturalized plant, the reed canary grass (*Phalaris arundinaceae*), formed limited communities which covered the ground to the exclusion of all other vegetation. As noted before, the boundary between this and the surrounding communities was sharp. The community occupied the lowest lying, wettest parts of the area, a favourite locality being along the banks of the lowest drains from whence it grew into the drains themselves. Drains must have been one of the main means of spreading the plant.

Beggar's Ticks Community

This community, of a naturalized annual plant, occupied fairly extensive areas in the low lying western parts. Its ecological status was difficult to determine, though later knowledge placed it as an ephemeral community. It seemed to be present mainly on areas where *Phormium* had been killed out, through flood waters lying on cut plants or for other reasons, and before other perennial plants had time to migrate to the area. (See Fig. 8.)

FIG. 8.—A deteriorated *Phormium* stand; raupo and beggar's ticks invading.

In the optimum facies of this community, beggar's ticks grew gregariously to the exclusion of most other species. Plants grew very closely to a height of 4 - 5 ft. and in the autumn produced an abundant crop of seed which germinated as the surface water receded in the spring. Beggar's ticks also appeared commonly on freshly broken or cultivated land.

Miscellaneous Weeds Community

This community, consisting mainly of low growing weed plants such as *Polygonum hydropiper, P. persicaria, Rumex* spp., *Juncus* spp., *Bidens vulgata, Ranunculus* spp. etc., also appeared to be an ephemeral community, which would give way to other plants in time. It occurred only in limited areas in the northern portion of the estate.

Tall Fescue Community

This naturalized species appeared as conditions became drier than those favoured by optimum *Phormium* stands. At first it occurred about the base of *Phormium* plants and as an invader on the tops of *Carex secta*. As drier conditions developed it tended to become the dominant plant growing as tufts which raised themselves from the ground. The most frequent occurrence of the community was within the high contours along the river bank or along the freer flowing drains. In the former position it was invariably accompanied by much goat's rue, and in the latter by such plants as creeping buttercup. Over extensive areas in the higher contours tall fescue was a sub-dominant to *Phormium*, and in plantations which had been established along the bank it had invaded to a serious extent.

Crack Willow Community

This naturalized species propagates itself readily from twigs, branches or stumps. An area such as Moutoa which is subject to inundation by floods carrying willow twigs and logs is an admirable propagating place. This was shown in the survey which determined that 20 per cent of the area was covered by willows varying from single trees to groves up to 20 ac. in extent. The trees grew to a height of about 35 ft., and eventually killed by shading all plants other than ground floor herbs. The groves became a tangled mass of stems as they were broken off by wind and flood damage and took root.

The distribution of the community was indiscriminate and depended mainly upon chance dispersal of propagating material. A certain amount was also propagated by using willow wood for tram sleepers and fencing posts.

Remnant Kahikatea Semi-Swamp Forest Community

Remnants of the forest, much damaged by animal grazing, occurred along the drier river bank. In the best preserved of these, the dominant trees were kahikatea and pukatea (*Laurelia novae-zelandiae*). Other plants making up this community are recorded in the appended list of species.

Sown Pastures

Along the river banks where the semi-swamp forest once grew almost continuously, but was early cleared for cultivation, pastures composed mainly of rye-grass and white clover were sown. Tall fescue and goat's rue invaded these to a considerable extent.

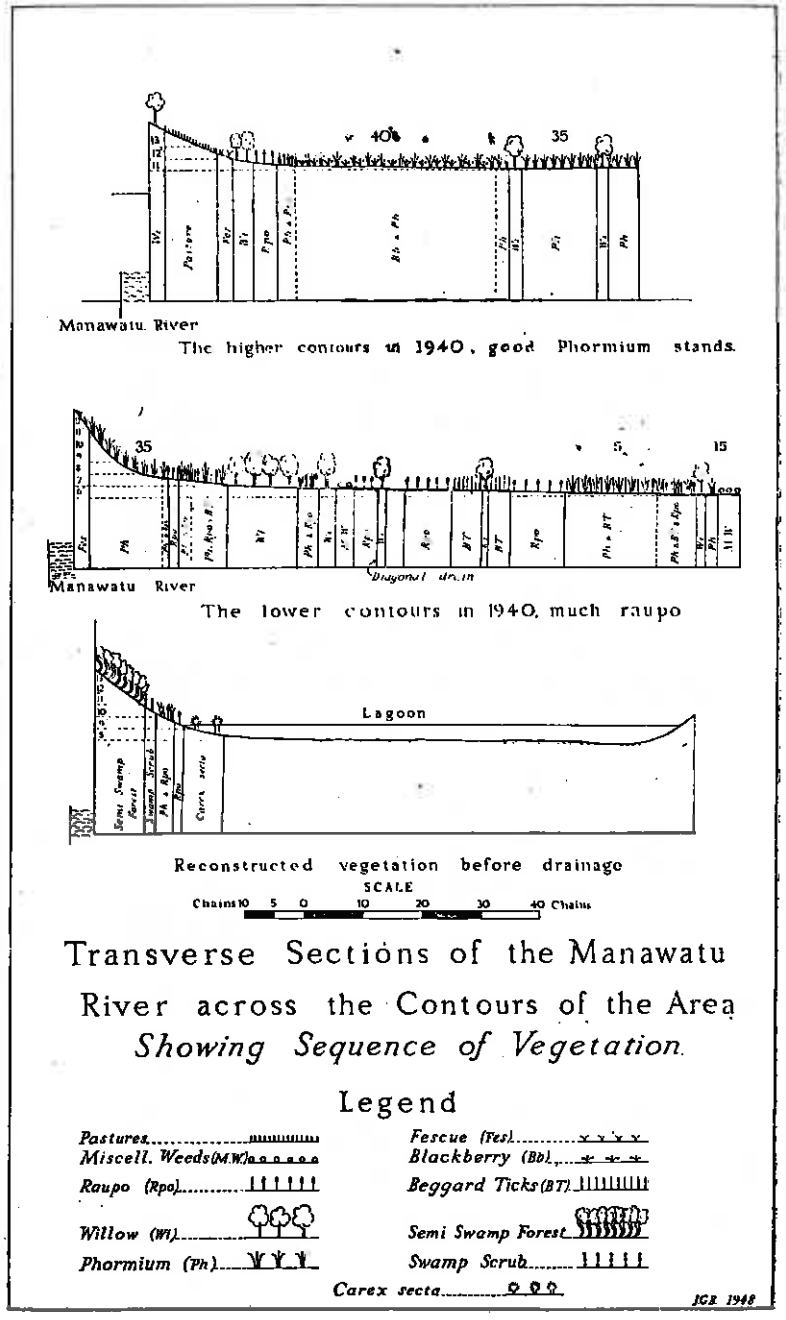


Fig 9

DISCUSSION ON THE DISTRIBUTION OF THE PLANT COMMUNITIES

From the vegetation map showing the distribution of the various communities, from remnant species and communities, and from old survey maps and verbal history, it has been possible to reconstruct the original vegetation and to trace the changes introduced by drainage and management. (See Fig. 9.)

In the virgin condition the vegetation consisted of a zonation of communities closely correlated with the spatial change in the height of the water table. The comparatively dry river bank supported a semi-swamp *Podocarpus* forest—a survey carried out in 1866 by J. Thompson, shows forest around the river bank of most of the Moutoa Estate—inside which would come a belt of swamp scrub consisting of *Coprosma* spp., *Cordyline australis*, etc. In this belt scattered *Phormium* would be present. It gradually increased to form a relatively pure but narrow belt inside the scrub. This in turn would give way to *Typha* forming fairly extensive communities. Inside this again would be open shallow water with scattered *Carex secta*.

The series of changes commenced by European occupation was initiated by the clearing of the forest and the cropping or sowing of pastures of European pasture species along the river banks. Drainage of the swamp proper then altered the water-table conditions, bringing about a change in dominant species of the different zones. Conditions in the *Typha* belt became such that *Phormium* invaded it, or that *Phormium* seedlings already present but undeveloped grew and became dominant. As drainage proceeded this also occurred to some extent in the shallow water areas where *Carex* was present. Burning and attempted clearing of parts did not alter the vegetation materially, because floods and wet winter conditions restored the dominants.

Then came the development of the *Phormium* industry, and the management of the area for *Phormium* leaf. The induced *Phormium* stands were fostered and weed species were cleared to some extent as the stands were cut over. On the poor margins of these stands, *Phormium* was "thickened" by planting and some planting was also done on the cleared dry river bank. In the course of time a number of adverse changes, i.e. adverse from the point of view of *Phormium* management, took place. The encroachment of a number of introduced weed species could not be halted. Tall fescue and goat's rue invaded areas too dry for optimum *Phormium* stands. In planted areas on the dry river bank, this invasion seriously affected the plant. Crack willow invaded any part where vegetative material happened to be spread by floods or human agency. Once crack willow became established there seemed no method of control other than removal of all parts of the tree. Ring-barking was only partially effective. In parts, scarcely too dry for optimum *Phormium*, blackberry became an invader, sometimes to such an extent that it hindered cutting operations. This again was a difficult weed to deal with, as it never seemed possible to eradicate it.

Drainage of the estate brought about some subsidence in the silt and sandy soils, and a considerable amount in the peaty soils. This reduced the effectiveness of the drains, particularly in the lower parts of the area. The main effect was the slow draining off of flood waters, which in turn brought about changes in vegetation, in particular the killing out of *Phormium* as a result of excessive wetness and flood waters lying on freshly cut plants. These areas were invaded temporarily, sometimes by the annual *Bidens vulgata* and finally by *Typha*, a reversal of the succession which took place after the original drainage. Where conditions were wettest—probably too wet at any stage for *Phormium*—sweet reed grass and reed canary grass invaded the area and formed pure communities.

From the above description it will be seen that *Phormium* was induced over wide areas by a succession of drainage activities. It would invade first the raupo belt and follow this into the lagoon areas as raupo found its way there following drainage. By planting it was extended into the swamp scrub and even cleared forest areas. It therefore finally covered many areas sub-optimal to it, but remained in these only as long as management practice was intense enough to keep competing weeds in check.

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LIST OF SPECIES PRESENT ON THE MOUTOA AREA

This list is compiled of plants seen on the Moutoa area between the years 1940-1948. It is possible a number of rarely occurring species have been missed though all important plants have been noted. The main habitat of the species has been divided roughly into river bank and semi-swamp. This was a good natural classification in 1940. Since then, drainage and stopbanking operations essential for plantation development have made conditions much drier. Subsequent vegetation surveys show that this has altered the distribution of some plant communities, as a result of which the original classification into river bank and semi-swamp has been modified.

Families and Species.	Indigenous (I) or Naturalized (N)	Main Habitat.	
		River Bank.	Semi-Swamp.
Monimiaceae			
Hedycarya arborea Forst.	I	Forest	
Laurelia novae-zelandiae A. Cunn.	I	Forest	
Lauraceae			
Beilschmedia tawa Hook. f.	I	Forest	
Ranunculaceae			
Ranunculus repens L.	N		X
Ranunculus sceleratus L.	N		X
Piperaceae			
Macropiper excelsum (Forst. f.) Mig.	I	Forest	
Fumariaceae			
Fumaria muralis L.	N	X	
Cruciferae			
Barbarea verna (Mill.) Asch.	N		X
Barbarea stricta Fries	N		X
Brassica campestris L.	N	X	