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THE EFFECT OF SOIL TYPE ON PRODUCTIVITY IN WHANGAREI COUNTY

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Farmers recognise the importance of soil type in determining land use and productivity when they talk of "good dairying land", "second-class sheep country", etc. The essential purpose of a soil survey is to recognise and map areas of similar soils in sufficient detail to indicate those differences important in determining land use and methods of soil management. Soil survey, therefore, seeks to establish and map on a scientific basis the same class of differences which the farmer already appreciates, and to further define differences in soil characteristics which may be important in determining fertilizing, drainage or other soil management practices.

The present study of Whangarei County constitutes an attempt to assess, in farming terms, the effects of soil type on production and its relationship to the use being made of the land. The method adopted was to group all the farms, utilizing only one soil type, and from data collected from various sources determine the average carrying capacity per acre of grassland, average production of butterfat per cow and per acre of grassland, average area of farms, etc. These data for some of the main soil types are shown in Table 1.

TABLE I.

CHARACTERISTICS OF SINGLE SOIL TYPE FARMS

Soil Type and Topography	No. of farms	Butterfat Production per cow lb.	Butterfat Production per acre lb.	Average Carrying Capacity Sh.U.p.a.	Av. Area in Grass Acres	% of Cult. Area in Crops	Percentage of Grassland Cut for Hay	Percentage of Grassland Topdressed with Fertiliser
FLATS:								
Whakapara alluvial	11	235	140	3.0 ± 0.7	73	2.0	6.6	85
Mangakahia "	7	221	113	2.5 ± 0.6	145	2.4	8.9	51
Waipu Meadow clay	21	261	132	2.9 ± 0.8	83	0.0	8.0	73
One Tree Point	13	241	145	2.9 ± 1.1	55	0.1	6.4	87
UNDULATING:								
Waiotira sandstone	6	200	80	1.8 ± 1.0	175	-	13.8	42
Marua, greywacke	8	198	85	1.7 ± 0.9	127	0.5	1.8	47
Mata clay	14	218	74	1.6 ± 0.6	105	0.4	3.2	38
Wharekohe gumland	28	234	107	2.4 ± 0.7	63	1.1	7.9	78
Maunu basalt	10	258	144	3.4 ± 1.2	64	2.4	11.3	91
Kiripaka basalt	15	240	128	2.7 ± 0.7	103	2.0	10.9	72
Whatatiri basalt	20	256	146	3.0 ± 0.7	129	2.0	14.8	65
Okaihau old basalt	16	200	74	2.0 ± 0.8	173	0.6	4.6	48
HILLY:								
Waiotira sandstone	9	212	-	1.6 ± 0.6	293	-	0.8	15
Marua greywacke	21	185	49	1.4 ± 0.7	233	0.1	0.5	15
Pukekauri "	4	185	41	1.3 ± 0.3	185	-		20
Mangakahia hills	22	208	-	1.5 ± 0.4	1454	-	0.1	9
Av. All Flat Types	121	237	120	2.6 ± 0.8	114	0.6	7.8	69
Av. Undulating "	187	235	115	2.5 ± 0.8	99	1.0	8.0	63
Av. Hilly "	68	188	45	1.4 ± 0.5	616	-	0.8	14

The range in butterfat per cow "at the pail" is from 185.0 lbs. on the Marua hilly clay loam to 285.4 lbs. on the Tikipunga basalt; in butterfat per acre, from 34 lbs. on Te Ranga (steep greywacke) to 187 lbs. on Tikipunga, and in carrying capacity from 1.3 sheep units per acre on Pukekauri hilly clay loam to 3.5 sheep units per acre on Tikipunga.

There are approximately 70 soil types in Whangarei County, and this wide diversity made it impossible to obtain many farms wholly on one soil type. On the main soil types we were usually able to find 10 to 20 farms, but on many of the areally less important types numbers were insufficient to give reliable averages. In order to check such averages, farms containing two soil types were also analysed. Examples of the type of result obtained are shown in Table 2.

TABLE 2.

COMPARISON OF PRODUCTIVITY OF PURE AND MIXED SOIL TYPE FARMS.

Soil Types Utilized	No. of Farms	Butterfat Production Per Cow lb.	Butterfat Production Per Acre lb.	Carrying Capacity Sh.Units per acre
Marua hilly clay loam	20	185	49	1.4
Marua hills + Whakapara alluvial ..	16	230	70	1.8
Whakapara alluvial	11	235	140	3.0
Whakapara alluvial + Pukekauri ..	5	227	71	1.7
Pukekauri clay loam	4	181	57	1.4
Pukekauri + Marua hills	15	206	69	1.5
Waipu meadow clays	21	261	132	2.9
Waipu clay + Mata clay	10	249	100	2.2
Mata clay	14	218	74	1.6

Such results were usually consistent with the single soil type averages and served to increase confidence in them. In other cases it appeared that some adjustment was necessary.

Having thus determined the main characteristics of the soil types, it is possible to take a blank print of the soil map and colour the soil types according to the average butterfat per cow or per acre achieved on each type assuming that the whole area were used for dairying at the present average level of management of the farms already on that type. The same can be done with carrying capacity.

Now, these three maps are based on the average of all farms on a soil type, and most farmers would probably regard the averages obtained as rather low, due to the inclusion of "poor" farms. An attempt was, therefore, made to estimate carrying capacity on the upper 10 per cent of farms on a soil type by taking the average carrying capacity plus twice the standard deviation. This was considered a more accurate measure than taking the top farm, especially where the number of farms in a group was small. In this way we arrived at what we have termed the "potential carrying capacity" of a soil type under good management. The figures so obtained were reviewed critically in the light of soil data and local knowledge of the area, and some minor adjustments made, while soil types for which insufficient data were available were interpolated on the same basis. These data form the basis of the "Potential Carrying Capacity and Land Use" map which divides the soil types into seven groups numbered 1 to 7. These groupings were used as a soil rating in estimating the effect of soil type on production.

There are three major elements in soil type which have important effects on farming characteristics: (1) Topography or slope of the land, (2) Parent material from which the soil is derived, and, (3) The stage of maturity of the profile which is influenced by parent material, age, vegetation, slope and climate, all of which affect the rate of leaching or profile development.

The effect of topography on production is very marked. Hilly land has a butterfat production per acre of less than half that of plowable land, and a carrying capacity of 1.36 sheep units per acre as against 2.44 sheep units per acre on plowable land. Table 3 below shows why this depression in productivity occurs:-

TABLE 3.

EFFECT OF TOPOGRAPHY ON PRODUCTION ON 774 DAIRY FARMS, 1940-41.

Soil Rating	No. of Farms	Butterfat Production		Carrying Capacity.	Av. Area in Grass	% of Area in Crops	% of Grassland	
		Per Acre	Per Cow				Cut for Hay	Topdressed with Fertiliser
All Plowable ...	510	108	241	2.44	108	0.9	7.9	69.5
Mainly Plowable ..	175	86	227	2.04	166	0.5	5.9	55.9
Mainly Hilly ...	73	79	222	1.91	176	0.3	3.6	56.7
All Hilly ...	16	49	191	1.36	195	0.1	0.7	27.4
Average all groups		100	235	2.28	128	0.7	6.8	64.5

Hilly land, that is land with many slopes over 12 degrees, virtually precludes cropping or hay-making which, under New Zealand conditions, are essentially mechanized operations. Topdressing, which can be done by hand, even on hilly land, is less affected by topography than cropping or hay-making. The percentage of grassland topdressed with fertiliser falls from 69.5 per cent on the "all plowable" farms to 27.4 per cent on the "all hill" group. Due to the much lower carrying capacity and lower production per cow on the hilly farms, however, the hill farmer topdresses 6.1 acres per 1,000 lbs. of butterfat produced as compared with 7.4 acres in the plowable group.

Table 4 shows the results of an analysis of covariance on butterfat production per cow and carrying capacity on the four topographical groupings when area of farm, and percentage of the area cropped, cut for hay, and topdressed, are held constant:-

TABLE 4.

Topography	No. of Farms	Butterfat per cow lbs.	Carrying capacity: Sheep units per acre
All plowable	510	236.2	2.28
Mainly plowable	175	231.9	2.25
Mainly hill	73	236.5	2.36
All hill	16	219.2	2.18

It is obvious from this analysis that topography per se has a very limited effect on productivity. In economic circumstances other than those pertaining in New Zealand today, hilly land might be farmed at something approaching the same level of intensity as plowable types derived from the same parent material and of similar maturity.

Since parent material and stage of maturity of the profile largely determine natural fertility and hence productivity of a soil type, their effect was much more apparent prior to the advent of topdressing. With topdressing and its induced fertility the story has become more complex. In a very broad grouping the effect of parent material is well illustrated by a comparison of plowable soil types derived from sedimentary rocks as compared with those derived from basalt.

TABLE 5.

SHOWING THE EFFECT OF PARENT MATERIAL ON AVERAGE PRODUCTIVITIES OF TWO GROUPS OF FARMS.

Parent Material	No. of Farms	Butterfat Production Per Cow	Butterfat Production Per Acre	Carrying Capacity	% of Area Cropped	% of Area Cut for Hay or Silage.
Sedimentary Rocks	84	225	100	2.1	0.6	6.0
Basalt	90	243	131	2.8	1.6	10.4

The average area of the farms in the two groups is similar and so is the amount of topdressing done, so that the differences shown are mainly due to parent material. The soils derived from basalt are of higher natural fertility, give a greater flush of feed in the spring, but suffer more severely from summer drought - hence the extra cropping and the larger amount of hay and silage conserved.

The effect of stage of development of the profile cannot be so simply stated and two examples will have to suffice.

TABLE 6.

THE EFFECT OF STAGE OF MATURITY OF THE SOIL PROFILE ON PRODUCTIVITY.

Soil Type	Stage of Maturity	Parent Material	Butterfat Per Cow	Butterfat Per Acre	Carrying Capacity
Whatitiri clay loam	Immature)	Basalt	256	146	3.0
Matarau and Ruatangata	Semi-mature)		257	117	2.5
Okaihau clay loam	Sub-mature)		200	74	2.0
Marua clay loam	Immature)	Greywacke	198	85	1.7
Pukekauri clay loam	Semi-mature)		181	57	1.4

It is dangerous, however, to generalise, since some mature soils, such as the gum-lands, while of exceedingly low natural fertility, can readily be modified by topdressing and liming, and attain a relatively high level of productivity.

In addition to tabulations of the type already presented, the total and partial multiple correlations for 12 factors affecting a group of 774 dairy-farms have been computed by the Biometrics Section under Mr. Dick, and are shown in diagrammatic form in Figs. 1 and 2. These diagrams illustrate more clearly than tabulations the inter-relationships between soil type and topography and the other factors of production.

The final point to which I want to make brief reference is the effect of soil type on the unit production curve of lactation. These curves represent butterfat supplied to the factory in a given month, divided by the number of cows in milk in January and corrected to a standard 30-day month. For ease of explanation I have chosen only four sharply contrasting soil types, and lactation curves for these are shown for four seasons - two good years and two years of autumn drought.

The main generalisations which emerge are two:-

(1) Differences between soil types are most marked in the spring and early summer months. Except with strongly contrasting types differences are much less marked in the autumn.

(2) Differences between <u>seasons</u> are most apparent in the autumn months.

<u>Fig. 1</u>: The average <u>total</u> correlations derived from an analysis of 774 dairy farms in Whangarei County (1940-41 data). The farms were divided into four groups according to topography and analysed separately, the arithmetical averages of the correlations being shown. The arrows indicate probable casual relationships. The double lines indicate relationships sustained by partial correlation.

<u>Fig. 2</u>: The average multiple <u>partial</u> correlations for the same group of 774 dairy farms. Partial correlations show the degree of association between any two factors when all other factors under consideration are held constant. This device eliminates many of the correlations shown in Fig. 1, and gives a clearer picture of cause and effect among the factors studied.

<u>Fig. 3</u>: Unit production curves for four sharply contrasting soil types. These curves represent butterfat supplied to the factory, month by month, divided by the number of cows in milk in January, corrected to a standard 30 day month. The same herds are included in both seasons shown. 1944-45 was a season of high production, 1945-46 a season of autumn drought. Differences between soil types are most marked in the spring and early summer months.

<u>Fig. 4</u>: Unit production curves for four soil types each shown for four seasons. Differences between seasons are most apparent in the autumn months.

<u>FIG. 1</u>:

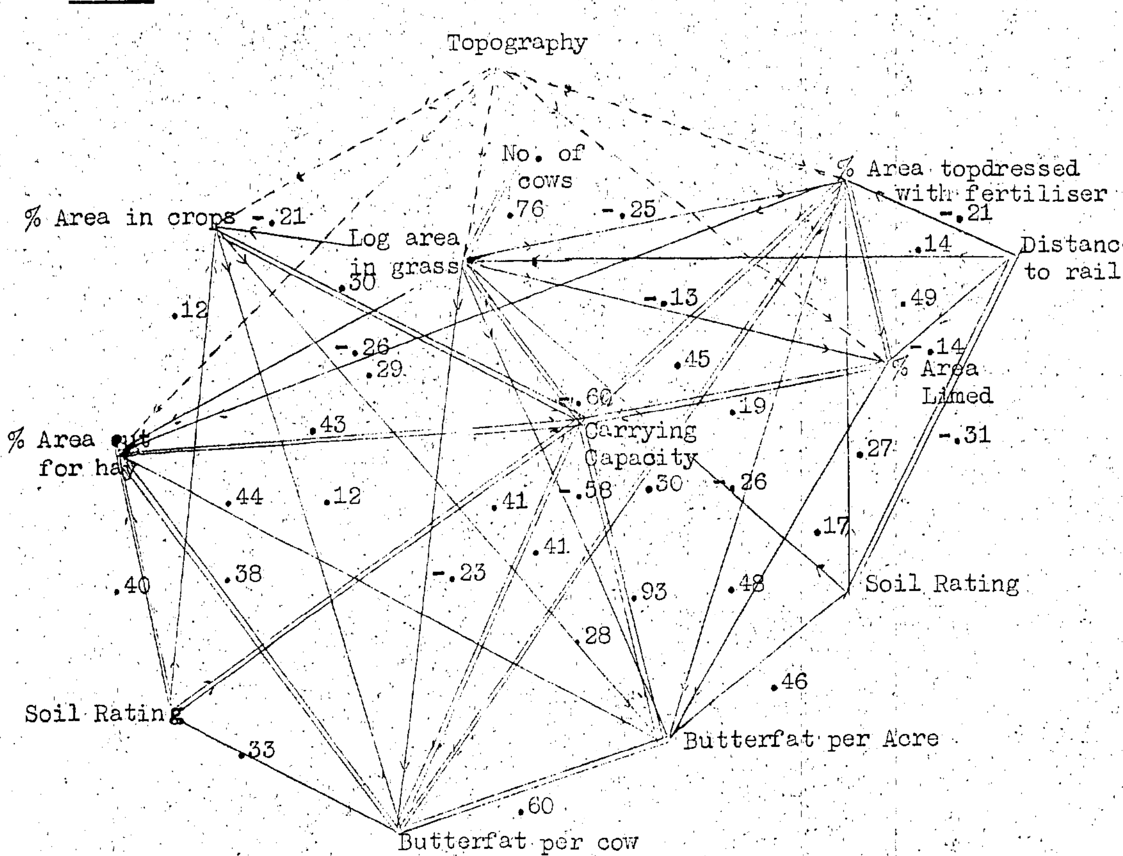


FIG. 2:

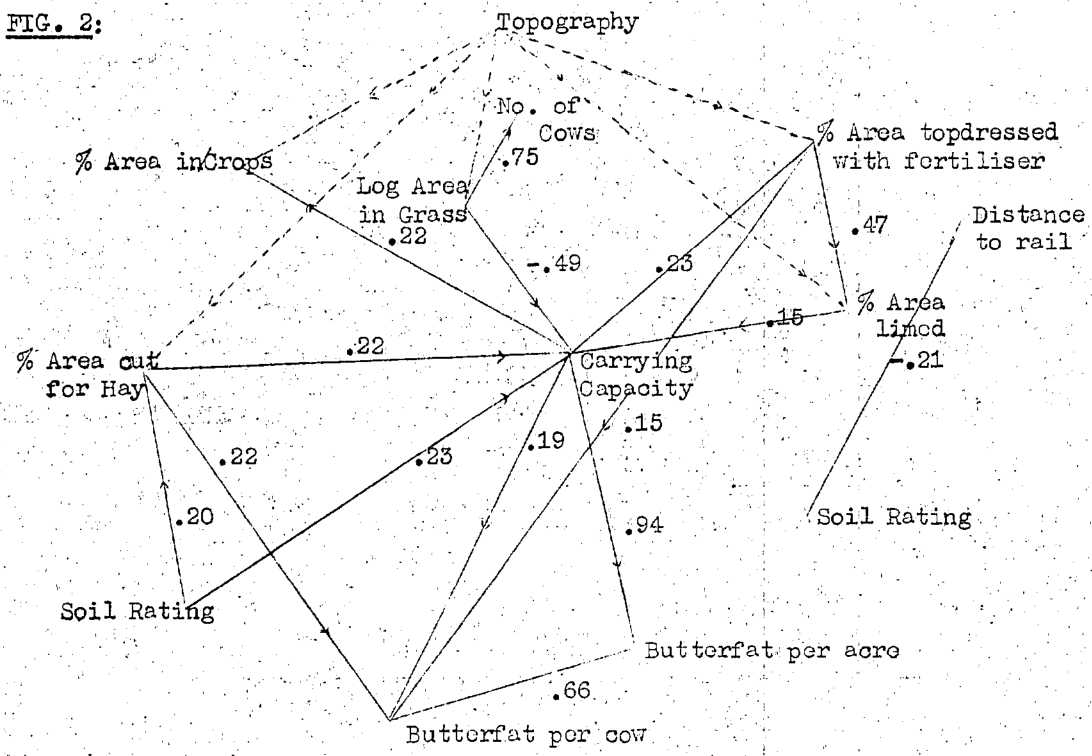

Topography
No. of Cows
.75
% Area in Crops
Log Area in Grass
.22
-.49
.23
% Area topdressed with fertiliser
.47
Distance to rail
% Area limed
.15
-.21
% Area cut for Hay
.22
Carrying Capacity
.15
.22
.23
.19
.20
.94
Soil Rating
Soil Rating
Butterfat per acre
.66
Butterfat per cow

FIG. 3:

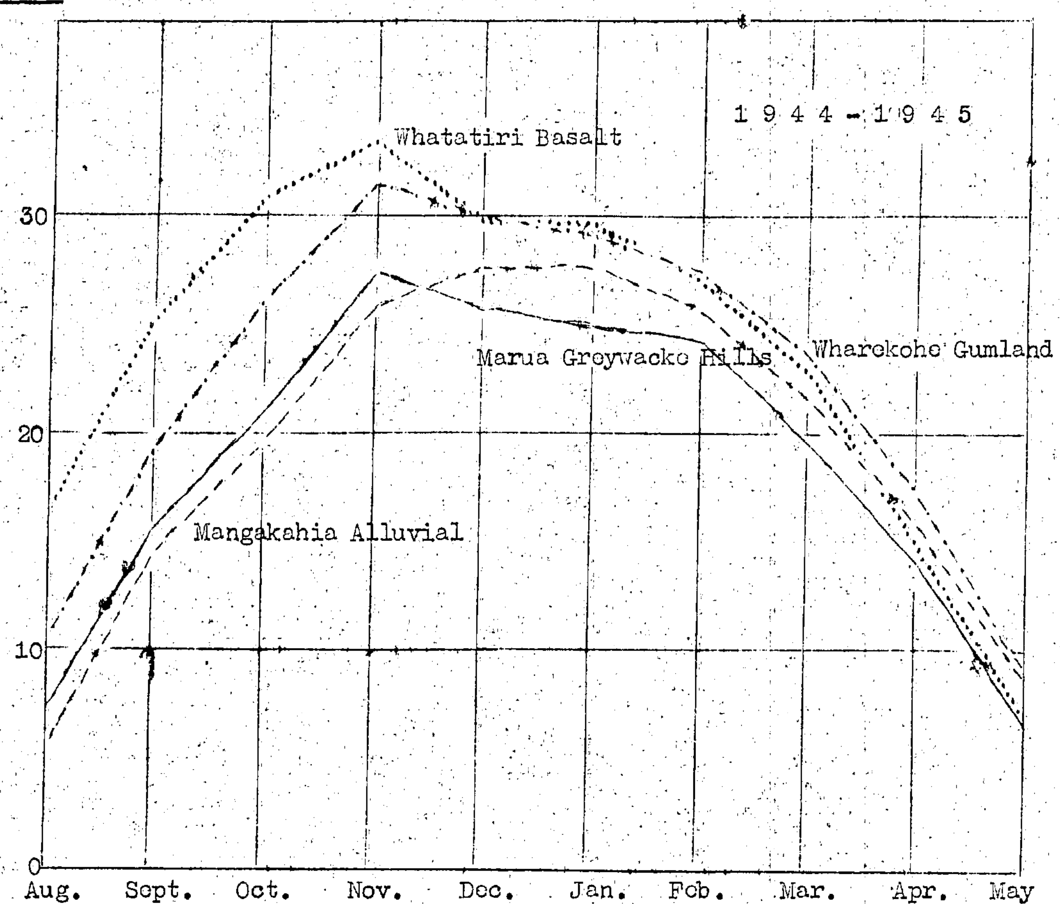

1 9 4 4 - 1 9 4 5
Whatatiri Basalt
Marua Greywacke Hills
Wharekohe Gumland
Mangakahia Alluvial
30
20
10
0
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May

FIG. 3. (cont'd.):

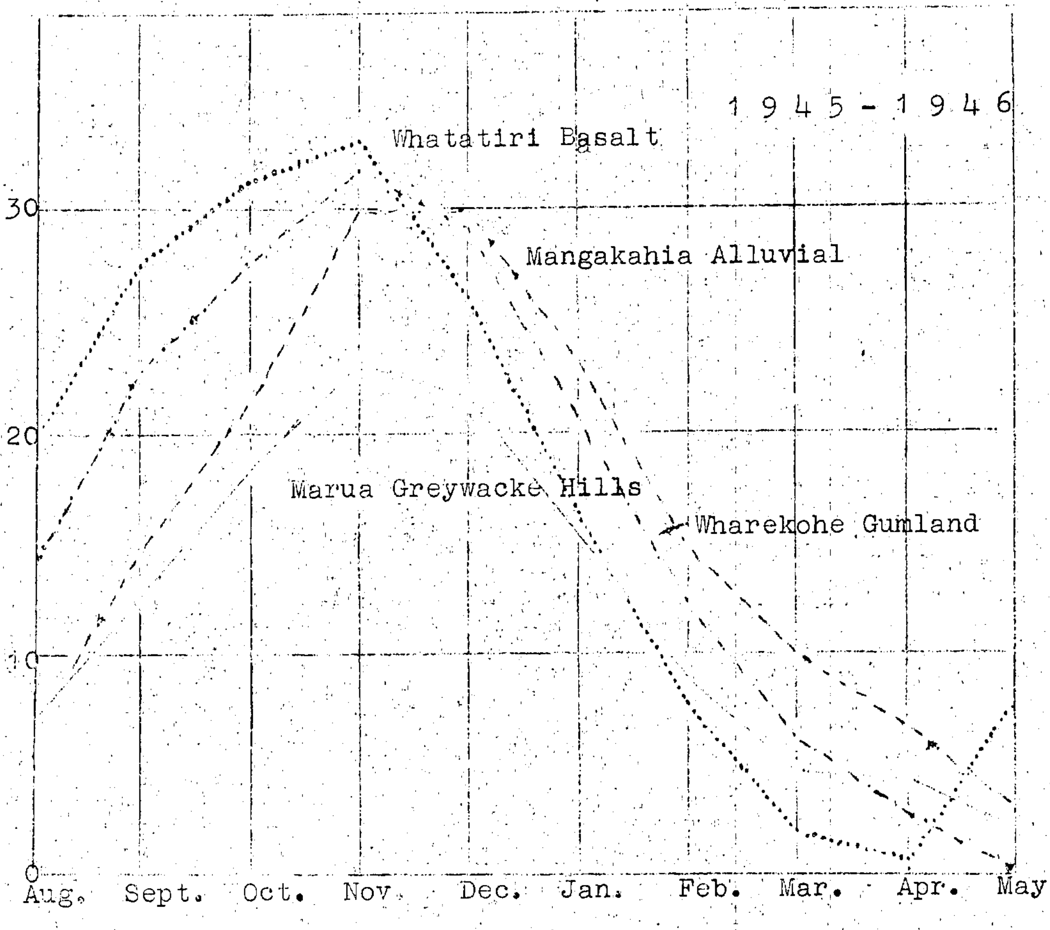
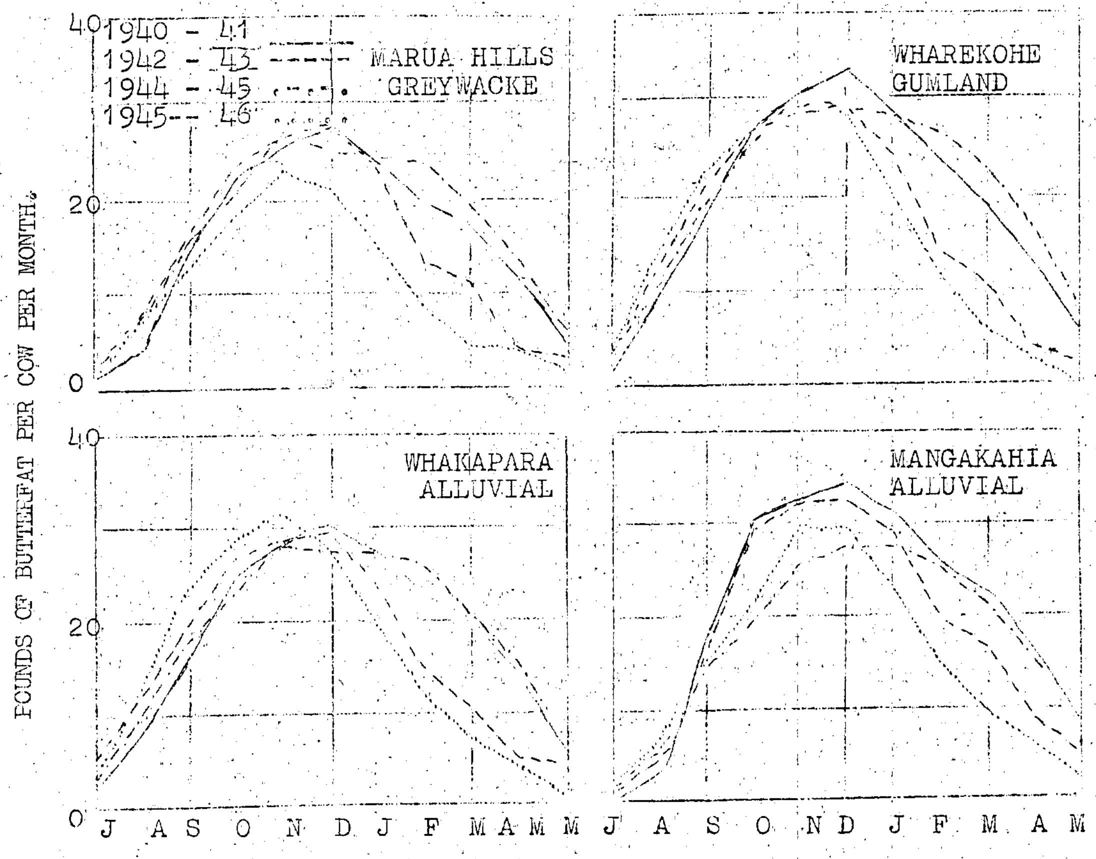


Fig. 4:



DISCUSSION ON DR. HAMILTON'S PAPER:

MR. HANCOCK: I would like to ask Dr. Hamilton whether he has taken into consideration in those calculations for the production capacity of hill country compared with other lands the fact that the effective grazing area on hill country is greater than that on flat land of the same area? If he has taken it into account, then, provided other factors are equal, there is a greater amount of energy wasted by the animal grazing on hill country.

DR. HAMILTON: Actually the increase in area is surprisingly small. On a slope of 15 per cent. the increase in area is about 3 per cent. and no allowance has been made.

MR. LYNCH: Would Dr. Hamilton give some indication of the relation of soil type to pasture types?

DR. HAMILTON: We have not actually any detailed information on that point. But from general observation one would say that there would be a very strong correlation between the pasture type and soil type. In fact I feel that the relationship would be so good that I doubt whether it would be worth while making a detailed pasture survey which would have to be on a paddock basis and would be difficult to assess.

MR. SMALLFIELD: Has Dr. Hamilton been able to get any information on the water supply position as far as dairying is concerned on the different soil types?

DR. HAMILTON: Mr. N.H. Taylor has a considerable amount of data on water supplies but that has not been taken into account in assessing soil type. There is no doubt, however, that there are farms where inadequate water-supply limits production. We have assessed the soil type on the basis of the average farm on that soil type with whatever shortcomings it may have.

MR. LONGWILL: Dr. Hamilton mentioned that within each soil type the best farms were producing practically twice the average for that soil type. There are two questions that I would like to raise from that. Has any historical survey been made which would interpret the increased production from those best farms? By that I mean is it a case of good management over a series of years, and also would not the more able managers tend to gravitate towards the better soil types? Did Dr. Hamilton think those factors worth while taking into consideration in the comparisons?

DR. HAMILTON: One factor which has a very big influence on production is size of farm because it has so much influence on the intensity of farming. In fact, about 25% of the variance in carrying capacity is associated with size of the farm. I have very carefully considered whether we should make some allowance for that in assessing soil type. For instance, take a highly fertile basalt soil such as Tikipunga in close proximity to Whangarei. It is densely settled in small fully improved farms, on a high level of intensity. The same soil type is found in a hilly inaccessible area where nothing is being done with it and production is virtually nil. It is hard to know whether one is giving the right picture by assessing production on the farms which are fully improved and intensely farmed and applying the same rating to the soil type in an inaccessible position where it is not productive. You could make the assessment of soil type so complicated that no one would follow all the adjustments. It would be difficult to do and so difficult to interpret that it would be almost valueless. Therefore I have preferred to analyse the factors which affect productivity, to give that information, and let each person make his own assessment of what allowances should be made for the factors which affect productivity.