Survey of Soils and Land Utilisation in the Parishes of Koo-wee-rup and Koo-wee-rup East.

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Introduction

The parishes of Koo-wee-rup and Koo-wee-rup East cover an area of 81 square miles, and contain the largest extent of reclaimed peat in the State. The district, still commonly known as the Koo-wee-rup Swamp, is densely settled, and has for many years had a reputation for high productivity. The swamp area, which occupies almost 95 per cent of the district, was drained towards the end of last century. The remaining area consists of low foothills along the northern boundary of Koo-wee-rup East.

This survey falls into two main sections, namely, the mapping and study of soil types, and the collection of information concerning the farmers' activities. The latter section was greatly facilitated by the willing co-operation of the Government Statist and his officers, whose help is greatly appreciated. Many figures have been taken from the Statist's records, which are collected annually from all farmers in the State and are grouped with the parish as the unit; they are referred to as "parish statistics." The instantaneous cross-section of the activities of some 500 farmers provides an accurate picture of the relative importance of the different types of farming. All information has been so tabulated that no details of individual farmers have been disclosed. The interpretation of these records was helped by interviews with 61 selected farmers. The soils were surveyed thoroughly on these selected properties and the soil map of the district completed with the aid of numerous observations of profiles at roadsides and drains.

Description of the Surveyed Area

Location
The location of the area is shown in fig. 1, together with the railways and chief towns in the neighbourhood. The district is excellently served by roads, which make the two main Gippsland highways and railways readily accessible. The most outlying parts are little more than 50 miles away from Melbourne and 20 miles away from either one of the market towns, Dandenong or Warragul. Dandenong is also the terminus of a suburban electric train service from Melbourne.

Population.
The total population of the area is about 3,500 of whom about 500 to 600 live in the principal township, Koo-wee-rup. There is a butter and cheese factory at Cora Lynn, a butter factory and milk depot at Bayles, and a flax mill at Koo-wee-rup. The flax mill is expected to employ 50 to 60 men during the peak periods, but the other two factories employ comparatively few.

Topography.
The country slopes gently from the 100-ft, contour in the north and north-east to Western Port Bay in the south-west. The district is flat, except for the small hills along the northern boundary of Koo-wee-rup East. The grade of the main drain varies from 3 feet per mile in the lower reaches to as much as 10 feet per mile near Bunyip. The grades are so slight in the Dalmore area the Cardinia drainage system is tidal for about 5 miles of its course. The flatness is sometimes broken by sandy areas, which usually take the form of meandering ridges from 1 to 5 feet high, and from a few yards to 1 or 2 chains wide.

The main eastern highlands of Victoria begin just to the north of the district.

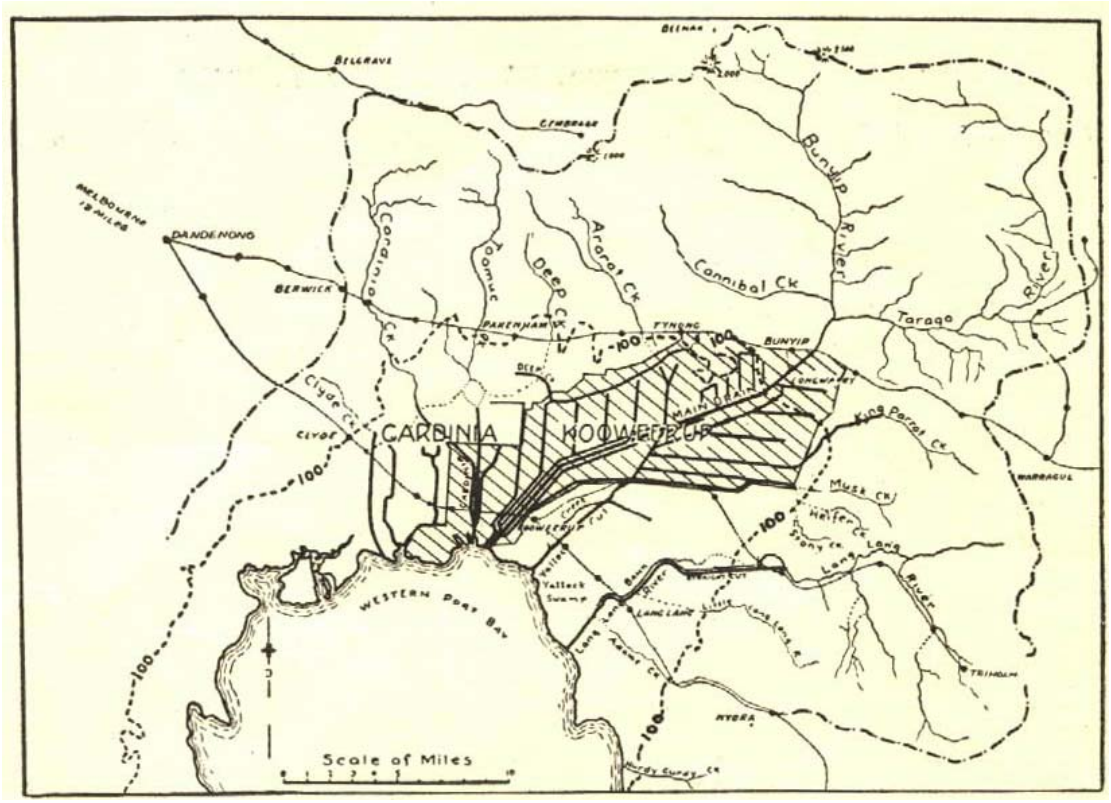

FIG. 1 – Map of the Koo-wee-rup Basin and surrounding land, showing major drains. The area of this survey is shaded. The watershed (alternate dash and dot) and the 100-foot contour are also shown. Based on Map in (3).

Geology.
The soil boundaries (fig. 3) indicate the main geological boundaries. The district consists predominantly of recent alluvial sand and clay together with large areas of peat, but the foothills of Tynong (in the north of Koo-wee-rup East) are of decomposed granite; also a narrow strip in the east of the district marked as podzol on the soil map consists of Pleistocene deposits.

Peat occurs in the central part of the district over an area of several thousand acres broken by only an occasional ridge of sand. Alluvial sand occurs in two main regions, both of which begin in the north-east as well-defined narrow ridges (too narrow to be marked on the map), and spread out as ridges and badly-defined sandy areas as they reach the flatter land in the centre of the district. Clay alluvium underlies both peat and alluvial sand, and also occurs as a fringe around the peat. The surface 3 to 6 feet of this alluvium in the Dalmore district contains more organic matter than elsewhere in the district.

The clay alluvium from the head of the Main Drain down to Iona has a comparatively steep fall towards the south and south-west. This represents the fan delta region of the Bunyip River.

Physiographic History.
The sandy regions probably represent old river beds in which sand collected as it now collects in the Main Drain.

Peat was formed and accumulated together with alluvium in the marshy areas beside the river courses. Peat was so widespread and so deep between Cora Lynn and Catani that it seems likely that this area was, before reclamation, a sheet of water that was nearly filled in by the accumulation of peat and alluvium. This seems curious in view of the fact that there was a slope of as much as 3 feet per mile in this area. Evidently the reeds and rushes and in places the tea-tree (*Melaleuca ericifolia*) grew thickly enough to make the flow of water extremely slow. Peat seems to have accumulated mainly from the remains of reeds and rushes. It is doubtful whether tea-tree has made any important contribution to the peat, though it grew densely on the heavy soils of the district. Two transects of the swamp made in 1868 show mainly reeds, rushes and water where peat has now been mapped, with a small area of stunted tea-tree noted on the eastern edge of the present peat.

After the district was reclaimed the marshy land shrank and consolidated, whereas the sandy ridges did not. Even before drainage many sand-ridges were exposed because the streams changed their courses, and thus reduced the waterlogging along their original beds. However, the old river beds often became reclamation emerged as peat-covered sand ridges.

Inorganic alluvial clay (marked as “swamp fringe” on the soil map) occurs where the natural drainage is good enough to have allowed sufficiently long periods of aeration to prevent the accumulation of peat. The organic alluvial clay in the Dalmore district is an intermediate stage where much organic matter accumulated, although more slowly than the clay, giving a highly organic black clay.

Climate

Average Annual Rainfall.
There is a remarkable lack of exact information in the closely settled country to the east and south-east of Melbourne. No stations in the surveyed area keep records of temperature, humidity, or evaporation; however, Koo-wee-rup and Tynong send monthly rainfall reports to the Weather Bureau at Melbourne. Koo-wee-rup has kept records regularly since 1902; the mean annual rainfall until the end of 1939 is 30.8 inches, and has ranged from 20.4 inches in 1938 to 41.8 inches in 1924. The rainfall rises sharply in the foothills to the north, where Tynong, Garfield, and Longwarry (the last two stations being just outside the north boundary of the district) have an average of 34.6, 34.9 and 35.3 inches respectively; but probably all except the extreme northern fringe of the true swamp has an average close to that of Koo-wee-rup. Personal records kindly supplied by local residents indicate that the central parts of the district may receive slightly less rain than the township of Koo-wee-rup.

Table I. – Mean monthly rainfall and number of dry months at Koo-wee-rup from 1902-1939; and mean temperature and evaporation at Melbourne.

–	January	February	March	April	May	June	July	August	September	October	November	December	Year.
Rain (Koo-wee-rup)	177	182	248	250	274	276	261	281	204	320	256	259	3,078
Evaporation (Melbourne)	643	504	401	241	149	113	109	150	232	336	454	574	3,906
Temperature (Melbourne)	67.4	67.6	64.6	59.4	54.1	50.4	48.8	51.0	54.1	57.7	61.3	64.9	58.4
Number of times in 38 years rain below 1 inch (Koo-wee-rup)	12	15	8	6	2	3	0	0	1	2	5	6	…

(Rainfall is in "points" of one hundredth of an Inch)

Distribution and effectiveness of rainfall.

The climate is essentially similar to that described in more detail for the neighbouring district of Berwick (4), being cool and wet in winter and early spring, and warm and dry in summer and early autumn. The monthly rainfall averages for Koo-wee-rup and mean figures for temperature and evaporation at Melbourne (as an approximation to local figures) are given in Table I. While minimum temperatures are often lower than in Melbourne, daytime conditions are probably similar.

At first sight, monthly rainfall appears to be evenly distributed throughout the year; however, during the warmer months it is usually inadequate owing to high evaporation. Moreover, it is unreliable, as may be seen from the last line in Table I, which shows the number of times in 38 years that the rainfall for any one month has been less than 1 inch. Dry spells of more than one month are frequent. Thus, in 20 seasons out of 37, at least two successive months were too dry for growth (using Trumble's principle (9) that soil moisture falls below the permanent wilting point for plants when the ratio of rainfall to evaporation is less than one-third); ten seasons had at least three successive dry months (fig. 2).

Perennial pasture species, maize, and summer forage crops are normally able to make some growth at such times because there are supplies of available moisture conserved in the subsoil. However, maize yields are consistently lower than those obtained further east, probably because of both lower rainfall and higher evaporation. Orbost, which is famous for its maize yields, receives during January and February an average of 1½ inches more rain than Koo-wee-rup, but there are no data concerning evaporation.

Pasture production normally shows a well-marked peak in spring, when temperatures are suitable for growth, and the rainfall reaches a maximum and is reliable. On the other hand, rainfall is unreliable in early autumn. If early falls in March are followed by sufficient rain to keep the soil moist throughout the autumn, then both annual and perennial pasture plants have time to develop a deep root system while the soil is still warm. Such well-established plants make some little growth during the cold wet months. If the autumn "break in the weather" is late, pastures make little growth until September.

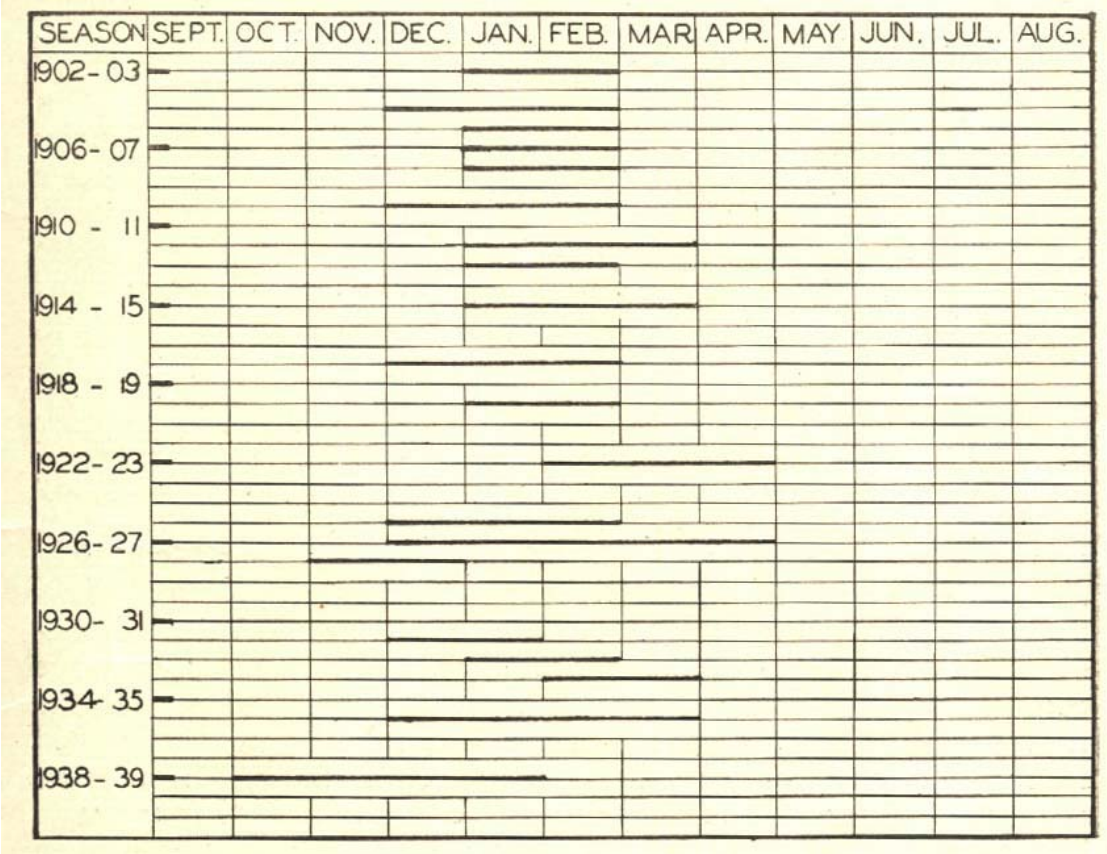

FIG. 2 – Occurrence of spells of two or more dry months in succession at Koo-wee-rup. Each month that is marked with a heavy line had rainfall less than one-third evaporation.

Frost.

Most reclaimed swamps suffer acutely from frost (1, 2). The Koo-wee-rup swamp is no exception, and receives more severe and frequent frosts than surrounding districts or Melbourne. This may be connected with the drift of air from the high land on the north and east. Frosts damage potatoes and maize even during the summer; ground frosts were reported in the district on 13th January and 13th February, 1940, when the respective ground minima at Melbourne were 42.9 degrees and 41.4 degrees. Though local conditions are thus peculiar, there are no precise records of minimum temperatures anywhere near Koo-wee-rup; in view of their great importance to potato and maize growing, this is surprising.

Frost damage is by no means uniform over the whole district. Crops grown on heavy "Swamp Fringe" soils (see p. 103) suffer less frequently than those grown on the peaty and burnt peaty soils. Certain Koo-wee-rup farmers say that frost damage is more severe on unburnt peaty soil than on adjacent burnt soil, and more severe on tilled soil than on adjacent untilled soil. This coincides with American observations, e.g., Always (1) in Minnesota. These differences can be predicted on account of relative conductivity – that is, the looser the surface soil, the slower the transfer of heat from the warmer lower layers to the chilled surface. Bouyoucos and McCool (2) have measured a great number of minimum soil temperatures over a period of four years. The following collection of minimum ground temperatures taken from adjacent plots on the same night is typical of their observations.

Clay loam (compact), 36.2°F.
Peaty soil (compact), 31.0°F.
Peaty soil (cultivated), 28.0°F.

Valuable frost-liable crops such as sweet corn would probably repay the expense required for the operation of heating equipment during frosty nights. The dew point on the previous evening (calculated from dry-bulb and wet-bulb thermometers) has been used for predicting the likelihood of frosts in orchards; its use could probably be extended to cover these Koo-wee-rup crops.

Soil Map and Description of Soil Types

Seven soil symbols are shown on the soil map of the parishes of Koo-wee-rup and Koo-wee-rup East. Six of these represent soils in the swamp group. The other represents a collection of miscellaneous podzols occurring on higher ground; these are of small extent, and are not representative of the district. The soil map is essentially a sketch map – the product of a reconnaissance survey – and is deliberately produced on a small scale. In general the uncertainty of any boundary does not exceed 400 yards. In the north-west of the district, the various transition phases between Dalmore clay, Koo-wee-rup peaty clay, and Swamp fringe are in places three-quarters of a mile wide. The doubtful areas have been divided between the major soil types concerned. Also, in the same area there was some difficulty in deciding the boundary between Koo-wee-rup peaty clay and the sandy complex, because the sandy typed are scattered and poorly defined. Any more detailed mapping in the sandier parts would call for an immense amount of work, since the pattern of the sandy strips is so intricate.

Swamp types.
The various streams, coming from areas derived largely from granite, have deposited sediments which vary in texture from coarse sand or gravel in the bed of the stream to clay, where water has spread out and remained stagnant.

Because of the frequency and duration of swampy conditions, waterlogging is the main pedogenic factor influencing the nature of these soil types. Peat accumulated where waterlogging was continuous or nearly so. Peat deposits were largely modified by inorganic sediments which settled during periods of flooding.

(1) ***Koo-wee-rup Peaty Clay (normal phase):*** This is the most widespread type, and it covers a large area on both sides of the middle reaches of the Main Drain. The characteristic profile is:-

Horizon 1 (0-9 inches) – brownish grey peaty clay.
Horizon 2 (9-17 inches) – dark-grey gritty clay.
Horizon 3 (17-33 inches) – grey gritty clay with some yellow and red mottling
Horizon 4 (below 33 inches) –light-grey gritty clay, yellow and red mottling.

The gritty character is caused by the presence of angular fragments of coarse sand and gravel, both quartz and felspar.

Horizon 1 normally contains from 15 to 30 percent, organic matter which modifies the clay as to give it a light loamy texture. However, some area of peaty clay, which usually only had a thin layer of peat to begin with, are now somewhat cloddy because the organic matter has been depleted by oxidation, to about 10 percent. Horizon 2 has an open, freely draining structure despite its high clay content. This is partly explained by the high content of organic matter, and partly by the presence of root tracks, yabby holes, and numerous persistent cracks. Lower horizons are impervious to water.

SOIL MAP OF THE PARISHES OF KOO-WEE-RUP AND KOO-WEE-RUP EAST.

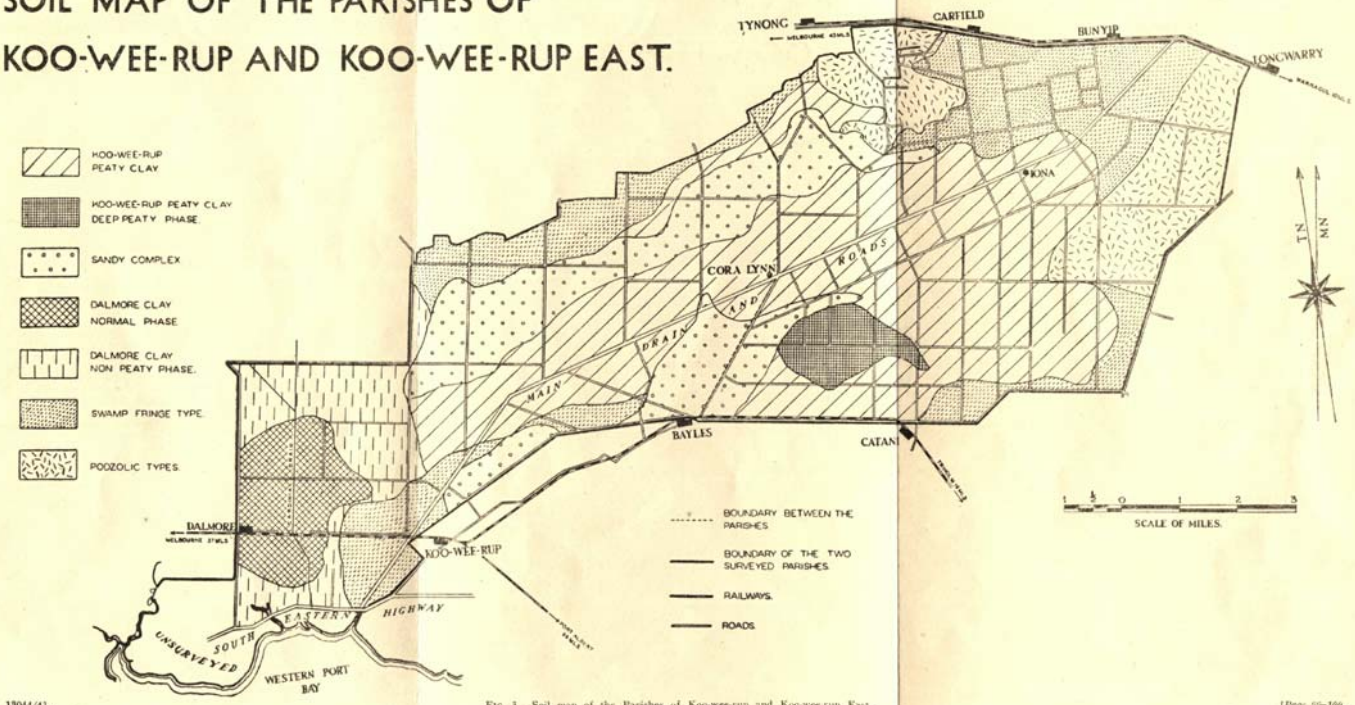

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FIG. 3.—Soil map of the Parishes of Koo-wee-rup and Koo-wee-rup East.

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(1b) ***Koo-wee-rup Peaty Clay (burnt peat phase):*** This phase cannot be mapped in detail because of the intricate way in which it is associated with the normal phase, and also because of the great variation in the effects of burning. All burned patches have therefore been included in the normal phase on the soil map. The deep burn, which usually occurred on relatively high ground, destroyed the organic matter right down to the dark-grey clay, although a thin surface crust commonly remained unburnt and subsequently enriched the ash with organic matter. Deep burning has occurred in several patches, some of which cover a square mile in area. Shallow fires have been widespread and occurred when the water table was high enough to protect some of the peat from burning. The ashes from these burns soon mixed with unburnt peat, and the mixture worked down to give a soil of a similar nature to the normal unburnt type.

(1c) ***Koo-wee-rup Peaty Clay (deep peat phase):*** This phase contains a layer of true peat up to a foot in thickness between horizons 1 and 2 of the normal profile. Remains of *Phragmites,* the bulrush *Typha,* and tea-tree were identified in this peat, and numerous unidentified plant remains were observed penetrating the underlying dark-grey clay. This peat consists approximately of 45 per cent organic matter, 45 per cent clay and 10 per cent of coarser mineral fractions.

(2) ***Sandy Complex****:* Sandy types are intricately associated with both Koo-wee-rup peaty clay and the swamp fringe type. "Sandy Complex" is mapped wherever a sandy type constitutes more than 20 per cent of the area. Nearly all the land so mapped is a complex of sandy types with Koo-wee-rup peaty clay; the main exception is a complex of sandy types and the swamp fringe type near Bayles. Isolated ridges run through all the other soil types except the podzols, but they are insignificant and have been ignored.

The complex occurs mainly in the north of the district as a thin strip running in a south-westerly direction. It also occurs to the south of the Main Drain as the north-eastern end of another parallel strip which crosses the parish boundary at Bayles.

The typical sandy profile is:-

Horizon 1 (0-4 inches) – grey loamy sand.
Horizon 2 (4-45 inches) – light-grey loamy sand.
Horizon 3 (45-50 inches) – light-grey clayey sand with some yellow mottling.
Horizon 4 (below 50 inches) – light-grey gritty clay, with yellow and red mottling.

The type varies in many respects. The second horizon may be from 2 to 5 feet deep or even more. The texture of the first two horizons may vary from sandy loam or peaty loam, to almost pure sand. The sand fraction may contain almost any proportions of fine sand, coarse sand or gravel. In general, coarse sand and gravel predominate in the north-east and fine sand in the south-west.

The sandy areas are quite commonly in the form of well-defined ridges (see p.95). This is especially true in the north-east of the main strip and throughout the southerly strip. Much of the main strip consists of ill-defined sandy areas in which horizon 1 is peaty loam, underlain by sandy loam. These areas are usually slightly elevated, but bores must be dug to make certain that the subsoil really is sandy.

Compared with other swamp types, these soils have a low water-holding capacity. Pastures and crops grown on this type therefore dry off much earlier in the summer. On the other hand, sandy areas are normally more productive than other swamp types during really wet winters. Ground water stands remarkably high here; a permanent water supply is commonly obtained by scooping shallow dams out of suitable ridges. The water level of some dams was within 8 feet of the surface throughout the 1938-39 drought.

(3) ***Swamp Fringe Type***: This surrounds the Koo-wee-rup peaty clay and probably represents the edge of the old swamp basin which was not waterlogged intensely enough to permit the accumulation of more than a few inches of peat.

The following profile is typical:-
Horizon 1 (0-10 inches) – grey clay loam.
Horizon 2 (10-16 inches) – light-grey clay loam.
Horizon 3 (below 16 inches) – light-grey clay, with yellow and red mottling.

The translation from this to peaty clay is very gradual, and every immediate type exists. The intermediate types are distinguished from Koo-wee-rup peaty clay by their greater cloddiness. The subsoil in certain areas becomes "spewy" when conditions are wet enough. Fine brownish-red mottling due to waterlogging often occurs in the upper horizons, giving the ploughed soil a brownish-grey appearance. The large area of soils developed on flat land to the east of the surveyed district (Yannathan and Yallock) are, judging by the few explanatory samples which were examined, very similar to the brownish-grey swamp fringe type.

(4a) ***Dalmore Clay (normal phase)*:** This type occurs in a continuous patch in the region of the Cardinia drainage system (fig. 1). The following profile is typical:-

Horizon 1 (0-7 inches) – black friable clay.
Horizon 2 (7-30 inches) – black plastic clay becoming somewhat lighter in colour with depth.
Horizon 3 (30-34 inches) – dark-brown decomposing peat.
Horizon 4 (below 35 inches) – grey gritty impervious clay with yellow mottling.

The first horizon is of a very workable nature, despite the high figure for clay (Table VII). This is explained by its 15 per cent of organic matter. Small amounts of red ash commonly seen in the surface horizon are relics of fires used by settlers during the clearing operations. Horizon 2 contains the same mineral fractions as Horizon 1, but the clayey texture is not greatly modified by organic matter. Below this horizon is a peculiar deposit of decomposed peat which, in the central regions of this phase, reaches a thickness of 2 feet. Seeds of the sedges *Scirpus and Lepidosperma* were identified in this peat.

(4b) ***Dalmore Clay (non-peaty phase):*** This phase is almost identical with that of the normal phase, except for the absence of Horizon 3. It occurs as a narrow fringe around the eastern and southern boundary of normal Dalmore clay, but extends to the north and north-west for a considerable distance beyond the boundary of the district. This phase appears to have an inferior surface texture which corresponds to its smaller reserve of organic matter than normal Dalmore clay (Table XI). This is to be expected because, being on higher ground, the soil would be formed under conditions less favourable to the accumulation of organic matter. Some of the outlying representatives of this type in the neighbouring parish of Sherwood are intractable in the surface and have an impermeable subsoil, which cannot be improved by under-drainage. These soils are very similar to Eumemmering clay (4); the non-peaty phase of Dalmore clay within the surveyed area is transitional to this type.

(4c) ***Dalmore Clay (salty phase)*:** This is represented by a very small unmapped patch of land near the sea which is periodically flooded with salt water. The clay has been solonised and supports salt marsh plants and, in the less affected areas, salt-tolerant plants.

Miscellaneous podzols.

The intensely podzolised type developed on decomposing granite in the north of the parish of Koo-wee-rup East has a profile very similar to that of Harkaway sand, which occurs to the north of Berwick. The following profile is typical:-

Horizon 1 (0-4 inches) – grey loamy sand.
Horizon 2 (4-13 inches) – light-grey clayey sand.
Horizon 3 (13-30 inches) – grey heavy clay, with yellow and red mottling.
Horizon 4 (below 30 inches) – decomposing granite.

Another group of podzols and deep sandy types occur along the eastern boundary of Koo-wee-rup East. They are derived mainly from unconsolidated tertiary deposits.

Land Utilisation

General considerations

Historical introduction.
The settlement of the surrounding country had begun by the middle of last century, and by 1880 a cheese factory was established at Caldermeade, supplied by one herd of over 200 cows. Materials and provisions were brought up the Yallock Creek by boat from Tooradin because the tea-tree in the Dalmore district was almost impassable. The Koo-wee-rup Swamp during this period was overgrown with tea-tree, reeds and rushes, with many lagoons. The land was occasionally leased for grazing. During the summer, animals were driven along the relatively dry sand-ridges and obtained some low-grade feed around the marshy reed beds and among the tea-tree on higher ground.

In 1882, Parliament considered draining the swamp and selling the reclaimed land to pay for the projected South-Eastern railway line. The proposal was rejected, but served to draw attention to the possibility of opening up a valuable new agricultural area. Such a scheme appeared very desirable because the fertility of reclaimed land and the cost of drainage were usually estimated optimistically. In 1888 specifications were drawn up for the drainage of the swamp and operations started under the direction of a Swamp Board. The Public Works Department soon assumed control and the operations continued as a scheme to relieve some of the unemployment caused by the bursting of the land boom in the early nineties.

The early reclamation works consisted of the Main Drain, which takes the Bunyip River across the Swamp to Western Port Bay, and a series of tributary drains which collect minor streams entering the Swamp. Much of the excavation was carried out with shovels and barrows; the labourers endured very bad conditions owing to the marshy nature of the land. The embankments of excavated mud were often the driest land available and had to be used both as roads and as the men's camping grounds.

The scheme of employment was than the men were allotted 20-acre blocks on the edge of the swamp and were given half-time employment on the drainage works, receiving 6s. 8d. per day. They were allowed to keep their blocks so long as they effected improvement to the value of £3 per month. Under this scheme 895 blocks had been allocated by April, 1894. General selection began in 1900, shortly after a big fire had burnt much of the tea-tree and other swamp debris. Prices of the blocks sold to settlers ranged from £1 10s. to £6 10s. per acre.

Newly-reclaimed peat land presented peculiar difficulties. The dry peat was at first so fibrous and incoherent that it would only support the weight of light animals. Calves were frequently used to effect preliminary consolidation because they had large feet relative to their weight. Buried tea-tree roots had then to be removed after the peat had settled and exposed them. Cropping and dairying were begun as soon as it was safe to bring heavier animals on to the peat. However, horses' feet and implement wheels had often to be wrapped in bags to prevent their sinking too far; cows formed sunken consolidated tracks leaving loose hummocks which later had to be levelled by hand. Peat fires were commonly lit in order to destroy the dry, loose peat, the buried tea-tree roots and the surface debris.

The primary drainage system could not cope with floods following heavy rain in the hills. It was enlarged in 1902, and again in 1913-16, and is at present being remodelled and enlarged in the light of experience gained from the disastrous flood of 1934.

In 1917 the Government drainage scheme was extended to include the existing private reclamation schemes at Dalmore and Cardinia. The drainage systems of these areas are also being improved at the present time (6). The cost of the new works will bring the total drainage costs of Koo-wee-rup and Cardinia to £600,000; even then, neither district will be completely immune to extensive floods in seasons of very exceptional rainfall, though these are unlikely to occur oftener than about once in ten years.

Flooding.
The total catchment area of the Koo-wee-rup Swamp Basin is 450 square miles, and its average annual rainfall is 44 inches. The Main Drain carries the runoff from about 260 square miles of hilly to mountainous country, some of which receives nearly 70 inches. It is therefore not really surprising that there have been nine floods recorded in the district during the last 29 years. These floods have come during every season except the height of summer. There is no exact information about the area flooded,

but the damage to crops has been considerable. The drainage system has always disappointed settlers and engineers in its capacity of the intensity of extraordinary floods.

The flood of 1st December 1934 was three times greater than any which have occurred since measurements began in 1907, and six times greater than the original estimate of an extraordinary flood. Potato and maize crops were ruined and nearly 3,000 head of stock were drowned. The water entered houses throughout the district, and stood 6 feet high in the streets of Koo-wee-rup. This catastrophe produced a profound reaction. Cropping, which was in any case becoming unpopular, gave way almost entirely to dairying; land values dropped and settlers agreed to a really expensive drainage system. This flood was, in fact, due to a freak storm. The rainfall at Warragul for 24 hours was 7.47 inches: the previous highest 24-hour fall during 52 years was 3.49 inches. A storm of such intensity is most unlikely to recur during a lifetime, but the impression of insecurity still influences agriculture in this district.

There has certainly been some increase in runoff because forest cover in the catchment area, especially in the headwaters of the Tarago, has been seriously damaged by fire and axe. However, in some areas (notably in the Strzelecki Ranges) forest has been replaced by first-class pasture which can probably retain water as efficiently as virgin forest.

The maintenance of drains has been a difficult problem in this district. Apart from the growth of tea-tree and reeds, drain capacities have been reduced owing to shrinkage of peat and to siltation. This shrinkage, which averages 3 to 4 feet over much of the district, was the main problem in the early days. All the effected had to be re-excavated down into the clay subsoil. Siltation mainly affects the Main Drain. The problem is not a recent one. By 1916 the Main Drain had deposited a layer of sediment 2 feet thick a mile and a half out to sea and there was up to 6 feet of sand in the bed of the drain (3). The upper reaches have scoured to a depth of nearly 25 feet and at present there are approximately 80,000 cubic yards of sand being deposited annually in the bed of the drain below Cora Lynn. The sand is ideal for concrete and is readily loaded into trucks by means of a suction dredge. However, it is accumulating more rapidly than it is being removed.

Agricultural development.

The only exact information on farming activities in the district is contained in parish statistics, which were first collected in 1907. Statistics have been kept continuously since then, giving a quantitative record of agricultural development. The agricultural income of the district in 1907 was chiefly derived from 1,300 milking cows, 2,500 other stock, and 1,600 acres of root crops.

The fluctuations and trends of the main farming activities (potatoes, dairying, oats for hay, and sheep) are shown in figs. 4 and 5. Fig. 6 has been included to show the similar trends in number of stock in the two parishes; the trends of other activities are also similar, consequently the statistics of the two parishes have been combined in this paper.

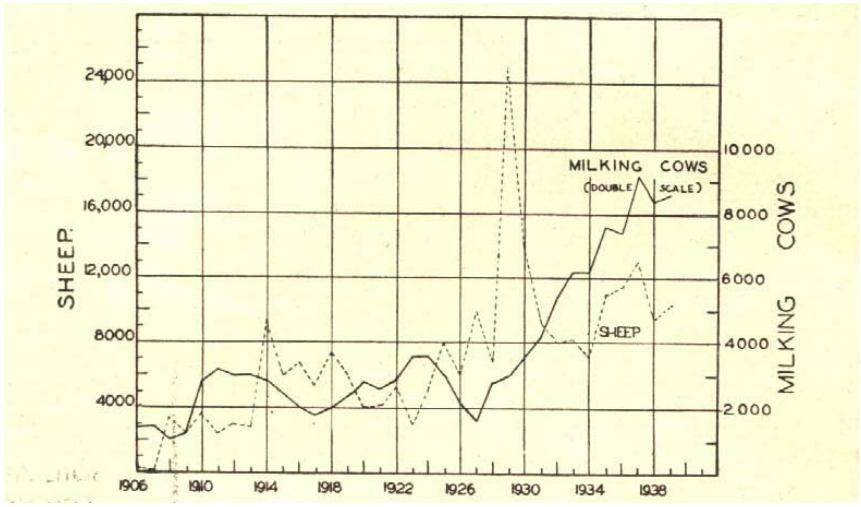

FIG. 4 – Numbers of sheep and milking cows, 1906-1939, in the parishes of Koo-wee-rup and Koo-wee-rup East.

The fluctuations of the potato crop (fig. 5) are particularly interesting. The district quickly established a reputation for potatoes and the acreage increased from 1,300 in 1907 to 15,800 in 1923. The subsequent decline to 1,400 acres in 1939-40 is partly a

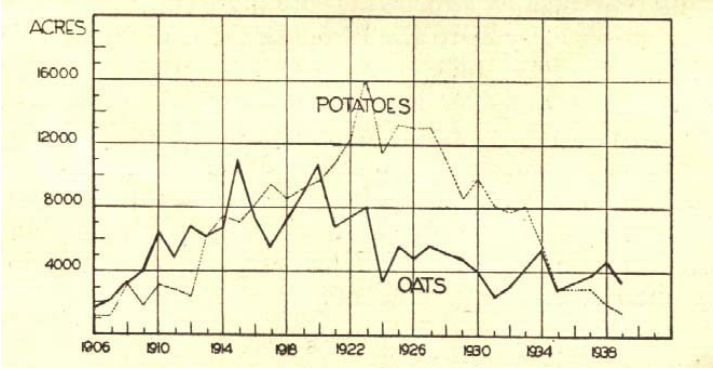

FIG. 5. – Acres under potatoes and oats, 1906-1939, in the parishes of Koo-wee-rup and Koo-wee-rup East.

reflection of the State-wide difficulties of the potato-growing industry caused by the low prices during the early thirties. Further, Koo-wee-rup farmers suffered an almost complete loss of their crop in the disastrous flood of 1934. Added to these misfortunes are the usual hazards of destructive spring and summer frosts, the attacks of potato moth *(Phthororimaea operculla)* and "sore-eye" *(Bacterium solanacearum)* and the difficulties of a market which fluctuates considerably from month to month. These monthly fluctuations are an unfavourable contrast to the relatively unvarying market price for milk and milk products. Many Koo-wee-rup farmers think than potato yields are lighter now than they were twenty years ago. However, statistics collected over the last fifteen years for country Mornington suggest than slightly higher yields have been obtained recently than during the peak years of potato growing.

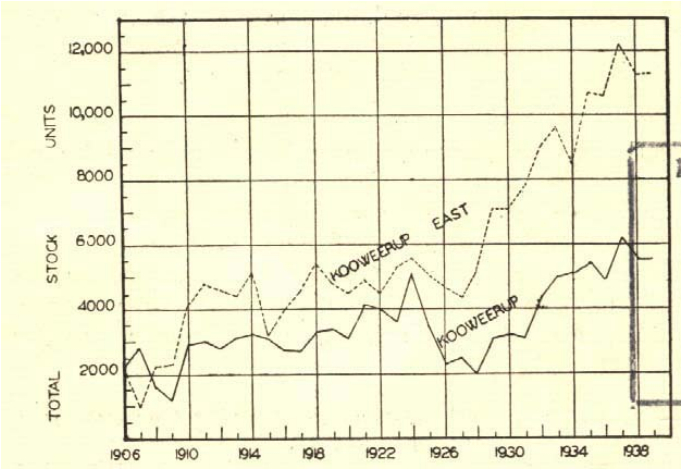

FIG. 6. – Numbers of stock in the parishes of Koo-wee-rup and Koo-wee-rup East, 1906-1939. A stock unit is defined as 1 cow, heifer, or horse, 2 calves, 10 sheep or 15 lambs.

Most farmers have turned from growing potatoes to dairying. The milking cow population, which had varies between 1,600 and 3,700 for the twenty years preceding the slump in potatoes, rose steadily to 9,700 by 1937 (fig. 4). The number has fallen slightly since then, mainly on account of the drought of 1938-39, but it may reasonably be expected to increase with better management and improvement of pastures.

Fig. 5 shows than between 1911 and 1923 over 6,000 acres of oats were grown annually for hay, and on two occasions the figure exceeded 10,000 acres (or one fifth of the total area of the district). Hay was then grown as a cash crop in rotation with potatoes, but is nowadays only used as supplementary fodder for dairy cows. This accounts for the smaller acreage during the last ten years. Yields of hay calculated over the last 30 years normally vary from 1¼ to 2 tons per acre.

In addition to these major activities, fairly large areas of grain crops (mainly wheat, oats, and maize) have been planted at various times.

During the late twenties over 1,000 acres of wheat were grown annually, the highest acreage being 4,000 in 1928. Yields averaged 28 bushels per acre over a number of years, and some farmers reported having harvested 40 bushels per acre. A few hundred acres of oats were harvested for grain over the same period, yields being somewhat lower than those of wheat.

The area of maize for grain to-day is almost equal to that of potatoes, and has remained steady during the last fifteen years. Annual wholesale price averages are far steadier than those of potatoes and onions.
In addition to these larger areas of crop, farmers of the district have for many years grown smaller areas of onions, carrots, peas, asparagus, pumpkins, melons, and other minor cash crops.

Individual occupations

Definition of farm types.
The occupations of farmers have been analysed by using the parish statistics for 1939-40. Occupation and size of holding are classified in Table II. There are 438 farmers whose production is considered to be significant; a farmer who is so classified has as a minimum 7 cows, or 5 acres of cash crop, or 80 sheep, or 10 head of other stock. This leaves 78 men whose names appear on the records as farmers, but who are classified here as "unproductive".

Table II – Distribution of farmers on basis of occupation and size of holding.

Number of Farmer of Given Occupation									
Size of Holding (Acres)	**Dairy**	**Dairy and Cash - Crop**	**Cash - crop**	**Cash - Crop and Other Stock**	**Sheep**	**Dairy and Sheep**	**Unpro ductive**	**Miscella neous Graziers**	**Total**
16 – 20	17		5				33	1	56
21 – 40	35	5	12				19	3	74
41 – 60	68	17	10		1		8	1	105
61 – 80	41	13	6				6	1	67
81 – 100	49	8	4	3	2		2	1	69
101 – 120	26	10	3	1		1	3		44
121 – 150	20	7	1	1	3	2	2		36
151 – 200	15	4	8	1	1	2	2	2	35
201 – 300	6	1	1	1	1	2	3	4	19
> 300	4		1	3	1			2	11
Total farmers	281	65	51	10	9	7	78	15	516
Total acres	24,410	5,775	4,540	2,505	1,743	2,356	3,740	3,440	48,509
Percentages of total area	50	12	9	5	4	5	8	7	100
Average size of farm (acres)	87	89	89	250	194	337	48	230	94

As Table II shows, the majority of men in the unproductive class are so because their farms are very small. Other men with larger farms are unproductive because much of their land is "uncleared". The 2,900 acres of "uncleared" land in the district consists mostly of salty land near the sea and of podzolic land under eucalypt cover in the north and north-east of the Parish of Koo-wee-rup East. The "unproductive" class necessarily includes a few poultrymen (since poultry are not now included in parish records), and graziers who happened to be running no when the statistics were collected.

The following is the basis of the classification of productive farmers. Men with at least 7 milking cows, 5 acres of cash crops, 80 sheep, or 10 head of other stock are grouped as dairymen, cash-crop farmers, sheep farmers, or "miscellaneous graziers" respectively. Farmers who derive 20 per cent of their income from each of at least two of these activities are classed as "mixed" – dairy with sheep, dairy with cash crop, and cash crop with other stock. For the purpose of this classification 1 acre of cash crop, two milking cows or twenty sheep are considered to produce the same income.

Forty-nine farmers were selected from a recommended list and personally interviewed, in order to obtain more detailed information concerning farm activities, pasture types and the history of the district. These farms were scattered fairly evenly over the whole district. In addition, twelve small farms were selected at random and visited because the recommended list contained too great a proportion of large farms to be truly representative. Some of the farmers with less than 40 acres have independent sources of income. Most of the remainder have to do some work on roads, drains, or other farms, in order to maintain a reasonable standard of living.

Dairy farmers.
There are 281 dairy farmers who derive more than 80 per cent of their income from dairying. The distribution of herd size and farm acreage is given in Table III, which shows that herds of 16-20 cows and farms of 41-60 acres are most frequent.

Table III – distribution of dairymen on basis of size of farm and size of herd.

Size of Holding (Acres)	Number of Milking Cows										Total Farmers
	7-10	11-15	16-20	21-25	26-30	31-35	36-40	41-50	51-60	>60	
16-20	10	6	1								17
21-40	7	13	14	1							35
41-60	8	18	25	13	1	2	1				68
61-80		8	15	8	6	4					41
81-100	2	6	5	11	15	5	3	1	1		49
101-120		1	2	4	8	4	5	2	2	1	26
121-150			2	4	2	5		6	6	2	20
151-200	1		2		2	4	2	2	2	1	15
201-300			3								6
> 300						1	2	1	1	4	4
Total Farmers	28	52	69	41	34	25	13	12	3	4	281
	"Small dairymen"			"Medium dairymen"				"Large dairymen"			

The activities of dairymen are most conveniently described by dividing them into three groups according to size of herd, viz., those with up to 20 cows (small dairying), those with 21-40 cows (medium dairymen), and those with more than 40 cows (large dairymen).

There are 149 small dairymen, the average holding being one of 58 acres with 15 milking cows, and other stock equivalent to 11 milking cows. Of this 58 acres, 51 acres consists of grassland, 20 acres of which are annually topdressed as the rate of 1.4 cwt per acre and 7 acres are sown to supplementary green fodders.

There are 113 medium dairymen, the average holding being one of 106 acres with 29 milking cows and other stock equivalent to 15 milking cows. (For stock equivalents see under fig. 6). Of this 106 acres, 90 acres consist of grassland, 42 acres of which are annually topdressed at the rate of 1.5 cwt per acre and 16 acres are sown to supplementary green fodders.

There are nineteen large dairymen, the average holding being one of 176 acres with 55 cows and other stock equivalent to 31 milking cows. Of this 176 acres, 145 acres consist of grassland, 85 acres of which are annually topdressed at the rate of 1.4 cwt per acre and 31 acres are sown to supplementary green fodders.

Milking machines have increased almost ten-fold in the last seven years, and are now operated by over half of the medium and large dairymen and by one-ninth of the small dairymen. Petrol, kerosene, or diesel engines are usually the source of power, although electric motors are used on some farms.

Many dairy farmers supply whole milk to Melbourne, either directly or through the milk depots at Bayles and Longwarry. Others supply whole milk or cream to the butter factories at Bayles and Longwarry, and to the cheese factory at Cora Lynn. Whole milk, other than city contract supplies, is paid for on a butter-fat basis, and commands a small premium over cream to allow for the factory value of skim milk.

Supplementary Fodder Crops: Eighty per cent of dairymen grow supplementary green fodder, most of the remaining 20 per cent have only small herds. More than half the dairy farmers grow oats to supplement pastures during the winter; cows turned in to graze the crop do not "bog up" the plants as they would in other districts of comparable rainfall because the excellent structure of these highly organic soils allows excess water to pass quickly through upper horizons and then laterally to artificial drains.

Farmers usually discontinue grazing oats in August so that the crop can later be cut for hay. Some farmers harrow in red clover seed after the last winter grazing, harvest the mixed crop, and retain the red clover stand as a good summer and autumn reserve of green fodder. Red clover makes good growth in this district, if it is properly established; it is, therefore, undesirable to sow and graze it with oats during the winter because the crown of the young plant is exposed to damage.

More than half the dairymen of the district grow maize, which is usually fed as a soiling crop during the pasture shortage of late summer and autumn. Some dairymen find that pastures are inadequate to provide succulent feed until maize is ready to cut, so that fairly large areas of millet and rape are sown.

Dairymen who supplement pastures with green fodder crops grow on an average half an acre per cow of oats, rape or millet, or one-quarter acre per cow of maize. Table IV shows that some dairymen in all three classes grow a combination of two or even three of these crops in an endeavour to maintain production throughout the year.

Table IV – distribution of dairymen according to the type of supplementary green fodder grown.

Classification by size and herd	Total Number of Men in the Group	Growing No Supplementary Green Fodder	Oats Alone	Maize Alone	*Other Green Fodder Alone	Oats and Maize	Oats and/or Maize and Other Green Fodder
Small dairymen	149	35	26	25	6	30	27
Medium dairymen	113	17	19	16	2	23	36
Large dairymen	19	1	4	2		7	5

* Mostly Millet or Rape.

Pasture Types*:* Pastures are by far the most important part (probably about 80 per cent) of a milking cow's diet in this district. Among dairymen, the area of grassland is about six times as great as the total area of green fodder crops.

Some 4,600 acres of this 35,000 acres of grassland were inspected during the autumn and spring of 1940, and four major types were distinguished; (*a*) one in which dense perennial rye grass is usually the dominant and in some cases the only species present, with cocksfoot, white clover, and red clover as the usual associates; (*b*) rather thin stands of perennial rye grass, a fairly dense stand of subterranean clover and varying amounts of Yorkshire fog, cocksfoot, and "water couch" (*Paspalum distichum*); (*c*) unimproved native pastures in which wallaby grass is dominant; and (*d*) a characteristic "volunteer" pasture association which appears after cropping. This usually consists of weeds and subterranean clover, but near the Main Drain, white clover also commonly volunteers. The usual weeds are rushes, thistles, flatweed, and sorrel; bracken, ragwort, and blackberries are seldom seen on the farms, but the reed, *Phragmites,* is common over large areas of this volunteer pasture, although it can be completely suppressed by proper management.

Only 15 per cent of the area of inspected farms consisted of the dense perennial type (*a*). By far the commonest type was the subterranean clover-perennial rye grass association (*b*), which has one serious drawback on light peaty loams and burnt loams, namely, that cows pull up many rye-grass plants during summer and autumn while soils are dry and loose and there is no binding mat of subterranean clover. The unimproved native pastures (*c*) were observed only in small patches on the poor podzolic

soils in the north and north-east of Koo-wee-rup East. Volunteer pasture (*d*) constituted 35 per cent of the area inspected.

Topdressing and Management: Topdressing only began during the late twenties; the average area topdressed annually rose to 17,000 acres (or one-half of the total grassland area) in 1938-40. Parish statistics unfortunately group applications of lime and superphosphate under the common heading of "manure". However, the difficulty is not as serious as it sounds, because inquiries among farmers show that at most one-twelfth of the topdressed area receives lime. The average rate of application of "manure" for 1939 was 1.4 cwt per acre.

The Victorian Pasture Improvement League have carried out pasture trials at Caldermeade, 3 miles east of Koo-wee-rup, on soil resembling the normal swamp fringe type, and have shown that 2 cwt per acre of superphosphate, applied annually, markedly increases the yield of pasture. Yields of dry matter per acre from mown plots ranged from 25 cwt in the drought season of 1938-1939 to 82 cwt in 1936-37 with an average of 55 cwt over eight seasons. (The season is reckoned from 1st March to 28th February). Although there is no doubt that topdressing is well worth while in the Koo-wee-rup district, it may easily be less so than elsewhere because of the residual effect of previous heavy applications of phosphate to the land.

There has been great interest in lime in this district as elsewhere in southern Victoria, but there is no evidence of an increase in yield of pasture subsequent to liming on the Caldermeade plots. In fact, other fertiliser treatments (nitrogen, potash, lime together with 2 cwt of superphosphate; also 3 cwt superphosphate) do not produce a significantly greater response than 2 cwt superphosphate alone.

The Caldermeade plots are cut and weighed at convenient intervals; they normally yield two-thirds of their annual bulk between mid-August and mid-November, a further one-sixth before the end of December, and the remaining one-sixth in the following eight months. It is clear from these observations that conservation of the spring pasture surplus is a necessary adjunct to topdressing. In 1937 – a fairly normal year – the average yield of grass hay per acre was one and a quarter tons, yet only 1 acre in every fourteen of grassland was cut for hay in this year. Evidently many farmers in the district have not yet realised the possibilities of this phase of pasture management. The exceptionally severe drought of 1938-9 and the abnormally vigorous autumn growth during 1939, following the fall of 7 inches of rain at the end of February, make it misleading to quote more recent figures as representative. Some farmers who baled their hay and who should therefore have reliable estimates, reported 3 tons per acre for the 1939 cut.

Among the farmers visited, nearly all harrow their pastures to spread cow manure, and none believe in the now obsolete practice of mutilating the sward as a means of increasing pasture growth. Ordinary harrows are commonly used with or without a reduction in the draught of teeth made by fitting a board along the front row of teeth, or by packing the whole set with wire netting.

Farms are usually divided into paddocks of 5-10 acres, yet only a few farmers carry out systematic rotational grazing. However, the bulk of fodder produced during summer, autumn, and winter is so small that it is doubtful if subdivision is worth while on mediocre pastures. But if the fences are already present, the farmer may as well practise rotational grazing and obtain the small increase in growth which is known to occur under this treatment.

Rate of Stocking: The average rate of stocking on dairy farms is one stock unit per 2.4 acres (a stock unit is arbitrarily fixed at one dairy cow, dry cow, heifer or horse, 2 calves, 10 sheep or 15 lambs). Farms of small area (fig. 7) are more heavily stocked than those of large area; the median rate of stocking on farms of less than 60 acres is 1.9 acres per stock unit compared with the corresponding figure of 2.7 for farms of more than 120 acres.

Relation of Superphosphate to Rate of Stocking: The exact relation between topdressing with superphosphate and rate of stocking cannot be worked out from the statistical records for two reasons. Firstly, there is a difficulty about the records themselves, since lime and superphosphate are grouped together as "manure". Secondly, many small farms are topdressed only in alternate years. However, enough farms are topdressed regularly to yield the surprising fact that there is hardly any correlation between topdressing and rate of stocking.

It is worth while to consider some of the reasons for this low correlation because pastures in this district certainly benefit from the application of superphosphate. A major reason is the residual effect of previous crop and pasture dressings. Dressings of half a ton of superphosphate were, and still are, commonly used on potatoes. The amount of phosphorus removed by a 4-ton crop of potatoes corresponds to only 64 lb of superphosphate, so that, after a number of years of intensive potato cropping, a considerable, though diminishing residual effect is quite natural. There are still men, especially in the Dalmore area, who regularly sow pasture in rotation with potatoes, and their pastures are outstandingly good. Supplementary fodders also raise the carrying capacity of a farm. Nearly all the 20,000 bags of grain, bran, and pollard which are normally bought every year are fed to milking cows. Further, the exceptionally large and well-disturbed area of road and drain frontage is commonly used to relieve the strain on over-grazed pastures.

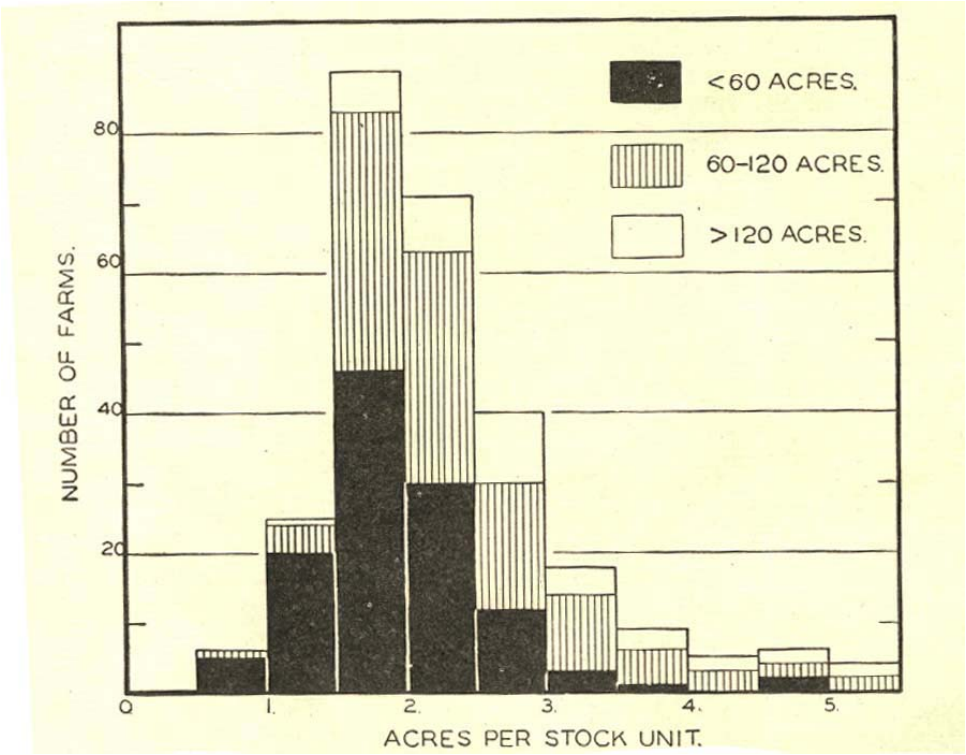

FIG. 7 – Distribution of farms in the two parishes according to rate of stocking. This figure also shows the relative importance of farms of different sizes for each rate of stocking.

The real criterion of farm efficiency is milk per acre or butter-fat per acre, but sufficient data could not be obtained to analyse these in relation to topdressing and pasture management.

The standard of animal nutrition varies strikingly from farm to farm. Wood (12) states that the extra ration required by the average Jersey cow to produce one and two-third gallons of milk is equal to its daily maintenance ration of five starch equivalents. Over-grazing at the expense of milk production is, therefore, alone sufficient to explain the abnormally high stocking of some small farms, and in particular of small farms not topdressed at all.

Cash-crop farmers.

General Discussion*:* Of the 126 farmers growing more than 5 acres of cash crops, 51 derive more than 80 per cent of their farm income from this source. Their average holding is 90 acres, half of which is cropped; but at Table II shows, a few large farms considerably affect the average size.

Stocking is generally very light, and the average man has three or four horses and one or two cows for domestic use. Nearly a quarter of the farmers have tractors as well.

The activities of the cash-crop farmers, as shown in Table V., vary widely. Potatoes and maize for grain occupy an area equal to the combined area of all the special crops, viz., sweetcorn, asparagus, onions, melons, pumpkins, carrots, parsnips, cabbages, parsley, and peas, the last seven of which have

been grouped as "Other vegetables" in Table V. Of the "Other Vegetables" green peas are by far the most important and, together with asparagus and sweetcorn, supply an appreciable proportion of the Victorian canned vegetable industry.

Table V – activities of the fifty-one cash-crop farmers.

	Potatoes	Maize for Grain	Sweetcorn	Asparagus	Onions	Other Vegetables
Total area (acres)	639	585	224	150	75	647
Number of growers	36	23	2	1	10	25
Average area grown (acres)	18	25	112	150	7	26
Number growing one crop	8	7				4

The texture of soils in this district is generally well suited to cash cropping, but much of the most suitable land is infested with *Phragmites.* This reed is very hard to control in cultivated paddocks because it grows quickly from a deep system of rhizomes; in fact, many people believe that cultivation causes a more prolific reed growth. This is probably correct except where cultivation is very intensive. The vigour of the reed can be greatly reduced by establishing a good pasture stand and keeping it well grazed for several seasons.

Potatoes*:* The better farmers select their seed from the previous season's crop and store it in racks under trees which allow sufficient light and provide shelter from the weather. Potatoes are usually sown during October on early November so that nearly half of the crop can be dug by the end of February. The normal rate of seeding is 10 to 15 cwt per acre with up to 10 cwt or even more of superphosphate, with or without ammonium sulphate. The better farmers realise that far higher yields can be expected, when potatoes are sown after a pasture stand two or three years old. The good effect is due mainly to a big reduction in the number of potato parasites. Sowing is followed by the usual cultivation between the rows to conserve moisture and soil nutrients. Most farmers "mould" their crops heavily, mainly to combat potato moth (*Phthororimaea operculella*) which, during dry seasons, is the most destructive potato parasite in this district. Moths reach the tubers more easily in heavy soils than in peaty soils because heavy soils crack during dry weather and the funnel-shaped hole formed by rotation of the main stalk during windy weather does not readily fit in. Losses are said to be more severe among early crops and especially with the variety Carman.

However, even with the utmost care in preparation and subsequent cultivation, the yield depends primarily on the occurrence of rain and the absence of frost. Soaking rains are especially necessary at flowering time; plants can suffer severe damage or even death from summer frosts (see p. 98).

Maize for grain and Sweetcorn: These two crops are very similar as to seeding, manuring and cultivation. Usually 8-12 lb per acre of seed are sown with a corn planter so that the crop can be cultivated in two directions. Superphosphate is usually applied at the rate of 1 to 2 cwt per acre, and farmers say that even this is not necessary if maize follows a heavily supered potato crop. Strict weed control is essential. The average yield of maize grain for country Mornington varies from 7.7 to 33.3 bushels per acre. The Victorian average yield over the same period is 33.8 bushels per acre which suggests that except for abnormal years, this district as a whole is too dry for really good yields, though some areas may be favoured with ground water accessible to the roots. Proximity to the canneries justifies the risk of failure with sweetcorn. Frost can be very serious, especially while the styles are extruded for fertilisation. Except in very unfavourable seasons when many crops are fed to stock in the same way as ordinary drilled maize, the cobs are picked at maturity and stored in cribs, or in the case of sweetcorn, picked some time before maturity and sent straight to the cannery. In this district, stover is normally worth about £1 an acre as stock feed.

Asparagus*:* Three of the six main Victorian asparagus farms are in this district. Each of the three grows over 100 acres under contract to canneries.

Seed selected by the cannery is sown in rows 6 feet apart, and after a year seedlings are transplanted at a depth of about 6 inches in rows of 4 feet to 6 feet apart. Growers usually apply ½ to 1 ton per acre of

manure (mainly superphosphate). The stand is ready to cut when three years old and growers find that tips do not begin to deteriorate for about fifteen years. The tips are cut daily from October to December.

Cutting is stopped during December so that the tops make sufficiently vigorous growth to replenish the food store of the rhizomes; canneries have to be free at this time to deal with other vegetables and soft fruits.

Asparagus beds are cultivated throughout the growing period to keep them weed-free and the crowns well covered with soil. During winter the tops die and are cut off. Weed control is not essential and stock can be turned in to graze the volunteer growth.

***Green Peas**:* usually 5 bushels per acre of seed are sown with a dressing of about 3 cwt of superphosphate. Where peas are grown under contract to a cannery, the whole plants are cut with a mower, loaded on to a motor truck and taken to the factory, where the peas are automatically shelled, processed, and canned. Selected areas are allowed to mature and the seed used for next season's crop.

***Other Cash Crops**:* The areas of the remaining cash crops are unimportant; however, the recent stimulus to the flax industry has resulted in the decision to erect a flax mill at Koo-wee-rup. Those farmers who have decided to grow flax are given access to expert advice, and what is very important, a guaranteed price. Nearly a thousand acres were sown in 1940-41.

"Dairy with cash-crop" farmers.
There are 66 farmers deriving their income from these two activities combined, and the general discussions on dairying and cash cropping apply equally to these men. The proportion of small, medium and large herds among these farms is practically identical with that of dairy farms. A crop-pasture rotation is beneficial from the stand-point of cash cropping, but apart from the small amount of feed obtained from crop refuse and cropland weeds, the stock management of this type of mixed farm only differs from that of pure dairying in the smaller total pasture area available. Much of the district is undoubtedly suited to cash crops, and many farmers will probably begin to grow them again should prices become reasonably stable.

The average mixed "dairy-with-cash-crop" farm is, at present, one of 89 acres, fourteen of which are annually sown to cash crop; it carries 22 milking cows and also fourteen other stock units. The relative importance of potatoes and maize for grain is given on Table VI.

Table VI – the relative importance of maize for grain and potatoes on "dairy with cash crop" farms.

	Maize for Grain	Potatoes	Other Cash-crops
Total area of crop	378	388	119
Average area gown per farm	12	9	9
Number of growers	31	41	13
Percentage of total "dairy with cash-crop" farmers	47	63	20

Of the twenty farmers growing two of these crops, eleven grow potatoes and maize. "Other cash crops" include sweetcorn, onions and other vegetable crops.

Minor occupations.
The four remaining agricultural activities may be dealt with summarily, because it is almost certain that if maximum farm income had to be realised, dairying would replace all forms of production other then cash cropping.

Cash-crop with other Stock: This is a group of ten cash-crop farmers who, in general, have large holdings and quite a lot of stock other than dairy cows. The average farm is one of 250 acres with 55 stock units and 52 acres of cash crops, 23 acres of which are potatoes or maize for grain while the rest is asparagus, sweetcorn or other vegetables. The stock consist mainly of sheep, but some farmers have quite large numbers of beef cattle. Among the eight men with sheep, the average flock is of 270 mature sheep and 130 lambs. Nearly all topdress a small proportion of their pastures and manure their cash crops at approximately the same rate as do the cash crop farmers.

Sheep Farmers: The nine farmers who derive the whole of their income from sheep have, on an average, a farm area of 195 acres and had a flock of 460 sheep with 145 lambs at the date when records were collected. Of the six men who topdress their pastures, only two topdress more than half their farm.

Intestinal parasites and footrot are usually troublesome and good farmers drench their lambs as often as once every three weeks and control the spread of footrot by strict quarantining of affected stock and by rotational grazing.

However, the sample of farmers is so small that nothing else can be said of their systems of management in general except that some fatten more sheep or lambs and others breed their own stock.

Sheep and Dairying: On seven farms sheep and dairying are combined as the main activity. These farms have an average size of 330 acres and are lightly stocked. Herds vary from 11 to 100 cows, the average herd being one of 30 cows. The average flock of 250 mature sheep yields from 7¼ to 9 lb of wool per sheep, and four of these men supplement their incomes with an average of 60 lambs. The proportion of their land topdressed and sown to green fodder crops is roughly the same as that for pure dairymen.

Miscellaneous Graziers: There are fifteen farmers whose farming activities cannot be classified under any of the preceding categories. Five of the farms have more than a quarter of their area uncleared. Four men run sheep as well as beef cattle, calves or heifers while the others run beef cattle, heifers or horses. Supplementary green fodder is not generally grown, but top dressing is nearly as popular as with dairymen.

VI. Physical and Chemical Analysis of Soil Types

Mechanical analyses.
Representative samples of the main soil types were separated into the mechanical fractions defined by the "International" limits, viz., coarse sand 2.0 to 0.2 mm, fine sand .2 to .02 mm, silt 0.2 to 0.002 mm, and clay less than 0.002 mm. Percentages, calculated on an oven-dry basis, are set out in Tables VII and VIII.

Table VII – Mechanical analyses of Koo-wee-rup peaty clay and Dalmore clay.

Soil Number	**K 06**			**K 12**		
Soil Type	**Koo-wee-rup Peaty Clay**			**Dalmore Clay**		
Horizon	**a**	**b**	**c**	**a**	**b**	**c**
Depth (inches)	**0-9**	**9-17**	**17-33**	**0-9**	**9-34**	**34-44**
Coarse sand	8.2	24.1	27.6	2.7	2.0	21.3
Fine sand	11.5	21.2	16.2	8.5	3.8	24.6
Silt	14.5	15.7	15.0	12.1	6.5	20.6
Clay	46.1	36.6	41.4	66.9	82.0	33.4
Carbon	10.2	2.9	1.0	7.9	3.8	1.2
Nitrogen	.68	.14		.43	.23	
pH	4.9	5.1	5.0	5.1	5.3	5.4

Table VIII – mechanical analyses of swamp fringe type and of a podzol on granite.

Soil Number	**K 25**			**K 31**		
Soil Type	**Swamp Fringe Type**			**Podzol on Granite**		
Horizon	**a**	**b**	**c**	**a**	**b**	**c**
Depth (inches)	**0-10**	**10-16**	**16-36**	**0-4**	**4-13**	**13-30**
Coarse sand	3.3	4.0	2.4	48.0	43.9	15.3
Fine sand	48.4	44.5	37.0	23.8	28.8	10.0
Silt	22.4	22.0	21.2	13.6	15.4	4.7
Clay	22.8	27.3	37.6	8.0	10.0	70.0
Carbon	2.6	1.3	1.0	3.9	0.6	
Nitrogen	.18					
pH	5.4	5.4	5.3			

The main characters of texture are shown in the tables – viz., the clayey texture of the surface and the gritty subsoil of both Koo-wee-rup peaty clay and Dalmore clay, and the silty nature of the swamp fringe type. Analyses of other surface samples of Koo-wee-rup peaty clay and swamp fringe type confirm the generally representative nature of these profiles; yet it must be borne in mind that a few small areas have been mapped as either of these major types when, in fact, their percentage of sand may exceed that of the type by as much as 25 per cent owing to the proximity of sandy areas. Likewise, although there is generally less than one per cent gravel in Horizon 1 of Koo-wee-rup peaty clay, some exceptional samples contain as much as 10 per cent.

The mineral fraction of Dalmore clay varies remarkably little.

Hydrochloric acid extract.
Representative soils were extracted with boiling hydrochloric acid (as in the International method). Potassium and phosphorus were estimated and the results conventionally set out in Table IX as percentage K_2O and P_2O_5 respectively. Although the number of samples is small, certain general relations are indicated.

Table IX – potassium and phosphorus dissolved by boiling hydrochloric acid.

Soil Type	Sample Number	Depth (Inches)	K_2O (Per Cent)	P_2O_5 (Per Cent)
Dalmore Clay	K 12a	0 – 9	.32	.164
	K 12b	9 – 34	.27	.036
	K 13a	0 – 10	.26	.124
Koo-wee-rup Peaty Clay	K 06a	0 – 9	.20	.150
	K 06b	9 - 17	.11	.025
	K 01a	0 – 10	.19	.158

The reserve of potassium is moderately good. Weathered felspar is a common constituent of the sand fraction and its potassium (which is not extracted by this method) makes the total reserve still higher. Sample K13a is a virgin Dalmore soil; K01a is a virgin burnt peat. They show no appreciable differences from cropped land; neither is there any difference between the burnt K01a and the unburnt K06a.

There is no significant difference between the HCl-soluble phosphorus of the swamp types; but it is remarkably high when compared with the 0.05 per cent or less of P_2O_5 which is typical of the nearby districts of Berwick and Pakenham. Phosphorus appears to be concentrated in the surface horizon. A report by Teakle (8) on the peat soils and related soils of Western Australia, includes many analyses of surface and subsoil HCl-soluble phosphorus which almost invariably show the same feature of surface concentration.

Organic matter.
The organic matter was estimated by Tiurin's rapid approximate method (using the figure 1 ml normal oxidising agent equals 3.3 mg carbon) and multiplying carbon by 1.72 to calculate organic matter.

Dalmore clay is consistently high in organic matter.

Koo-wee-rup peaty clay generally has over 15 per cent organic matter but the figures for the badly burnt phase and for the transition phases are naturally lower. The range of organic contents is a good indication of how much the peaty type varies in colour and texture. Both burnt and unburnt samples of Koo-wee-rup peaty clay may contain less than 15 per cent of organic matter. Of these, the burnt soils are often reddish-brown ash, depth of colour being mainly determined by organic content; the unburnt soils may be sandy, or if not are grey and somewhat cloddy. Those soils with over 15 per cent organic matter are generally dark grey and very friable, yet may contain enough ash to impart a red tinge.

Table X – organic content of surface soils (Tiurin's method).

Soil Type	Number of Samples	Mean (%)	Distribution of Samples				
			5-9 %	10-14 %	15-19 %	20-24 %	> 25 %
Koo-wee-rup Peaty Clay	15	15.0 15.5	1	5	6	2	1
Dalmore Clay	4	7.7		2	2		
Swamp Fringe	3		3				

The Swamp fringe type contains less than 10 per cent organic matter; subsoils of all the swamp types contain less than 5 per cent except where raw peat occurs.

Total nitrogen was determined by Kjeldahl's method. The results given in Tables VII and VIII go to show how large is the nitrogen reserve of the highly organic swamp types. The C/N ratio is quite favourable for the decomposition of organic matter and the production of nitrate. Raw peat from Catani (containing nearly 45 per cent organic matter) has a ratio of 22:1 compared with the ratio of 15:1 to 20:1 on normal swamp soils.

pH values.

The soil reaction was determined by means of the glass electrode using two parts by weight of soil to three of water. The figures for fifteen unburnt surface samples of swamp types are remarkably constant, ranging from 4.8 to 5.4 eleven lie within the range of 5.0 to 5.2. Burnt soils have a consistently higher reaction, the average being 5.6. Otherwise there is no significantly different reaction between swamp types; nor is there a significantly different reaction between surface and subsoil horizons. The acidic character of Koo-wee-rup soils is not at all abnormal when compared with the usual mineral soils found in the neighbouring districts of Berwick and Pakenham.

Readily available phosphorus.

Readily available phosphorus was extracted from the soil with a large excess of 0.002N H_2SO_4 and estimated by Truog's modification of the Deniges colorimetric method. Truog (10) says that, if readily available phosphorus approaches or exceeds 45 parts per million (p.p.m), it may be concluded that the soil is sufficiently well supplied with phosphorus to produce good crops of cereals and legumes although 75 p.p.m or more is desirable for most cash crops. However, if the amount extracted falls below 10 p.p.m it is certain that there is insufficient readily available phosphorus in the soil to produce satisfactory crops.

Table XI – readily available phosphorus content of surface soils (Truog's method).

Soil Type	Number of Samples	Mean (p.p.m)	Distribution of Samples (Pts/Million)		
			0-10	11-25	26-45
Koo-wee-rup Peaty Clay	14	16	5	8	1
Dalmore Clay	4	26		2	2
Swamp Fringe	3	9	2	1	

Table XI shows that on this basis all soils of the district which were examined are low in readily available phosphorus. Dalmore soils are relatively rich and swamp fringe soils relatively poor. Analyses were made of virgin soils from both Dalmore and Koo-wee-rup types, and results, viz., 13 and 3 p.p.m respectively, were so low as to suggest that all results in Table XI essentially measure the cumulative effect of applications of phosphatic fertiliser. Subsoils contain extremely small amounts of readily available phosphorus.

Exchangeable cations.

(1) ***Calcium, Magnesium, Sodium, Potassium*** – The four main metallic cations extracted by leaching with normal ammonium acetate at pH 7 are recorded in Table XII. Their relative importance is quite typical of the soils of southern Victoria. Calcium and magnesium predominate in the surface horizon with magnesium becoming increasingly important in the subsoil. Sodium is rather high in one peaty sample, owing to the proximity of the sea. The figure for exchangeable potassium gives useful information as to the amount of available potassium. The analyses indicate that Koo-wee-rup soils are well supplied with available potassium, due no doubt to its constant replenishment from the breakdown of primary minerals.

Table XII – exchangeable cations) other than hydrogen) in soils leached with ammonium acetate.

Soil Type	Sample Number	Depth (In.)	Exchangeable Cations					pH	% Clay	% Organic Matter
			Percentage of Total				Total in Milli Equiv per 100g Ovendry Soil			
			Ca	Mg	Na	K				
Dalmore Clay	K 12a	0-9	49	36	2	13 3	37.2 29.6	5.1	66.9	14 6
	K 12b	9-34	31	58	8	3	10.4	5.3	82.0	2
	K 12c	34-44	29	57	11			5.4	33.4	
						4 4	13.0 16.3			…
Koo-wee-rup Peaty Clay	K 033a	0-10	52	42	2 7	2 3	10.1 10.8	5.1	…	18 5
	K 06a	0-9	51	38	10			4.9	46.1	2
	K 06b	9-17	35	53	9			5.1	36.6	
	K 06c	17-33	23	65				5.0	41.4	

(2) ***Hydrogen and its relation to the metallic cations*** – Exchangeable hydrogen at pH 7 was determined on a representative set of samples using the p-nitrophenol method of Schofield (7). Total exchange capacity was estimated on the same soils using the rapid approximate method of shaking with excess N/20 HCl and back-titrating the filtrate to pH 7. Exchangeable calcium was estimated directly on this filtrate by precipitation as oxalate at pH 4.0. Results are collected in Table XIII which shows that the approximate values agree well with the accurate figures of the Table. The consistently low Ca/H ratio is quite in keeping with the low pH; in fact the lime theoretically required to bring the surface 8 inches to neutrality ranges from 10 tons per acre on K06a and K025a to 3½ tons on the burnt soils K01a and K031a. The burnt peaty soils always have a lower cation exchange capacity and a higher pH than the neighbouring unburnt soil.

Table CIII – exchangeable hydrogen at pH 7 compared with calcium and total exchange capacity.

Soil Type	Sample Number	Depth (In.)	Exchangeable ions Equiv. Per 100g Milli. Ovendry Soil.				Remarks
			Total Capacity at pH 7	Ca	H	Ca/H	
Dalmore Clay	K 12a	0 – 9	65	18	28	.64	Well farmed
	K 13a	0 – 8		11*	39	.28	Virgin land
	K 14a	0 – 8	56*	12*	36	.33	Well farmed
Koo-wee-rup Peaty Clay, normal phase	K 06a	0 – 9	54	8	40	.20	Normal farm
	K 025a	0 – 7	53*	8*	42	.19	Normal farm
Koo-wee-rup Peaty Clay, burnt phase	K 01a	0 – 10		6*	13	.46	Normal farm
	K 031a	0 – 8	27	9*	14	.64	Limed
Peaty Loam over Sand	K 020a	0 – 8	19*	4*	15	.24	Very sandy, sand 65 %
Swamp fringe	K 21a	0 – 7	29*	7*	21	.33	Normal farm

* Rapid approximate estimation.

Although the pH is low and the exchangeable calcium (except on Dalmore types) is only moderate, there is no evidence that lime is needed. The healthy growth of red clover on many areas gives, in fact, substantial evidence to the contrary. But the possibility remains that some of the most acidic soils (those of pH 4.8) may be found to respond to lime. This distract contains only very small patches of such soil, and most of the economic plants (maize, oats, potatoes, subterranean clover, white clover, and rye grass) are quite tolerant of pH values down to 5.0.

General Discussion

Black swamp soils enjoy great prestige, largely because of the impressive luxuriance of natural swamp vegetation and also because the dark colour of many mineral soils is associated with the idea of fertility. But, although river flats are certainly more fertile than the surrounding hills, this observation cannot be generalised to include peaty swamps.

The peaty Koo-wee-rup Swamp shared the prestige of river flats. However the properties of peaty soils vary greatly according to the source of the organic material. Probably much of the opposition to its reclamation came from men who knew the poverty of many Irish bog soils.

The main dividing line is drawn between:- (1) “Lowmoor” peats which are developed in lakes, and are derived from reeds and associated plants, and (2) “Highmoor” peats which in Europe commonly develop on top of lowmoor peat and are usually derived from sphagnum moss. The former peats, to which this swamp belongs, are far more fertile than the latter, which are not only highly acid (pH below 5) but physically undesirable. Koo-wee-rup peat, although lowmoor in origin, is rather poorly endowed with calcium, and its pH of 5, although not exceptionally acidic, is more so than are many other lowmoor peats. Its supply of readily available phosphorus is inadequate for intensive agriculture. However this is a common feature among peats, and a characteristic of most soils of southern Australia. On the other hand, the C:N ratio has the favourable low value expected of good lowmoor peats and there is evidently a good production of available nitrogen. Plant remains quickly decompose and lose their identity in the cultivated zone. Also the reserve of potassium is remarkably large for a

peaty soil, a character which is undoubtedly due to the felspathic fraction of the sediments derived from granite. The Koo-wee-rup peat may well be described as “fair average quality”.

The peat has disappeared with striking rapidity. Fibrous peat which was often more than 6 feet deep, has after 40 years of agriculture, been mostly reduced to 8 inches or so of peaty clay or else to a bed of ashes. Less than 10 per cent of the original deep peaty area still contains raw peat. Losses of a similar magnitude have occurred over most reclaimed peat lands of the world, and have in many cases caused problems of drainage and productivity which are far more serious than those of Koo-wee-rup. The famous fens of Lincolnshire, in England, which still produce prolific crops, are known to have shrunk many feet since their reclamation. Investigators (11) have studies in detail the subsidence of the widespread peats of the Everglades of Florida and of the Sacramento-San Joaquin delta in California. The chief causes of subsidence in these areas are:-

(1) Compaction by implements and animals.
(2) Shrinkage due to drying
(3) Burning.
(4) Windblowing.
(5) Oxidation.

The Californian surveys were carried out for fourteen years and showed an average annual subsidence of 2 inches, one half of which was due to burning. The experimental area had been previously cultivated for twenty years, so that compaction and shrinkage were negligible over the period of survey. Windblowing and oxidation therefore account for a loss of 1 inch per annum.

During the first few years after cultivation the virgin Koo-Wee-Rup peat probably lost over half its volume through compaction and drying. Also, strong winds have undoubtedly removed a considerable amount of dry soil from cultivated paddocks. For example, the gale of 13th and 14th December, 1938, is said to have removed almost a foot of soil from certain areas.

Burning has caused the greatest loss of peat in the Koo-wee-rup district. A shallow burn usually shows an immediate profit because it liberates plant foods and destroys crop parasites; but many fires burnt all the peat leaving a bed of ashes which would not grow satisfactory crops. The ill effects appear to be due to two factors. Firstly, the ash has a low water-holding capacity because the organic colloids are destroyed and much of the clay is baked to form coarser aggregates; secondly, there is no source of nitrogen in the ash. Fortunately, most of the burnt land consists of 8 to 12 inches of ash underlain by a reasonably fertile organic clay loam which can be plowed up and mixed with the ash to ameliorate both of these faults. The nitrogen level can be further raised by the continued use of clovers. A few small patches of land on which the porous ash bed is as much as 2 feet thick will always suffer badly from dryness. A shallow ashbed is not altogether undesirable. It has a consistently higher pH than the unburnt soil, which may be a good thing; it will also have a permanently friable texture, whereas the unburnt soil is in danger of becoming cloddy.

Some farmers have, in fact, noticed that continually cultivated paddocks of peaty soil have already become quite cloddy. This is the result of cultivation accelerating the oxidation of organic matter. The normal equilibrium for a well-drained clay under pasture in this climate is certainly no more than 10 per cent organic matter but may be as low as 6 per cent under intensive cultivation. It is impossible to estimate how long it will take for peaty soils to reach this equilibrium because of their variability in depth and present organic content and because of the factor of management; besides which, the rate of depletion will decrease as equilibrium is approached.

The dairymen or grazier on Koo-wee-rup peaty clay really has nothing to fear from this change, because a denser texture implies a greater supply of soil moisture for summer pastures, and oxidation causes no loss of mineral nutrients from the soil; and the present generation of cash crop farmers has but little cause for pessimism because they can maintain quite a good texture by the use of approved pasture rotations; but the soil may deteriorate with unpleasant rapidity under continual cultivation.

Dalmore soil is inherently richer in exchangeable cations than other swamp soils; its pH is the same. Although highly organic it has always been a mineral, not a peaty soil. The Dalmore farmer can expect a similar deterioration in texture as organic matter is lost, although drainage will always be reasonably good on the normal phase owing to the buried stratum of peat. Such deterioration would be shown by an increasingly narrow range of moisture contents over which the soil can be satisfactorily worked. The

change will naturally be slow, but the non-peaty phase which was originally not so richly endowed with organic matter has already presented this difficulty to cultivation. As before, pasture rotations slow down the change and prevent the ultimate formation of an unworkable soil.

Relation of carrying capacity to soil type.
As in many other dairying districts of fairly generous rainfall, carrying capacity depends to a far greater extent on management than on soil. There is no evidence of any significant difference between the carrying capacity of the swamp soils, other than the sandy type; this requires a very efficient system of improvement and management in order to realise its potential carrying capacity, which appears to be a little less than other swamp types. The podzolic soils are, as yet, mostly undeveloped, although similar types near Berwick are now carrying stock at the rate of one cow to two acres.

The black land of Dalmore is the only part of the district which gives the visitor an impression of prosperity. The general impression that conditions are far from prosperous over much of the district is borne out by the fact that a large proportion of farmers in the district have come under the farmers' debt adjustment scheme. This proportion varies with the size of farm, rising from 15 per cent of the farms below 40 acres to a maximum of 31 per cent in the group between 91 and 120 acres. This maximum among the larger farms is surprising, and may well be due to bigger proportional losses in potato-growing.

Land values have fallen to almost half their peak levels reached during the potato boom of the late twenties; nowadays Koo-wee-rup soils commonly change hands at about £30 an acre, the inherently more fertile Dalmore soils at about £40 an acre. Apart from past troubles, it seems reasonable to expect under present economic conditions modest prosperity on farms as small as 60 acres, because the land has a potential carrying capacity of at least one cow to two acres.

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