STOCKING RATES IN THE BERRIQUIN AND WAKOOL IRRIGATION DISTRICTS.*

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1. SUMMARY.

1. A survey of 82 farms in the Berriquin and Wakool Irrigation Districts was carried out in late 1952. The purpose of the survey was to measure the carrying capacity of different types of pasture on three main soil types within the Wakool Irrigation District and in the Berriquin Irrigation District. These two districts are situated in the southern portion of the Riverina (see Map I). Both districts derive their irrigation water from the Murray River.

2. Irrigation commenced in 1935-36 in the Wakool District and in 1939-40 in the Berriquin District. Before irrigation water became available the majority of farms in the Berriquin area produced wool and/or wheat; whilst in the Wakool area wool-growing was the most important type of production. Of the 82 survey farms, 74 now produce fat lambs, while seven have remained wool producers. (One farm is devoted to dairying and beef cattle only.) In addition, wheat, beef cattle and dairying are important sidelines in both districts. In the Wakool District, rice-growing has also become very popular.

3. The average area of the survey farms in the Wakool District was 3,137 acres, but this average conceals considerable differences between the farms on different soil groups in that district. The average area of farms irrigating on inundated clays and treeless plains soils was approximately 3,720 acres, while for farms irrigating on red-brown earths the average area was 1,843 acres. In the Berriquin District the average size of the survey farms was 1,236 acres, but the most frequent size group was 750 acres to 1,000 acres.

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4. In the Wakool District, of 47 farmers, 10 ran Merino ewes and 30 used crossbred ewes of one type or another, the most popular type being the Border Leicester-Merino first cross ewe. Twenty farmers used Dorset Horn rams and 14 used Border Leicester rams. In the Berriquin District of 32 survey farmers, 22 used crossbred ewes, the Border Leicester-Merino first cross ewe again being the most popular. Most of the other farmers ran Merino or Corriedale ewes. Ram breeds most frequently used were: Dorset Horn (13), Corriedale (6), Southdown (4), and Border Leicester (4).

5. Carrying capacity may be defined as the maximum number of stock which can be grazed on a unit area of land without the stocking resulting in a deterioration of the pasture concerned. In this sense carrying capacity is extremely hard to measure because it is difficult to ascertain whether a pasture is in fact deteriorating at a particular point of time.

6. This study has therefore aimed at measuring stocking rates, i.e., the actual number of stock carried per acre during a recent three-year period. However, such stocking rates are likely to differ from the carrying capacity of the pastures concerned because—

(*a*) Available evidence suggests that the carrying capacity of dry land in both Irrigation Districts—but especially in the Wakool District—has declined gradually for about 30 years. This decline is probably the result of over-stocking in past years, and it is at least possible that similar overstocking is still common. Hence existing stocking rates may in fact lead to a deterioration of the pastures concerned and thus over-estimate real carrying capacity.

(*b*) The information regarding stocking rates was obtained for the three years 1949-50 to 1951-52. During these three years the Berriquin Irrigation District enjoyed very favourable seasons; farmers in the Wakool District also had better-than-average seasonal conditions. Hence stocking rates during this period probably exceeded the safe limit over the long run.

(*c*) Stocking rates vary to some extent with the area of each farm. Generally speaking, stocking rates are relatively higher on the smaller farms—even when all farmers have land of similar quality. This may be the result of more efficient management on smaller farms or of economic factors, such as the small farmer's greater need to maximize income or to maintain a certain minimum income level. This may lead the smaller farmer to more optimistic estimates of how many stock can be safely carried. On the other hand, it may be wise for the large landholder to play safe and to understock. For him the long run capital value of his asset is more important than a small addition to income—especially in view of current income tax rates. The large landholder may also understock because his income is already at a satisfactory level, while more stock means more risk, work and responsibility. Whatever the reasons, the fact of differing rates of stocking on large and small farms has been noted by many students of Australian rural life.

7. In order to compare stock numbers on a group of farms it is necessary to convert all livestock to a common unit. In this particular case the unit used is *one crossbred ewe plus lamb* which is regarded as equal to two dry sheep, in terms of feeding requirements. (Dairy and beef cattle are converted at values corresponding approximately to their feeding requirements.) The figures given in Table I should be regarded as the most likely single estimate of stocking rates which can be made as a result of the survey during the three-year period 1949-50 to 1951-52. The stocking rates given relate to a farm of average size within each soil group.

TABLE I.

Average Stocking Rates on Survey Farms.

(1949-50 to 1951-52.)

Type of Soil.	Average Size of Farm.	Stocking Rates in terms of Crossbred Units (1 unit = 1 crossbred ewe plus lamb).				
		Dry Land.	Flood Land.	All Irrigated Pastures.	Irrigated Winter Pasture.	Irrigated Summer Pasture.
	Acres.					
Wakool—Treeless Plains ...	3,720	1 unit to 4 acres.	1 unit to 2 acres.	3 units to 2 acres.	*	*
Wakool—Inundated Clays	3,711	1 unit to 4 acres.	3 units to 4 acres.	2 units per acre.	*	*
Wakool—Red-brown Earths	1,843	1 unit to 3 acres.	...	3 units per acre.†	11 units to 4 acres.	15 units to 2 acres.
Berriquin	1,236	1 unit to 2 acres.	...	7 units to 2 acres.†	11 units to 4 acres.	15 units to 2 acres.

* The number of farmers in the Treeless Plains and Inundated Clays groups who had summer pasture was so small that any stocking rates obtained for summer pasture for these two groups would have little validity.

† These two results were obtained in a slightly different manner to the others, but they are strictly comparable with stocking rates in other soil groups and on different types of pasture.

2. DESCRIPTION OF THE SURVEY.

The survey of 82 farms in the Berriquin and Wakool Irrigation Districts was carried out during the latter part of 1952. The main purpose of the survey was to ascertain the carrying capacity on three main soil types within the two districts.

The location of both districts is shown in the inset of Map I. The different soil types in the Wakool Irrigation District are shown in the main part of that map[1]. The three main soil types which are irrigated in the Wakool District are: (1) Red-brown Earths (type A on Map I);

[1] A detailed description of soils, climate and vegetation in the Wakool Irrigation District is to be found in Bulletin 162, C.S.I.R., Melbourne, 1943.

(2) Grey soils subject to inundation (type B, also referred to as "Inundated Clays"); (3) Grey and brown soils of the Treeless Plains (type C, also referred to as "Treeless Plains Soils".) No equally detailed study of soils in the Berriquin Irrigation District has been made. Most farmers in that district irrigate on soils of the red-brown earth type. The remainder farm on grey and brown soils of heavier texture. It was considered that available knowledge of soil types in the Berriquin District was insufficiently detailed to warrant an analysis similar to that undertaken for the Wakool District. Known differences in carrying capacity on different soil types in the Berriquin District are much smaller than in the Wakool District[2].

The Wakool Irrigation District contains 251 holdings, comprising 486,192 acres[3]. Water was first supplied to some landholders in the district in 1935. Most of the district has an average annual rainfall of 13 to 14 inches. The Berriquin Irrigation District contains 892 holdings, with a total area of 654,000 acres. Water first became available to farmers in the eastern portion of the district in 1939-40. The Berriquin District is more densely settled than the Wakool District. Practically the whole of the Berriquin District has an annual average rainfall exceeding 15 inches, and over half the area has an average rainfall of 16 inches or more. Both districts derive their water supplies for irrigation from the Hume Reservoir on the Murray River. Water supplies in both districts are controlled by the Water Conservation and Irrigation Commission of New South Wales. Every farm in the two districts is entitled to a certain quantity of water—based on the area of the farm. In the Wakool District, for every ten acres, one acre-foot of water (also referred to as one water right) is provided. A similar arrangement existed in the Berriquin District until 1949 when the Water Conservation and Irrigation Commission gave landholders the opportunity to increase their water rights from one for every ten acres to one for every three acres—with a maximum of 200 water rights for any one farm. The majority of farmers applied for the increased water rights. In addition, landholders in both districts can purchase additional water from the Commission when it is available. Most farmers have used water in excess of their water rights in recent years.

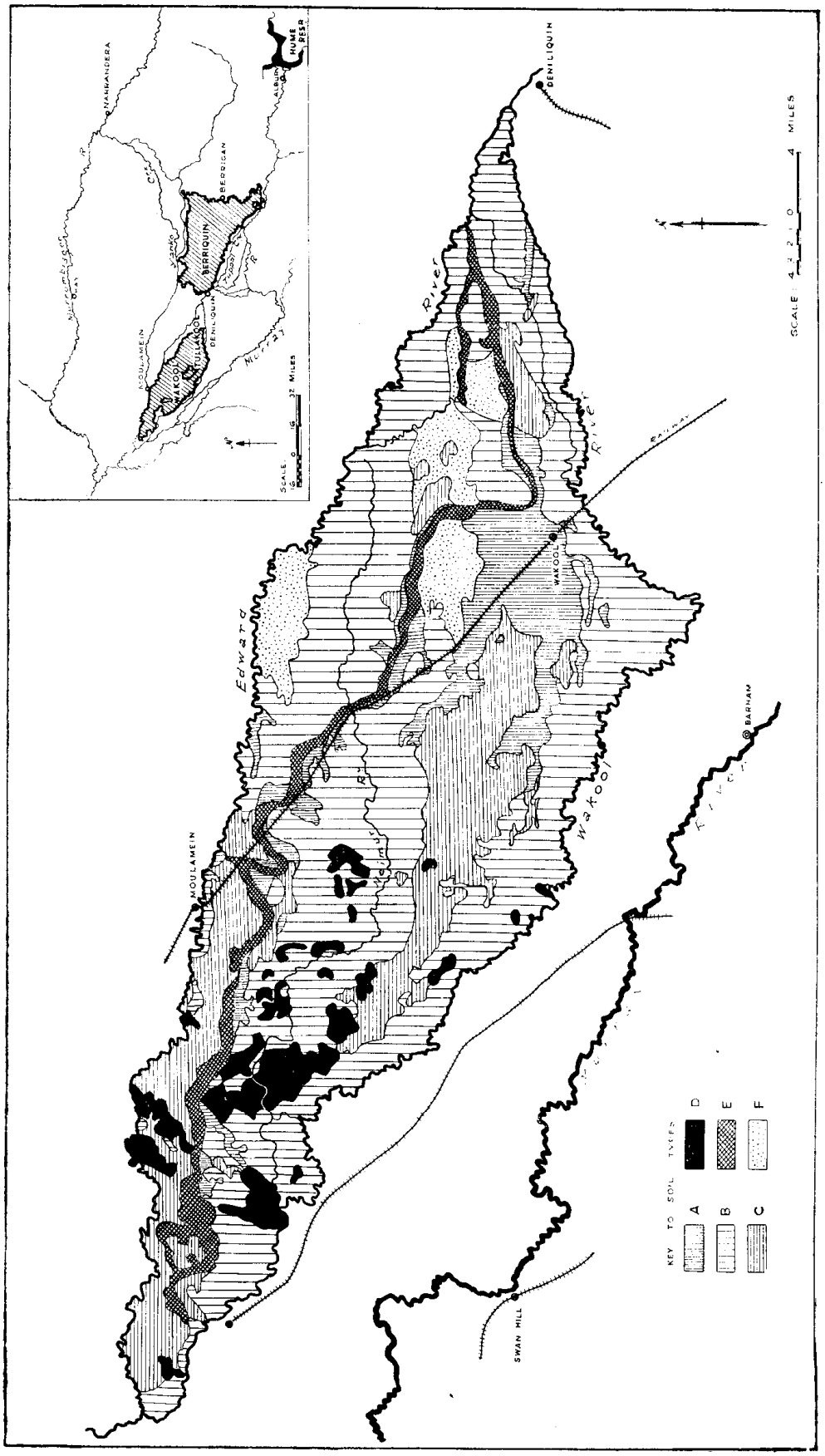
For the purpose of the survey 32 farms in the Berriquin District were selected at random[4]. In the Wakool District the sample was chosen so as to ensure that a sufficient number of farms fell within each of the three major soil groups. Within each of the soil groups the selection was at random[5]. One major bias was discovered after the

[2] A reconnaissance soil survey in the Berriquin District was carried out in 1943; C.S.I.R. Bulletin 189 gives a generalized soil map of the Berriquin District and a description of the climate and vegetation of the district.

[3] This excludes the Tullakool Irrigation Area which is wholly within the Wakool Irrigation District.

[4] The sampling procedure is discussed in Appendix II.

[5] While the sample was selected at random within the three major soil groups, the sample cannot be regarded as representative of the Irrigation District as a whole. The reason is that the proportion of survey farms in each soil group does not correspond to the proportion of such farms in the District. A more adequate sample in this respect would have required a survey of at least twice as many farms.



Map I.—Generalized Soil Map of the Wakool Irrigation District, New South Wales.

(*Adapted from Bulletin 162, C.S.I.R., Melbourne, 1943.*)

Soil type A=Red-brown Earth; B=Inundated Clays; C=Treeless Plains; D=Mallee Rises; E=Yarrein Complex; F=Soil types A, B and C are in such close proximity that they cannot be distinguished on this map.

sample was completed. This had the effect of giving undue weight to the larger farms in both districts. However, it is unlikely that this bias has a significant effect on the estimates of stocking rates given below.

3. FARM ENTERPRISES.

Before irrigation water was supplied to the two districts, most of the survey farms ran Merino sheep. In the Berriquin District the majority of farmers combined this with wheat-growing. After irrigation water became available, all but five of the survey farms switched to the production of fat lambs. In the last three years, under the influence of very high wool prices, two farmers in the Wakool District have returned to pure Merino flocks, and many others have laid more stress on wool (e.g., by turning from Border Leicester-Merino crossbred ewes to Corriedale or Merino ewes) while still producing fat lambs.

TABLE II.

Types of Farm Production before Irrigation.

Type of Product.	Number of Farms.		
	Berriquin.	Wakool.	Total.
Wool only	9	35	44
Wool and Wheat	14	5	19
Predominantly Wheat (with little or no grazing)	6	0	6
Fat Lambs and Wheat	2	3	5
Breeding Crossbred Ewes	0	2	2
Breeding Merinos and Fat Lambs	0	2	2
Fat Lambs and Beef	1	1	2
Total	32	48*	80*

* In two cases no information on pre-irrigation farming was available.

In 1952, 22 of 30 survey farms in the Berriquin District grazed crossbred sheep—of these the Border Leicester-Merino first cross ewe was the most popular type (15 farms). Four farmers used Merino ewes and four Corriedales. In the Wakool District 32 of the 47 survey farms ran mainly crossbred sheep, Border Leicester-Merino cross again being the most popular (14 farms). Five farmers used Merino ewes whilst still breeding fat lambs[6].

Of ram breeds, by far the most popular in both districts was the Dorset Horn (Wakool 20 farms, Berriquin 14). This was followed in the Wakool District by Border Leicesters (14 farms), Southdown (6), Merino (5) and Corriedale (3). In the Berriquin District, after Dorset Horn, Corriedale rams were the most popular (6 farms), followed by Southdown (4), Border Leicester (3) and Merinos (2).

[6] Of the ten remaining survey farmers in the Wakool District, five ran Merino sheep but did not produce fat lambs.

TABLE III.

Types of Farm Production on Survey Farms, 1951-52.

Products.	Number of Farms.		
	Berriquin.	Wakool.	Total.
Fat Lambs and Wool	29	45	74
Wool (without Fat Lambs)	2	5	7
Wheat	20	16	36
Rice	...	28	28
Beef	7	16	23
Dairy Products	7	4	11
Lucerne Hay	...	1	1
Vegetables	...	2	2
Crossbred Ewes	...	1	1

Irrigation has enabled farmers to diversify their farming operations considerably. In the Berriquin District dairying and beef cattle raising have become profitable sidelines, while some of the smaller farmers rely on dairying for the whole, or a major portion, of their income. However, dairying and beef raising are still restricted to a small proportion of all farms in the district. In the Wakool District, beef cattle and to some extent dairying have become important sidelines, but the most important new form of land use—apart from fat lamb production—is rice-growing. Twenty-eight of the 50 survey farmers in the Wakool District grew rice in 1951 and/or 1952[7]. Rice is a popular crop, largely because it is very profitable. In addition, it is believed that rice will improve the permeability of the soil for the subsequent irrigation of pasture. The Water Conservation and Irrigation Commission of New South Wales controls the area of rice which each landholder is allowed to plant. This control is exercised because of the large amount of water used for rice-growing (rice needs about four to five times as much water per acre as irrigated pasture). The object of this control is to conserve water for pasture and to prevent the occurrence of water-logging and similar problems which may appear after years of intensive rice-growing.

[7] This proportion probably exceeds the percentage of all farmers in the Wakool District growing rice because of over-representation in the sample of farms on treeless plains soils where more rice-growing has been permitted than on other soils.

Table IV shows the major combinations of enterprises on the survey farms. In the Berriquin District two-thirds of the farms produce fat lambs (and wool) alone or in conjunction with wheat, with no other sideline.

TABLE IV.

Major Combinations of Farm Enterprises on Survey Farms, 1951-52.

Products.	Number of Farms.		
	Berriquin.	Wakool.	Total.
Fat Lambs (and Wool) only	8	11	19
Fat Lambs, Wool, Wheat...	13	1	14
Fat Lambs, Wool, Rice	...	9	9
Fat Lambs, Wool, Wheat, Rice	...	7	7
Fat Lambs, Wool, Wheat, Beef, and Dairying...	4	1	5
Dairying and Beef	...	2	2
Wool and Beef	...	2	2
Total*	25	33	58

* This table includes only those combinations which exist on two or more farms. In addition there were seven farms in the Berriquin District and seventeen in the Wakool District with different (individual) enterprise combinations.

4. FARM SIZE.

The distribution of farms according to total acreage is shown in Table V. Two farmers in the Wakool District owned land outside the Irrigation District; this last was farmed in conjunction with land within the district. In these two cases the total farm area given in Table V includes the area outside the Irrigation District. There were considerable differences in average farm size between farms on different soil groups in the Wakool District. Average farm size in the Wakool District was 3,720 acres for the treeless plains farm group, 3,711 acres for farms with irrigation on inundated clays, but only 1,843 acres for the best soils—the red-brown earth group. Average farm size of the inundated clays group (3,711 acres) has perhaps been unduly influenced by one property in this group of 10,000 acres. If this property were omitted, the average for the group would be 3,629 acres. Average farm size in the Berriquin District was 1,236 acres, but the range was very wide, the smallest farm being 92 acres and the largest 5,050 acres. The most common size group in the district was between 750 and 1,000 acres.

TABLE V.

Distribution of Farms According to Total Area.

Group.	Acres.								Total.
	Less than 500.	501–750.	751–1,000.	1,001–1,500.	1,501–2,000.	2,001–3,000.	3,001–5,000.	Over 5,000.	
Wakool—Treeless Plains	...	...	3	...	2	3	5	6	19
Wakool—Inundated Clays ...	...	...	1	1	2	3	5	3	15
Wakool—Red-brown Earths ...	...	1	2	3	4	1	3	...	14
Total Wakool* ...	...	1	6	4	9	8	13	9	50
Total Berriquin	3	7	9	5	5	2	...	1	32

* This total includes two farmers who were irrigating mainly on Yarrein Complex type of soils.

5. "CARRYING CAPACITY" AND STOCKING RATES.

The original purpose of the survey was to obtain a measurement of carrying capacities on different types of pastures in the Wakool and Berriquin Irrigation Districts. Carrying capacity may be defined as the maximum number of stock which can be grazed on a unit area of land without the stocking resulting in any deterioration of the pasture concerned. Carrying capacity in this sense is a term often used in popular discussion, but rarely in scientific studies. The concept may be very useful to a person who is considering the purchase of farm land, but it is almost impossible to measure accurately in any particular case.

The figures which were obtained from farmers make it possible to estimate the actual number of stock carried on the survey farms in the two districts in recent years. However, the number of stock actually carried per acre (*i.e.*, stocking rates) can be regarded as an estimate of carrying capacity only if the best possible methods of pasture management are used by the survey farmers, including stocking rates used by farmers which do not lead to any deterioration of the pasture. The difficulty could be overcome to some extent by regarding the stocking rate obtained as equivalent to the carrying capacity, given an average degree of skill in pasture management, but the problem of pasture deterioration requires more detailed examination.

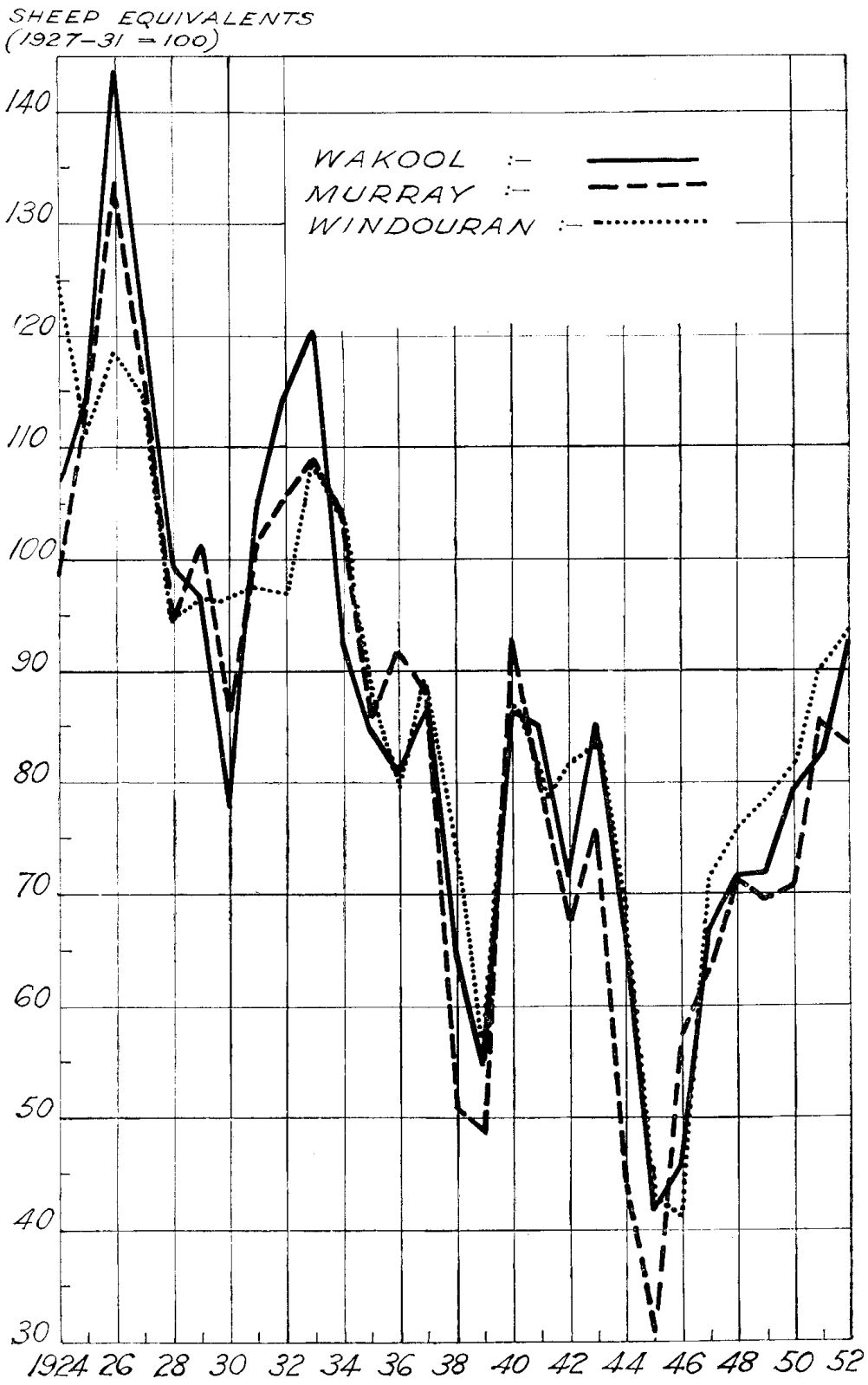


Fig. 1.—Changes in Sheep Equivalents in the Shires of Wakool, Murray and Windouran, 1924–1952.

(1927 = 100.)

(All sheep = 1; all cattle and horses = 8).

In many parts of Western New South Wales there has been a marked deterioration in pastures since the establishment of the pastoral industry, suggesting that graziers have been over-optimistic as to the carrying capacity of their lands. Available evidence shows that stocking rates on dry land in the Wakool Irrigation District have been declining for many years. Figure I shows changes in sheep equivalents (all sheep = 1; all cattle and horses = 8) for the Shires of Wakool, Murray and Windouran since 1924. These shires contain the Wakool Irrigation District and large areas surrounding it[8].

Figure II shows the changes in sheep equivalents for the Shire of Berrigan (which contains about 50 per cent. of the Berriquin Irrigation District) and the adjoining Shire of Jerilderie[9]. The trend in sheep equivalents in Berrigan Shire before irrigation and in Jerilderie Shire for the whole period, suggests that stocking rates on dry land in both shires have been declining, though at a slower rate than in Wakool, Windouran and Murray Shires.

If a survey similar to that now under consideration had been conducted in, say, 1935, the stocking rates obtained would probably have been in excess of carrying capacity at that time. Similarly, it is possible that present-day stocking rates exceed current carrying capacity. As the scope of this analysis is limited to an estimation of stocking rates, the figures obtained may not correspond with actual "carrying capacity" as defined above.

6. CLIMATIC CONDITIONS DURING THE PERIOD.

Table VIII shows stocking rates and related information for the different groups of survey farms. The stocking rates obtained relate to the period from 1st July, 1949, to 30th June, 1952. During these three years (1949-50, 1950-51 and 1951-52) farmers in both districts enjoyed very good seasonal conditions. Annual rainfall was considerably above average in all three years in the Berriquin District. In the Wakool District, 1950-51 and 1951-52 rainfall was approximately equal to the long-run average, but in 1949-50 rainfall figures were considerably higher than normal. (See Table VI.)

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[8] Windouran Shire is north-east of, and Murray Shire south-east of Wakool Shire. Wakool Shire has a total area of 1,180,000 acres. The irrigation district accounts for less than 25 per cent. of the area of the Wakool Shire, so that the effect of irrigation on sheep equivalents is obscured. The increase in sheep numbers in the Wakool Irrigation District as a result of irrigation has probably been in the neighbourhood of 90,000 dry sheep equivalents. This increase is not apparent in Figure I because approximately 70 per cent. of the increase took the form of a change from Merinos to crossbred sheep (for which the graph makes no allowance), and because the decline in stock numbers depastured on dry land in Wakool Shire was much greater than the residual increase resulting from irrigation.

[9] Berrigan Shire has an area of 506,000 acres, of which approximately 300,000 acres, or 60 per cent., are within the Berriquin Irrigation District. This irrigation portion of Berrigan Shire obtained water relatively early (1939-40), and has probably been more fully developed than other portions of the Berriquin Irrigation District. The divergence in sheep numbers between Berrigan and Jerilderie Shires since the introduction of irrigation is most striking. Jerilderie Shire borders on Berrigan Shire to the north. It has an area of 842,000 acres, of which approximately eight per cent. is within the Irrigation District.

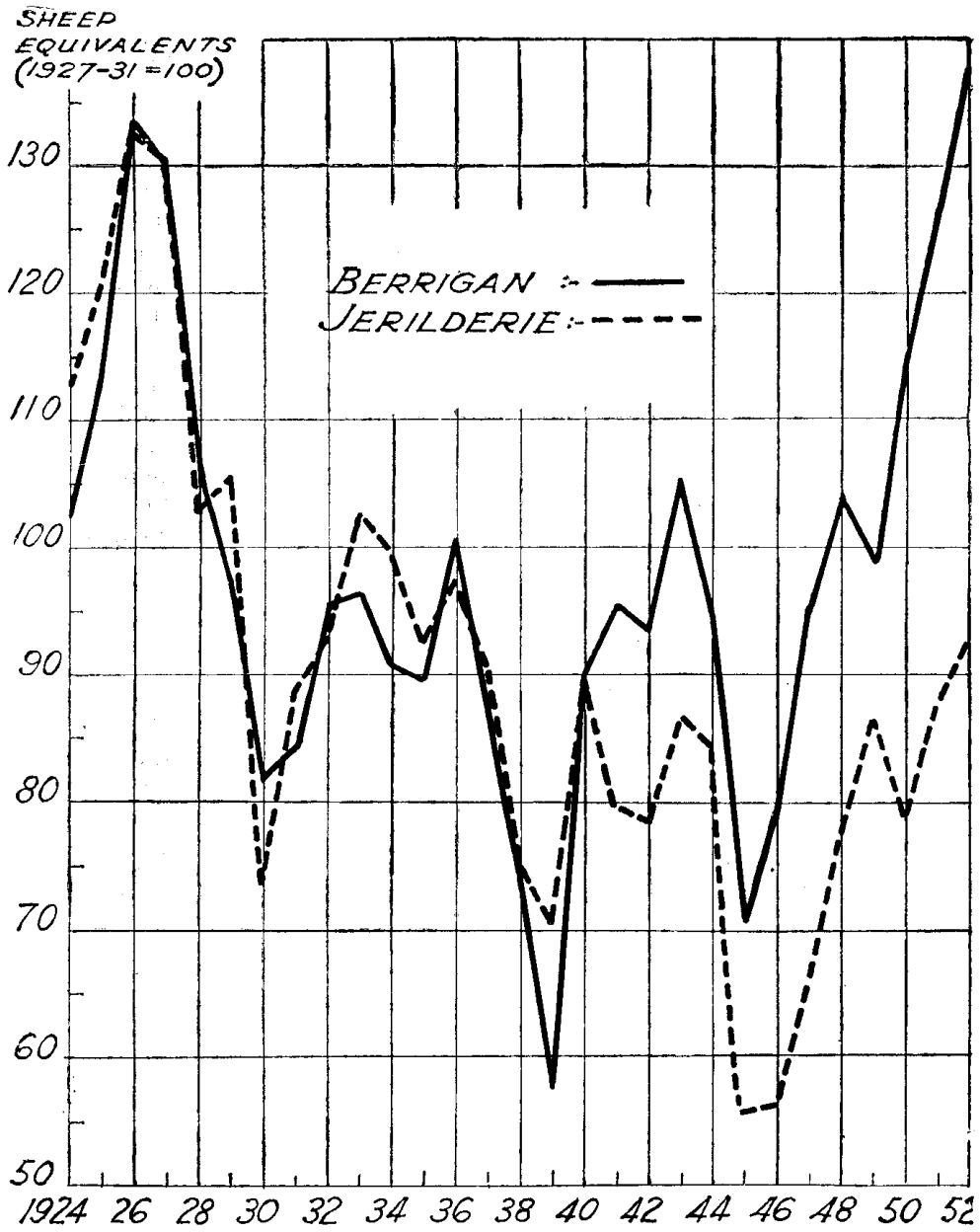

Fig. II.—Changes in Sheep Equivalents in the Shires of Berrigan and Jerilderie, 1924–1952.
(1927=100.)
(All sheep=1 all cattle and horses=8.)

TABLE VI.

Rainfall at Three Localities Adjacent to the Irrigation Districts.

Period.	Berrigan.	Deniliquin.	Moulamein.
	inches.	inches.	inches.
Average annual rainfall (1911–1940) ...	16·93	15·46	14·12
1949–50	21·20	24·12	17·53
1950–51	18·51	16·96	14·21
1951–52	18·52	15·74	13·89

Rain is vital in both districts in March and April to ensure satisfactory germination of the native plants. In both districts March-April rainfall was very high in 1950 and 1952. In 1951 it was below average, but this was to some extent compensated for by high rainfall in February and May of that year. Generally speaking, the three years for which stock numbers are available were very favourable seasons for the farmers in both districts. There is little doubt that stocking rates on dry land in these years were at levels which are in excess of the average which would be maintained over a long period.

TABLE VII.

Rainfall in March and April at Three Localities Adjacent to the Irrigation Districts.

March–April Rainfall.	Berrigan.	Deniliquin.	Moulamein.
	inches.	inches.	inches.
Average (1911–1940)	2·61	1·99	1·66
1950	7·12	7·57	3·71
1951	1·02	1·00	1·68
1952	4·44	3·13	3·42

7. METHOD OF ESTIMATING STOCKING RATES.

To obtain stocking rates it is necessary to convert all livestock on the survey farms to a common unit. The ratios between different types of livestock should represent, as closely as possible, the relative feeding requirements of the animals concerned. In this study the following ratios were used[10]:—

1 crossbred ewe and lamb = 2 dry sheep.
1 ram = 2 dry sheep.
1 merino ewe and lamb = $1\frac{1}{3}$ dry sheep.
1 milking cow = 9 dry sheep.
1 steer or heifer = 5 dry sheep.
1 weaner calf = 3 dry sheep.
1 adult fattening beast = 9 dry sheep.
1 adult store beast = 6 dry sheep.
1 bull or draught horse = 10 dry sheep.
1 hack = 8 dry sheep.

[10] These ratios (except for one addition and one alteration) were originally used in a survey of the Tongala-Stanhope Irrigation Area in Victoria, carried out by the Bureau of Agricultural Economics. The writer is indebted to the Bureau of Agricultural Economics for this information.

The calculation of dry sheep equivalents is arbitrary and at best only an approximation. However, it provides the only way in which comparisons of stocking rates between different farms can be made. To estimate stocking rates on different types of pasture, a multiple correlation analysis was used. The essential point of the method in this case is that it attempts to explain how variations in the number of crossbred ewe equivalents on the survey farms are related to differences in the area of dry land and in the area of irrigated pasture[11].

The survey farms were divided into five groups. In the Wakool District the basis of the division was the predominant soil type of the irrigated paddocks. The three soil groups were: Treeless Plains, Inundated Clays and Red-brown Earths[12]. (See Map I.) In the Berriquin District most of the survey farmers were irrigating pasture on red-brown earths. The grouping of farms in the Berriquin District was according to size; one analysis included thirty farms (two farms had to be rejected because of insufficient information) and another correlation was run with "small" farms (under 1,000 acres) only.

The stocking rates given in Table VIII need further explanation. The figure in the top left-hand corner of each "box" gives the increase in the numbers of crossbred ewes which a farmer in each of the soil groups could have carried (during 1949-50 to 1951-52) if he had had one additional acre of dry land (or flood land or irrigated land, whichever the case may be). The plus and minus figure to the right of these stocking rates gives the standard error for each particular estimate[13].

The figure given below the original estimate of stocking rates represents a second estimate of stocking rates. Where this second figure is *higher* than the original estimate, it indicates that the smaller farms within each soil group are being stocked more heavily than the average, and *vice versa*. As was mentioned earlier, the sample originally selected was biassed in favour of the larger farms, so that in this case the second figure, which in three out of four correlations gives the higher result, may perhaps be regarded as a more accurate estimate of average stocking rates.

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[11] An attempt is made in Appendix III to explain by means of a simple example how multiple correlation analysis has been used to calculate stocking rates.

[12] In addition to these broad soil groups there are some areas of Mallee soil in the Wakool District, but these are on high ground and are not commandable by gravitational irrigation. There are some farmers who irrigate mainly soils of Yarrein Complex. Two of these were included in the sample. They were not included in the subsequent analysis.

[13] Thus in the case of the treeless plains soil group, 13 of the 19 survey farmers (i.e., 68.3 per cent.) had stocking rates on irrigated pastures which were between 1.40 and 1.76 ewes per acre, and 18 of the 19 survey farmers (i.e., 95.45 per cent.) had stocking rates between 1.22 and 1.94 ewes per acre.

TABLE VIII.

Stocking Rates on Survey Farms and Related Information.

Farms Classified by Districts, Predominant Soil Type Irrigated or Size.	Number of Farms.	Average Areas on Survey Farms.			Average Size of Farms.¶	Average Age of Irrigated Pastures.	Stocking Rates (Crossbred Ewes and Lambs per acre).*				
		Dry Land.	Flood Land.	Irrigated Pastures.			Dry Land.	Flood Land.	All Irrigated Pastures.	Irrigated Winter Pastures.	Irrigated Summer Pastures.
		Acres.	Acres.	Acres.	Acres.	Years.					
Wakool—											
Irrigated Pastures predominantly :											
Treeless Plains ...	19	2,557	568	330	3,720	7·0	·24 ± ·02§	·46 ± ·04	1·58 ± ·18	...	...
							·24 ‖	·46	1·58	...	...
Inundated Clays ...	15	2,402	645	273	3,711	5·4	·24 ± ·15§	·73 ± ·17	1·80 ± ·35	...	...
							·25 ‖	·77	1·95	...	...
Red-brown Earths	14	1,487	58	229†	1,843	7·4†	·31 ± ·12§	...	...	3·18 ± ·89	9·56 ± 4·11
				18‡	...	6·8‡	·29 ‖	...	...	2·70	7·24
Berriquin—											
All Farms	30	914	...	178†	1,236	6·8†	·49 ± ·02§	...	...	2·67 ± ·39	6·88 ± 1·44
				33‡	...	6·2‡	·50 ‖	...	...	2·75	7·49
"Small" Farms ...	19	521	...	149†	769	6·8†	·48 ± ·07§	...	...	2·71 ± ·48	7·21 ± 1·41
				36‡	...	6·1‡	·51 ‖	...	...	2·84	7·74

* To convert stocking rates to dry Merinos, multiply the number of crossbred ewes per acre by 2.
† Irrigated winter pastures.
‡ Irrigated summer pastures.
§ The top figures in each row of stocking rates represent the normal regression coefficients.
‖ These are the regression coefficients taken through the origin. The standard errors (i.e., the ± figures) were obtained only for the top row, but have similar values for most of the lower figures.
¶ The average area of dry land, flood land and irrigated land on each soil type falls short of the average size of farms in each group for the following reasons :— (1) Land which is cropped (usually wheat or rice) has been excluded for the season when the crop is in; (2) In the case of many farms on treeless plains and inundated clay soils, large areas of flooded land were completely inundated for more than one year. (This is largely the result of better-than-average rainfall between 1949–50 and 1951–52.) Such completely inundated areas were excluded from the classification "flood land."

8. INTERPRETATION OF STOCKING RATES.

Stocking rates on dry land do not appear to differ appreciably between soil types in the Wakool District. On farms on both the treeless plains and inundated clay groups of soils, the stocking rates were approximately one crossbred ewe to four acres (or one dry sheep to two acres). The corresponding figure for farms on the red-brown earths group in the Wakool District was slightly higher. This may be the result of smaller farm size in that group. In addition, most of the farms irrigating on red-brown earths are in the eastern sector of the Wakool District and receive a slightly higher annual rainfall. In any case the error term (.12) is large enough to suggest that there is little difference in stocking rates on dry land as between the three soil groups within the Wakool District.

Twenty of the 34 farmers in the treeless plains and inundated clay soil groups had land which was subject to periodic inundation from neighbouring streams. As some farms relied to a considerable extent on such flood land for feeding their sheep, it was decided to use such land as a separate variable for these two soil groups[14].

Stocking rates for flood country among farmers irrigating mainly treeless plains soils were approximately one crossbred ewe to two acres, whilst the equivalent stocking rate for flood country among the farms on inundated clays was between .6 and .9 crossbred ewe equivalents per acre. The differences in stocking rates on essentially similar types of land between these two different groups of farmers are difficult to explain. However, flood lands varies tremendously in quality. Some areas are flooded regularly for several months of the year, others receive only occasional inundation in years of very high rainfall. A possible explanation is that the flood land of the farms on inundated clays is flooded more regularly and/or more heavily.

Approximately 90 per cent. of all pasture irrigated in these two soil groups was winter pasture—predominantly subterranean clover and Wimmera rye. It was therefore decided to measure stocking rates in both cases on all irrigated pasture together and to ignore differences between irrigated winter and irrigated summer pasture[15]. Stocking rates on irrigated pastures on treeless plains soils were between 1.4 and 1.76 ewes per acre. The corresponding figure for the inundated clay group of farms was 1.4-2.5 ewes per acre. Most farmers in the inundated clay group obtained the benefit of irrigation later than farmers in the other soil groups.

The carrying capacity of irrigated pastures increases with the age of the pasture. In the case of irrigated summer pasture this increase is probably continuous for eight to ten years, whereas irrigated winter pastures reach their peak carrying capacity after about three or four years and then remain at a more or less constant level as long as the pasture is properly managed. The average age of

[14] Only two out of 14 survey farms in the red-brown earth group in the Wakool District had such flood lands.

[15] The number of farmers in these two soil groups with irrigated summer pasture was so small that any result obtained for stocking rates on summer pasture would be of doubtful validity.

pastures on the survey farms in the inundated clay group is comparatively low and the proportion of irrigated pasture which has been laid down within the last three years comparatively high. This factor suggests that stocking rates on inundated clays comparable to stocking rates on other soil groups in the Wakool District would be above the 1.8 crossbred ewes given as the average in Table VIII[16].

The analysis of the farms in the red-brown earth group in the Wakool District is probably the least satisfactory. This group contains the smallest number of farms and, partly as a result of that, the probable range of stocking rates is the largest. In addition, this is the only group where the stocking rates obtained by the second method[17] are lower than the first estimate. In other words, stocking rates in this group are higher among the larger farms. This is the result of an unusual factor. All the large landholders in this group (i.e., with farms above average size) have been operating their farms since irrigation commenced in this area, namely, since 1936. Four of the smaller farmers are soldier settlers who obtained their farms in 1947-48. Over 60 per cent. of the irrigated pasture on these four farms has been laid down since 1949, whereas only 10 per cent. of the irrigated pasture on the larger farms was laid down after 1949.

In the Berriquin District stocking rates for both small and large farms on dry land were approximately one crossbred ewe to two acres. Stocking rates on both irrigated winter pasture and on irrigated summer pasture were relatively lower among the larger farms. The stocking rates on irrigated winter pasture were between 2.4 and 3.2 crossbred ewes to the acre. The equivalent range for summer pastures was 5.5 to 8.3 crossbred ewes per acre. On smaller farms stocking rates were relatively larger, but for both groups the average stocking rates were within the ranges given above. It seems likely that there is little or no difference in stocking rates on irrigated pastures between farms in the Berriquin District and farms on the red-brown earths in the Wakool District.[18]

Finally, one limitation of the stocking rates given in Table VIII must be mentioned. The stocking rates obtained relate, in each case, to a definite group of farms and can be applied only to farms which are similar in terms of combination of pasture areas to one or more of the farms studied. For instance, in the Berriquin District, it was found that an increase of two acres of irrigated summer pasture on the survey farms was associated, on the average, with an increase of 15 crossbred ewes (plus lambs). However, it cannot be inferred from this that

[16] A higher stocking rate is also suggested by the lower figure (i.e., 1.95). A figure comparable to the other soil groups would therefore probably be in the neighbourhood of two crossbred ewes per acre.

[17] i.e., by regression lines through the origin.

[18] The estimate by means of the first method (i.e., the ordinary regression coefficients) for the farms in the Wakool District is somewhat higher, but for purposes of comparison three factors have to be considered:

(*a*) The large difference between the stocking rates of large and small farmers in the red-brown earth group;

(*b*) The comparatively large standard errors (of the regression coefficients) in this group;

(*c*) The lower average age of pastures in the group of farms in the Berriquin District.

two acres of irrigated summer pasture will carry 15 crossbred ewes in any circumstances. In the case of the survey farms in the Berriquin District the average area of irrigated summer pasture was 33 acres, that of winter pasture 178 acres and the average area of dry land was 914 acres. If these proportions are changed materially, the number of sheep which could be run on such a farm could not be calculated by means of the figures given in Table VIII. The average survey farm in the Berriquin District carried approximately 1,200 crossbred ewe equivalents. Given the stocking rates in Table VIII, it is not possible to state that a farm with 100 acres of dry land, 178 acres of irrigated winter pasture and 87 acres of irrigated summer pasture would have carried about the same number of sheep because the proportions have been changed so radically that stocking rates possible in these circumstances have probably been altered very considerably.

APPENDIX I.

History and Development of the Wakool and Berriquin Irrigation Districts[19].

Wakool Irrigation District.

The origin of pastoral penetration into the Western Riverina might well be attributed to the exploration of Captain Charles Sturt, who traced the course of the Murrumbidgee River in 1829-30, and who was followed by Major Mitchell to the Murray River in 1835-36. Stockmen followed close on the heels of the explorers and squatted without authority along the banks of the river, which were then beyond the "limits of location" or within the unsettled districts. Licences to depasture stock outside the settled districts came into being in 1837, and by 1847-48 the whole of the area along the banks of the rivers in the Western Riverina was dotted with stock stations. Under the 1846-47 Waste Lands Act or "Squatters Act", pastoralists were forced to apply for the stations they occupied as "Runs". It is from this period that the first meagre particulars of the properties in the Wakool area are available. In 1848 the area between the Wakool and Edward Rivers was held in large areas of from 50,000 to 200,000 acres. The carrying capacity of the virgin land apparently ranged from a sheep to four acres to a sheep to 15 acres. Under the Crown Lands Alienation Act of 1861, better known as Robertson's "Free Selection before Survey", settlers were enabled to take up areas within runs to 640 acres, at £1 per acre. Sale of Crown Lands for settlers, inclusive of town and suburban land, continued at £1 per acre, and large areas were disposed of by both conditional purchase and sale in the area between the Wakool and Edward Rivers. At the present time the greater part of the land, except that reserved for forestry and other purposes, is held on a freehold basis. Since the free sale of Crown Land in 1861 the size of the holdings has gradually decreased, due chiefly to the increased carrying capacity consequent on improvements of holdings by clearing, fencing and the provision of water supplies. By 1918 the holdings

[19] The Department of Lands kindly supplied the information on land settlement. The section on the Wakool Irrigation District was originally published in C.S.I.R. Bulletin No. 162—"The Soil and Land Use Survey of the Wakool Irrigation District, New South Wales," Melbourne, 1943, pp. 10-12.

varied in size from 5,500 to 70,000 acres, with an average carrying capacity of one sheep to two and a half acres. This period of 60 years was generally one of great economic stability for the area. Undoubtedly, temporary setbacks occurred when sheep and wool prices became depressed, but the recovery from these economic ills was rapid, because the structure of the area was sound. Holding areas had not been allowed to become too small nor had holdings become over-capitalized.

The post-war decade was a period of land settlement and subdivision in the Wakool District. The First Closer Settlement Act of 1904 proclaimed estates all over New South Wales which could not be subdivided, but must be sold as units. The purpose of the Act was to prevent land from being subdivided and sold privately at exorbitant prices. Proclaimed properties could be resumed by the State at prices ruling at the time the Act was passed. However, after World War I the Victorian Railways offered to push their railways across the border provided subdivision of estates 15 miles on each side of the railway line was made. The ban on subdivision of proclaimed estates was lifted, provided subdivision followed a design approved by the New South Wales Lands Department. From 1924 until 1928 land was subdivided by the estates and sold at public auction at highly competitive prices, which frequently reached £7 and occasionally £9 per sheep area, whereas 20 years later valuation by the Lands Department ranged from £3 10s. to £4 10s. per sheep area. Some land was bought in lots of less than 1,000 acres for the purpose of wheat-growing, and when this proved to be impracticable the holdings were found to be too small for efficient grazing management. Holdings that had been acquired for grazing purposes were often too small and many were over-capitalized. With the onset of the economic depression in 1929, the collapse of world prices for primary products and the restriction of credit placed the new landholders in a difficult financial position. Many of the holdings reverted to the vendors because of non-payment of commitments, whilst most of the settlers needed financial accommodation of some kind to enable them to carry on.

The supply of irrigation water to the Wakool District has been made possible by the regulation of the flow of the Murray River chiefly by the building of the Hume Reservoir. Water is diverted to the Edward River by keeping the Murray River at a fairly constant level. However, with the completion of the Mulwala Canal as far as the Edward River during the latter part of 1941, it became possible to supplement the flow of the Edward River with escape water from the canal. When the Lawson siphons carry the water of the Mulwala Canal across the Edward River at Deniliquin, the Wakool Irrigation District will be partially supplied with water diverted from the Murray River at the Yarrawonga weir. The proposal for the constitution of the Wakool Domestic and Stock Water Supply and Irrigation District was gazetted in January, 1931, and later agreed to by the landowners. The scheme involved the construction of Stevens Weir, a concrete structure about 200 feet wide across the Edward River, 15 miles from Deniliquin, and the excavation of 352 miles of irrigation channels. The work was commenced in March, 1933, and completed during 1939, although water had been made available during 1935 in the eastern part of the area. The

Wakool Stock and Domestic Water Supply and Irrigation District was constituted on 4th July, 1941, when a total of 38,700 water rights had been allotted to 214 holdings with an aggregate area of approximately 500,000 acres.

The annual charge for water for irrigation purposes was fixed at four shillings per acre-foot in the first year of irrigation, to be increased by two shillings per acre-foot each year until landowners paid ten shillings per acre-foot. In 1940-41 the maximum charge was reduced from ten shillings to 6s. 6d. per acre-foot. Since then there have been three increases in water charges. In 1947-48 the rate was raised to 8s.; in 1950-51 to 10s., and in 1952-53 to 20s. per acre-foot for the water supplied as regular water right, and to 15s. per acre-foot for water used in addition to the water right. Furthermore, there was a charge of 1d. per annum per acre of land within the Irrigation District for water for stock and domestic purposes. This charge was increased to 2d. in 1952-53.

Water use since the commencement of irrigation in the Wakool District is given in Table IX. Most of the water is used either for the irrigation of pastures or of rice fields. Water used for rice has been included in a separate column to show the fluctuations in water used

TABLE IX.

*Water Use in the Wakool Irrigation District.**

Year.	Total Water Use (excluding Water used for Rice).	Area of Pastures and Crops Irrigated.							Rice Water Use.
		Winter Pasture.	Lucerne.	Summer Pasture.	Native Grasses.	Cereals.	Fodder Crops.	Rice.	
	Acre-feet.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acre-feet.
1935–36	9,415	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	...	...
1936–37	15,912	1,455	993		15,055	n.a.	1,587	...	...
1937–38	57,720	5,567	n.a.		23,718	n.a.	5,866	...	...
1938–39	27,720	6,560	1,147		20,558	n.a.	3,644	...	...
1939–40	24,373	9,852	1,259		16,088	n.a.	1,974	...	...
1940–41	50,189	13,134	1,653		22,182	n.a.	5,506	...	...
1941–42	41,294	12,288	1,557		20,209	371	873	...	...
1942–43	39,627	14,262	1,738		21,814	300	323	n.a.	n.a.
1943–44	56,786	17,375	1,361		26,029	505	1,689	4,104	24,292
1944–45	76,206	17,386	1,600		24,385	1,700	3,935	4,803	28,550
1945–46	22,991	15,836	1,261		4,791	1,748	832	4,104	21,389
1946–47	38,956	19,321	959	740	11,963	1,326	508	...	...
1947–48	33,012	17,641	1,008	1,061	9,033	1,042	85	...	...
1948–49	44,004	20,262	958	1,125	10,259	1,926	831	3,426	18,380
1949–50	27,394	25,113	987	609	2,136	1,919	345	7,264	39,102
1950–51	36,442	25,306	918	429	3,707	1,717	644	8,890	55,069
1951–52	41,388	26,512	1,116	859	3,005	3,092	1,748	7,430	33,842

n.a.—not available.

* The figures for the area of pasture watered must be read with some caution. For instance, in years when March–April rainfall is high, many winter pastures, normally irrigated, may not be watered. Some of the fluctuations in area of irrigated pastures are therefore the result of differences in seasonal conditions.

for pastures. Periodic peaks in water use on pastures are the result of dry conditions when more water is needed for irrigated pastures. In addition, many farmers flood some of their natural grasses with water at such times. This is not recommended as a general practice, as the land soon becomes waterlogged and swamps and lagoons may be formed. The area of natural grasses watered has declined markedly in recent years. This is partly due to good seasons, but is probably also to some extent the result of improved knowledge of irrigation practices.

Berriquin Irrigation District.

Originally almost the whole of this area was included in the run taken up by Benjamin Boyd. He had come to Australia as manager for the Royal Bank of Scotland, and is first recorded as holding the run, called Deniliquin, in 1847. He was possibly in occupation a few years prior to that date. His territory embraced approximately the land between Tuppal and Tocumwal on the east, Warbreccan on the west, along the Edward River to Moira southward and Conargo northward.

Until the passing of the Waste Lands Act, 1846-47, the occupation of runs was by pasturage licences, which were issued annually. After that Act was passed, this somewhat unsatisfactory system was discarded and the areas of runs were defined and their occupation was by lease. In supplements issued to the *Government Gazette* in 1848, Benjamin Boyd's run was estimated as having an area of 700,000 acres and an estimated grazing capacity of 70,000 sheep. It was noted also in the *Gazette* that this run had been transferred to William Sprott Boyd, in whose name the lease was to be prepared. To the east of Deniliquin run, George Hillas is listed as occupying Burrongo Run, the extreme western part of which lies in the Berriquin Irrigation District. This run had an estimated area of 64,000 acres and estimated grazing capabilities of 500 horned cattle, 20 horses and 3,000 sheep. George Shaw's Carrabunganung Run, and Brougham and Woodford's Coree Run—which was transferred to Henry Burchett, in whose name the lease was prepared—both met Boyd's Run on the north. These two runs were also of wide extent, having estimated areas of 44,800 and 134,000 acres respectively; only very small portions of the southern parts of these runs lie in the Berriquin Irrigation District of to-day. To the south of Deniliquin Run, Redfern and Alexander held Morooa Run; Hennessey and Lester held Belubula Run, which had been transferred from Messrs. Huon and Lester; and Charles Barber held Wannock.

A survey carried out by Surveyor Townsend in 1848 of the south-western portion of the Murrumbidgee squatting district shows the type of country in the area which now comprises the Berriquin Irrigation District. East of the present town of Deniliquin, he notes that there are "very extensive plains"; and to the north of this, "level country interspersed with plains and forest destitute of water"; The country north and parallel to Billabong Creek is described as being "beautiful grazing country with a few belts of timber intervening between the saltbush plains."

Another survey completed by Townsend, dated May, 1848, shows the general direction of the main roads of proposed reserves thereon in the southern and western portions of the Murrumbidgee District. The

western road is shown as following the course of the Murray River and Tuppal Creek to Deniliquin, while the Great Road to Melbourne is shown running almost due south from Deniliquin. Reservations are noted at Tocumwal, Tuppal (at that time unnamed) and Deniliquin on the western road.

By the end of 1865 the runs mentioned above passed to new holders. In some instances they were split up, and many new holdings were taken up in the district and its immediate vicinity. This was the result of the Act of 1861, which provided for the unlocking of land held in runs. In 1865 approximately 725,000 acres, including most of the present Berriquin Irrigation District, was held in 14 runs which ranged in area from 8,000 to 148,000 acres. Further subdivision proceeded throughout the 'seventies. In the vicinity of Berrigan, wheat-growing began in the 'eighties; the farmers teamed their wheat to Jerilderie, where rail transport was available. Agitation for a railway to Berrigan became vocal and the plan and book of reference for the line was confirmed in 1895. The line was opened in 1896.

Finley was first known as Murray Hut, being on the main track from Tocumwal to Jerilderie. The surrounding country was in like manner more closely settled under the land legislation of 1861 and later the line crossed the bridge and Tocumwal was linked with Victoria. New South Wales then set about to recapture the trade passing from Tocumwal to Victoria, and finally, in 1914, a line from Finley was completed.

The advent of rail transport in the district meant the opening up of the land to the smaller holder and the shift from large sheep stations to cultivated holdings was assured. In addition to this, the legislation providing for closer settlement (which began with the First Closer Settlement Act of 1904) accelerated this subdivision. In a report for 1913 giving details of areas so affected, it is noted that most of the estates were formerly used as sheep runs, requiring only a few men to look after them. The acquisition and disposal of these estates meant a substantial gain to the whole State and a great increase in the rural population. For example, the Tuppal Estate (49,605 acres) was gazetted on 16th November, 1910, having been acquired by the Government for this purpose under agreement with the owners, and was subdivided into 116 farms, 18 of which were small areas. By 1911 the whole area had been allotted, and it is recorded that "many new settlers were experienced men, accustomed to wheat farming with a limited rainfall, and generally well equipped financially." The population of this area was then 355 persons and the area under cultivation 17,415 acres; the number of horses, cattle and sheep in the area was 1,044, 989 and 8,389 respectively. By the end of the nineteen-twenties, it is recorded that the land had increased greatly in value since its acquisition by the Government at approximately £4 per acre, so much so that land changed hands in places up to £10 and £12 per acre.

The number of wheat farms in the district has fluctuated considerably. This has probably been caused by changing economic conditions and a comparatively unreliable rainfall. Experience has shown that the eastern part of the district near Berrigan, Finley and Tocumwal is a comparatively safe area for cultivation, while much of the land further west on the Deniliquin side is not so well adapted to this purpose.

A proposal for the constitution of the Berriquin Irrigation District was first notified in the *Government Gazette* in September, 1933, and the constitution of a provisional district in March, 1934. Construction work commenced in the district in March, 1935, and proceeded until February, 1942, when construction ceased on account of the war. Late in 1943 further work on a much reduced basis was commenced, and the main district works were completed in October, 1944[20]. Water was first supplied to some landholders in the eastern portion of the district in 1939-40.

Water is sold to landholders in the Berriquin Irrigation District on the same terms as in the Wakool District. In 1939-40, when water was first made available, landholders paid 4s. per acre-foot; in 1940-41, 6s. From 1941-42 until 1947-48 the rate was 6s. 6d. per acre-foot. Since then there have been three increases in water charges, the last being in 1952-53, when the price was raised to 20s. per acre-foot for the water right and 15s. per acre-foot of surplus water used. Table X shows the changes in total water usage since 1940-41 and the areas of pasture and cereals which have been watered each year.

TABLE X.

Water Use in the Berriquin Irrigation District.

Year.	Total Water Use.	Area of Pastures and Crops Irrigated.*					
		Winter Pasture.	Lucerne.	Summer Pasture.	Native Grasses.	Cereals.	Fodder Crops.
	Acre-feet.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
1940–41	35,052	6,163	2,535		13,333	4,539	8,746
1941–42	38,950	9,931	6,050		15,184	4,701	2,214
1942–43	39,980		21,713		14,366	1,002	555
1943–44	74,796	22,693	7,705		21,335	6,660	4,210
1944–45	152,797	33,370	9,218		22,773	24,842	15,433
1945–46	58,324	26,528	7,299	2,495	5,809	26,992	1,778
1946–47	110,974	42,130	13,248		10,128	22,925	2,304
1947–48	91,995	44,679	11,509	4,082	10,689	10,371	1,375
1948–49	118,240	55,944	12,459	6,944	11,420	20,922	3,766
1949–50	101,692	56,762	12,775	7,172	3,471	21,614	2,190
1950–51	156,622	80,096	11,445	6,000	12,167	7,353	2,439
1951–52	134,066	70,682	11,254	8,629	6,574	1,958	2,133

* The same reservation has to be made regarding the accuracy of the area of pastures irrigated as in Table IX.

APPENDIX II.

Sampling Procedure.

The Water Conservation and Irrigation Commission of New South Wales has a complete list of the owners of all holdings in each Irrigation District. For both district samples all holdings were numbered, and with the use of tables of random numbers, the holdings whose owners were to be interviewed were selected.

[20] Altogether 703 miles of channels had to be excavated; of this, 93 miles were main canals (i.e., the Mulwala Canal and the Berrigan Channel).

For the Berriquin District an original sample of 30 holdings and a replacement sample of 15 holdings were prepared. The replacements were used in the case of (*a*) outright refusals; (*b*) where the information on stock numbers was not complete or detailed enough; (*c*) owners who had obtained their farms after June, 1949. The last qualification excluded most of the ex-servicemen who had obtained farms under the War Service Land Settlement Scheme. It is believed that this factor is responsible for the discrepancy which was found between the average area of all holdings in the Berriquin District (733 acres) and the average area of the survey holdings (765 acres).

For the Wakool District a similar procedure was followed, except that holdings were checked against a soil map so as to ensure adequate representation of all three major soil types. When the original sample of 45 holdings was checked with a soil map it was found that an insufficient number of holdings on red-brown earths had been included to allow for a satisfactory analysis of stocking rates in this group. Further holdings were therefore selected by means of random numbers, but only those additional holdings were included in the original Wakool sample which were situated predominantly on red-brown earths. Three replacement sample lists (one for each soil type) were also prepared and used in cases of refusals, insufficient information or recent settlers.

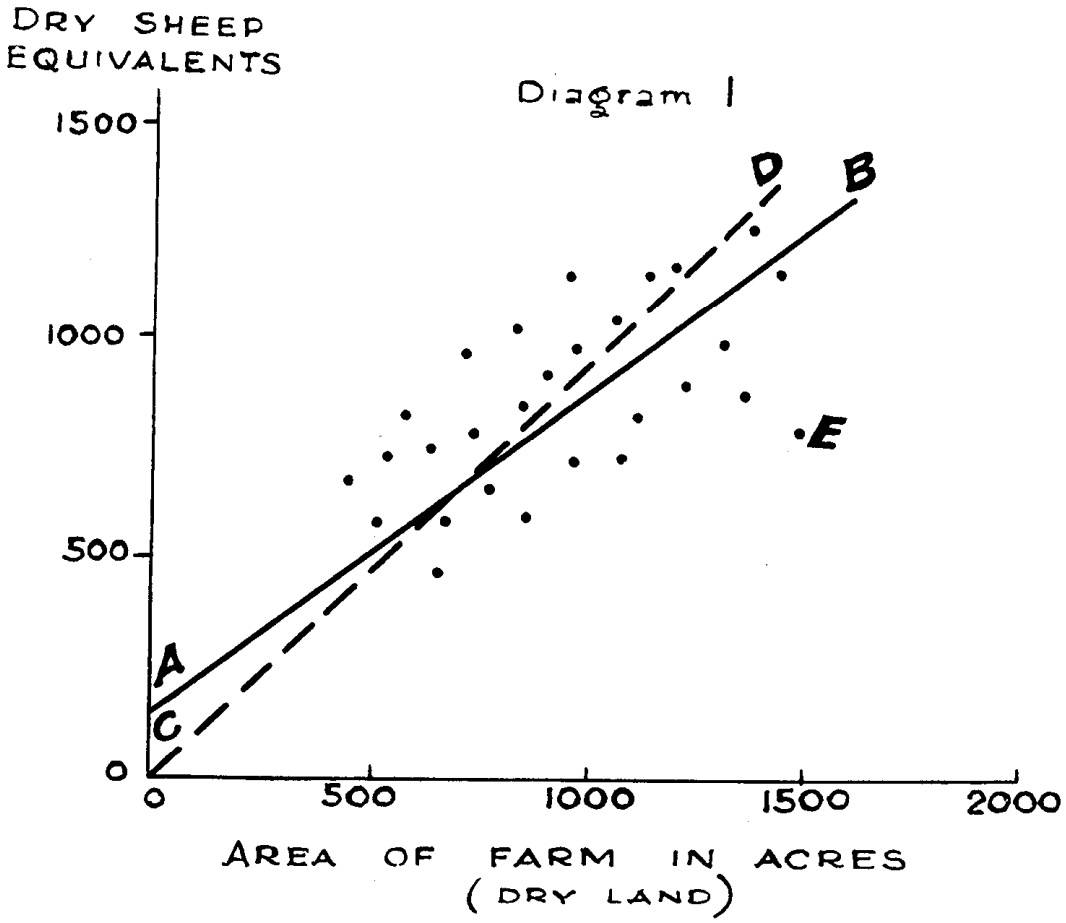
The main defect of the sample is that it was originally designed as a random sample of *holdings* and not of *farms*. Many farmers in both districts (especially in the Wakool District) operate two or more holdings as one farm. (In many cases several holdings are owned by different members of one family, but are operated as a single unit.) A farm consisting of two holdings, therefore, had twice as great a chance of being included in the sample as a farm comprised of only one holding. Although holdings differ in area, most of the two-holding farms are larger than the one-holding farms. The sample is therefore biassed in favour of the larger farms.

APPENDIX III.

Statistical Method Illustrated.

The method used can best be illustrated by a hypothetical example relating to stocking rates on farms not irrigating. If the number of sheep equivalents on a group of farms and the area of dry land on each of these farms is plotted on a diagram, we obtain a series of dots as in Diagram I. Each of these dots represents one farm. For instance, the dot next to the letter E represents a farm with 1,480 acres which carried 820 sheep.

Theoretically, if all the farm land were of uniform quality and managed identically, all the points would lie on one line. However, in actual fact there are many factors which will affect stocking rates, apart from the area of land operated by each farmer, so that some degree of scatter about the true line will always exist. In this case the line would have to be drawn in such a way as to fit the observations (i.e., the dots on the diagram) most closely. In the example given above, this would be the line AB. This line gives the increase in sheep equivalents on that group of farms which was observed to be associated with an increase in the area of land available. The slope of the line will give the stocking rates required. In this hypothetical example, the line AB does not



go through the point of origin on the graph. This leads to the nonsensical conclusion that a farmer with no land can still have some sheep! This paradox exists in the above diagram and in three correlations undertaken in this study because, generally speaking, farmers on small areas tend to stock more heavily than their bigger neighbours, even if they are both on similar land. However, it is known that the actual line should go through origin, i.e., that farmers with, for instance, 1,000 acres should be able to run twice as many sheep as farmers with 500 acres of similar country. Hence a second line—CD in Diagram I—can be drawn which is similar to line AB, but which has the additional characteristic of going through the origin. The slope of this new line CD provides another estimate which may in some cases be regarded as a more accurate estimate of average stocking rates.

The example which has been discussed above allows for the influence of only one variable, namely, dry land, on stock numbers. For the study of stocking rates in the Wakool and Berriquin Districts, three variables were used, but the principle involved is exactly the same as in Diagram I.

APPENDIX IV.

Statistical Results Obtained.

X_1 = Number of crossbred ewe equivalents.

X_2 = Area of dry land (land which has been cropped was excluded for one season).

X_3 = Area of flood land.

X_4 = Area of all irrigated pastures.

X_5 = Area of irrigated winter pastures.

X_6 = Area of irrigated summer pastures (including lucerne).

M_{x1}, M_{x2}, M_{x3}, etc., are the averages of X_1, X_2, X_3, etc., for each group of survey farms.

$\bar{R}^2$ = Square of the multiple correlation coefficient adjusted according to the size of the sample.

S = Standard error of estimate.

$s_{b12\cdot34}$ = Standard error of estimate of regression coefficient $b_{12\cdot34}$

Wakool Treeless Plains—

$M_{x1} = 1{,}410\cdot5$ $M_{x2} = 2{,}556\cdot7$

$M_{x3} = 567\cdot6$ $M_{x4} = 330\cdot3$

$X_1 = \cdot2444X_2 + \cdot4585X_3 + 1\cdot5813X_4$

$X_1 = 9\cdot472 + \cdot2421X_2 + \cdot4571X_3 + 1\cdot5818X_4$

$\bar{R}^2 = \cdot8986$ $S = 346\cdot75$

$s_{b12\cdot34} = \cdot0245$ $s_{b13\cdot24} = \cdot0410$

$s_{b14\cdot23} = \cdot1704$

Wakool Inundated Clays—

$M_{x1} = 1{,}611\cdot35$ $M_{x2} = 2{,}402\cdot7$

$M_{x3} = 645\cdot0$ $M_{x4} = 273\cdot4$

$X_1 = \cdot2510X_2 + \cdot7691X_3 + 1\cdot9532X_4$

$X_1 = 82\cdot4 + \cdot2351X_2 + \cdot7332X_3 + 1\cdot7985X_4$

$\bar{R}^2 = \cdot8974$ $S = 1{,}030\cdot9$

$s_{b12\cdot34} = \cdot1515$ $s_{b13\cdot24} = \cdot1686$

$s_{b14\cdot23} = \cdot3552$

Wakool Red-brown Earths—

$M_{x1} = 1{,}175\cdot2$ $M_{x2} = 1{,}486\cdot7$

$M_{x5} = 228\cdot6$ $M_{x6} = 18\cdot4$

$X_1 = \cdot2927X_2 + 2\cdot6953X_5 + 7\cdot2426X_6$

$X_1 = -184\cdot12 + \cdot3067X_2 + 3\cdot1826X_5 + 9\cdot5550X_6$

$\bar{R}^2 = \cdot7881$ $S = 285\cdot556$

$s_{b12\cdot56} = 1\cdot241$ $s_{b15\cdot26} = \cdot8898$

$s_{b16\cdot25} = 4\cdot111$

Berriquin Total—

$$M_{x1} = 1{,}197{\cdot}5 \qquad M_{x2} = 913{\cdot}6$$
$$M_{x5} = 178{\cdot}1 \qquad M_{x6} = 32{\cdot}7$$
$$X_1 = {\cdot}5069X_2 + 2{\cdot}7504X_5 + 7{\cdot}4892X_6$$
$$X_1 = 45{\cdot}869 + {\cdot}4930X_2 + 2{\cdot}6737X_5 + 6{\cdot}8831X_6$$
$$\bar{R}^2 = {\cdot}9321 \qquad S = 129{\cdot}587$$
$$s_{b12{\cdot}56} = {\cdot}0269 \qquad s_{b15{\cdot}26} = {\cdot}3878$$
$$s_{b16{\cdot}25} = 1{\cdot}4346$$

Berriquin Small Farms—

$$M_{x1} = 969{\cdot}9 \qquad M_{x2} = 520{\cdot}8$$
$$M_{x5} = 149{\cdot}3 \qquad M_{x6} = 35{\cdot}8$$
$$X_1 = {\cdot}5190X_2 + 2{\cdot}8369X_5 + 7{\cdot}7418X_6$$
$$X_1 = 38{\cdot}045 + {\cdot}4813X_2 + 2{\cdot}7134X_5 + 7{\cdot}7130X_6$$
$$\bar{R}^2 = {\cdot}8411 \qquad S = 171{\cdot}6$$
$$s_{b12{\cdot}56} = {\cdot}0689 \qquad s_{b15{\cdot}26} = {\cdot}4778$$
$$s_{b16{\cdot}25} = 1{\cdot}4106$$

APPENDIX V.

A Comparison with Tongala-Stanhope District.

A similar survey was carried out by the Commonwealth Bureau of Agricultural Economics in November and December, 1949, on fat lamb farms in the Tongala-Stanhope Irrigation District in Victoria. The northern boundary of this district is approximately 45 miles south of Deniliquin. Climatic conditions are broadly comparable with those in the Berriquin Irrigation District.

Stock numbers quoted for the Tongala-Stanhope District relate to the period July 1st, 1946, to June 30th, 1949. The writer has used a multiple regression analysis on the data obtained for that district. The notation used is the same as that used in Appendix IV.

$$M_{x1} = 983 \qquad M_{x2} = 123$$
$$M_{x5} = 206 \qquad M_{x6} = 72$$
$$X_1 = {\cdot}906\ X_2 + 2{\cdot}3419X_5 + 5{\cdot}4428X_6$$
$$X_1 = 129{\cdot}8 + {\cdot}9579X_2 + 2{\cdot}0740X_5 - 4{\cdot}2604X_6$$
$$\bar{R}^2 = {\cdot}7410 \qquad S = 278{\cdot}027$$

The stocking rates on dry land are much higher than those in the Berriquin Irrigation District and the stocking rates on irrigated pastures —especially irrigated summer pastures (which includes lucerne)—much lower. Factors which may explain these discrepancies are:—

(1) In converting different stock to a common denomination—that of crossbred-ewe equivalents—the Bureau of Agricultural economics assumed that 1 crossbred ewe = $1\frac{3}{4}$ dry sheep, whereas the writer assumed that 1 crossbred ewe = 2 dry sheep. This difference could account for a relative understatement in total stock numbers and therefore of stocking rates of, at most, 10 per cent. in the Tongala-Stanhope District as compared with the Berriquin District.

(2) In the present study the area of irrigated pastures used in the regression analysis was the area of pasture which had been sown prior to January, 1951—i.e., pastures which were less than 18 months old were excluded. In the case of the Tongala-Stanhope analysis no data were available on the age of the pastures, so that all irrigated pasture sown at the time of the survey was included. The writer believes that this factor is partly responsible for the comparatively low value of $\bar{R}^2$ obtained for the Tongala-Stanhope analysis. This difference in the data may have led to an understatement of stocking rates on irrigated pastures in the Tongala-Stanhope District of approximately 20 per cent. as compared with the Berriquin District.

(3) Even after reasonable allowance is made for the two factors mentioned above, there is a considerable discrepancy in stocking rates on dry land and on irrigated summer pasture. In the case of dry land, this discrepancy becomes more surprising when the rainfall figures for the two districts in the respective three-year periods are examined. The average rainfall in Kyabram (on the eastern edge of the Tongala-Stanhope Irrigation District) was 18.34 inches for 1946-47 to 1948-49. In Deniliquin the average annual rainfall for 1949-50 to 1951-52 was 18.94 inches, and for Berrigan the corresponding figure was 19.41 inches. Yet the survey farmers in the Tongala-Stanhope District apparently carried twice as many crossbred sheep per acre of dry land as the survey farmers in the Berriquin District.

One striking difference between farms in the two districts which may explain this discrepancy is the very much smaller proportion of dry land on survey farms in the Tongala-Stanhope District. It is recognised as good farming practice when producing fat lambs under irrigation to have some dry land pasture to provide roughage. However, five out of the 30 survey farms had no dry land (apart from the house area and surrounding gardens, etc.) and 13 of the survey farms had 20 acres or less of dry land.

It is likely, therefore, that the area of dry land on survey farms in the Tongala-Stanhope District assumes an importance out of proportion to the actual volume of the nutrients provided by it. In other words, it is suggested that the dry area available to farmers in that district constitutes a limiting factor in fat lamb raising. This would account for the relatively high stocking rates on dry land which were obtained by the regression analysis.

The lower stocking rates on irrigated summer pastures for the Tongala-Stanhope farmers may also be attributed to the differences in the proportion of different types of pasture. On the survey farms in the Tongala-Stanhope District a larger proportion of all irrigated pastures consists of summer pastures. This greater use of summer pastures in the Tongala-Stanhope District is probably the result of smaller farm size in this district and a consequent pressure to use more intensive irrigation methods.

Finally, it should be stressed that while these explanations are plausible from an agricultural and statistical point of view, there is no other evidence available to confirm it.