PRODUCTION IN RELATION TO RAINFALL, SUPERPHOSPHATE AND EROSION*

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Using regression analysis, this paper studies the influence of rainfall, superphosphate and erosion on wool and wheat production in parts of Victoria. It shows that quantitative account can be taken of erosion, as well as of rainfall and superphosphate; and that the impact of erosion is much more significant relative to grain production than to wool production.

The effects of rainfall, superphosphate and erosion on production in two wheat and/or wool producing regions of Victoria are discussed in this paper.

The two regions studied are not mutually exclusive. The first region encompasses 36 shires covering about 30,000 square miles in the central and western parts of Victoria, as shown in Figure 1. The second region covers 58 parishes, or about 3,000 square miles in the Victorian Mallee, as shown in Figure 2. These two regions were studied in the light of published and unpublished agricultural statistics, rainfall records and erosion maps.

In the study of the selected shires, average figures for each of the four years 1958/59 to 1961/62 were used. For the parishes, 1961/62 figures were used. No statistics had been compiled for shires before 1958/59 or retained for parishes before 1961/62. During the periods chosen for study, the average annual rainfall ranged from 13 to 31 inches in the shires and from 12 to 15 inches in the parishes. The annual rainfall of the parishes was above average, but the April-October rainfall was considerably below average. For all practical purposes, irrigation areas were excluded from both regions, as were all shires or parishes with a sheep to cattle ratio smaller than 25 to 1.

Sources of Data

All data used in the study were obtained from the Commonwealth Statistician except those for rainfall, erosion and prices. Rainfall records were obtained from the Meteorological Bureau for 136 stations within the selected shires and for 42 stations within, or adjacent to, the selected parishes. There was some overlap in the two sets of stations. The number of rainfall stations varied between 2 and 11 per shire according to the availability of records for the period concerned; usually there were more stations for the larger shires. In the Mallee the paucity of rainfall stations and the number of parishes with ten or more holdings limited the study to 58 parishes. The location of these parishes and the rainfall stations is shown in Figure 2.

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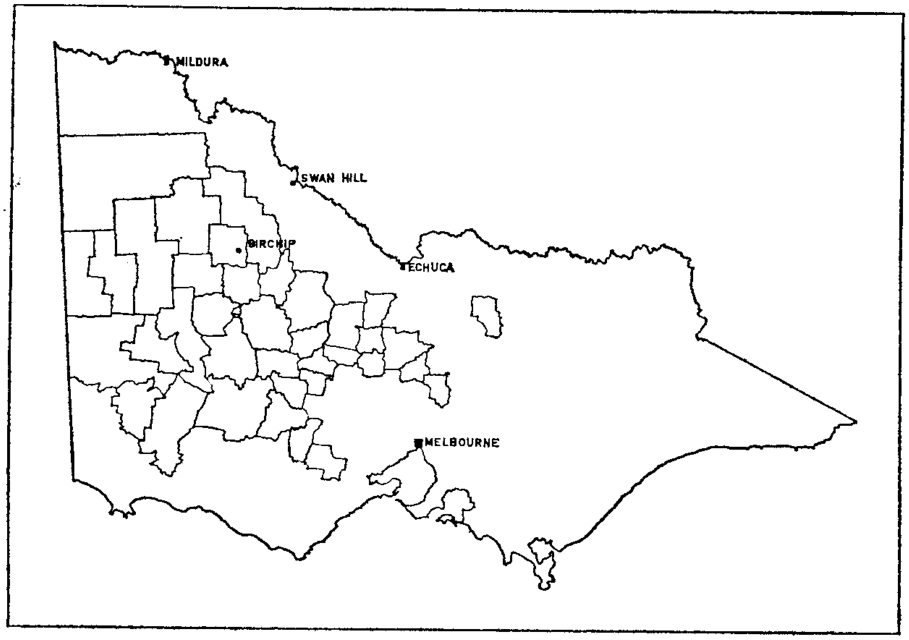

FIG. 1—Location of the 36 shires.

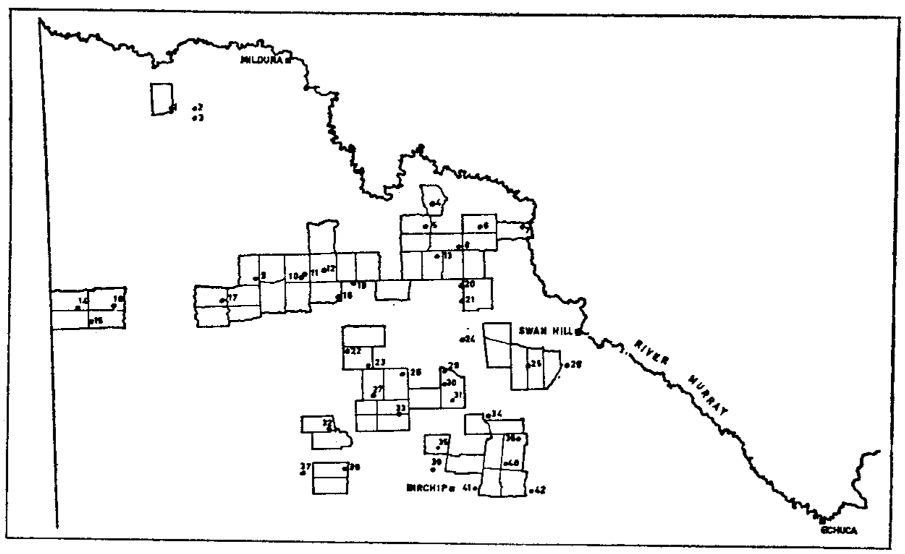

FIG. 2—Location of the 58 parishes in relation to the rainfall stations.

The extent and degree of erosion in the area covered by the shires was assessed from an unpublished erosion map of Victoria. This map was compiled from information submitted by the Conservation Officers of the Soil Conservation Authority of Victoria. In large part, it was based on the Conservation Officers' local knowledge as distinct from field surveys. The assessment of erosion in the area covered by the Mallee parishes was, however, made from a land system map compiled in the course of a field survey.[1]

[1] J. N. Rowan and R. G. Downes, *A Study of the Land in North-Western Victoria*. Soil Conservation Authority of Victoria, Melbourne, 1964.

The Australian Wool and Wheat Boards' prices were used in the calculation of values, while various woolbroking firms provided the approximate shearing dates in the different shires.

Details of Data

The following data were used for analysis. They represent shire and parish averages.

(i) *Production of wool* (excluding lambs' wool) was expressed per acre of the productive agricultural area of a shire or parish. *Production of wheat* was expressed per acre sown for grain in a parish.[2] These production variables constituted the dependent variables in the analysis. They were related via regression analysis to the variables outlined below.

(ii) *Acreages of native pasture, improved pasture and lucerne* were expressed as per cent of the productive agricultural area of a shire or parish.

(iii) *Rates of superphosphate applied* were calculated per acre of the area sown for wheat grain and per acre of the total area of pasture (as distinct from the area of topdressed pasture).

(iv) *Rainfall in relation to wool production* in the shires was calculated as the average annual rainfall over the four year period, while rainfall in the parishes was calculated for a period of 12 months. Both periods ended one month before the commencement of shearing in 1961. *Rainfall in relation to wheat yields* in the parishes was calculated for the "growing season" (April to October, 1961).

(v) *Erosion* was classified into three classes in the area covered by the shires and a weighted average index was computed for each shire. Erosion in the Mallee parishes was grouped into five classes by the field surveyor and a weighted average index was calculated for each parish.

(vi) *Sheep to cattle ratio* was also calculated as a further independent variable.

As described above, the variables considered were all calculated on a "per acre", rather than on a "per farm" basis. This is in accord with the aim of the investigation, namely, to examine in a purely empirical way the relative importance of various physical factors affecting wool and wheat productivity. The regression equations estimated below are not to be interpreted as farm-firm production functions.

Findings of the Statistical Analysis

Statistical analysis was carried out by transforming the data to logarithms and estimating multiple regression equations linear in the logarithms. Multicollinearity is, presumably, not a serious problem here because the intercorrelations of the variables are less than 0·80. Independent variables with regression coefficients not significantly different from zero were deleted and the equations recalculated. In consequence, all the coefficients retained in the equations shown below are significant.

[2] Insufficient data were available to allow fat lamb production to be included in the analysis.

Wool Production

(a) *36 shires (1958/59 to 1961/62 data)*

The initial regression equation for shire wool production included the following independent variables: average annual rainfall, superphosphate usage on pastures, sheep to cattle ratio, and improved pasture. The last two variables, however, did not contribute significantly to the prediction of wool production and have been omitted. The final regression equation was:[3]

$$\log \text{wool (lb./ac.)} = -0{\cdot}700 + 0{\cdot}950\ (\pm 0{\cdot}365) \log \text{rainfall (in.)} + 0{\cdot}284\ (\pm 0{\cdot}076) \log \text{superphosphate (100 cwt./ac.)}.$$

The equation as a whole accounted for 92 per cent of the variation in the logarithm of wool production per acre.

(b) *58 parishes (1961/62 data)*

The initial regression equation for parish wool production included the following independent variables: annual rainfall, erosion index, superphosphate applied to wheat, and per cent of native pasture. The first and last of these variables did not contribute significantly to the prediction of wool production and the final regression was reduced, therefore, to:

$$\log \text{wool (lb./ac.)} = 0{\cdot}132 - 0{\cdot}185\ (\pm 0{\cdot}124) \log \text{erosion (index)} + 1{\cdot}791\ (\pm 0{\cdot}693) \log \text{superphosphate (1 + cwt./ac.)}.$$

Unlike the variables shown for the shires, which accounted for 92 per cent of the total variation in the logarithm of wool production, the variables shown for the parishes account for only 39 per cent of the variation. This difference is probably due to the relatively more frequent dealings in sheep by farmers in the Mallee parishes than in the wide range of wool producing regions covered by the shires. Consequently, in the parishes, shearing of sheep may take place more frequently on holdings other than where the wool was grown. This would result in less accuracy in the recorded wool production on the relatively small number of farms in a parish.

The inclusion in the equation of a rate of superphosphate application to wheat in 1961 presumes that the *level* of superphosphate application was of the same order in the preceding years as in 1961. As mentioned earlier, parish statistics for the years preceding 1961 were not available. The reason for the significant effect on wool production of superphosphate application to wheat is probably that about 80 per cent of the total superphosphate usage in the Mallee is for wheat. The residual effect of this superphosphate is much greater than that of the immediate effect of the relatively small amounts applied directly to pasture.

Wheat Production (58 parishes, 1961/62 data)

The initial regression equation for wheat production included the following independent variables: rainfall (April to October), erosion

[3] Throughout, bracketed values indicate 95 per cent confidence limits for the regression coefficients.

index, and superphosphate applied to wheat. All coefficients were significant and the resultant equation was:

$$\text{log yield (bush./ac.)} = 0{\cdot}566 + 0{\cdot}674\ (\pm 0{\cdot}393)\ \text{log rainfall (in.)} - 0{\cdot}338\ (\pm 0{\cdot}102)\ \text{log erosion (index)} + 0{\cdot}943\ (\pm 0{\cdot}675)\ \text{log superphosphate (1 + cwt./ac.)}.$$

The equation as a whole accounted for 63 per cent of the variation in the logarithm of wheat yield per acre.

It has to be borne in mind, however, that in the Mallee the degree of erosion is closely associated with soil type and that there is no satisfactory method available for distinguishing their associated effects by the construction of separate indices. Therefore, the true effect of erosion on wheat yields is likely to be somewhat less than indicated by the preceding regression equation.

The rate of superphosphate application is influenced by the response in wheat yields. Yields respond, however, not only to the variables shown in the above regression equation but also to the physical features of the soil (which affect moisture availability) and to soil fertility (particularly levels of soil nitrogen in addition to phosphate). It is possible, therefore, that superphosphate had less effect on yields than is indicated by the regression equation if higher rates were used on the more fertile soils.[4]

The rapid increase in wheat acreage in the Mallee (about 28 per cent between 1958/59 and 1961/62) has included ploughed-up improved pastures of high legume composition. In recent years, these legume pastures had significantly raised the nitrogen level of the soil. This increase of nitrogen, if combined with relatively high rates of superphosphate application and a reasonable season, could have accentuated the effect of superphosphate on wheat yields. Because parish statistics were not retained for the years before 1961/62, it remains a moot point whether the increase in wheat acreage was any greater in the parishes with relatively high rates of superphosphate application than in those with relatively low ones.

Implications of Statistical Analysis

The relative influence of each of the significant independent variables on production is illustrated by the differences in production over the range of each variable (when the other variables are held at their geometric means). Thus, as given in Table 1, the averages of the six highest and six lowest figures of each independent variable were calculated and these, together with the listed geometric means, were used for predicting the wool and wheat production from the appropriate regression equations. Table 2 shows the predicted production per acre in physical and financial terms for various combinations of the independent variables. Essentially the same conclusions could be reached by a consideration of standardized regression coefficients, but such manner of presentation would be much less explicit.

[4] Soil fertility and soil texture of the parishes were rated for wheat growing by weighted average indices. No relationship could be established between these indices and either wheat yields or the quantity of superphosphate applied to wheat.

TABLE 1

Levels of Independent Variables Used for Predicting Production

Independent variable	Levels of variable		
	Average of highest six figures	Average of lowest six figures	Geometric mean
Shires			
Annual rainfall (in.)	27·54	13·49	19·59
Superphosphate (cwt./ac.)	0·57	0·02	0·17
Parishes			
April-October rainfall (in.)	9·48	5·60	7·60
Superphosphate (cwt./ac.)	0·90	0·35	0·54
Erosion index (1 to 5)	5·00	1·05	3·28

Wool Production

The last two columns of Table 2 show that in the shires the output of wool is only slightly less affected by the difference in the "high" and "low" annual rainfall levels than by the difference in the "high" and "low" levels of superphosphate application. Difference in the levels of erosion in the parishes shows a relatively small differential impact of 0·7 lb. per acre (equivalent to 24·8 per cent) on wool production, or, in terms of money, as little as three shillings per acre.

Wheat Production

Unlike wool production, wheat yields show a big difference (40·8 per cent) between the low and high levels of erosion (Table 2). In terms of money, the difference amounts to £5.9.0 per acre in the value of wheat yields. The shortcomings of the erosion index, due to its confounding with soil type, are equally applicable to both wool and wheat yields and, therefore, probably do not detract from the validity of the relative magnitude of these results. The gap between three shillings per acre and £5.9.0 per acre would be reduced only slightly by any reasonable change in the relative wool and wheat prices.

It is also shown in Table 2 that the difference between high and low levels of superphosphate applications results in about the same difference in wheat yields (27·7 per cent) as the difference between high and low levels of the April to October rainfall (29·8 per cent).

Concluding Comments

The overwhelming influence of rainfall and superphosphate on the production of wool is shown in the study of 36 shires. One can conclude, therefore, that it is likely to be futile to embark on production function analysis over *broad areas* of Australia unless variations in rainfall and superphosphate usage are taken into account. Finally, though this paper represents but a first attempt at the quantitative measurement of the impact of erosion on a *regional* basis, it indicates that such measurement is feasible; also, that the impact of erosion is much more significant relative to grain production than to wool production.

TABLE 2

Predicted Wool and Wheat Production per Acre under Various Combinations of Superphosphate, Rainfall and Erosion

Variable(s) at geometric mean	Variable at high or low level	Product	Production per acre	Gross return per acre [a]
Shires				
Superphosphate	Rainfall (high)	wool	10·3 lb.	£2·40
	Rainfall (low)	wool	5·2 lb.	1·20
Rainfall	Superphosphate (high)	wool	10·6 lb.	2·50
	Superphosphate (low)	wool	4·1 lb.	0·95
Parishes				
Erosion	Superphosphate (high)	wool	3·2 lb.	0·60
	Superphosphate (low)	wool	1·7 lb.	0·35
Superphosphate	Erosion (high)	wool	2·2 lb.	0·40
	Erosion (low)	wool	2·9 lb.	0·55
Rainfall and superphosphate	Erosion (high)	wheat	12·6 bush.	8·65
	Erosion (low)	wheat	21·3 bush.	14·10
Erosion and rainfall	Superphosphate (high)	wheat	17·8 bush.	12·20
	Superphosphate (low)	wheat	12·9 bush.	8·80
Superphosphate and erosion	Rainfall (high)	wheat	16·8 bush.	11·55
	Rainfall (low)	wheat	11·8 bush.	8·10

(a) Based on a greasy wool price for shire analyses of 56·05d. per lb. (1958/59 to 1961/62 average, six statistical divisions) and for parish analyses of 44·68d. per lb. (1961/62 average, Mallee division); and a wheat price at the farm gate of 13·73s. per bushel.