ECONOMIC IMPLICATIONS OF DROUGHT LOSSES AMONG AUSTRALIAN SHEEP FLOCKS

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In years of extreme drought large losses of sheep occur in the drier parts of Australia. Many of these losses could be prevented if sheep were hand fed during the drought. However, some economic studies suggest that it is often cheaper for the individual grazier to allow sheep to die or sell them at a low price and restock at a higher price after the drought than to keep sheep alive by hand feeding.[1, 2]

It is possible that although feeding is unprofitable for the individual grazier it may be economic from the national point of view. This situation could exist if the price for which sheep are purchased and sold by graziers is less than the capital value of the sheep to the nation.

Attention was drawn to this point by Campbell in 1958, who stated:

> "Immediately one mentions fodder conservation, the first reaction is to say that this should be the farmer's responsibility. Many farmers do make adequate provision for the storage of fodder. But there are several good reasons why it may not be economic for every farmer to store fodder, despite, in some cases, the existence of concessional credit schemes to encourage him to do so. . . . In short, this may well be a case where specific action is not economic to the individual, but is economic to the State." [3]

In 1963 Powell attempted to test this hypothesis by estimating the cost of feeding sheep in Queensland and then comparing this with the value sheep would need to reach before feeding became economic, assuming a given mortality rate.[4] On this basis Powell was able to suggest that for feeding to be economic sheep values would have to be two to three times their sale value. This approach is perfectly legitimate providing it is accepted that the sale price is a true reflection of the income-earning capacity of the sheep. If graziers do not regard sheep as an income-earning asset then market price will be a poor reflection of the true value of sheep. Under free market conditions price will be determined by the demand for and the supply of sheep, but the income-earning capacity of ewes will be determined by their ability to replace themselves and increase the size of the nation's sheep flock.

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[1] J. L. Dillon and R. G. Mauldon, "Inventory Analysis of the Economics of Fodder Conservation", *Economic Record,* Vol. 35, No. 71 (August, 1959), pp. 209–18.

[2] J. L. Dillon and A. G. Lloyd, "Inventory Analysis of Drought Reserves for Queensland Graziers", *Australia Journal of Agricultural Economics,* Vol. 6, No. 1 (September, 1962), pp. 50–67.

[3] K. O. Campbell, "The Challenge of Production Instability in Australian Agriculture", *Australian Journal of Agricultural Economics,* Vol. 2, No. 1 (July, 1958), pp. 3–23.

[4] A. A. Powell, *A National Fodder Reserve for the Wool Industry,* University of Sydney, Department of Agricultural Economics, Mimeographed Report No. 3, 1963.

Because it is estimated that the sheep carrying capacity of the Wheat and Sheep and High Rainfall Zones of Australia could be at least doubled there is every reason for calculating the income-earning capacity of different sexes and ages of sheep separately and then attempting to estimate whether feeding during droughts is worthwhile from a national point of view.[5] Before proceeding to do so, however, it is necessary to examine the likelihood of graziers financing hand feeding so that the economics of hand feeding from a national and graziers' point of view may be compared.

GRAZIERS' DROUGHT STRATEGIES

The exact amount which a grazier should spend on drought feeding will depend on the price of feeding, the number of sheep lost, the cost of restocking and the net income lost during the drought because of reduced sales of sheep and wool.

Dillon and Lloyd considered that the cost of restocking after a drought could be calculated from the formula,

$$\left(\frac{N - C}{U_t} \times U_r\right) + (\$0.01 \times D) + C$$

where N = the normal average value of sheep in $.
C = the cast for age value of sheep in $.
U_t = the total useful life of a sheep in months.
U_r = the remaining useful life of the sheep in months at time of death during the drought.
D = the length of the drought in months.

If the normal useful life of a sheep is 48 months, the cost of replacing a one-year-old sheep valued at $10 with a cast for age value of $2.20 would be,

$$\left(\frac{\$10 - \$2.20}{48} \times 36\right) + (\$0.01 \times 6) + \$2.20 = \$8.11$$

In addition, 0.85 lb of wool per sheep dying would be lost for each month of drought. At the same time variable costs would be reduced by $0.30 per sheep dying for each month of drought.[6] Thus if wool is valued at $0.50 per lb then the loss suffered by an individual grazier for each sheep lost during a six-month drought would be $8.86. Sheep can be kept alive during a drought by feeding 5 lb of wheat per week. With wheat available at railway silos at $1.50 per bushel the cost of feeding might vary between 10 cents and 20 cents per week depending on the distance wheat has to be transported and whether extra labour is needed for feeding out. It is necessary to feed all the sheep in any one flock during a drought although only a proportion of the flock may die.

[5] "Some Aspects of Heavy Stocking", *Rural Research in CSIRO*, Bulletin No. 52 (September, 1965), pp. 2–9.

[6] Dillon and Lloyd, *op. cit.*

The proportion of the flock which would have to die before it is cheaper for the grazier to save sheep by hand feeding is equal to the ratio between the cost of feeding per head and the financial loss per sheep dying. If hand feeding costs 15 cents per sheep per week and the loss per sheep dying is $8.86, as Dillon and Lloyd suggest, then the number of sheep which would have to die in a six-month drought for feeding to be economical would be the ratio

$$\frac{\$0.15 \times 26 \text{ weeks}}{\$8.86} = 0{\cdot}44$$

If feeding were carried out for six months 44 per cent of the flock would have to die before the financial loss suffered by the grazier in allowing sheep to die exceeded the cost of feeding. If sheep valued at $10 at the commencement of the drought could be sold for $4 during the drought then the grazier's loss during the drought would be $4.86. If feeding were carried out for six months

$$\left(\frac{\$0.15 \times 26 \text{ weeks}}{\$4.86}\right) = 0{\cdot}80$$

Thus eighty per cent of the flock would have to be sold before hand feeding became more profitable than selling sheep at a low price and purchasing at a higher price after the drought. Under these circumstances graziers would prefer to let sheep die and restock at a higher price after the drought. Some graziers who have spent years in developing a particular line of sheep may be prepared to feed at an uneconomic level to preserve the flock, but the large decline in sheep numbers which can occur in some areas during major droughts suggests that most act in an economic manner.

In the severe drought of 1940–47 the national flock declined from 125 million to 96 million sheep, a decrease of only 23 per cent. Even in Western New South Wales, the region where the heaviest losses occurred, the average decrease in sheep numbers was only 48 per cent and this includes sheep sold during the drought. In this area sheep might have required feeding for more than a year to prevent losses. In the light of these results the graziers' decision to let sheep die or to sell at a low price and restock after the drought at a high price was a rational decision.

THE NATIONAL INCOME EARNING CAPACITY OF SHEEP

If the capitalized net income which would have been earned by the sheep lost during a drought is larger than the financial loss suffered by individual graziers due to the drought then hand feeding may be economically justified from a national point of view although it is unprofitable for individual graziers.

A survey of the Australian sheep industry was carried out by the Bureau of Agricultural Economics in 1964.[7] In this investigation the capital value of assets, costs and output of sheep in different grazing zones in all the Australian States was established for the years 1960–61 to 1962–63 by studying a sample of 576 typical sheep farms. This data can be used to estimate the average return per sheep net of variable costs in any grazing

[7] Bureau of Agricultural Economics (May, 1961), *The Australian Sheep Industry Survey* 1960–61 *to* 1962–63, (Canberra).

zone in any State. The individual cost items listed in the B.A.E. survey divided into costs which would be avoided if sheep perished in a drought and the fixed costs which would have to be met in any event are as follows:

Fixed Costs	*Variable Costs*
Fuel	Wages (including shearing, crutching and contracts)
Fertilizer	Fodder
Feed	Packs, bags and twine
Vermin destruction	Drenches, dips and licks
Plant maintenance	Shearing supplies
Maintenance of improvements	Freight and cartage
Rates and taxes	Marketing wool
Insurance	Marketing stock
Rent	Droving and agistment
Depreciation	Miscellaneous
Owner's living allowance	

The average return net of variable costs can be obtained by deducting the variable costs from the gross revenue from the sheep enterprise. As the variable costs listed include some elements of a fixed nature (e.g., part of wages and miscellaneous costs) the calculation tends to underestimate the income from sheep lost during a drought.

The income which will be derived from wethers is limited to that obtained during the animal's life, but ewes contribute to income during their own life and by replacing and expanding the nation's flocks. Thus the value contributed to national income by the wethers and ewes must be calculated separately. Similarly the simple assumption that only variable costs will increase if sheep are saved during drought must be modified when ewes are considered. If ewes are kept alive flocks will expand. While some expansion may be possible without further investment in water, pastures, fencing, buildings and labour, it is unlikly that this process can be continued indefinitely, particularly if the rate of increase without losses due to drought is sufficient to give large increases in sheep numbers over a relatively few years. It is possible that all fixed costs including such items as rates which depend to some extent on the improved value of the property will increase in proportion to the number of sheep carried. On the other hand only a few farms produce nothing but sheep. In the Pastoral Zone many farms also run cattle. In the Wheat and Sheep Zone wheat is produced and cattle are grazed and in the High Rainfall Zones mixed cropping, beef cattle and even dairying are carried out in conjunction with sheep farming. Under these circumstances it seems reasonable to assume that costs per sheep are the same proportion of total costs that gross revenue from sheep forms of total gross farm revenue. In calculating the national value of ewes from the accumulated net income from ewes and their progeny the results are presented using all three bases of estimation, i.e., variable costs only, total costs, and a proportion of total costs equal to the proportion that gross revenue from sheep forms of total gross farm revenue.

In the Wheat and Sheep Zone this system was modified because such a high proportion of total costs are associated with wheat growing that the total costs per farm could not be applied to the sheep enterprise alone. When calculations for this zone were made using total costs, the total cost per sheep for the high rainfall zone in the same State were assumed to apply. In Queensland, where no High Rainfall zone exists, the total cost per sheep in the Pastoral zone were applied.

Ewes

The number of ewes existing at any one time together with the age structure of the ewe flock, the length of their reproductive life, their mortality rate, the percentage of lambs obtained from them and the age at which sheep are sold determines the future size of the flock and hence the income which will be obtained from it. If all of these factors were known the discounted net income earned by a ewe over any time period could be calculated. However, the statistics available merely record the number of breeding ewes, the total number of sheep and the lambing percentage in a particular area. It is possible to calculate the average rate of increase in sheep numbers over any period of time by averaging the percentage increases or decreases for each year over a number of years.

In severe and prolonged droughts sheep numbers at first decline rapidly, then, after the drought breaks, increase rapidly and finally after the recovery from the drought increase at a slower rate (see Figure 1). By examining the pattern of increases and decreases in each grazing zone it was discovered that sheep numbers had increased at a relatively steady rate between the recovery from the long drought of 1940–47 and 1963.

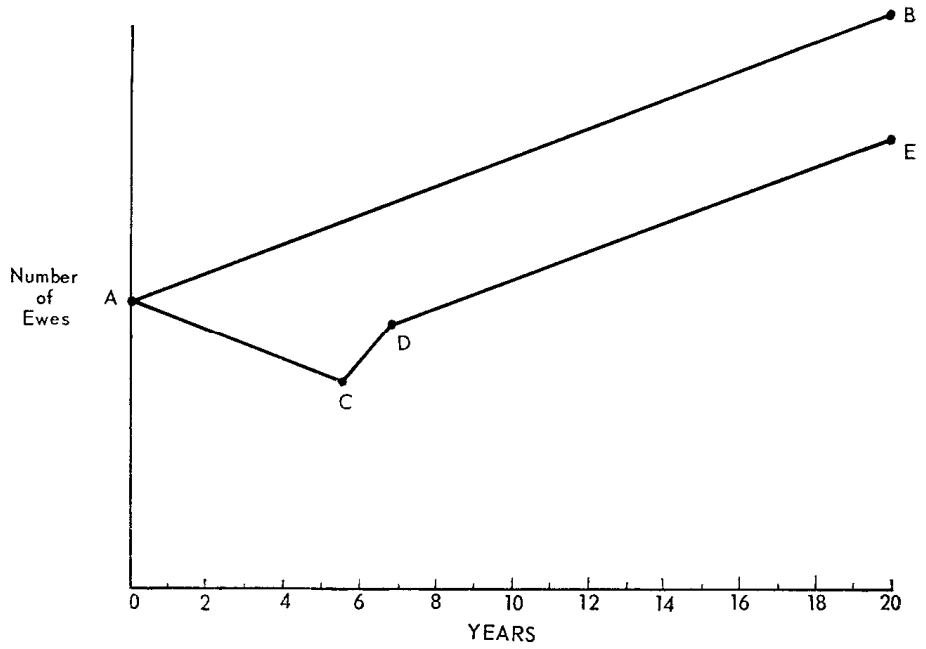

Figure 1. Changes in Ewe Population in Drought and Non-Drought Periods.
A–B = Expansion excluding drought.
ACDE = Expansion including a period of severe drought.

The average annual percentage rate for the period between the recovery from this long drought and 1963 are shown in Table 1. The year in which this period commences varies for different zones as the drought was more prolonged in some areas than others. More recent statistics of the number of ewes are available for some zones than others and this also also alters the period over which the calculation can be carried out.

TABLE 1

Rates of Increase in Sheep Numbers in Different Grazing Zones

Zone	State	Years Over which Increase is Calculated (Years Inclusive)	Average Rate of Increase
Pastoral	Q'ld ..	1949–50 to 1961–62 13 years ..	2·244
	N.S.W. ..	1948–49 to 1963–64 16 years ..	3·289
	S.A. ..	1948–49 to 1962–63 15 years ..	3·225
	W.A. ..	1948–49 to 1962–63 15 years ..	0·835
Wheat-Sheep ..	Q'ld ..	1949–50 to 1961–62 13 years ..	3·517
	N.S.W. ..	1949–50 to 1964–65 16 years ..	2·806
	Vic. ..	1948–49 to 1963–64 16 years ..	2·865
	S.A. ..	1948–49 to 1962–63 15 years ..	2·806
	W.A. ..	1948–49 to 1962–63 15 years ..	3·996
High Rainfall ..	N.S.W. ..	1948–49 to 1963–64 16 years ..	2·853
	Vic. ..	1948–49 to 1963–64 16 years ..	3·155
	Tas. ..	1947–48 to 1962–63 16 years ..	3·980
	S.A. ..	1948–49 to 1962–63 15 years ..	7·321
	W.A. ..	1948–49 to 1962–63 15 years ..	6·749

This particular period was selected because no prolonged and severe droughts occurred in any region. A decline in sheep numbers was not recorded in two consecutive years in any zone. The increases in sheep numbers might be considered as being typical of those which would occur if sheep were fed in any severe drought providing farmers adopted the same breeding policies assuming the same lambing percentages and mortality rates prevail. Naturally any change in any of these three factors or the occurrence of a severe drought in which sheep were not hand fed would alter the rate of increase expected in the future. Selecting Merino sheep on a basis of fertility rather than on their ability to produce wool would probably have a larger effect on the rate of increase in sheep numbers than any other technical innovation.

A study of the rates of increase in sheep numbers during the last twenty years suggests that weather is the main factor determining the rate of increase or decrease in any one year. There is no apparent correlation between the price of wool in the same or in previous years and the rate at which sheep numbers increased in any zone.

An additional advantage of examining the expansion in sheep numbers between the end of the drought in the mid 1940's and 1963 is that this was a period of rapid technical advance in the sheep industry. The area of improved pastures expanded rapidly and myxomatosis practically eliminated the rabbit pest. Under these conditions there was no environmental factor other than weather to prevent sheep numbers increasing.

In the high rainfall zone alternatives to sheep breeding are limited by the lack of markets for alternative products. In the pastoral region they are limited by climate. In these two areas the rates of increases calculated should be a relatively accurate indication of the increases which might be obtained in the future unless ewe mortality rates and lambing percentages are changed by the introduction of new techniques. In the High Rainfall Zone the rate of increase could also be affected by a change in the relative price of wool and fat lambs. The breeds of ewe used in fat lamb production have higher lambing percentages than wool-producing breeds such as the Merino and Polworth and female lambs are often sold as fat lambs. Thus a change from one breed of ewe to another could affect the rate of increase in sheep numbers in this zone.

In the Wheat and Sheep Zones the rate of increase can also be affected by the relative prices of wool, meat, and wheat. Changes in the ratios of these prices could cause farmers to devote more land to either sheep or wheat. Thus the estimated expansion rates of sheep numbers in the Wheat and Sheep Zone are probably less reliable than in other zones.

It is also necessary to select a period over which the discounted net income earned by ewes and their progeny is calculated. In theory this could be an indefinite period, but such an assumption implies that Australia could carry unlimited numbers of sheep and sell unlimited quantities of wool at known prices. A twenty-year period would seem to be the maximum period over which prices and costs are likely to remain stable enough to have any real meaning. The increase in sheep numbers which will occur during this period can be calculated from the equation.

$$\log_e x = \lambda t + \log_e C \qquad (1)$$

where C = the number of sheep at the commencement of the period.
t = the length of the period in years.
λ = the average rate of expansion of the flock per annum.
x = the number of sheep at the end of the period.

The percentage increases in flock numbers which would occur in the different grazing zones over a twenty-year period assuming that the rate of increase in each zone is the same as that which occurred between the end of the drought of the 1940's and 1963 are as follows:

	Q'ld %	N.S.W. %	Vic. %	Tas. %	S.A. %	W.A. %	Aust. %
Pastoral Zone	57	93	..	..	91	18	66
Wheat and Sheep Zones	102	65	77	..	75	122	80
High Rainfall Zones ..	..	77	88	122	322	286	136

Research carried out by the C.S.I.R.O. suggests that sheep numbers could be doubled in the Wheat and Sheep Zones and trebled in the High Rainfall Zones without seriously overstocking either region and in both of these zones stocking rates have increased in the last five years.[8] It is by no means certain that stocking rates could be increased in the Pastoral Zone. However, even if all of the additional increase in this zone were

[8] "Some Aspects of Heavy Stocking", *op. cit.*

absorbed by the Wheat and Sheep Zone in addition to its own natural increase the number of sheep in the Wheat and Sheep Zone would only increase by 110 per cent. If the increase in the Pastoral Zone were absorbed by the High Rainfall Zone the net increase in this Zone would increase from 136 per cent to 178 per cent. Thus, there is little doubt that Australian sheep population could be allowed to grow for a twenty-year period without serious overstocking providing the surplus from the Pastoral Zone were transferred to other grazing zones. As the overall increase in sheep numbers is of the order of 100 per cent during the twenty-year period it is optimistic to assume that this could be achieved by simply charging the variable costs per sheep as the sole extra charge. It is far more likely that the correct cost per sheep is equal to the same proportion of total costs that gross revenue from sheep forms of total gross farm revenue in each zone. It will certainly not be higher than the total fixed and variable costs of farming per sheep.

A further criticism which might be aimed at using the concept of net income per ewe over a twenty-year period as a measure of the value of ewes lies in the assumption that net income in each zone will be similar to that obtained during the period 1960–61 to 1962–63. Net income is most likely to vary because of a decline in the price of wool as the supply of wool increases. Between 1929 and 1965 the quantity of wool

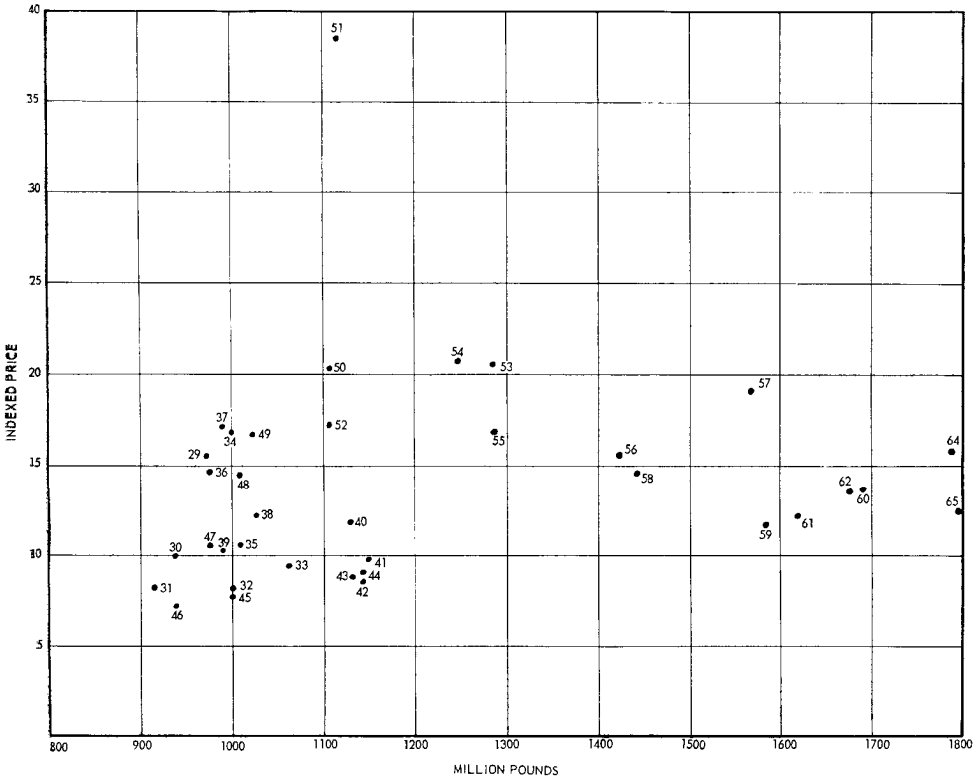

Figure 2. Wool Prices and the Supply of Wool. Figures refer to year in which wool was produced, e.g. 65 = 1965.

produced in Australia doubled but the prices obtained in the 1960's adjusted on an index based on the import purchasing power of Australian wool are similar to those obtained in the early 1930's. In the decade 1955–1965 wool output increased by 30 per cent without any marked decline in this adjusted price. (See Figure 2.) Prices of wool could decline rapidly because of radical changes in the techniques associated with the manufacture of synthetic fibres, but there is certainly no evidence of this during the last thirty years or even in the past ten years. In spite of vigorous competition from synthetic fibres the net incomes obtained per sheep in the period 1960–61 to 1962–63 are similar to those obtained in the preceding three years.[9] The price predictions of the Food and Agriculture Organization of the United Nations suggest that a larger quantity of wool will be sold for a lower price in 1970 than in 1960.[10] In 1965 13 per cent more wool was sold for a higher price than in 1959.

These past changes in the prices and quantities of wool supplied are no guide to the price which might be obtained for an increased supply of wool in the future, but they do indicate that a large increase in the amount of wool exported can take place without an automatic decline in the price of wool.

Because the supply of wool would be increased if drought losses were prevented and as no future prediction suggests that wool prices will increase, any calculation of estimated future earnings by ewes and their progeny based on 1960–63 prices must be regarded as a maximum estimate. With the strong demand for sheep caused by the discoverey that improved pastures in the High Rainfall and Wheat and Sheep Zones are capable of carrying at least double the number of sheep carried at present, there is little reason to suppose that sheep prices will fall relative to costs unless wool prices decline.

There are some disadvantages in using the additional discounted net income which would be earned if ewes were kept alive during a drought as the sole measure of the economic advantages or disadvantages which might arise from drought feeding. Such an assumption ignores any secondary benefits which might be obtained by avoiding fluctuations in graziers' incomes or from maintaining the level of exports. In the latter case the gain may be more apparent than real, particularly if wheat is the main drought fodder, because a future expansion in the exports of wool would only be maintained by a large immediate decline in wheat exports. Some research which has been carried out in this field suggests that there is no significant relationship between the volume of wool exported and the income earned from exported wool.[11]

The value of the discounted net income earned per sheep over a twenty-year period assuming a given rate of increase can be calculated using the formula—

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[9] Bureau of Agricultural Economics (1961), *The Australian Sheep Industry Survey,* 1957 *to* 1959 (Canberra).

[10] Food and Agricultural Organization of the United Nations (1962), *Commodity Predictions for* 1970 (Rome).

[11] Powell, *op. cit.* pp. 37–41.

$$DNE = \frac{Ce^{\lambda}}{1+r}\left[\frac{\left(\frac{e^{\lambda}}{1+r}\right)^{t}-1}{\left(\frac{e^{\lambda}}{1+r}\right)-1}\right] \times R \qquad (2)$$

Where λ = rate of increase.
C = number of sheep at the commencement of the period.
r = the discount rate.
t = the period over which the increase took place.
R = the expected annual net income per ewe.
DNE = discounted net income over the period t.

The estimated discounted net income per ewe for the different grazing zones for a twenty-year period are shown in Table 2 assuming a discount rate of seven per cent and that annual net income equals—

(*a*) gross revenue from sheep per sheep—variable costs per sheep,

(*b*) gross revenue from sheep per sheep—

$$\left[\frac{\text{total farming costs} \times \frac{\text{gross revenue from sheep}}{\text{total gross farm revenue}}}{\text{total sheep carried}}\right]$$

(*c*) gross revenue from sheep per sheep—total farming costs per sheep.

Both costs and gross revenue in each zone are assumed to be equal to the average calculated in the B.A.E. Sheep Survey for the years 1960–63. This discounted net income is the additional income which will be obtained for each sheep in existence at the commencement of the drought. However, all of it will be created by the breeding ewes in the flock as these replace the flock and determine its rate of increase in the future and hence the future size of the flock and the future income from both ewes and wethers in any grazing zone.

The discounted net income which will be created by the average breeding ewe can be obtained by dividing the discounted net income per sheep by the proportion breeding ewes form of the total flock in the first year of the period over which the increase is calculated. It is always possible that the proportion ewes formed of the total sheep in the various grazing zones was abnormal in this year. If this were so a wrong estimate could be obtained. A comparison between the proportion ewes formed of the total flocks in this year and in the following two years revealed that the proportion was relatively constant. The variation never exceeded three per cent in any zone.

The discounted net income per ewe will vary between zones with the average annual net income per sheep, the rate of expansion of the flock and the proportion ewes form of the total flock. Thus the average annual net income per sheep for the Queensland Wheat and Sheep Zone assuming that only variable costs are charged, is $2.330 and for the same zone in South Australia is $4.010. Yet the discounted net income per ewe for the twenty-year period is $106 in Queensland and only $74 in South Australia, because the rate of flock growth in South Australia is lower and the proportion ewes form of the total flock is far greater than in Queensland. The other large discrepancy is between the net returns obtained per ewe in the High

TABLE 2

Discounted Net Incomes Excluding Drought

Zones and States	Discounted Net Income per Sheep			Ewes as Proportion of Flock	Discounted Net Income per Ewe		
	Variable Costs	Proportional Costs	Total Costs		Variable Costs	Proportional Costs	Total Costs
	$	$	$		$	$	$
Pastoral—							
Q'ld	27.62	15.74	11.10	0·44	62.78	35.78	25.22
N.S.W.	55.98	38.64	34.10	0·50	111.96	77.28	68.20
S.A.	58.98	37.24	35.00	0·58	101.68	64.20	60.34
W.A.	21.08	15.40	9.74	0·44	47.90	35.00	22.14
Wheat-Sheep—							
Q'ld	35.02	26.04	19.68	0·33	106.12	78.90	59.64
N.S.W.	43.88	30.40	27.76	0·46	95.38	66.08	60.34
Vic.	59.70	39.52	40.62	0·52	114.80	76.00	78.12
S.A.	44.76	30.46	22.64	0·60	74.60	50.76	37.74
W.A.	53.94	36.96	35.76	0·52	103.72	71.08	68.76
High Rainfall—							
N.S.W.	42.78	26.72	9.54	0·36	118.84	74.22	26.50
Vic.	53.40	33.56	16.22	0·44	121.36	76.28	36.86
Tas.	46.36	24.24	*	0·41	113.08	59.12	*
S.A.	83.26	49.88	23.72	0·48	173.46	103.92	49.42
W.A.	70.40	44.40	14.00	0·40	176.00	111.00	35.00

* Net income per ewe is negative if total cost are charged.

Rainfall Zones of New South Wales, Victoria, and Tasmania, and the relatively high returns obtained in the same zone in South and Western Australia. In Western Australia the net income is higher because the average rate of increase in the size of flocks is greater. This is partly due to the absence of minor droughts which reduce the annual rate of increase in flock size in the Eastern States (see Table 2).

Ewes at different ages will contribute different amounts to the average increase in flock size. Young ewes will produce more lambs than older ewes. Although no data is available concerning the age structure of ewe flocks it is obvious that the number of ewes in a younger age group will exceed that in an older group as some ewes die. The discounted net income over the twenty-year period for ewes of any age can be calculated from that of the average ewe using the formula

$$A + B + C + D + E = 5R \qquad (3)$$

where A, B, C, D, and E are the discounted net incomes from ewes of 1, 2, 3, 4, and 5 years of ages respectively and R is the average discounted income created per ewe during a twenty-year period.

The discounted net income of ewes of different ages will be affected by the variations in the following factors:

(*a*) The weight of wool cut per sheep.

(*b*) The mortality rate of ewes.

(*c*) The number of lambs a ewe will produce in her lifetime.

(*d*) Differences in lambing percentage.

The age composition of the flock could affect the amount of wool produced but as this is unknown it cannot be allowed for. Ewes reach maximum fleece weight at 2–3 years and thereafter decline at the rate of 3–4 per cent per annum.[12] Thus the income per ewe will be overestimated for young and old ewes and underestimated for ewes of medium age. As the total number of ewes in any grazing zone is largely self replacing the number of young ewes will be greater than the number of older ews. The rate of decrease will depend on the mortality rate of ewes at different ages. Observations of a Merino flock under experimental conditions suggest that the mortality rate is a constant 2 per cent for ewes between two and five years of age. Under field conditions it is probably at least 5 per cent for ewes more than one year old and 10 per cent for one year old ewes. As ewes normally produce their first lamb when they are two years old and are sold at five years of age, one and two year old ewes would produce four lambs during the remainder of their life, three years old ewes three lambs, four year old ewes two lambs and five year old ewes one lamb, if a 100 per cent lambing were obtained. Experimental flocks appear to have lambing percentages in the proportion of 1.00, 1.085, 1.176, and 1.233 for two, three, four, and five year old ewes respectively.[13]

[12] G. C. Doepel and H. N. Turner, "Causes of Variation in Average Fleece Weight", *Quarterly Review of Agricultural Economics,* Vol. 12, No. 2 (April 1959), p. 53.

[13] H. N. Turner, "Vital Statistics for an Experimental Flock of Merino Sheep", *Australian Journal of Agricultural Research,* Vol. 10, No. 4 (July, 1959).

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TABLE 3

Discounted Net Income Per Ewe Over a Twenty Year Period for Ewes of Different Ages Excluding a Drought Period

	Assuming Variable Costs Only					Assuming Proportional Costs					Assuming Total Costs				
Age of Ewe	1 Year	2 Years	3 Years	4 Years	5 Years	1 Year	2 Years	3 Years	4 Years	5 Years	1 Year	2 Years	3 Years	4 Years	5 Years
Zone and State	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
Pastoral—															
Q'ld	94.80	85.38	65.92	45.20	22.60	54.04	48.66	37.57	25.76	12.88	38.08	34.30	26.48	18.16	9.08
N.S.W.	169.06	152.27	117.56	80.61	40.31	116.69	105.10	81.14	55.64	27.82	102.98	92.75	71.61	49.10	24.55
S.A.	153.54	138.28	106.76	73.21	36.60	96.94	87.31	67.41	46.22	23.11	91.11	82.06	63.36	43.44	21.72
W.A.	72.33	65.14	50.29	34.49	17.24	52.85	47.60	36.75	25.20	12.60	33.43	30.11	23.25	15.94	7.97
Mean	122.43	110.27	85.13	58.38	29.19	80.13	72.17	55.72	38.20	19.10	66.40	59.81	46.18	31.66	15.83
Wheat and Sheep—															
Q'ld	160.24	144.32	111.43	76.41	38.20	119.14	107.30	82.85	56.81	28.40	90.06	81.11	62.62	42.94	21.47
N.S.W.	144.02	129.72	100.15	68.67	34.34	99.78	89.87	69.38	47.58	23.79	91.11	82.06	63.36	43.44	21.72
Vic.	173.35	156.13	120.54	82.66	41.33	114.76	103.36	79.80	54.72	27.36	117.96	106.24	82.03	56.25	28.12
S.A.	112.65	101.46	78.33	53.71	26.86	76.65	69.03	53.29	36.55	18.27	56.99	51.33	39.63	27.17	13.59
W.A.	156.62	141.06	108.91	74.68	37.34	107.33	96.67	74.63	51.18	25.59	103.83	93.51	72.20	49.51	24.75
Mean	149.38	134.54	103.87	71.23	35.61	103.53	93.25	71.99	49.37	24.68	91.99	82.85	63.97	43.86	21.93
High Rainfall—															
N.S.W.	179.45	161.62	124.78	85.56	42.78	112.07	100.94	77.93	53.44	26.72	40.02	36.04	27.83	19.08	9.54
Vic	183.25	165.05	127.43	87.38	43.69	115.18	103.74	80.09	54.92	27.46	55.66	50.13	38.70	26.54	13.27
Tas.	170.75	153.79	118.73	81.42	40.71	89.27	80.40	62.08	42.57	21.28	*	*	*	*	*
S.A.	261.92	235.91	182.13	124.89	62.45	156.92	141.33	109.12	74.82	37.41	74.62	67.21	51.89	35.58	17.79
W.A.	265.76	239.36	184.80	126.72	63.36	167.61	150.96	116.55	79.92	39.96	52.85	47.60	36.75	25.20	12.60
Mean	212.23	191.15	147.57	101.19	50.60	128.21	115.47	89.15	61.13	30.57	55.79	50.24	38.79	26.60	13.30

* Net income per ewe is negative.

If these weightings are applied to equation (3), the values of A, B, C, D, and E can be obtained as follows:

$$A + 0.9A + 1.085 \times 0.75 \times 0.95 \times 0.9A + 1.176 \times 0.677 \times 0.95\ (0.75 \times 0.95 \times 0.9A) + 1.233 \times 0.5 \times 0.95\ [0.677 \times 0.95\ (0.75 \times 0.95 \times 0.9A)] = 5R.$$

If R = 1 then the following values are obtained for equation (3).

$A = 0.302$
$B = 0.272$
$C = 0.210$
$D = 0.144$
$E = 0.072$

If these values are substituted in equation 3 the discounted net income of ewes of different ages is obtained. The results of this calculation for each grazing zone using the three different bases of cost calculation are shown in Table 3.

The adoption of this procedure does not assume actual lambing percentages of mortality rates for ewes of any age. These are predetermined by using the annual rate of flock increase. The procedure merely gives ewes of various ages a weighting for various factors in calculating the share of future income created by the average ewe of a particular age.

TABLE 4

Decreases in Sheep Numbers During Drought and Increases after Drought Over a 20-year Period

Zone and State	Period of Decline		Period of Rapid Increase		Period of Steady Increase	
	Rate of Decrease per annum	No. of Years of Decline	Rate of Increase per Annum	No. of Years of Rapid Increase	Rate of Increase per Annum	No. of Years of Steady Increase
	per cent		per cent		per cent	
Pastoral—						
Q'ld	6·24	7	*	*	2·24	13
N.S.W. ..	10·40	5	21·83	2	3·29	13
S.A.	11·86	5	26·15	2	3·23	13
W.A.	5·23	2	5·18	2	0·84	16
Wheat and Sheep—						
Q'ld	6·55	6	10·87	2	3·52	12
N.S.W. ..	3·78	6	7·81	2	2·50	12
Vic.	6·39	5	15·31	2	2·87	13
S.A.	6·58	5	16·57	2	2·81	13
W.A.	4·18	3	3·77	1	3·99	16
High Rainfall—						
N.S.W. ..	2·83	6	*	*	2·85	14
Vic.	5·85	5	8·10	2	3·16	13
Tas.	4·42	6	7·97	1	3·98	13
S.A.	4·53	6	11·26	1	7·32	13
W.A.	1·68	6	10·52	1	6·75	13

* Period of rapid increase did not occur in these zones.

Assuming that only variable costs increase as sheep numbers increase, the net income earned over a twenty year period by one year old ewes varies between \$72 per head in Pastoral Western Australia and \$266 in the High Rainfall Zone of the same State. These net incomes represent an annual net income of \$3.6 and \$13.3 per ewe in the respective zones. If young ewes can be purchased for \$16 per head then the annual marginal return on the capital invested in one-year-old ewes is 23 per cent in the Pastoral Zone of Western Australia and 83 per cent in the High Rainfall Zone. These figures represent the minimum return which might be expected as young ewes can normally be obtained for less than \$16 per head. At first sight these returns appear to be extremely high. However, they only represent the return which would be obtained after deducting the variable costs. Returns are much lower if fixed costs are also deducted. Nevertheless, they do indicate that farmers who are able to increase their stocking rates without increasing their fixed costs or employing additional regular labour can pay far higher prices for young ewes than the current market price and still obtain a satisfactory return on the capital invested in them, if seasons similar to those since the 1940–47 drought continue.

It is easier to reconcile the income earning capacity of ewes with their sale price if some account is taken of future risk. The income earning capacity of ewes shown in Table 3 assumes that no serious drought will be encountered. During the drought of 1940–47 sheep numbers declined. After the drought they increased rapidly for a short period of time and then continued to rise steadily. The normal pattern is that shown in Figure 1, although in some zones the period of rapid increase is missing. The annual rates of increase and decrease and the number of years over which these were sustained are shown in Table 4. The discounted net incomes per ewe for a twenty year period including a period of drought similar to that sustained between 1940 and 1947 can be calculated using the following equation:

$$DNE = R\left[x_1\left(\frac{x_1^{t_1}-1}{x_1-1}\right) + x_1^{t_1}x_2\left(\frac{x_2^{t_2}-1}{x_2-1}\right) + x_1^{t_1}x_2^{t_2}x_3\left(\frac{x_3^{t_3}-1}{x_3-1}\right)\right] \quad (4)$$

Where DNE = the discounted net income per sheep.

R = the annual net income per sheep.

$x = \dfrac{e^{\lambda}}{1+r}$.

λ = the rate of average increase or decrease in sheep numbers.

r the discount rate.

t = the number of years over which any rate of increase or decrease applied.

The subscripts 1, 2 and 3 apply respectively to the period of decline during the drought, the period of rapid recovery in sheep numbers after the drought and the period of slower increase following recovery. The rates of decline and increase and the periods over which they occurred are shown in Table 4. The discounted net incomes per ewe of different ages which would be obtained over a twenty year period including a period of drought similar to that experienced in 1940–47 calculated in this way are shown in Table 5. Although the discounted net incomes are much less than those obtained for a period excluding drought the price of young ewes is still three to ten times as high as the ruling market price, assuming

TABLE 5

Discounted Net Income Per Ewe Over a Twenty Year Period for Ewes of Different Ages Including a Drought Period

	Assuming Variable Costs					Assuming Proportionate Costs					Assuming Total Costs				
Age of Ewe	1 Year	2 Years	3 Years	4 Years	5 Years	1 Year	2 Years	3 Years	4 Years	5 Years	1 Year	2 Years	3 Years	4 Years	5 Years
Zone and State	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
Pastoral—															
Q'ld	63.30	56.96	40.47	25.60	12.11	36.10	32.47	23.08	14.59	6.90	25.45	22.90	16.27	10.29	4.87
N.S.W.	126.14	113.48	80.65	51.01	24.11	87.07	78.33	55.68	35.21	16.64	76.79	69.08	49.10	31.05	14.69
S.A.	114.56	103.07	73.26	46.32	21.91	72.32	65.06	46.24	29.25	13.82	67.94	61.12	43.45	27.48	12.98
W.A.	73.75	66.36	47.16	29.82	14.11	53.92	48.50	34.47	21.80	10.32	34.13	30.70	21.82	13.80	6.53
Mean	94.44	84.97	60.39	38.19	18.06	62.35	56.09	39.87	25.21	11.92	51.08	45.95	32.66	20.66	9.77
Wheat and Sheep—															
Q'ld	112.13	100.86	71.70	45.34	21.44	83.45	75.07	53.37	33.74	15.96	63.00	56.69	40.29	25.48	12.05
N.S.W.	118.98	107.04	76.09	48.10	22.74	82.39	74.12	52.69	33.31	15.75	75.24	67.70	48.12	30.42	14.40
Vic.	144.49	129.99	92.41	58.43	27.63	95.68	86.08	61.19	38.69	18.30	98.28	88.42	62.85	39.76	18.79
S.A.	95.19	85.63	60.86	38.49	18.20	64.79	58.29	41.43	26.19	12.40	48.17	43.33	30.81	19.48	9.22
W.A.	131.34	118.18	84.00	53.12	25.12	90.03	81.00	57.58	36.40	17.21	87.07	78.34	55.69	35.20	16.64
Mean	120.43	108.34	77.01	48.70	23.03	83.27	74.91	53.25	33.67	15.92	74.35	66.90	47.55	30.07	14.22
High Rainfall—															
N.S.W.	142.94	128.59	91.41	57.80	27.34	89.26	80.31	57.08	36.09	17.06	31.85	28.65	20.36	12.88	6.10
Vic.	139.68	125.68	89.32	56.48	26.71	87.77	78.97	56.13	35.49	16.79	42.40	38.16	27.12	17.15	8.11
Tas...	121.47	109.30	77.68	49.11	23.23	63.53	57.15	40.62	25.69	12.15	*	*	*	*	*
S.A.	156.96	141.22	100.38	63.48	30.00	94.03	84.62	60.14	38.03	17.97	44.68	40.20	28.58	18.07	8.54
W.A.	254.65	229.12	162.85	102.99	48.70	160.62	144.51	102.71	64.95	30.72	50.66	45.57	32.40	20.48	9.68
Mean	163.14	146.78	104.33	65.97	31.20	99.04	89.11	63.34	40.05	18.94	42.40	38.15	27.12	17.15	8.11

* Net income per ewe is negative.

costs are proportionate to the amount sheep output forms of gross output. In purchasing ewes farmers only consider the net income a ewe will earn during her lifetime. This would be little more than the sale price. It is also probable that farmers discount future earnings of ewes at a higher rate than seven per cent, or consider that other forms of investment are more profitable than purchasing ewes. The discounted net incomes earned by ewes during a twenty year period either excluding or including a drought suggest that they are of greater value to the nation than their sale price suggests. If losses during severe drought could be prevented the value of ewes in any grazing zone would be their net income earning capacity over a twenty year period excluding a serious drought (see Table 3). The value of avoidance of losses in a current drought is the discounted net income earning capacity of ewes over a twenty year period less the discounted probable cost of avoiding drought losses over the next twenty years.

The cost of feeding sheep will vary with the price of wheat, the distance it has to be transported, and cost of feeding wheat out. Wheat is available at silos in New South Wales as stock feed for $1.53 per bushel less the freight from the silo to the normal shipping port. To this cost must be added the freight to the railway siding where the sheep are to be fed and the cost of bags. A Sydney firm supplying feed wheat to graziers will deliver wheat at the following sidings at the prices listed below:

Bourke	$1.69 per bushel
Armidale	$1.67 per bushel
Cooma	$1.68 per bushel
Narromine	$1.51 per bushel

As the difference in the price of wheat at different places is not great, Bourke might be taken as being typical of the Pastoral Zones, Narromine as being typical of the Wheat and Sheep Zones, and the average of Cooma and Armidale as being typical of the High Rainfall Zones in all States. The distance wheat would have to be carted from the siding to the grazing property will vary, but it will be greatest in the Pastoral Zones. If it is assumed that the average distance is 100 miles in the Pastoral Zones, 40 in the Wheat and Sheep Zones, and 20 miles in the High Rainfall Zones, and that road cartage costs 10c per ton mile then the total cost of feed wheat landed on the property would be as follows:

	Price of wheat at rail siding	Cost of road haulage to farms	Cost of wheat on farm	
			Cost per bus	Cost per lb
	cents per bus	cents per bus	cents	cents
Pastoral Zone	169	27	196	3·27
Wheat and Sheep Zone ..	151	11	162	2·70
High Rainfall Zone	167	5·4	172·4	2·87

In an extremely detailed study of the price of feed wheat, Powell concluded that the price would vary between 2.16 and 3.08 cents per lb in pastoral Queensland with wheat selling at $1.26 per bushel.[14] If feed wheat

[14] Powell, op. cit., p. 104.

costs $1.53 per bushel the comparable figures at 1965 prices are 2.6 and 3.5 cents per lb. Thus the accuracy of the calculation should not be affected by the somewhat arbitrary manner in which the price of feed wheat has been calculated.

A ration of 5 lb of wheat is sufficient to sustain wethers and dry ewes during a drought, but mated ewes and ewes rearing lambs require larger rations. The following rations are considered necessary for breeding ewes at particular periods:

8.0 food units per week for 4 weeks before lambing = 11.11 lb wheat.

10.0 food units per week for 15 weeks after lambing = 13.89 lb wheat.

The actual wheat fed to mated ewes would vary with the lambing percentage as ewes without lambs could be fed on a maintenance ration.[15]

The actual quantities and cost of wheat required to feed mated ewes in each grazing zone for one year calculated on this basis using the prices of wheat estimated for each zone are as follows:

	Pastoral Zone		Wheat and Sheep Zone		High Rainfall Zone	
	Quantity	Cost	Quantity	Cost	Quantity	Cost
	lb	$	lb	$	lb	$
Q'ld	399	13.05	426	11.50	..	..
N.S.W.	424	13.85	428	11.56	431	12.37
Vic.	..	..	443	11.96	439	12.60
Tas.	..	..	..	..	459	13.17
S.A.	420	13.73	430	11.61	445	12.77
W.A.	385	12.59	423	11.42	424	12.17

As dry ewes, including unmated one year old ewes, only require 5 lb of wheat per week the total cost of feeding each ewe for one year in the various zones would be as follows:

Pastoral Zone	$8.6 + labour $0.4 = $9.0
Wheat and Sheep Zone	$7.0
High Rainfall Zone	$7.4

In the High Rainfall Zone and the Wheat and Sheep Zones it can be assumed that the normal farm labour force would be sufficient to feed sheep. In the Pastoral Zone where sheep flocks are large and the stocking rate low this could not be assumed. If an additional man is required for every 3,000 sheep fed at a wage of $1,600 per annum the cost of feeding would be increased by $0.4 per sheep fed per annum.

The ratio between the discounted net income which will be created by a ewe of a particular age in any grazing zone shown in Table 3 and the cost of feeding a ewe for any period will indicate the proportion of ewes of a particular age which would need to die before feeding all the ewes

[15] G. L. McClymont, "Hand Feeding of Sheep", *Agricultural Gazette of N.S.W.*, Vol. LXVII (1956), pp. 394–401, 443, 455–63, 537–44, 553, 593–600.

TABLE 6

Percentage of Ewes of Each Age Which Would Have to Die Before Feeding for One Year Becomes Economic

Zone and State	Assuming Variable Costs Only					Assuming Proportional Costs Only					Assuming Total Costs				
Age of Ewe	1 Year	2 Years	3 Years	4 Years	5 Years	1 Year	2 Years	3 Years	4 Years	5 Years	1 Year	2 Years	3 Years	4 Years	5 Years
	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
Pastoral—															
Q'ld	9	15	20	29	58	17	27	35	51	101	24	38	49	72	144
N.S.W.	5	9	12	17	34	8	13	17	25	50	9	15	19	28	56
S.A.	6	10	13	19	38	9	16	20	30	59	10	17	22	32	63
W.A.	12	19	25	37	73	17	26	34	50	100	27	42	54	79	158
Wheat and Sheep—															
Q'ld	4	8	10	15	30	6	11	14	20	41	8	14	18	27	54
N.S.W.	5	9	12	17	34	7	13	17	24	49	8	14	18	27	53
Vic.	4	8	10	14	29	6	12	15	22	44	6	11	15	21	43
S.A.	6	11	15	22	43	9	17	22	32	64	12	23	29	43	85
W.A.	4	8	10	15	31	7	12	15	22	45	7	12	16	23	46
High Rainfall—															
N.S.W.	4	8	10	14	29	7	12	16	23	46	18	34	44	65	130
Vic.	4	8	10	14	29	6	12	16	23	46	13	25	33	47	95
Tas...	4	9	11	16	32	8	16	21	31	62	*	*	*	*	*
S.A.	3	5	7	10	20	5	9	12	17	34	10	19	25	36	72
W.A.	3	5	7	10	19	4	8	10	15	30	14	26	33	48	97

* Net income per ewe is negative.

in a particular age group becomes economic from a national point of view. The proportion of ewes which would have to die in any grazing zone to justify one year's feeding of all ewes in each age group is shown in Table 6. Only a small proportion of the younger ewes would need to die before feeding was justified from a national point of view. On the other hand, the losses of older ewes which would have to occur during a year would need to be very high before feeding could be justified on national economic grounds. Although it is possible to calculate the decline in ewe numbers in any grazing zone during any period of drought the decline in numbers in any particular age group is unknown. This problem can be overcome by calculating the proportionate decline which would occur in ewe flocks if all of the different age groups declined to the point where feeding became economical. Assuming the normal ewe has a life of five years then the composition of the flock can be expressed as

$$A + B + C + D + E = T \qquad (5)$$

where A, B, C, D, and E are the numbers of sheep of 1, 2, 3, 4, and 5 years of age respectively and T is the total number of ewes in the flock. Assuming that there is a 10 per cent mortality among one-year-old ewes and a 5 per cent mortality per annum in all older ewes than in a flock of 100 ewes

$$A + 0.9A + (0.95 \times 0.9A) + (0.95 \times 0.95 \times 0.95A) + (0.95 \times 0.95 \times 0.95 \times 0.9A) = 100$$

In equation (5)

$A = 23.0$
$B = 20.8$
$C = 19.7$
$D = 18.7$
$E = 17.8$

By multiplying these percentages by the proportion of sheep in each age group which would need to die before feeding became economical and summing the result, the total decline in the flock which would have to occur before hand feeding is economical is obtained. The results of this calculation are shown in Table 7.

The losses indicated in Table 7 can be compared with the decline in ewe numbers in the various grazing zones in the long drought of 1940–47. If the total decline was due to deaths caused by drought then the number of years over which feeding would be economically justified from a national point of view can be obtained by dividing the percentage decline in ewes by the percentage of ewes which would need to die to justify feeding during one year. This period can then be compared with the length of drought as calculated by Foley during the period 1940–47 (see Table 8). If it is assumed that only variable costs are charged, the period over which feeding is justified only exceeds the period of the drought in the Victorian Wheat and Sheep Zones and the Western Australian High Rainfall Zone. In the High Rainfall Zone of Western Australia it is doubtful if the decline in ewe numbers was due to drought as no drought is recorded. As sheep numbers would more than double during a twenty-year period not seriously affected by drought or if ewes were kept alive by feeding during a serious drought it is far more likely that costs would equal the proportion of total costs that gross revenue from sheep forms of total gross farm revenue.

TABLE 7

Ewe Losses as a Proportion of Total Flock if Ewes in Each Age Group Die in the Proportion Warranting Feeding for One Year

Zone and State	Decline in ewe numbers during 1941–47 drought	Assuming variable costs only	Assuming proportional costs only	Assuming total costs
	per cent	per cent	per cent	per cent
Pastoral—				
Q'ld	23	25	44	62
N.S.W.	49	15	21	24
S.A.	42	16	26	27
W.A.	3	32	43	68
Wheat and Sheep—				
Q'ld	21	13	17	23
N.S.W.	24	14	21	23
Vic.	33	12	19	18
S.A.	21	18	27	36
W.A.	3	13	19	20
High Rainfall—				
N.S.W.	27	12	20	55
Vic.	17	12	20	40
Tas.	13	14	26	*
S.A.	15	9	15	31
W.A.	12	8	13	42

*Net income per ewe is negative.

TABLE 8

The Number of Years in which Feeding is Economic as a Proportion of the Years of Drought 1940–47*: Assuming Ewes Die in the Same Proportion as Feeding is Economically Warranted*

Zone and State	Period of Drought During Which Ewe Numbers Declined	Length of Drought Estimated by Foley	Years During Which Feeding is Economically Warranted as a Proportion of Years of Drought Assuming—		
			(a) Variable Costs	(b) Proportional Costs	(c) Total Costs
Pastoral—					
Q'ld	6	5·0	0·18	0·11	0·07
N.S.W.	4	4·5	0·74	0·51	0·45
S.A.	4	5·5	0·47	0·30	0·28
W.A.	1	1·0	0·09	0·06	0·04
Wheat and Sheep—					
Q'ld	4	3·5	0·46	0·34	0·26
N.S.W.	6	5·5	0·30	0·21	0·19
Vic.	3	2·5	1·06	0·70	0·72
S.A.	4	2·25	0·50	0·34	0·25
W.A.	1	1·0	0·20	0·14	0·13
High Rainfall—					
N.S.W.	4	3·0	0·73	0·46	0·16
Vic.	4	2·5	0·54	0·34	0·16
Tas.	3	1·5	0·65	0·34	*
S.A.	4	2·25	0·76	0·45	0·22
W.A.	2	....	†	†	†

*Net income per ewe is negative.
†Not applicable because there was no drought.

Making this assumption the period over which feeding is economically warranted is less than seventy per cent of the length of the 1940–47 drought in all zones and less than one half of the length of the drought in most zones. In the pastoral Zone of Western Australia it is less than 1/10th of the length of drought. It should not be forgotten that this method of calculation over-estimates the losses caused by droughts as it assumes that the total decline in ewe numbers is caused by deaths during the drought. In fact an unknown proportion of the ewes is sold for slaughter giving some additional reutrn which is not accounted for.

Although large decreases in ewe numbers do occur during severe droughts in most of the sheep grazing zones of Australia the additional income which would be obtained from these ewes over a twenty-year period is certainly less than the cost of feeding all ewes throughout the whole period of the drought.

The major weakness in this conclusion is that the period over which sheep would have to be fed during the drought is unknown. For many zones this may not appear to be a serious limitation. In the Queensland pastoral zone the income earning capacity of ewes only warranted feeding ewes for one tenth of the long drought of 1942–48. However, Powell using a formula based on effective rainfall estimated that during this drought hand-feeding in the Aramac Shire in pastoral Queensland would only be necessary for 10 months. While Powell also pointed out that there was very little correlation between the decline in sheep numbers and the number of months during which feeding would be required, his suggestion that 10 months of feeding was the total required to maintain sheep numbers during a six year drought does suggest that feeding of the younger ewes may be worthwhile during a long drought.[16] Thus at first sight it would appear that farmers in acting in their own interest in allowing ewe numbers to decline rather than in retaining them by feeding are also acting in the best interest of the nation. But in view of Powell's evidence on the period over which sheep would have to be fed this conclusion must be regarded as tentative, because the exact number of ewes dying in each age group in each grazing zone and the period over which ewes would have to be fed to prevent these deaths is unknown.

Any government support to graziers for feeding sheep would have to be given early in the drought when its length and the percentage of deaths which are likely to occur are unknown. As the losses incurred in the severe drought of 1940–47 were not sufficient to economically justify additional feeding there is little evidence to support a State subsidy for graziers for drought fodder in the interest of the national economy unless the period over which feeding is required is much less than the length of the drought.

Wethers

If it is doubtful if ewes are worth feeding from a national point of view in a severe drought it is unlikely that wethers will be worth maintaining for even a short period of time if hand feeding is necessary.

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[16] Powell, *op. cit.*, p. 201.

The income earning capacity of wethers of any age group is the amount of wool they will produce in future plus their value when sold for meat with both meat and wool discounted to its value at the commencement of the drought. Wethers are sold at varying ages but some idea of the age at sale can be obtained from the ratio of wethers to ewes in sheep flocks in any grazing zone. If it is assumed that ewes are only sold when they are five or six years old then the age at which wethers are sold can be obtained by establishing the ratio between the percentages of wethers to ewes in the total flock in each grazing zone. The results of this calculation are shown in Table 9. The ratio of wethers to ewes varies between 0.8 and 0.3 for different grazing zones indicating that wethers may be sold at ages varying between two and four years old. Wether prices vary throughout the year and monthly average prices are published for particular grades. Prices are lowest when most wethers are sold and a higher proportion of premium wethers are obtained from the better rainfall areas. However, the exact proportion of each quality from each zone is unknown. It is necessary to allot wether prices on a somewhat arbitrary basis. In most States the average prices of four classes of wethers are quoted. In the High Rainfall grazing zones the average price of the second best class of wethers was selected. In the Pastoral Zone and the Wheat and Sheep Zone the average price of the second and third classes was used. In addition prices were weighted on the assumption that large numbers of wethers are sold during the months when prices are low. The exact weightings used depended on the published data available and are shown in the notes to Table 10. Possible inaccuracies in the estimation of the sale price of wethers will have a far larger effect on the total estimated income of wethers slaughtered when they are one or two years old than of wethers slaughtered when they are four or five years of age. In the latter case the income from the carcase will be only a small proportion of the income obtained from wool during the wether's lifetime. The actual sale prices allotted to wethers for various grazing zones and the basis on which these prices were calculated are shown in Table 10.

TABLE 9

The Ratio of Wethers to Ewes in Sheep Flocks in Different Grazing Zones

State	Pastoral			Wheat and Sheep			High Rainfall		
	Sheep as Percentage of Flock		Ratio of Wethers to Ewes	Sheep as Percentage of Flock		Ratio of Wethers to Ewes	Sheep as Percentage of Flock		Ratio of Wethers to Ewes
	Ewes	Wethers		Ewes	Wethers		Ewes	Wethers	
	per cent	per cent		per cent	per cent		per cent	per cent	
Q'ld	45·5	37·4	0·823	44·8	40·3	0·899	*	*	*
N.S.W.	56·0	18·6	0·332	52·2	26·8	0·515	44·5	36·5	0·820
Vic.	†	†	†	48·1	30·9	0 642	50·2	28·0	0·557
Tas.	‡	‡	‡	‡	‡	‡	50·4	24·5	0·486
S.A.	57·2	20·4	0·357	54·9	22·6	0·412	44·5	34·1	0·766
W.A.	48·5	32·4	0·668	53·5	23·8	0·448	43·4	37·7	0·868

* Queensland has no High Rainfall Zone.

† Victoria has no Pastoral Zone.

‡ Tasmania has no Pastoral or Wheat and Sheep Zone.

TABLE 10

Estimated Wether Prices for Different Grazing Zones 1960–61 *to* 1962–63*

	Price per Head
	$
Pastoral Zone—	
Queensland	4.752
N.S.W.	4.952
S.A.	5.196
W.A.	3.304
Wheat and Sheep Zone—	
Queensland	4.752
N.S.W.	5.426
Victoria	5.472
S.A.	5.466
W.A.	4.172
High Rainfall Zone—	
N.S.W.	5.998
Victoria	6.046
Tasmania	6.046
S.A.	6.534
W.A.	5.412

* In all States the average prices for the 3 years 1960–61 to 1962–63 were used, but they were calculated as follows:

N.S.W. and S.A. prices are published on a monthly basis. The price used was

$$\frac{\text{highest monthly price} + (\text{lowest monthly price} \times 2)}{3}$$

Queensland only the average annual prices are published and these were used for both pastoral and wheat and sheep zones.

W.A. prices are published on a shorn and unshorn wool basis. The price used was the average annual $\frac{(\text{shorn price} \times 2) + \text{in-wool price}}{3}$

No prices are published for Victoria. These were estimated from the N.S.W. prices by weighting by the ratio of export wether prices from N.S.W. and Victoria.

Tasmanian prices are not published and Victorian prices were used.

The B.A.E. Survey merely states the value of wool obtained per sheep in each particular grazing zone. A more accurate estimate of the value of wool per sheep can be obtained if the composition of the flock and the ratios of wool weights from different types of sheep are known.[17] It is then possible to calculate the number of dry ewe equivalents per 100 sheep in the flock. The total value of wool produced in the zone divided by the total number of dry ewe equivalents gives the average value of wool per dry ewe equivalent. The value of wool produced by any type of sheep can be obtained by multiplying this value by the ratio between the wool weight of any particular type of sheep and the weight of wool produced per dry ewe. The annual value of wethers' wool at the average prices ruling from 1960–61 to 1962–63 estimated in this way is shown in Table 11.

[17] H. N. Turner, "Production per Head" in Alan Barnard (ed.), *The Simple Fleece* (Melbourne University Press, 1962), p. 52.

TABLE 11

Estimated Average Value of Wool Produced per Wether per Annum in Different Grazing Zones 1960–61 *to* 1962–63

	$
Pastoral Zone—	
Queensland	5.144
N.S.W.	6.044
S.A	6.210
W.A.	4.434
Wheat and Sheep Zone—	
Queensland	5.192
N.S.W.	5.050
Victoria	5.284
S.A.	5.408
W.A.	4.866
High Rainfall Zone—	
N.S.W.	5.810
Victoria	5.544
Tasmania	5.176
S.A.	5.992
W.A.	5.294

Both the revenue received from the sale of wethers' wool and from the final sale of the sheep itself and the annual variable cost of supporting the wethers must be discounted to calculate the actual net income a farmer can expect from wethers. This calculation can be carried out using the formula—

$$DNW = \frac{W_1 - C_1}{1 + r} + \frac{W_2 - C_2}{(1 + r)^2} + \ldots\ldots + \frac{W_n - C_n}{(1 + r)^n} + \frac{V_c}{(1 + r)^n}$$

Where DNW = Discounted net income from a wether.
W = The annual revenue from wool.
V_c = The revenue from the sale of the wether.
C = The annual variable cost of maintaining a wether.
r = The rate of discount.

Subscripts 1, 2, etc., are the years after the drought commences and n is the number of years from the commencement of the drought until the wether is sold.

The estimated discounted net incomes (DNW) expected from wethers for different grazing zones in the various States are shown in Table 12. These assume the values of wool shown in Table 11, the values of carcases shown in Table 10, the annual variable cost of retaining sheep stated in the B.A.E.'s Sheep Industry Survey, an average mortality rate of 5 per cent, and a discount rate of 7 per cent.

The cost of feeding wethers would be similar to that of feeding dry ewes, namely—

$9 per head in the Pastoral Zone
$7 per head in the Wheat and Sheep Zone
$7.40 per head in the High Rainfall Zone.

TABLE 12

Average Discounted Net Income from Wethers Assuming 1960–61 *to* 1962–63 *Costs and Prices*

Age Sold	2 Years		3 Years			5 Years			
Age in Years at Commencement of Drought	<1	1	<1	1	2	<1	1	2	3
Zone and State	$	$	$	$	$	$	$	$	$
Pastoral Zone—									
Q'ld	5·728	6·800	7·376	8·650	6·800	10·162	11·768	10·298	8·650
N.S.W.	7·078	7·890	9·418	10·514	7·890	10·566	14·944	12·854	10·514
S.A.	7·360	8·202	9·754	10·888	8·202	13·806	15·422	13·282	10·888
W.A.	3·994	5·000	5·346	6·514	5·000	7·628	9·070	7·866	6·514
Wheat and Sheep Zone—									
Q'ld	5·302	6·416	6·590	7·860	6·416	8·668	10·298	9·148	7·860
N.S.W.	5·802	7·142	7·168	8·672	7·142	9·474	11·254	10·038	8·672
Vic.	6·034	7·354	7·530	9·036	7·354	10·066	11·872	10·532	9·036
S.A.	6·892	8·030	8·614	9·964	8·030	11·532	13·226	11·686	9·964
W.A.	5·770	6·630	7·730	8·824	6·630	11·040	12·530	10·784	8·824
High Rainfall Zone—									
N.S.W.	6·602	8·436	8·542	9·044	8·436	11·828	14·286	12·552	10·612
Vic.	6·156	8·134	7·838	10·000	8·134	10·652	13·148	11·662	10·000
Tas.	4·306	6·984	5·052	7·824	6·984	6·318	9·238	8·570	7·826
S.A.	7·384	9·166	9·480	11·518	9·166	13·026	15·486	13·614	11·518
W.A.	6·576	7·882	8·532	10·150	7·882	11·732	13·812	12·056	10·090

The proportion of wethers which would need to die for feeding to be more economical than allowing the wethers to die is equal to the ratio between the cost of feeding and expected income from the wether. This proportion for the different grazing zones using the stated costs of feeding for a drought lasting one year are shown in Table 13. The lowest value obtained is for the High Rainfall Zone in New South Wales where 52 per cent of one year old wethers would need to die before feeding for 12 months in any drought was economically justified. In the long drought of 1940–47 the decline in wethers in this region was only 24 per cent. Even in the pastoral zone of New South Wales wether numbers only declined by 53 per cent over the six-year drought period 1940–46. A decline of 56 per cent would have been necessary to make one year's feeding economical in this region. All of these declines include sales of wethers as well as deaths, but the proportion of each is unknown. Thus even in this area in a prolonged drought there is no evidence to suggest that the additional net national income obtained from wethers kept alive by feeding would have exceeded the cost of feeding them even if feeding were only necessary during one-sixth of the period of drought. On the basis of the contribution made by wethers to future national income there appears to be no reason why state assistance should be given to feed them.

THE NATIONAL COST OF DROUGHT

A second measure of whether sheep are or are not worth feeding during a period of drought can be obtained by finding the difference between the discounted net income per sheep over a twenty-year period free from drought and the discounted net income per sheep over a similar period containing a period of severe drought. The discounted net income per sheep for each grazing zone assuming no drought is shown in Table 2, and the discounted net income per sheep for each zone assuming a drought as serious as that of 1940–47 can be calculated by applying equation (4) to the rates of decline in sheep numbers during a drought and the rates of recovery after a drought for the periods shown in Table 4. The difference between these two sets of net income multiplied by the number of sheep in each grazing zone in 1963 will give the cost of a drought as severe as the 1940–47 drought if prices and costs were the same as those ruling in 1960–63, and if the same proportion of sheep died in each area as in 1940–47. The results of this calculation are shown in Table 14.

If the only additional costs were the variable cost of keeping a ewe the total national loss over the twenty-year period would be $1,880 million. As sheep numbers would approximately double it is far more likely that costs are equal to the proportion income from sheep forms of gross income. Under these conditions the national loss of income would be approximately $1,272 million. This sum is approximately one-third larger than the $900 million which would be required to feed Australia's 75 million ewes a breeding ration for a period of one year. Feeding is warranted from a national point of view if ewes would require feeding for less than one and one-third years in a twenty-year period. Younger ewes would be worth feeding for a much longer period and older ewes for a shorter period.

TABLE 13

Proportion of Wethers Which Would Need to Die Before Feeding was Economical for One Year

Age at Commencement of Drought	Sold at 2 Years Old		Sold at 3 Years Old			Sold at 5 Years Old				Cost of Feed per Annum
	<1	1	<1	1	2	<1	1	2	3	
State and Zone	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	$
Pastoral Zone—										
Q'ld	100	100	100	100	100	88	76	87	100	9.00
N.S.W.	100	100	95	86	100	85	60	70	86	9.00
S.A.	100	100	92	83	100	65	58	68	83	9.00
W.A.	100	100	100	100	100	100	99	100	100	9.00
Wheat and Sheep Zone—										
Q'ld	100	100	100	89	100	81	68	76	89	7.00
N.S.W.	100	98	98	81	98	74	62	70	81	7.00
Vic.	100	95	93	77	95	69	59	66	77	7.00
S.A.	100	87	81	70	87	61	53	60	70	7.00
W.A.	100	100	90	79	100	63	56	65	79	7.00
High Rainfall Zone—										
N.S.W.	100	88	87	82	88	62	52	59	70	7.40
Vic.	100	91	94	74	91	69	56	63	74	7.40
Tas.	100	100	100	94	100	100	80	86	94	7.40
S.A.	100	81	78	64	81	57	48	54	64	7.40
W.A.	100	94	87	73	94	63	53	61	73	7.40

TABLE 14

Estimated Losses in National Income in Different Grazing Zones Assuming a Drought as Severe as that of 1940–47 with 1960–61 to 1962–63 Sheep Numbers, Prices and Costs

Zone and State	Total Income Lost		
	Assuming Variable Costs Only	Assuming Proportional Costs Only	Assuming Total Costs Only
	$m	$m	$m
Pastoral—			
Q'ld	184·50	105·18	74·24
N.S.W.	154·52	106·64	94·06
S.A.	43·00	27·16	25·52
W.A.	*	*	*
Wheat and Sheep—			
Q'ld	46·34	34·48	26·00
N.S.W. (Slopes)	210·52	145·78	133·44
N.S.W. (Central Plain)	268·22	185·78	166·50
Vic.	116·00	76·72	78·94
S.A.	73·80	50·30	37·40
W.A.	125·50	86·00	83·10
High Rainfall—			
N.S.W.	190·82	119·14	42·36
Vic.	271·28	170·50	82·52
Tas.	55·90	29·20	†
S.A.	179·32	107·40	51·10
W.A.	44·36	28·00	8·80
Total	1,964·08	1,272·28	903·98

* Expansion in sheep numbers between commencement of the drought of the 1940's and 1963 was greater than the expansion between the end of the drought and 1963.
† Net income per ewe is negative.

A similar calculation was carried out by Franklin who suggested that the drought of 1940–47 had cost Australia $1,200 million during the ten-year period of 1944–54.[18] The discrepancy between Franklin's calculation and the one carried out above is caused by Franklin using the undiscounted gross value of wool produced rather than the discounted net income from sheep. The period studied by Franklin also included the years 1951 and 1952 when wool prices were extremely high. While Franklin overestimated the cost of the drought by approximately 100 per cent the loss is still substantial.

The total national loss in national income calculated in Table 14 assumes that sheep numbers would increase at a steady rate unless the growth in flock size were checked by drought. The actual amount of the net national income lost is represented by the difference in total sheep numbers including and excluding drought. This is the shaded area ABCDE in Figure 3. If the number of sheep is regarded as being constant because of lack of markets for wool or of an inability to graze more sheep the

[18] M. C. Franklin "Drought", in Alan Barnard (ed.), *The Simple Fleece* (Melbourne University Press, 1962) pp. 267–277.

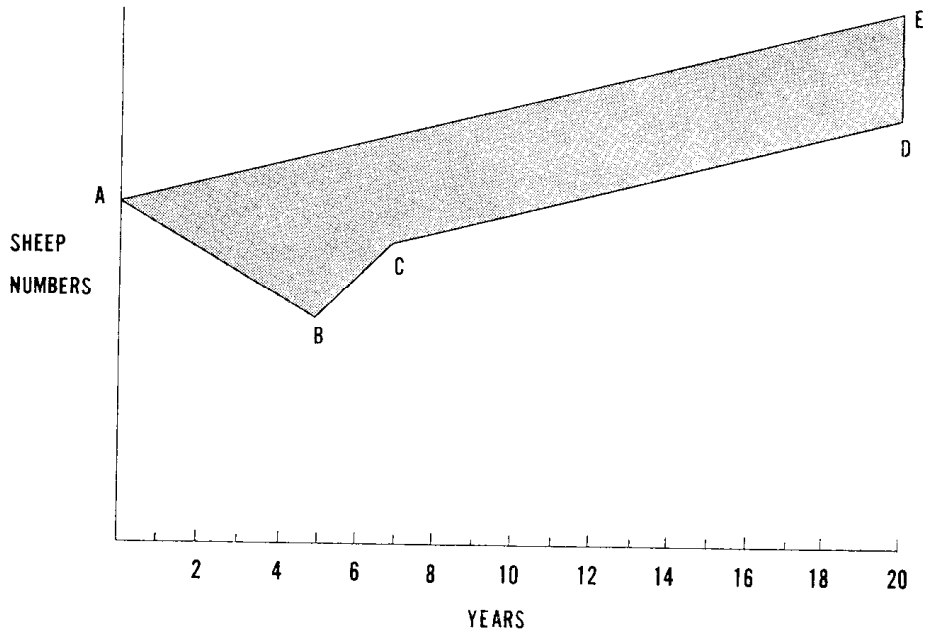

Figure 3. Difference in Sheep Numbers in a Twenty Year Period Including and Excluding Drought Assuming Sheep Numbers are Expanding.

loss would be much smaller. It would be the difference between the income obtained from a constant number of sheep which would have existed if the drought had not occurred and the smaller number of sheep which would exist for a number of years during and after the drought until the original number of sheep were regained. This situation is shown diagrammatically in Figure 4. The income lost is represented by the area ABCD: The discounted net income obtained from a constant number of sheep in any grazing zone can be calculated from the formula—

$$DNI = \frac{R}{(1 + r)} \left[\frac{\left(\frac{1}{1 + r}\right)^t - 1}{\frac{1}{1 + r} - 1} \right] \times N \quad (6)$$

where DNI = discounted net income without drought.

R = the annual net income per sheep.

t = the time period between the commencement of the drought and when the original flock numbers are established after the drought.

r = the discount rate.

N = the number of sheep in the grazing zone at the commencement of the drought.

The income obtained assuming a period of drought and recovery can be obtained from equation (4) using the rates of decline and recovery in sheep numbers shown in Table 4. The period of decrease in sheep numbers during the drought and of rapid recovery after the drought are also those shown in Table 4. The additional period required to establish the original sheep numbers at the normal rate of flock growth can be established by calculating the value of t_3 from the following equations:

$$\log_e x_2 = \lambda_1 t_1 + \log_e x_1$$
$$\log_e x_3 = \lambda_2 t_2 + \log_e x_2$$
$$\log_e x_1 = \lambda_3 t_3 + \log_e x_3$$

where x_1 = the number of sheep at the commencement of the drought.

x_2 = the number of sheep at the end of the drought.

x_3 = the number of sheep at the end of the period of rapid recovery.

λ_1, is the rate of decline, during the drought and λ_2, and λ_3 are the rates of rapid increase and steady increase after the drought. Periods t_1 and t_2 are the respective lengths of the periods of decline and recovery, and t_3 is the period of normal flock growth needed to restore flock numbers to those which existed at the beginning of the drought.

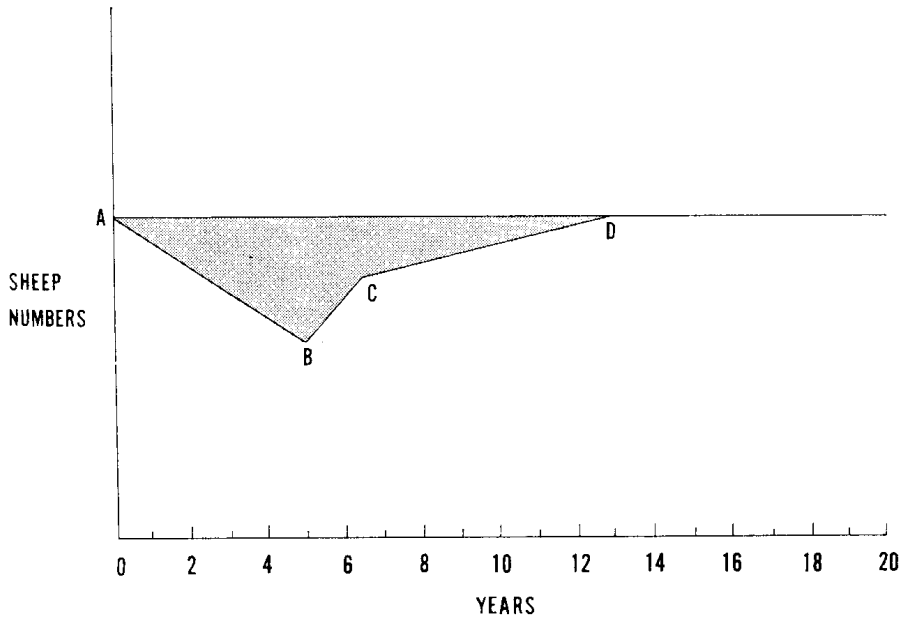

Figure 4. Difference in Sheep Numbers During a Period of Drought Assuming Sheep Numbers are at a Maximum at the Commencement of the Drought.

TABLE 15

Discounted Net Income Lost During a Drought of the Severity of the 1940–47 *Drought Assuming* 1960–61 *to* 1962–63 *Sheep Numbers, Costs and Prices; Assuming that Sheep Numbers would have Remained Static if the Drought had not Occurred*

Grazing Zone and State	Total Sheep, 1963	Net Income per Sheep, 1960–1963	Years Taken to Regain Sheep Numbers	Total Discounted Net Income Excluding Drought	Total Discounted Net Income Including Drought	Discounted Net Income Lost Because of Drought
	('000)	$	years	$m	$m	$m
Pastoral—						
Q'ld	18·196	2.14	26·56	464·14	366·84	97·30
N.S.W.	9·388	5.94	9·55	251·68	203·90	47·78
S.A.	2·483	4.18	9·16	68·48	53·98	14·50
W.A.	3·415	1.86	3·82	20·74	19·60	1·14
Total	33·482	....	....	805·04	644·32	160·72
Wheat and Sheep—						
Q'ld	3·927	2.42	12·97	79·34	66·76	12·58
N.S.W. (Slopes)	23·377	3.32	10·81	575·40	493·30	82·10
N.S.W. (Central Plain)	20·505	3.64	10·18	527·18	452·36	74·82
Vic.	9·221	4.38	7·48	229·90	197·88	32·02
S.A.	8·273	3.32	15·63	256·10	248·86	7·24
W.A.	8·549	3.56	6·20	148·92	139·52	9·40
Total	73·852	....	....	1,816·84	1,598·68	218·16
High Rainfall—						
N.S.W.	18·105	3.14	11·95	451·76	413·88	37·88
Vic.	18·250	3.82	11·13	529·06	458·96	70·10
Tas.	3·570	3.06	11·66	85·26	75·04	10·22
S.A.	4·981	4.14	9·18	136·20	119·54	16·66
W.A.	6·762	3.52	6·95	127·56	123·88	3·68
Total	51·668	....	....	1,329·84	1,191·30	138·54
Grand Total	159·002	....	....	3,951·72	3,434·30	517·42

The discounted net income for each grazing zone assuming sheep numbers are held constant and that obtained assuming they decline and later return to the original number and the period taken to attain the original numbers are shown in Table 15. As sheep numbers do not increase above the number at the beginning of the drought the net income including and excluding a period of drought is calculated using variable costs. The difference between the total net income for a period including a drought and a period excluding a drought for each grazing zone calculated on this basis is shown in Table 15.

The total national loss of net income due to a drought as severe as that of 1940–47 assuming sheep numbers will not exceed those in 1963 is $517 million. This is approximately half the loss of $1,272 million sustained over a twenty year period assuming sheep numbers expand at a normal rate after recovery from a drought and costs are proportionate to the proportion income from sheep forms of the total farm income of sheep farms. Thus almost half of the loss caused by drought is caused by the effect drought has on the future rate of expansion in flock numbers rather than by the decline in sheep numbers which occurs during the drought. As sheep numbers are expanding rapidly with little or no decline in the price of wool or sheep the loss of $1,272 million may be regarded as the more realistic estimate under existing conditions.

Although the net income earning capacity of ewes is far higher than their sale price while flocks are expanding, it is impossible to conclude whether the nation is justified in giving aid to graziers to prevent ewes losses during droughts. Such a conclusion could only be drawn if the following data were available for each grazing zone:

(1) The number and the age of ewes dying or sold for slaughter because of drought.

(2) The probable amount of fodder which would have to be fed to ewes to prevent these losses.

Any field investigations of the effect of drought should be aimed at establishing these two points. If this information were available a tentative conclusion could be drawn using the method outlined in this paper. However, such a conclusion would still be dependent on Australia's ability to double her sheep numbers, the price received for wool and the cost of maintaining sheep during the next twenty years.