TOWARDS THE DETERMINATION OF OPTIMUM STOCKING RATES IN THE HIGH RAINFALL ZONE

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1. INTRODUCTION

In recent years, an increasing awareness of the important role of stocking rate in attaining efficient pasture utilization, has led to considerable investment in stocking rate experiments. The primary aim of this paper is to suggest a method whereby data from these experiments may be used as a basis for determining most profitable farm stocking rates. To enable a more realistic illustration of the problem and recognition of the most important deficiencies in our present state of technical knowledge, farm production and climatic data from the New England Region is used, rather than hypothetical data. The empirical content of this study, although based primarily on the New England Region, is considered to have widespread implications for the high rainfall zone as a whole.

The study has been motivated by the following related considerations:—

(1) Large areas within the high rainfall zone, notably in the New England Region, have recently been sown to improved pastures and attention is now being increasingly focussed on the problem of pasture utilization.

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(2) Based on a review of grazing experiments and a survey of pasture improved properties in the New England Region, the author considers that in this area and in many other areas of the high rainfall zone, it is likely that there is an immediate potential for increased stocking rates. That improved pastures are at present being under-utilized in years of average and above-average pasture production is suggested by some empirical observations which show that there has been little variation in per sheep production between years of high and low pasture production. Also in spite of two years of relatively low pasture production (1958, 61) levels of hand feeding in the New England Region for the period 1957-64 have been low.

(3) The above assertion is also given weight by results from a rapidly increasing number of stocking rate experiments which indicate that it is possible, at least under experimental conditions, to increase physical production of wool and meat by 200 to 300 per cent above the present per acre production on commercial properties. This is a very much larger gap than normally exists between experimental and commercial farm production and is particularly significant as it has apparently been largely achieved by simply increasing stocking rates. In particular, the experiments are highlighting the fact that with improved pastures there is a wide range of technically feasible stocking rates, and associated levels of production per sheep, which may be used to convert a given quantity of pasture into wool and meat. Furthermore taking production per sheep as a measure of grazing pressure,[1] there is a considerable variation of grazing pressure between properties. This is reflected both in differences in the quantity of paddock reserves of pasture and in the different levels of per sheep production. On the basis of technical information alone it can only be specified that the optimum grazing pressure-stocking rate lies within the region bounded by maximum production per sheep on the one hand and maximum production per acre on the other. For a particular property this may be anywhere between a very low grazing pressure of one sheep per acre clipping 14 lb. of wool and a very high grazing pressure of seven sheep per acre, each clipping 8 lb. of wool. It follows

[1] A definition of some related terms used in this paper is given below:—

(1) Stocking rate: sheep per acre.

(2) Grazing pressure: generally this term is defined in terms of available pasture per sheep.* However, for the purposes of this study it is assumed that the level of production per sheep is a direct measure of grazing pressure. In this context, in addition to available pasture per sheep, grazing pressure also incorporates the effects of grazing method, genetic quality, sex, age and so forth.

(3) Carrying capacity: the stocking rate at the most profitable grazing pressure.

* See K. W. Clark, "Stocking Rate and Sheep-Cattle Interactions". *Journal of Wool Technology and Sheep Breeding,* Vol. X, No. 1 (July, 1963), and G. O. Mott, "Grazing Pressure and the Measurement of Pasture Production", Proceedings of the 8th International Grasslands Conference (1960).

that determination of the optimum economic balance between production per acre and production per sheep is likely to be of utmost importance.

(4) A considerable volume of research has now been published relating to the determination of optimum fodder reserves in drought-prone environments.[2] In these studies the usual approach has been to assume the current farm stocking rate as fixed and to determine the optimum fodder reserve for the pre-determined stocking rate by means of inventory analysis. However, to date little work of an economic nature has been published on this topic relating to the high rainfall zone.[3]

2. THE STOCKING RATE PROBLEM

The overall problem of determining optimum farm stocking rates may be divided into two distinct, but closely related problems. First, for any given stocking rate what is the optimum level of fodder reserves to meet future drought requirements, the likelihood of which can only be specified in terms of a probability distribution? Second, knowing the hand feeding requirements and optimum fodder reserve for a number of feasible stocking rates, what is the most profitable stocking rate?

The importance of knowing the optimum level of fodder reserves in relation to the place of other drought strategies such as purchasing fodder at an inflated price during a drought; obtaining agistment; selling some sheep and replacing them when the drought has broken; or letting some sheep die, is largely dependent upon the degree of climatic variation between years. Where this is marked, for instance in the drought prone environments Dillon and Lloyd *op. cit.* studied, the problem becomes extremely important as hand feeding costs constitute a major item and the incidence of drought has large effects on relative sheep values and supplementary fodder prices. On the other hand, in the high rainfall zone, in contrast to severe drought environments, determination of optimum stocking rates is likely to be the factor of overriding importance, rather than determination of the optimum drought strategy for the present levels of stocking. In the present study the real world is simplified by assuming that the grazier adopts only one drought strategy. The strategy being to maintain, by hand feeding, the entire flock on the property throughout all droughts. No attempt is made to determine what proportion of the total supplementary fodder requirements should be held in reserves and what proportion should be purchased as required. This simplification, combined with the exclusion of alternative drought strategies from the analysis, will tend to give rise to an over-estimation of drought costs, providing of course hand feeding

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2 See J. L. Dillon and A. G. Lloyd, "Inventory Analysis of Drought Reserves for Queensland Graziers: Some Empirical Analytics". *Australian Journal of Agricultural Economics,* Vol. 6, No. 1 (1962), which also contains a comprehensive list of references on this topic. And A. A. Powell, "A National Fodder Reserve for the Wool Industry", Department of Agricultural Economics, University of Sydney Report No. 3 (1963).

3 For some closely related research see A. G. Lloyd, "Fodder Conservation in the Southern Tablelands Wool Industry", this *Review,* Vol. 26, No. 4 (December, 1958). And W. R. McManus, *et al.* "Some Aspects of the Economics of Increased Stocking Rates". Unpublished manuscript, School of Wool Technology, University of New South Wales.

requirements are correctly estimated. At this point it should also be made clear that this paper is confined solely to determining the optimum stocking rate for any given long term level of pasture production and grazing management system. No attempt is made to determine the optimum level of pasture production,[4] degree of paddock subdivision, system of grazing management and so forth.

Within the above framework the problem is conveniently treated in two parts. First, the determination of the most profitable stocking rate for a single or typical years pasture production. In this section consideration is given to alternative methods for determining optimum farm stocking rates, the stocking rate experiments, assessment of the net value of production per sheep for a range of wool clips, and finally the derivation of estimates for the crucial sheep per acre-production per sheep relationship. Hand feeding costs will not play a dominant part in this estimation except in areas characterized by a critical grazing period in a normal feed year. The above determination would only provide a reliable estimate of the long term optimum stocking rate for a utopian environment having a constant climatic pattern from one year to the next. The second part of this paper therefore concerns itself with the effects of seasonal variability on the most profitable long term stocking rate. This involves prediction of the long term probability distribution of pasture production, and its effect on the level of production per sheep and hand feeding requirements for a range of stocking rates.

3. THE MOST PROFITABLE STOCKING RATE FOR A SINGLE SEASON

Briefly, the alternative methods for determining optimum farm stocking rates that suggest themselves are:—

(1) Direct data from farms that have increased stocking rates over a number of years whilst holding all other inputs constant. Needless to say there are few, if any, farms which fulfill these requirements and even if this data was available the true effects of stocking rate would tend to be obscured by annual fluctuations in pasture production.

(2) Derivation of whole farm production functions by which the marginal value productivity of livestock is predicted by means of a multiple regression technique. In an attempt to treat livestock as a separate farm input using this method of estimation Duloy[5] states:—

> "In some empirical experimentation it was found that the effect of including the value of livestock as an input was to produce high standard deviations and non-sensical values for the coefficients of other inputs".

Derivation of useful estimates by this method therefore at present does not appear possible.

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[4] See R. G. Moyle, "Economics of Superphosphate in Wool Production: An Economic Analysis of the Relationship Between Levels of Superphosphate Application and Stocking", Unpublished M.Ag.Ec. Thesis, University of New England (April, 1964), for a joint consideration of optimum rates of fertilizer application and stocking levels.

[5] See J. H. Duloy, "The Allocation of Resources in the Australian Sheep Industry", particularly pp. 63-64, unpublished Ph.D. dissertation, Sydney University (1963). A selection of the above is published under "The Allocation of Resources in the Woolgrowing Industry", *Australian Journal of Agricultural Economics*, Vol. 5, No. 2 (1961), pp. 113-122.

(3) The third and most feasible method which suggests itself is to use estimates of the sheep per acre—production per sheep relationship obtained from stocking rate experiments as a basis for predicting stocking rate effects on farms. At present there is a large number of these experiments in progress throughout Australia from which interim results, at least, are available. The method of approach adopted in this study is based on information from all sheep stocking rate experiments [6] in Australia known to the author. The experimental results tabulated in Appendix I, show that a given amount of pasture may be utilized by any one of a number of alternative stocking rates. Each stocking rate will result in a particular production of wool [7] per acre and a corresponding production of wool per sheep. Usually an increased stocking rate results in a higher wool production per acre and a lower wool production per sheep ; that is more sheep are substituting for more land. In the experiments given, stocking rates ranging between 1.5 and 14.5 sheep per acre resulted in a range of wool clips per sheep between 7 and 15 lb. and a per acre wool production of between 18 and 134 lb. These results indicate that the range of technically feasible stocking rates on pasture improved properties is likely to be large. To determine the optimum economic balance between production per acre and production per sheep estimates of the basic physical relationships between stocking rate and production per acre, or conversely, production per sheep, must be specified. Given these empirical estimates it is then necessary to introduce resource costs and product prices for a range of feasible price levels.[8] The following procedure is adopted.

Gross Margin Per Sheep

The initial step has been to classify the experimental results. In all, 40 sets of observations were available. Each individual set of observations normally provides physical production per sheep and per acre for at least three levels of stocking. Each of these sets of observations has been classified into one of three sheep classes, namely merino wethers, merino breeding ewes for wool production and crossbred breeding ewes for combined fat lamb and wool production. Within each of these classes the total production and related Gross Margin has been estimated for two price regimes and for wool clips ranging from 8 to 14 lb. per sheep. The Gross Margin is defined as gross revenue less direct variable costs per sheep. The breakdown of variable costs together with assumptions

[6] This data, the wool production records of which are tabulated in Appendix I, was obtained from published research papers, research station reports and personal communications. A list of the main data sources is given in Appendix I.

[7] For simplicity of description wool is taken as the only product; in the actual analysis, however, net revenue per sheep is the pertinent variable. It should also be pointed out that in these experiments stocking rate constituted the only experimental treatment, with the exception in some isolated instances of small quantities of hand feeding at high stocking rates.

[8] The basic method of analysis for a single season together with a hypothetical example was originally proposed by W. V. Candler in "Wool and Wethers", University of New England, Farm Management Report No. 1 (1958).

regarding flock depreciation, death rate, wool quality, lambing percentages, relative lamb prices and so forth for each level of per sheep production are given in Appendix II. From the Gross Margin estimates overhead expenses, such as fertilizer application and depreciation on farm buildings must be deducted before deriving the farm Net Profit. Overhead expenses are assumed to be constant for all stocking rates and hence do not enter the analysis.[9] The analysis is thus purely in terms of Gross Margins. The Gross Margin estimates for each sheep class are sumarized in Table 7, Appendix II. The next step is to derive, via the experimental results, estimates for the farm stocking rate—production per sheep relationship.

Experimental Stocking Rate—Production per Sheep Relationship

To determine the most profitable stocking rate from the Gross margin estimates we require an estimate of the stocking rate-production per sheep relationship.[10]

In deriving estimates of the experimental relationship the initial step has been to classify each set of observations according to the estimated carrying capacity of the experimental plot from which it was obtained. Thus a distinction is made between one set of observations with stocking rates of two, four and six sheep per acre and respective wool clips of 10, 9 and 8 lb. per sheep and another set with the same stocking rates and wool clips of 14, 12 and 11 lb. respectively. These two sets of observations belong to two separate production functions. The first may have come from an experimental area producing 4,000 lb. D.M. pasture per acre and the second from an area producing 8,000 lb. There is no good *a priori* reason for suggesting that two production functions, one from an environment with a high carrying capacity and another from an environment with a low carrying capacity should parallel each other. Adopting a two way, sheep class-carrying capacity, classification of the experimental observations it was considered that the relationship between stocking rate and production per sheep could, in general, be approximated by a straight line.

There is an exception to the straight line relationship for some experiments based on areas with a high potential carrying capacity. In a number of these experiments production per sheep was higher for the medium stocking treatment than the low. This strongly suggests that at the medium stocking level the extra sheep had a beneficial effect on the under-grazed pasture and that a complementary, or at least a supplementary range of production exists.[11]

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[9] If an increase in stocking rate necessitates an increase in "overhead expenses"; for instance, extensions to a woolshed, interest on this additional capital investment should be deducted as a variable expense of increased stocking. However, as these are lumpy inputs, extremely variable between farms and not likely to be a very significant cost item they have been excluded from the analysis.

[10] Henceforth the stocking rate—production per sheep relationship is abbreviated to the "relationship" and is defined as the decrease in wool clip per sheep for each successive increase in stocking rate of one sheep per acre.

[11] The likely existence of a complementary and supplementary range of production for sheep has been asserted by K. O. Campbell and W. F. Musgrave in ""Economic Aspects of the Association of Beef Cattle with Sheep Production in South-Eastern Australia", University of Sydney, Department of Agricultural Economics, Res. Bull. No. 3. (1958.)

For the range of stocking rates, levels of pasture production and general environments represented by the experiments the following points emerge:—

(1) For sets of observations within the competitive range of production the overall average rate of decline in wool clip per sheep is 0.55 pounds for each successive increase in stocking rate of one sheep per acre. The variation of the value of the relationship between sets of observations is zero to 1.2 pounds, with approximately 75 per cent of the observations within the range 0.25 to 0.75 pounds.

(2) Within each sheep class the average relationship is 0.4, 0.5, and 0.7 pounds for merino ewes, crossbred ewes and merino wethers, respectively.

(3) With the exception of observations having a complementary or supplementary range of production, the relationships for sets of observation based on areas with different carrying capacities were comparable.

(4) The maximum relationship for sets of observations with a minimum of three stocking treatments is 1.2 pounds. The maximum relationship for two successive stocking rates is 1.9 pounds. However, too much weight should not be placed on isolated sets of observations between only two stocking levels as with the generally small number of sheep in each experimental treatment much of the difference could be explained by differences in the genetic quality between the two groups. In some instances this could also lead to a mistaken complementary range of production.

Some points arising from these results bear comment. The first is the surprisingly small rate of decline of production per sheep as stocking rate is increased. Two possible explanations could account for this. First it is possible that in the long term an increase in stocking rate will in itself increase the quantity and/or quality of pasture produced. There is certainly ample evidence to show that stocking rate influences pasture composition. However, the author is not aware of any clear cut experimental evidence which attributes an increase in pasture production directly to an increase in stocking rate. There are some indirect indications that in the long term the quantity and/or quality of pasture is increased through higher stocking rates from several experiments which have been run for a number of years. In these experiments there was a tendency for the difference in the wool clip per sheep between the low and high stocking rate treatments to be reduced with time, although this trend could be partly explained by better seasons in latter years or, by management techniques for high stocking rates becoming more effective with experience. Furthermore, if this is in fact a significant factor it does not provide an adequate explanation as many of the observations are from experiments which have only been run for a year or two. The main explanation favoured by the author is that significantly higher utilization of pasture is achieved at high stocking rates. Apart from the visual observation by experimenters of patch grazing at very low stocking rates the experimental results suggest that even at relatively high stocking rates, when wastage of pasture is not visibly apparent, pastures may in fact be significantly under-utilized. This assertion is based on the reasoning that a curvilinear relationship between stocking rate and production per sheep would be expected if the proportion of the pasture utilized was constant for all stocking rates. That is, if say, 80 per cent of the pasture grown was consumed irrespective of the stocking rate. This assertion is simply based on the fact that there is a much greater reduction of available pasture per sheep moving from a stocking rate of one to two sheep per acre than from four to five sheep. Hence it would be expected that the decline in production per sheep would become progressively smaller for each successive increase in stocking rate. That this is not borne out by the experimental results suggests that although the incremental reduction of available pasture per sheep becomes progressively smaller, the successive reduction in intake and per sheep production remains reasonably constant due to a higher utilization of available pasture at higher stocking rates. At least for the range of stocking rates and grazing pressures represented by the experiments. One further explanation could be that a larger change in the level of intake may be required to increase wool clip per sheep from say 13 to 14 lb. than from 8 to 9 lb.

Farm Stocking Rate—Production Per Sheep Relationship

Using the experimental results as a basis the question now is what inferences can be made about the stocking rate—production per sheep relationships on farms?

First it should be noted that although stocking rate constitutes the only experimental treatment, there are clearly a host of variables between experiments in different areas. For instance, soil type, pasture composition and form of annual growth cycle, genetic quality of sheep, grazing and stock management techniques and so forth. In the light of these differences and the wide range of climatic environments on which the experiments are based it is encouraging to find that for 75 per cent of all sets of observations the relationship falls within the region 0.25 to 0.75 pounds. Furthermore it is considered that a number of sets of observations with values outside this region can be explained on the grounds of a complementary or supplementary range of production. The maximum relationship (1.2 pounds) is the highest recorded in Australia from either experimental or farm sources that the author is aware of. It was achieved under rather exceptional drought conditions with an experimental pasture mixture which virtually broke down under the high stocking treatment. It therefore seems reasonable to accept this as an upper limit.

Attention is now turned to the farm data. The farm data is based on a survey of fifteen pasture improved properties situated in the Guyra district of the New England Region. In terms of the essential parameters, namely stocking rate and level of production per sheep, the farms are reasonably representative of the New England Region, as a whole. For an average year[12] the farms had an average stocking rate of two ewe equivalents per acre and a per sheep wool clip of 11.5 lb. Between farms the stocking rates ranged from one to three ewe equivalents per acre and the wool clips from 9 to 14 lb.

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[12] That the production figures were for an average year's pasture growth was checked by a comparison of monthly, seasonal and annual rainfall and pasture production records and was also substantiated by grazier opinion. Henceforth the average survey farm will simply be termed "the farm".

An important supposition is now made. It is proposed that those experiments which for their low stocking treatment, have both an equal stocking rate and wool clip per sheep, to that on the survey farms, have a comparable carrying capacity to those farms. That is the two production functions are similar and they therefore in a sense constitute "identical" production units. This assumption is based simply on the reasoning that per acre pasture production on the farms is at least as high as on the relevant experimental areas, as it is extremely unlikely that farms are achieving the same wool production by better utilization of less pasture or alternatively that the genetic quality of farm stock is overall better than experimental stock. Hence on the basis of a comparable level of pasture production, identical per acre and per sheep wool production at low stocking rates, and stocking rate being the only experimental treatment it is proposed that these experiments may be used as a basis for predicting stocking rate effects on the survey farms. In fact as the pertinent factor, namely rate of decline in wool clip per sheep, is comparable within the competitive range of production for all experiments, irrespective of their carrying capacity, there is no need to be restricted to any one class of experiments. It should be made clear that usually experimental areas have a significantly higher carrying capacity than even the top producing farms in their surrounding district and it is not being suggested that commercial farms can economically achieve this level of stocking. The proposition is simply that within the competitive range of production, regardless of the initial stocking rate and level of production per sheep, an increase in stocking rate leads to a relatively constant rate of decline of production per sheep.

Attention is now turned to a consideration of possible reasons explaining why the experimental relationship may underestimate the farm relationship, resulting in an overestimation of optimum farm stocking rates. For this to be true there would need to be some inputs which are consistently used in experiments for all stocking treatments, and not on farms, which benefit high stocking treatments proportionately more than the low. The most probable inputs in this category are general stock management, such as frequency and timing of drenching, and grazing management. Grazing management is likely to assume more importance at higher stocking rates when pasture becomes relatively scarce than at lower stocking rates when it is relatively abundant. However, this point should perhaps not be overstressed as a number of results are from experiments adopting a simple continuous grazing system.[13] Errors could also arise when comparing results from two different environments due to the differences in the pasture production cycles. For instance, an overall grazing pressure producing ten pounds of wool per wether could come about in two very different ways. It could be achieved as a result of a uniform grazing pressure maintained throughout the year or, as a result of nine months of luxury feeding and three months bare maintenance. Whereas in the former case stocking rate could be increased, an

[13] Also in a comprehensive review of grazing management experiments J. L. Wheeler has concluded that contrary to popular opinion there is no conclusive evidence showing that rotational grazing gives appreciably higher production than continuous grazing. See J. L. Wheeler, "Field Experiments on System of Management for Mesophytic Pasture", *Divisional Report No.* 20 (1960), Division Plant Industry, C.S.I.R.O. and by the same author, "Experimentation in Grazing Management" *Herbage Abstracts,* Vol. 32, No. 1 (1962).

attempt to increase stocking rate in the latter case, in the absence of a period of hand feeding, would probably lead to high death rates. Partly for this reason and partly due to variation in pasture growth between years it is necessary to have knowledge of the underlying pasture production cycle. Although there is a relatively critical feed period in the late winter months (July and August) in the New England Region it does not appear to have unduly effected experimental results in this area, nor results in areas such as Goulburn or East Gippsland with similar critical periods in the feed year.

Summarizing the foregoing discussion, it is considered that the maximum experimental relationship can be taken as a ceiling to the farm relationship and that, if anything, the farm relationship is likely to be higher than the average experimental relationship. Within this region the procedure has been to test the sensitivity of the optimum stocking rate to relationship values of 0.5, 0.75 and 1.0 pounds, which are rather arbitrarily taken to represent minimum, most likely and maximum farm values respectively. Hence the most likely farm relationship is taken to be approximately 50 per cent above the average experimental relationship.

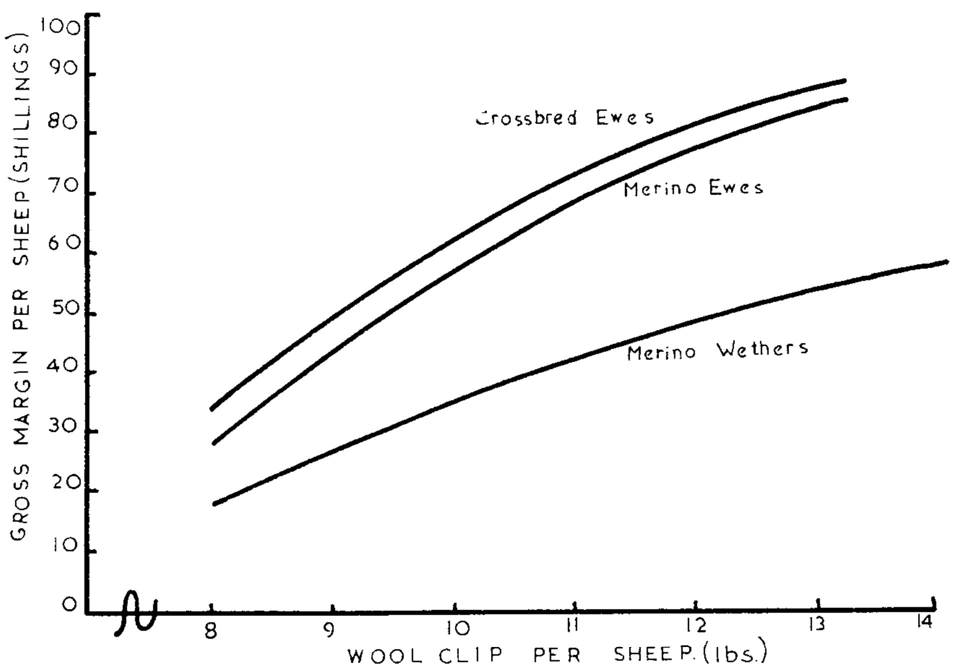

Fig. 1. Relationship Between Wool Clip and Gross Margin

The procedure for determining the optimum stocking rate for a typical season, or for an environment with a very small between year fluctuation in pasture production is now illustrated for merino wethers. A wool price of 70d. lb. is assumed. First, from the Gross Margin estimates given in Appendix II and illustrated in Figure I a series of iso-income curves have been constructed. These are illustrated in Figure 2. Each curve is a simple graph showing all the possible combinations of production per sheep and sheep per acre providing an equal per acre Gross Margin. For example, at a wool price of 70d. per lb., a Gross Margin of

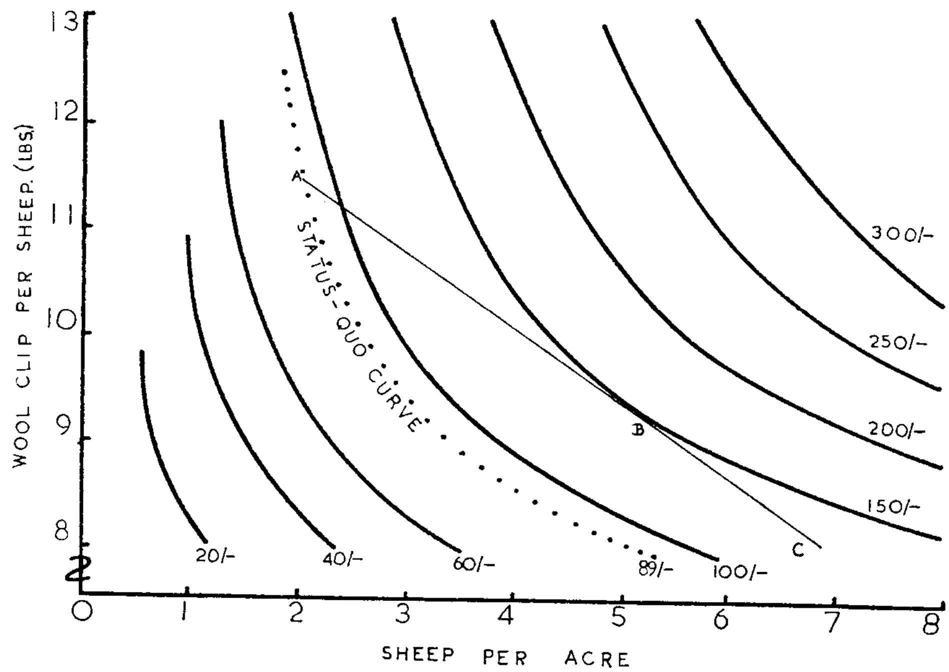

Fig. 2. Iso-Income Curves—Gross Margins Per Acre

approximately 89 shillings per acre could be attained either with a stocking rate of two wethers per acre each clipping 11.5 lb. of wool, or with four wethers per acre each clipping 8.6 lb. of wool, or with any other stocking rate—production per sheep combination lying on the *status quo* income curve. It should be made clear that the iso-income curve is quite a separate entity to the actual experimental, or farm, stocking rate—production per sheep relationship. The *status quo* income curve is simply that particular curve containing all combinations of stocking rate and production per sheep providing an equivalent Gross Margin to that at present being attained on the survey farms. The present farm stocking rate is two sheep per acre, each clipping 11.5 lb. of wool. Starting from this point the curve therefore indicates what the maximum rate of decline in production per sheep with increased stocking would need to be to just maintain the present per acre Gross Margin. Next, starting from the present farm stocking rate and wool clip per sheep (A) the estimated sheep per acre-production per sheep relationship (A, B, C) is shown. The optimum stocking rate coincides with the tangency point (B) between this relationship and the outermost iso-income curve. The additional income earned through adjusting the stocking rate from the present to the optimum level is readily determined from the graph. For instance, a move from two sheep per acre clipping 11.5 lb. of wool to five sheep per acre clipping 9.3 lb. provides additional farm income, net of variable expenses, of 61 shillings per acre.

These results, although a useful guide for an environment with a variable climatic pattern, are only directly applicable to a single season or, an environment with a relatively constant climatic pattern between years. It will now be shown that the long term optimum stocking rate is generally lower than the optimum stocking rate for the average season.

4. THE MOST PROFITABLE LONG TERM STOCKING RATE

Fluctuations in the level and distribution of pasture production between years greatly complicates the stocking rate problem. Except in the complementary and supplementary range of production an increase in stocking rate both reduces the standing reserve of pasture and decreases sheep bodyweights. These two factors increase the probability of having to hand feed sheep in years of low pasture production. Determination of the optimum long term stocking rate is in this respect analogous to the inventory problem of determining optimum drought reserves for a pre-determined stocking rate. The problem being given a fluctuating supply of pasture between years and assuming it is not feasible to adjust the stocking rate from year to year, what is the optimum number of sheep to utilize this pasture? For each stocking rate penalty costs will be incurred through being overstocked in years of low pasture production whilst on the other hand profits will be foregone through being understocked in years of high pasture production.

If overstocking in a particular year is such that sheep fall below a specified minimum bodyweight, or an unacceptable death rate is reached, it will be necessary to begin drought feeding from a reserve or with fodder purchased as needed. The aim is to select the particular stocking rate which will, *ex ante,* maximize the present value of long term future profits. Results from stocking rate experiments run over the normal period of two to five years are unlikely to be truly representative of the long term variability in pasture production, and the resultant sheep production and hand feeding requirements. Any attempt to predict long term hand feeding requirements at different stocking levels appears to be fraught with difficulties due to a paucity of technical data. In an effort to allow for seasonal variability, the first step is to give a brief description of the annual pasture production cycle in the New England Region.

Late autumn and early spring are usually the most critical growing periods in the New England feed year. The former because autumn grown pasture provides the bulk of the winter feed and the latter because the crucial early spring growth is frequently dependent upon rain in this period, due to a low winter rainfall. Summer rainfall is generally high and pasture is not normally limiting over this period. Rainfall and pasture production in winter are normally low, although low temperatures rather than rainfall is the main factor limiting winter pasture production. In an attempt to incorporate the effects of variation in annual pasture production between years and to specify a probability distribution of pasture production, the following procedure has been adopted. Thirty-eight years of monthly rainfall records, three complete years of monthly pasture production and five years of autumn pasture production records[14] have been assembled. Rainfall for the months of June and July were excluded from the analysis partly because pasture production was low in these months and partly because of a very low correlation between rainfall and pasture production in these months. For the remaining months the relative weightings given to rainfall are 1.25 units for early spring (August-September) and late autumn (April-May), 1.0 units for the months of October, November and March and 0.75 units for the months of December, January and February. The average monthly, seasonal and annual rainfall figures were then calculated for the 38 years' rainfall records. For each year the percentage above or below average rainfall for each month has been calculated and weighted. Based on the weighted rainfall figures each year has been classified into one of six pasture production classes, thus enabling a probability distribution of pasture production to be specified. It should be stressed that the above is a very meagre set of data on which to base even a tentative probability distribution of pasture production. There are many problems that have been virtually ignored in the present study, particularly those relating to the effects on animal production of the way in which a given annual yield of pasture is produced.[15] Clearly there is an infinite number of possible monthly, weekly and daily pasture growth combinations that could produce an annual pasture yield of 5,000 lb. D.M., most of which would result in a different level of animal production. These and other imperfections mean that the pasture production distribution specified below must be regarded as a very tentative guide until more complete data becomes available. It is definitely considered, however, that incorporation of annual fluctuations in pasture production based on existing limited data, enables a more reliable estimate of optimum stocking rates than its complete exclusion which would appear to be the only alternative method of analysis. Also it should be kept in mind that variations of rainfall and temperature records between farms in the same district, and even in different paddocks on the same farm, imposes a ceiling on the extent to which continued refinement of the above data is justified.

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[14] These pasture records were obtained from E. J. Hilder, Chiswick, C.S.I.R.O., Experimental Station, Armidale, and R. G. Moyle, *op. cit.* The rainfall records are those of the Guyra Post Office. Pasture production records (improved pastures) were not available for the Guyra district, hence the use of Armidale data. Although use of data from one area for prediction in another is not entirely satisfactory it should be pointed out that these areas are very similar and that the main purpose of this data is to provide a measure of between year variation in pasture production, rather than the absolute level of pasture production. In this respect a comparison of rainfall records has shown that differences in rainfall records between some survey farms were as large as those between Armidale and Guyra. For some work on climatic records and droughts see: E. A. Fitzpatrick, "Probability Analysis of Rainfall Factors in New South Wales" (Sydney; Rural Bank of N.S.W., 1953, mimeo). J. C. Foley, "Droughts in Australia—Review of Records from Earliest Times of Settlement", Commonwealth Meterological Bureau Bulletin No. 32 (Melbourne: Commonwealth Bureau of Meteorology, 1957). S. L. Everist, and G. R. Moule, "Studies in the Environment of Queensland, 2. The Climatic Factor in Drought", *Queensland Journal Agricultural Science*, Vol. 4, No. 3 (September, 1947), pp. 21-59. In some preliminary work at the Chiswick Research Station by K. J. Hutchinson (C.S.I.R.O., Armidale), it appears that up to 95 per cent of the between year variation in spring-summer pasture production may be explained by differences in the temperature adjusted precipitation records.

[15] See W. M. Willoughby, "Limitations to Animal Production Imposed by Seasonal Fluctuations in Pasture and by Management Procedures", *Australia Journal of Agricultural Research*, Vol. 10 (1959). Also by the same author, "A Relationship between Pasture Availability and Animal Production", *Proceedings, Australian Society of Animal Production*, Vol. 2 (1958).

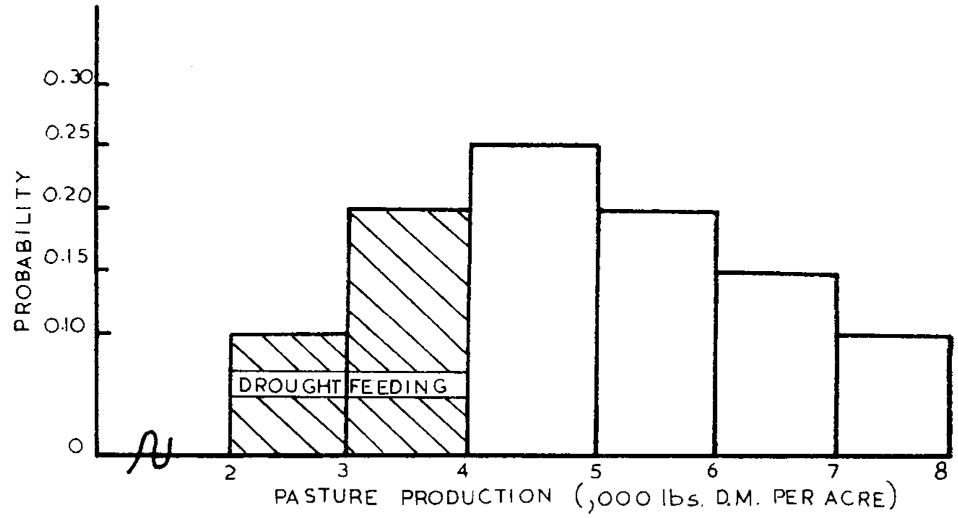

Fig. 3. Probability Distribution of Annual Pasture Production

In Figure 3 the predicted farm probability distribution of annual pasture production is illustrated. Annual pasture production fluctuates between a lower limit of 2,000 lb. D.M. and an upper limit of 8,000 lb. D.M. per annum. Within this range of pasture yields six discrete levels of pasture production and their probability of occurrence are distinguished. For instance, an average year's pasture production of between 4,000 and 5,000 lb. D.M. occurs approximately one year in four, whilst pasture production is between 3,000 and 6,000 lb. D.M. in almost seven years in ten. It will be apparent that for each stocking rate there will be a fluctuation in the wool clip according to the level of pasture production. Or in another light there will be an optimum stocking rate for each level of pasture production. If, for example, the pasture is stocked at five wethers per acre clipping 9.4 lb. of wool when 5,000 lb. D.M. pasture is produced, in the long run the pasture will be understocked in 4.5 years in 10 and overstocked in 5.5 years in every 10. In 3.5 years in 10 the degree of overstocking would be such as to necessitate hand feeding.

The function to be maximized in the long term may now be simply summarized as:—

$$S^* = \sum_{i=1}^{6}(G)\ (S)\ (P) - \sum_{i=1}^{6}(HF)\ (P)$$

where S* = long term optimum stocking rate

i = level of pasture production in the ith year

G = gross margin per sheep

S = sheep per acre

P = probability value

HF = hand feeding costs

Values for the above function have been obtained in the following manner. First, for each stocking rate and level of pasture production, the quantity of available pasture per sheep is specified. Then knowing the present farm stocking rate and wool clip per sheep, and the estimated stocking rate—wool clip per sheep relationship, the wool clip per sheep for each stocking rate for the average season is determined. The final step based on the predicted wool clips and levels of available pasture per sheep for the average year has been to determine per sheep wool clips for all combinations of stocking rate and pasture production. The procedure for calculating the results given in Tables 1, 2 and 3 is illustrated in Appendix III.

To determine hand feeding costs it is necessary to specify a minimum acceptable level of production per sheep, the wool clip chosen has been 8.5 lb. The difference between the minimum level of available pasture, necessary to just maintain the sheep, and the actual pasture production has then been expressed as a percentage of the maintenance level of pasture production. For example, if at a stocking rate of four sheep per acre the maintenance level of pasture production is 4,000 lb. D.M., and in a particular year the actual production is 3,000 lb. D.M., it is assumed that sheep are completely dependent upon hand feeding for one quarter of the year. The fodder is assumed to be either oaten grain or hay (or any other fodder with an equivalent feed value per unit cost), the overall costs of purchase, storage, and feeding out being 9s. 2d. per bushel and £15 per ton, respectively. It is also assumed that one ton of hay has a feed value of 730 S.E. and that 0.8 tons of hay has an equivalent feed value to 0.5 tons of oaten grain. The maintenance rations allowed per sheep are 10.0, 12.5 and 15.0 S.E. per week for merino wethers, merino ewes and crossbred ewes,[16] respectively.

The final results are summarized in Tables 1, 2 and 3. Table 1 sets out the derivation of the Gross Margins, assuming a 0.75 lb. relationship. Table 2 shows the Gross Margins for a number of combinations of wool price and stocking rate-production per sheep relationships, while Table 3 gives the Gross Margins for years of minimum, average and maximum levels of pasture production, respectively.

[16] The feed values and maintenance requirements are based on the references given below, although maintenance requirements are considerably more liberal than those generally recommended.

"Drought Feeding of Sheep", C.S.I.R.O. Leaflet Series No. 23 (Melbourne, 1958).

D. Cocks, "Feeding and Stocking Policy on Sheep Properties in the Central Western District of Victoria", Unpublished M.Agr.Sc. Thesis, Melbourne University (1963).

L. J. Lambourne and T. F. Reardon, "Effects of Environment on the Maintenance Requirements of Merino Wethers", *Australian Journal of Agricultural Research*, Vol. 14, No. 2 (1963).

J. H. E. Taplin, "Winter Feeding for Increased Fat Lamb Production in the Central and Northern Tablelands of New South Wales", this *Review*, Vol. 31, No. 2 (June, 1963).

Table 1

Long Term Optimum Stocking Rates

(*Shillings per Acre*)

Sheep Class	Sheep per Acre				
	1	2	3	4	5
Merino Wethers					
Wool per Sheep lb.	12·4	11·4	10·6	9·8	9·0
Wool per Acre lb.	12·4	22·8	31·8	39·2	45·0
Gross Margin per Sheep ..	49·9	44·0	38·5	33·2	29·1
Gross Margin per Acre	49·9	88·0	115·5	132·8	145·5
Less Hand Feeding Costs ..	0	0	2·2	19·2	66·6
Adjusted Gross Margin per Acre	49·9	88·0	113·3	113·6	79·5
Additional Gross Margin per Acre.	38·1	24·5	0·3		
Merino Ewes					
Gross Margin per Sheep ..	81·0	72·8	63·5	54·3	46·8
Gross Margin per Acre	81·0	145·6	190·5	217·2	234·0
Less Hand Feeding Costs ..	0	0	2·8	24·0	83·3
Adjusted Gross Margin per Acre	81·0	145·6	187·7	193·2	150·7
Additional Gross Margin per Acre.	64·6	42·1	5·5		
Crossbred Ewes					
Gross Margin per Sheep ..	83·1	75·0	66·5	58·9	52·1
Gross Margin per Acre	83·1	150·0	199·5	235·6	260·5
Less Hand Feeding Costs ..	0	0	3·3	28·8	99·9
Adjusted Gross Margin per Acre	83·1	150·0	196·2	206·8	160·6
Additional Gross Margin per Acre.	66·9	46·2	10·6		

The above Gross Margins are based on a 0.75 pound wool clip per sheep—sheep per acre relationship and wool prices from top to bottom of 70d., 70d. and 45d. respectively.

TABLE 2

Effects of Wool Price and the Production per Sheep—Sheep per Acre Relationship on Optimum Stocking Rates

Sheep Class	Wool Price (Pence per Pound)	Value of Relationship	Sheep per Acre 1	2	3	4	5
			Gross Margin—Shillings per Acre				
Merino Wethers	70	0·5	49·5	89·4	122·1	143·7	145·4
	70	0·75	49·9	88·0	113·3	113·6	79·5
	70	1·0	51·7	86·4	97·9	68·3	..
	50	0·5	30·3	53·4	71·4	80·9	70·4
	50	0·75	30·7	52·2	64·4	54·8	..
	50	1·0	31·8	51·6	50·5	..	..
Merino Ewes ..	70	0·5	80·6	148·0	201·9	238·6	244.0
	70	0·75	81·0	145·6	187·7	193·2	..
	70	1·0	82·6	143·2	165·0	130·2	..
	50	0·5	61·5	113·6	153·6	177·8	173·0
	50	0·75	61·7	111·4	141·5	137·6	..
	50	1·0	64·4	109·4	119·1	77·4	..
Crossbred Ewes	65	0·5	115·1	213·6	296·4	360·3	390·1
	65	0·75	115·7	210·8	281·4	310·0	281·6
	65	1·0	117·7	208·4	253·9	236·0	..
	45	0·5	82·6	152·6	210·0	251·5	261·1
	45	0·75	83·1	150·0	196·2	206·8	160·6
	45	1·0	84·7	147·8	177·4	138·0	..

TABLE 3

Income Variance between Years

Sheep Class	Sheep per Acre 1	2	3	4
	Gross Margin—Shillings per Acre			
Merino Wethers—				
Minimum	44·0	72·0	—28·7	—231·8
Average	49·9	88·0	113·3	113·6
Maximum	53·0	98·0	135·0	168·0
Merino Ewes—				
Minimum	75·0	114·0	—7·4	—259·8
Average	81·0	145·6	187·7	193·2
Maximum	84·0	160·0	225·0	280·0
Crossbred Ewes—				
Minimum	77·0	122·0	—16·1	—315·7
Average	83·1	150·0	196·2	206·8
Maximum	86·0	164·0	231·0	288·0

The main points arising from the tables are:—

(1) Adopting reasonably conservative estimates for the important parameters, the general trend of results show that the optimum farm stocking rates, at their present level of pasture production, are approximately 50 per cent above the present levels of stocking. Clearly as individual properties differ in the quantities of pasture being produced one property may be understocked at five sheep per acre and another overstocked at four sheep per acre. For this reason grazing pressure is a better universal measure of optimal stocking than stocking rate per se.

(2) Results from Table 1 indicate that the long term optimum stocking rate is such that the grazing pressure in an average year results in a per sheep wool clip between 9.8 and 10.5 pounds. Farms with a per sheep wool clip above 10.5 pounds are likely to be understocked, whilst a wool clip below 9.8 pounds is probably indicative of overstocking. Table 1 also indicates that sheep with a relatively high Gross Margin (crossbred ewes) should, in general, be stocked at a slightly higher grazing pressure than sheep with a lower Gross Margin (merino wethers). For instance, the optimum grazing pressure for merino wethers tends towards 10.5 lb. whilst the optimum grazing pressure for crossbred ewes tends towards 9.8 lb.

(3) Adjustment from the present farm stocking rate to the optimum farm stocking rate is estimated to provide an immediate return to capital investment, of the order of magnitude of 15 to 25 per cent. The lower limit allows for additional labour expenses of ten shillings per sheep whereas the upper limit represents the situation where the present supply of labour is adequate.

(4) The cost of hand feeding sheep in years of low pasture production is a very significant determinant of the optimum stocking rate, and increases at an increasing rate for successively higher stocking rates. This is due to a higher probability of a drought and a greater number of sheep to be fed during a drought at higher stocking rates.

(5) Hand feeding costs cause the long term optimum stocking rate to be lower than the optimum stocking rate for the average feed year. In other words in the long run it pays to be understocked in the average feed year. For instance, whereas for the average feed year the optimum stocking rate is five wethers per acre in the long term it is approximately 3½ wethers per acre. It follows that the divergence between the most profitable stocking rate for the average feed year and in the long term increases with the degree of between year pasture variation. In two environments which have the same long term average level of pasture production, but differ in that one has marked climatic variation between years and the other relatively constant, the correct stocking in the first may be three sheep per acre clipping eleven pounds of wool and in the latter five sheep per acre clipping nine pounds of wool.

(6) The optimum stocking rate is moderately sensitive to wool prices. For instance, the optimum stocking rate for merino ewes at a wool price of 50d. lb. is three ewes per acre and at 70d., four ewes per acre.

(7) The optimum stocking rate is somewhat more sensitive to the relationship between production per sheep and sheep per acre, although hand feeding costs tend to lessen this effect. For example, assuming a wool price of 45d. per lb. the optimum stocking rates for crossbred ewes for relationships of 1.0, 0.75 and 0.5 are three, four and five sheep per acre, respectively.

(8) As stocking rate is increased to the optimum level the rise in the average Gross Margin is accompanied by an increase in the variation of income between good and poor years. In years of very low pasture production the Gross Margin for the long term optimum stocking rate is below that of lower stocking rates and may even be negative. There is thus a small probability that, in terms of the present value of future income, the *ex ante* optimum stocking rate will not correspond with the *ex poste* optimum stocking rate due to an initial run of poor seasons. The extent to which a higher average annual income is sacrificed in order to achieve a lower variation of annual income will be dependent on the aversion to risk of the particular individual. The minimum incomes given in Table 3, would on average only be incurred once in every 50 years.

5. CONCLUSION

Rather than provide any definitive empirical results, the main aim of this paper has been to illustrate the economic importance of stocking rate and to suggest a method whereby experimental data may be used as a basis for determining optimum levels of stocking on farms. However, in relation to existing rule of thumb procedures for determining optimum farm stocking rates, and insofar as the general trend of results indicates that in the New England Region an increase in farm stocking rates of the order of magnitude of 50 per cent appears to offer a very profitable investment, the empirical results are of interest in themselves. First it should be made quite clear that the validity of the empirical results is utterly dependent on a number of assumptions, many of which are at present based on imperfect technical knowledge. The reasonableness of these assumptions cannot be tested by any statistical means and in the final instance, can only be truly tested at the farm level. However, as stocking rate experiments appear to be the most promising, if not the only, basis for determining optimum farm stocking rates the usefulness of the method suggested in this paper should perhaps be judged in relation to existing rule of thumb procedures rather than in any absolute sense. The main factors which can be claimed to give some weight to the empirical results is that their sensitivity has been tested over a range of values for the most vulernable parameters and that the main conclusions are based on a conservative estimate of these variables. For instance, that the hand feeding allowances are liberal, is in part confirmed by the actual amount of hand feeding incurred on a few properties which are already adopting a high grazing pressure system.

In view of the likely high returns to extra stock the discussion would not be complete without briefly considering possible reasons explaining the divergence between present farm stocking levels and predicted optimum levels. It is suggested that a combination of the following factors has contributed to the present situation.

During the phase of pasture improvement there is a marked tendency to use the extra pasture to increase the level of intake per sheep, rather than maintaining the original intake level by increasing stocking rate more rapidly. This tendency appears to be initially due to restricted finance for purchase of stock followed by a general disinclination to purchase sheep for a breeding flock when finance becomes available, largely due to the risk of introducing disease, particularly footrot which New England graziers claim to be a major deterrant to buying in sheep. In addition it is considered that graziers are not fully aware of the implications arising from the results of stocking rate experiments, tend to under-estimate the potential carrying capacity of improved pastures and overstress the effects of drought. Finally there appears to be a general tendency to accept condition and production per sheep as a measure of success rather than financial profits per acre. For the present land-sheep value relationship, however, high production per sheep and maximum net profits appear incompatible goals, mainly because high production per sheep is only attained at the expense of a low level of pasture utilization. A large scale survey aimed at obtaining graziers attitudes towards higher stocking rates would clearly be a valuable adjunct to the present study.

Consideration is now briefly given to stocking rate experiments as a source of data for determining optimum farm stocking rates. First, it should be pointed out that most of these experiments were not set up explicitly to provide data for an economic analysis of stocking rates. Generally the aims were of a more technical nature, such as recording the effects of high grazing pressure on pasture composition, sheep bodyweights, wool quality, teeth wear and so forth. It is the author's opinion, however, that in view of the overhead expenditure involved in establishment of these experiments the additional cost of recording all the information needed for a complete economic assessment is relatively small. In general, whilst experiments usually provided full information on the quantity and quality of wool production for each stocking level; data providing the relative values of cull stock, death rates and quality of fat lambs is inadequate. Also it has been suggested that optimum stocking rate recommendations based on two or three seasons experimental results are likely to be misleading and that pasture production and rainfall-temperature records appear to offer the only basis for incorporating long term seasonal variability. Few experiments, however, provided estimates of monthly pasture production. Needless to say there remains a large research field in correlating climatic data with pasture production and short term fluctuations in pasture production with animal production. Two further suggestions are first, that experiments should aim for a treatment level at which physical production per acre begins to decrease; many experiments did not even reach the point at which per acre net profits were a maximum. And second, that in some experiments, at least, other experimental inputs, such as the application of fertilizer, should be held at a level commensurate with normal farm practice. In particular, an attempt should be made to state explicitly what changes in management, if any, are required for successively higher stocking rates. The most important information that it is hoped future experimental results will provide is undoubtedly more precise estimates for the crucial sheep per acre—production per sheep relationship, although clearly more information on the effect of grazing pressure on lambing percentages and such like is also important.

Finally, if, as appears likely, there is an immediate potential for increased stocking rates in the New England Region and probably other areas of the high rainfall zone, it should be kept in mind that ultimately the rate of reproduction imposes a ceiling on the rate at which the Australian sheep flock can expand. Hence any increase in regional demand will cause sheep prices to rise. The important problem then becomes one of ranking regions in Australia according to their predicted marginal returns to increased sheep numbers.

APPENDIX I

Experimental Data

Tables 4 and 5 summarize the wool production data for all the stocking rate experiments in Australia known to the author in 1964. Within the stocking rate columns in each table, the column of figures on the left represents wool clip per sheep, whilst those on the right represent wool clip per acre. For instance, in Table 4 the first row of figures shows that in this observation for stocking rates of two, four and six wethers, the respective wool clips were 14.8, 14.0 and 12.2 lb. per wether and 29.6, 56.0 and 73.2 lb. per acre. The irregular array of data is due to observations having differing stocking rate combinations. References to the main sources of this data are given below.

G. W. Arnold and I. G. Bush, "The Effects of Stocking Rate and Grazing Management on Fat Lamb production", *Proceedings of Australian Society of Animal Production*, Vol. 4 (1962).

G. W. Arnold and W. B. McManus, "The Effect of Level of Stocking on Two Pasture Types upon Wool Production and Quality", *Proceedings of Australian Society of Animal Production*, Vol. 3 (1960).

K. W. Clark, "Stocking Rate and Sheep-Cattle Interactions", *Wool Technology and Sheep Breeding*, Vol. X, No. 1 (July, 1963).

F. R. Drake and N. M. Elliot, "Rates of Stocking Investigated at Bergwarden", *The Victorian Journal of Agriculture*, Vol. 61 (December, 1963).

H. Lloyd Davies, "Studies of Time of Lambing in Relation to Stocking Rate in South Western Australia", *Proceedings of Australian Society of Animal Production*, Vol. 4 (1962).

N. M. Elliot and B. C. Curnow, "Seasonal Pasture Production and the Performance of Sheep in East Gippsland", *Proceedings of Third Australian Grasslands Conference*, 1963.

M. J. Sharkey, *et al.*, "The Effect of Previous and Current Nutrition on Wool Production in Southern Victoria", *Australian Journal Experimental Agriculture and Animal Husbandry*, Vol. 4 (February, 1964).

D. E. Tribe and A. G. Lloyd, "Effect of Stocking Rate on the Efficiency of Fat Lamb Production", *Journal Australian Institute of Agricultural Society*, Vol. 28, No. 4 (December, 1962).

J. B. Truscott, "More Wool Per Acre", *Rural Development*, May, 1963.

J. G. Watson, "Achieving Maximum Stocking Rates by Management", *Proceedings Australian Grasslands Conference*, November, 1963.

In addition to published material data has also been obtained via personal communications or annual reports from the following research stations:—

Chiswick: C.S.I.R.O., Experiment Station, Armidale.

Shannonvale: Department of Agriculture, Experiment Station, Glen Innes.

Ginninderra: C.S.I.R.O., Experiment Station, Canberra.

Bergwarden Experiment: Department of Agriculture, Victoria.

Werribee: Department of Agriculture, State Research Farm, Victoria.

Kojonup: C.S.I.R.O., Experiment Station, Western Australia.

Wollogorang Pastoral Co., Goulburn.

TABLE 4

Wool Production per Sheep and per Acre

Stocking Rate—Wethers per Acre																	
1		2		3		4		5		6		7		8		9	
		14·8	29·6			14·0	56·0			12·2	73·2						
		12·7	25·4			10·6	42·4			9·5	57·0						
		12·1	24·2			12·0	48·0			9·9	59·4						
		12·8	25·6			14·2	56·8			13·3	79·8						
		13·4	26·8			14·6	58·4			12·3	73·8						
		13·0	26·0			14·4	57·6			14·1	84·6						
		13·7	27·4			11·5	46·0			9·7	58·2						
		13·7	27·4			12·6	50·4			10·1	60·6						
		14·1	28·2			14·9	59·6			14·7	88·2						
		12·0	24·0			13·0	52·0			13·6	81·6					12·8	115·2
		11·3	22·6			11·5	46·0			10·4	62·4					12·4	111·6
		11·4	22·8			10·6	42·4			10·3	61·8					10·2	91·8
13·7	13·7	13·1	26·2	12·8	38·4	11·4	45·6	11·0	55·0								
11·8	11·8	10·5	21·0	10·7	32·1	9·6	38·4	9·2	46·0								
12·3	12·3	11·6	23·2	11·8	35·4	10·7	42·8	11·0	55·0								
9·1	9·1	8·3	16·6	8·5	25·5	8·0	32·0	8·4	42·0								
13·0	13·0			11·0	33·0					7·5	44·5						
				13·9	41·7	12·0	48·0	11·3	56·5	10·9	65·4	9·2	64·4				
						9·9	39·6							9·3	74·4		
				14·0	42·0											10·0	100·0

TABLE 5

Wool Production per Sheep and per Acre

Stocking Rate—Merino And Crossbred Ewes Per Acre															
1·5		3·0		4·0		5·0		6·0		7·0		8·0		9·0	
10·4	15·6	9·4	28·2			8·5	42·5								
10·6	15·9	9·8	14·7			8·7	43·5								
9·8	14·7	10·0	30·0			9·0	45·0								
9·9	14·9	9·7	29·1			9·3	46·5								
9·1	13·7	10·0	30·0			10·2	51·0								
8·2	12·3	7·7	23·1			7·4	37·0								
8·0	12·0	7·7	23·1			7·1	35·5								
9·4	14·1	8·8	26·4			8·5	42·5								
		11·4	34·2	11·4	45·6	11·5	57·5	10·1	60·6	9·3	65·1				
9·1*		11·8		14·5											
9·9	90·1	8·7	102·7	8·8	127·6										
10·4		12·6		14·1											
10·6	110·2	9·6	121·0	9·5	134·0										
9·1		11·5		14·4											
9·5	86·5	8·6	98·9	8·4	121·0										
8·0		10·0		12·0											
8·6	68·8	8·2	82·0	7·6	91·2										
9·1	72·8	7·6	76·0	7·2	86·4										
9·4	75·2	7·7	77·0	7·4	88·8										
10·0	15·0			9·0	36·0									8·0	72·0
				10·1	40·4					9·3	65·1				
				10·4	41·6					9·2	64·4				
				11·1	44·4					10·1	70·7				
				8·2	32·8					6·1	42·7				
				8·7	34·8					6·1	42·7				
				8·9	35·6					6·1	42·7				

* Stocking Rate.

APPENDIX II

Derivation of Gross Margin Per Sheep

The method of deriving Gross Margins is illustrated by outlining the procedure in detail for merino wethers and tabulating the assumptions for a breeding flock.

Merino Wethers

1. *Variable Costs per Wether*:

	s.	d.
4 drenches at 6d.	2	0
2 jettings at 3d.	0	6
1 dipping at 4d.	0	4
1 shearing (including two crutchings and wigging)	3	6
Miscellaneous and veterinary	2	0
Wool selling charges	1	8
Variable Costs per Wether	10	0

2. *Annual Flock Depreciation*:

(i) For wethers clipping 10-14 lb. of wool. It is assumed the policy is to purchase rising 2-tooth wethers at 75s. and 65s. corresponding to wool prices of 70d. and 50d., respectively. The wethers are sold after four years' production as five-year-olds for 45s. and 40s. respectively. It is assumed that it is possible to fatten cull wethers at this grazing pressure.

The death rate is assumed to be two per cent for all grazing pressures in the above range. For a 1,000 wether flock the flock composition therefore is:—

260 2-tooths.
253 4-tooths.
247 3-year-olds.
240 4-year-olds.

(ii) For wethers clipping 8 and 9 pounds of wool the death rate is assumed to be five and three per cent and the value of cull wethers 35s. and 40s. respectively. The flock compositions for a 1,000 wether flock therefore is:—

	8 lb.	9 lb.
2-tooths	275	265
4-tooths	258	255
3-year-olds	242	245
4-year-olds	225	235

Annual Depreciation (Shillings Per Wether)

Wool Price	Wool Clip per Wether (Pounds)		
Pence per Pound	8	9	10—14
50	11·1	9·0	7·3
70	12·7	10·5	8·7

Interest is charged at 6 per cent on the capital value of a sheep, which is on average 4s. per sheep.

The total variable costs per wether are tabulated below.

Total Variable Costs per Wether (Shillings)

Wool Price	Wool Clip per Wether						
	8	9	10	11	12	13	14
50d.	25·1	23·0	21·3	21·3	21·3	21·3	21·3
70d.	26·7	24·5	22·7	22·7	22·7	22·7	22·7

The Gross Margins given in Table 7 are derived by deducting the above variable costs from the per wether wool receipts. A slightly lower per pound value of wool has been allowed for sheep clipping below ten pounds than above. For instance, for wool clips between 10 and 14 pounds the price is taken as 50d., whereas for clips of 9 and 8 pounds the price is 48d. and 46d. lb. respectively. In fact, this difference may be unduly penalizing light weight fleeces, as some data from the stocking experiments indicates that the decrease in value due to a higher percentage of faulty and cotted light fleeces is likely to be offset by the lighter fleeces having a higher quality count.

Crossbred Ewes

TABLE 6

Variable Costs and Returns per Crossbred Ewe

	Wool Clip per Ewe (Pounds)					
	8	9	10	11	12	13
Lambing Percentage	90	95	100	105	107	107
Deaths Percentage	6	4	3	2	2	2
Variable Costs—			Shillings			
Flock Depreciation	16·0	14·5	13·5	12·5	11·5	11·5
Variable Costs	16·0	16·0	16·0	16·0	16·0	16·0
Total Variable Costs	32·0	30·5	29·5	28·5	27·5	27·5
Wool Price (65d.)						
Fat Lamb Returns per Ewe ..	45·0	55·0	63·0	70·0	75·0	75·0
Wool Receipts per Ewe ..	40·7	47·3	54·2	59·6	65·0	70·4
Wool Price (45d.)						
Fat Lamb Returns per Ewe ..	37·0	46·0	53·0	59·0	63·0	65·0
Wool Receipts per Ewe ..	28·7	33·0	37·9	41·3	45·0	48·8

TABLE 7

Gross Margins per Sheep (Shillings)

Sheep Class	Wool Price	Wool Clip per Sheep (Pounds)						
		8	9	10	11	12	13	14
Merino Wethers ..	50d. lb.	5·6	13·0	20·4	24·5	28·7	32·9	37·0
	70d. lb.	17·3	26·5	35·6	41·5	47·3	53·1	59·0
Merino Ewes ..	50d. lb.	17·9	30·2	42·3	53·4	60·4	64·5	68·6
	70d. lb.	27·9	42·4	56·9	69·8	78·4	84·2	90·0
Crossbred Ewes ..	45d. lb.	33·7	48·5	61·4	71·8	80·5	86·3	..
	65d. lb.	53·7	71·8	87·7	101·1	112·5	119·9	..

APPENDIX III

Basic Data For Calculations

TABLE 8

Available Pasture Per Sheep

(Pounds Dry Matter)

Per Acre Pasture Production	Sheep per Acre							
	1	2	3	4	5	6	7	8
2,000	2,000	1,000	667	500	400	333	286	250
3,000	3,000	1,500	1,000	750	600	500	429	375
4,000	4,000	2,000	1,333	1,000	800*	667	571	550
5,000	5,000	2,500	1,666	1,250	1,000	833	714	625
6,000	6,000	3,000	2,000	1,500	1,200	1,000	857	750
7,000	7,000	3,500	2,333	1,750	1,400	1,167	1,000	875
8,000	8,000	4,000	2,666	2,000	1,600	1,333	1,143	1,000

* Minimum level of available pasture without hand feeding.

The figures in Table 8 are simply derived by dividing the available pasture by sheep per acre.

TABLE 9

Wool Clip Per Sheep—Pounds

Per Acre Pasture Production	Sheep per acre						
	1	2	3	4	5	6	7
2,000	11·2	9·4	H F	H F	H F	H F	H F
3,000	11·9	10·6	9·4	H F	H F	H F	H F
4,000	12·3	11·2	10·3	9·4	8·5	H F	H F
5,000	12·6	11·6	10·8	10·1	9·4	8·7	H F
6,000	12·8	11·9	11·2	10·6	10·0	9·4	8·8
7,000	13·0	12·2	11·5	10·9	10·4	9·9	9·4
8,000	13·0	12·3	11·7	11·2	10·7	10·3	9·9

H.F.—Hand feeding necessary to maintain sheep.

The figures in Table 9 have been obtained using the derived sheep per acre-production per sheep relationship. Use of Table 9 in conjunction with Table 8 enables the calculation of hand feeding costs (For full explanation see page 19).

TABLE 10

Gross Margin per Wether

(Shillings Per Acre—Wool Price 70d. pound)

Annual Per Acre Pasture Production	Probability of Obtaining Pasture Production	Sheep per Acre						
		1	2	3	4	5	6	7
2,000-3,000	0·10	4·4	3·6	2·6	2·2	2·2	2·2	2·2
3,000-4,000	0·20	9·4	8·2	6·8	5·1	4·4	4·4	4·4
4,000-5,000	0·25	12·6	11·0	9·8	8·2	6·4	5·5	5·5
5,000-6,000	0·20	10·3	9·2	8·3	7·5	6·7	5·4	4·4
6,000-7,000	0·15	7·9	7·1	6·5	6·0	5·5	4·9	4·1
7,000-8,000	0·10	5·3	4·9	4·5	4·2	3·9	3·6	3·2
Average Gross Margin per Sheep.		49·9	44·0	38·5	33·2	29·1	26·0	23·8
Average Gross Margin per Acre.		49·9	88·0	115·5	132·8	145·5	156·0	166·6
Less Hand Feeding ..		0	0	2·2	19·2	66·6	..	..
Adjusted Gross Margin		49·9	88·0	113·3	113·6	79·5	..	..

The figures given in the upper body of Table 10 are the Gross Margins (Table 7) for each respective wool clip (Table 9) multiplied by the probability of obtaining that wool clip. The sum of each column in Table 10 multiplied by the stocking rate represents the unadjusted Gross Margin. Finally, the deduction of hand feeding costs from this sum provides the adjusted Gross Margin per acre. The latter are the Gross Margin estimates appearing in Tables 1, 2 and 3.