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# **The Stock-Carrying Capacity of Hill Grazings in Scotland**

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## THE STOCK-CARRYING CAPACITY OF HILL GRAZINGS IN SCOTLAND.

In the year 1929 Sir Robert Greig and the late Dr J. S. King drew attention to the fact that, although the live-stock population of Scotland had remained fairly stationary during the previous half-century, changes of considerable magnitude and importance had occurred in the distribution of stock among the various counties.<sup>1</sup>

In particular it was shown that significant declines in the numbers of both cattle and sheep had taken place in certain counties, notably the Highland group comprising Argyll, Perth, Inverness, Ross and Cromarty and Sutherland. On comparing the five-year period 1871-75 with the corresponding period 1924-28 it was found that for these counties the decline in the aggregate numbers was no less than 28,400 cattle and 699,500 sheep. Expressed in percentages these figures worked out as 11·5 in the case of cattle and 22·7 for sheep.

That these decreases occurred almost entirely in counties where the proportion of unimproved to improved land was relatively high, was indicated in Table I of this article. Here the live-stock population of each county was for convenience expressed in terms of live-stock units. The significant decreases in the live-stock population for the period under review were more or less limited to the following counties, all of which have a high proportion of rough grazing to improved land.

<i>County</i>	<i>Loss of Live Stock Units. per cent</i>	<i>Area of Rough Grazings per Acre of Improved Land (deer forests excluded). acres</i>
Argyll - -	24	12·2
Inverness - -	24	10·9
Perth - -	11·8	2·7
Ross and Cromarty - -	10	7·7
Sutherland - -	12·5	32·0
Zetland - -	8·2	12·5

In practically all the other Scottish counties increases in the

<sup>1</sup> *Scot. Jour. Agric.*, Vol. XII. (1929).

number of live-stock units were observed while in the few where declines were registered these declines were insignificant. The point to note, however, is that in most of the other Scottish counties the amount of land under crops and grass is either equal to or greater than the amount of rough grazing land.<sup>1</sup>

The article referred to was written some nine years ago. Since then it would appear that the general downward trend in the sheep population of the Highland counties still continues, although the rate of decline has been considerably reduced. This is indicated by the following table, which gives the total number of sheep in the counties of Argyll, Inverness, Perth, Ross and Cromarty and Sutherland for the three periods named, with the total annual decreases.

<i>Period</i>	<i>No. of Sheep</i>	<i>Decrease over Period</i>	<i>Average Decrease per annum</i>
1871-75	- 3,082,700	—	—
1924-28	- 2,383,200	699,500	13,200
1933-37	- 2,329,650	53,600	5,950

While these decreases in the sheep population of the Highland counties appear to be a marked feature of the past sixty years it should be pointed out, as has been done by Professor J. A. S. Watson,<sup>2</sup> that the sheep industry in the Highlands appears to have reached a well-marked peak period in the eighties of last century.

This may be illustrated by the following table, which shows the average number of sheep in each of the five counties named for five three-year periods.

<i>Three-year period</i>	<i>Argyll</i> thousands	<i>Inverness</i> thousands	<i>Perth</i> thousands	<i>Ross and Cromarty</i> thousands	<i>Sutherland</i> thousands	<i>Total</i> thousands
1855 to 1857*	827	588	550	302	204	2,471
1880 to 1882	1,013	701	685	353	221	2,973
1905 to 1907	839	542	670	269	199	2,519
1930 to 1932	714	505	659	333	215	2,426
1935 to 1937	669	458	624	318	210	2,279

\* The figures for this period are from the Report of the Highland and Agricultural Society of Scotland.

A further point made by Professor Watson in the same article was that, in spite of the considerable reductions of the sheep population, the number of ewes kept and the number of lambs reared had shown little variation throughout the whole period. The reductions were attributed mainly to the decline in the number of wethers. The two- and three-year-old wethers, so common a feature of the higher sheep grazings some sixty to seventy years ago, have now practically disappeared.

<sup>1</sup> The only two other counties having over 3 acres of rough grazing for 1 acre of improved land are Peebles with 3.3 and Selkirk with 4.8.

<sup>2</sup> *Trans. High. and Agric. Soc.*, 5th Ser. Vol. XLIV. (1932).

*Causes of Decline.*—The causes for this considerable decline in the sheep population of the Highland counties have been variously stated. Direct displacements of large numbers of sheep to make room for deer were constant features of the period 1850-1914. Since the war sheep have to some extent been displaced to make room for forest plantations. Another cause of the general decline in the numbers of sheep grazed is stated to be the deterioration of the grazings. This is attributed to such factors as the increase of the numbers and extent of the bracken and scrub areas, the failure of those responsible to keep the heather sufficiently burned or the land sufficiently dry, the depletion of soil minerals through the selling off of young stock, the prevalence of disease and the bad effects attributed to the grazing of moorland pasture by sheep alone. Many of these factors can be attributed to the economic changes which since 1880 have militated against the system of sheep farming as carried out in the Highlands. On the credit side practically no constructive improvement work has been effected or at least applied to Scottish hill grazings. In order to appreciate the situation properly it is desirable that the effects of each alleged cause and the probable effect of suggested improvements should be fully discussed.

*Deer Forests.*—One of the main causes of the decline in sheep stocks in the Highland counties has been the establishment of deer forests. There have always been red deer in Scotland, but prior to 1750 the areas devoted exclusively to deer were few in number and relatively small in extent. The effect of the introduction of the system of sheep-farming into the Highland counties about 1750 was at first to restrict the numbers of deer and to reduce the area of the deer forests. It has been stated that the area devoted exclusively or mainly to deer reached its lowest point between 1780 and 1790. Before the conversion of forests into sheep farms was complete, however, a reaction had set in. On some estates sheep were cleared off the ground in order to make way for deer before the close of the eighteenth century.<sup>1</sup>

It was not until the middle of the nineteenth century, however, that deer forests began to have an appreciable letting value for shooting purposes. As will be shown later when discussing economic changes, sheep farming was then enjoying prosperity. In the eighties, however, a marked fall in the price of both mutton and wool took place. Rents for grazings were subsequently reduced by fifty per cent., while in certain instances proprietors were forced to take farms into their own hands as no offers to lease them were forthcoming. Tempted by the increased demand for Highland shootings which had developed since the middle of the

<sup>1</sup> *Report of Departmental Committee on Deer Forests, 1922.*

century, many landlords found it more profitable to turn their grazing farms into modern deer forests. Sheep were cleared off the land in order partly to provide more keep for the deer, which had always been there and which were allowed to multiply naturally, and partly to avoid any possible complications with shooting tenants through the presence of sheep spoiling a stalk. The change over from sheep to deer was thus almost inevitable. The movement became so pronounced that from time to time various Committees and Commissions enquired into the matter. Even as early as 1872-3 a Select Committee reported on the matter. The Commission of 1883 estimated that 1,975,209 acres were at that time under deer forest and that this land was capable of carrying one sheep to every five acres. The Return of Deer Forests made in 1891 led to the appointment of the Royal Commission (Highlands and Islands) in 1892. The total extent of deer forests was then estimated to be 2,472,133 acres. By 1912, according to the report of the Departmental Committee on Deer Forests, the deer forest area had reached its zenith and amounted to 3,584,966 acres. In recent years there has been an appreciable decline due partly to the deer being replaced by sheep and partly to the Forestry Commission acquiring deer forest areas for afforestation purposes.

The following table shows the various changes in area that have taken place since the first return was made in 1883 :—

ESTIMATED AREA OF DEER FORESTS AT DIFFERENT PERIODS.

1883	-	-	1,975,209 acres.
1892	-	-	2,472,133 "
1912	-	-	3,584,966 "
1920	-	-	3,432,385 "
1937	-	-	3,357,754 "

The estimates of the numbers of sheep displaced by deer as put forward by the different Committees and Commissions show considerable variations. The earlier figures as to the numbers of sheep displaced would appear to have been overstated. Taking everything into consideration, however, it would appear that probably 600,000-700,000 sheep had at one time or other been displaced. As ninety per cent. of the deer forests are located in the counties of Argyll, Inverness, Perth, Ross and Cromarty and Sutherland, it may be assumed that well over half a million were displaced from these counties alone. If these figures are approximately correct, it would appear that at least 75 per cent. of the losses in the sheep stock may be attributed directly to replacements by deer.

Indirectly deer may be responsible for certain reductions. The Departmental Committee<sup>1</sup> drew attention to the fact that the

<sup>1</sup> *Report of Departmental Committee on Deer Forests, 1922.*



heather in many deer forests was badly in need of burning, that the drainage was often neglected, and that for these reasons deer sometimes invaded neighbouring sheep farms.

Moreover, in certain deer forest areas too little was being done to keep down such vermin as foxes and hooded crows. It has also been stated<sup>1</sup> that the risk of damage being done by deer to arable crops was one of the factors in discontinuing cultivation in sheep-farming areas. The result of this is usually reflected in a general lowering of the extent and productivity of the old in-taken land and ultimately a decrease in the number of both sheep and cattle kept.

*Formation of State Forests.*—Since the Forestry Commission commenced its operations its attentions have been directed largely to the planting of land that was not being grazed by sheep. The Commission has, however, acquired considerable stretches of poor grazing land in Argyllshire, and in these areas the sheep stock has had to be cleared. The percentage which the number displaced bears to the total number of sheep in the county is comparatively insignificant. It should be noted that in all cases before such land was acquired very careful consideration was given to the reconciliation of the requirements and interests of the Commission with those of agriculture. It has been the policy of the Commission so far as is practicable to avoid any disturbance of the existing utilisation of the land.

*Bracken.*—Since the war bracken would appear to have spread rapidly over considerable portions of the grazing areas of the Highland counties. This increase is largely due to the gradual cessation of the practice of cutting bracken, the depletion of cattle from the grazings and incorrect management of heather areas. Prior to the war it was customary on many grazings to keep bracken under control by cutting. During the war scarcity of labour was responsible for this practice being largely given up. After the war when labour once more became available cutting was resumed to a modified extent only. In part this was due to the relatively high rate of wages that had to be paid, in part to the hold that bracken by this time had acquired. Each successive year that the bracken remained uncut the stronger it became and the more expensive it was to cut. In despair many farmers refrained from all attempts to deal with the pest.

Another factor which exercised a significant influence on the spread of bracken was the gradual diminution in the numbers of cattle kept on the grazings. The relative prosperity which sheep enjoyed in the agricultural depression of the post-war years as compared with cattle, induced many farmers either to replace cattle by sheep or to give up the summer grazing of cattle

<sup>1</sup> "Agricultural Surveys," *Scot. Jour. Agric.*, Vol. XIII. (1930).

altogether. This movement of replacing cattle by sheep was also fostered by farmers cultivating less of their marginal land and thus failing to provide winter food for cattle. The effects, so far as the spread of bracken were concerned, were, to say the least, unfortunate. Cattle not only tend to check the growth of bracken by crushing the young fronds but the pathways which they make enable a considerable amount of grazing to be done by the sheep. Furthermore, the growth of dense bracken tends to make herding extremely difficult; "struck" sheep are frequently lost because of their habit of hiding under the bracken.

Moreover, since bracken is usually most in evidence where the soil is most fertile the damage done is out of all proportion to the acreage infested. In many instances arable fields, which had been laid down to permanent pasture, have become so infested with this plant that they are now useless for grazing. It is difficult to estimate the loss thus caused. In some grazings the stock is said to have been reduced by as much as twenty per cent. This may be considered to be exceptional. In a survey of an Argyllshire parish carried out<sup>1</sup> in 1929-30 by the Department of Agriculture for Scotland it was estimated that 10 per cent. of the rough grazings was covered with bracken. It may confidently be stated that considerable declines in the stock-carrying capacity of such counties as Argyll, Perth, Dunbarton and Inverness can be attributed to the spread of bracken.

*Unbalanced Grazing by Sheep.*—The gradual disappearance of cattle from many grazings was followed not only by an increase in bracken but also by a general decrease in the nutritional capacity of the other parts of the grazings. Sheep are selective in their grazing habits; they prefer the shorter and sweeter herbage to the rougher. The rougher portions are in consequence uneaten and in time tend to dominate the sweeter portions. Furthermore, the making of a good pasture is largely influenced by the treading which the sward receives. The treading of cattle has a much better effect on pasture than that of sheep. It should also be noted that deer like sheep are selective in their grazing habits and it may be that the invasion of sheep grazings by deer is in part at least due to the shortage of the particular grazing plants sought after by the deer.

Apart altogether from any deterioration in the pasture that may have been brought about by the reductions of cattle on hill grazings it would appear that at the period immediately after that when sheep farming was introduced to the Highlands the grazings were distinctly better than they are now, largely owing to the fact that the sites of the old crofts and of the cattle folds bore a sweet and palatable herbage which has since mainly dis-

<sup>1</sup> *Scot. Jour. Agric.*, Vol. XIV. (1931).

appeared. The type of husbandry practised before that date tended towards the gradual collection on these areas of the fertilising ingredients voided by the cattle kept on the hills. Moreover, the custom of collecting the cattle for milking and folding at night tended to check the growth of the heather. The green herbage of such patches in association with the general herbage found on the hill was most valuable especially during the winter months.

This old system gave place to one that reversed the general arrangements so far as manuring was concerned. The sheep grazed the lower and more fertile ground during the day and at night lay on the higher and less fertile land. On such land the beneficial effect of their droppings was largely wasted. The net result was that heather and inferior grasses have largely usurped the place of the better plants which formerly were to be found on old crofting land.

*Heather.*—In certain areas in the Highland counties heather may so dominate the vegetation that practically all other plants are excluded. Heather is of considerable grazing importance, particularly in winter. Its tender green shoots are according to Lauder<sup>1</sup> approximately equal in feeding value to medium hay; Thomas<sup>2</sup> who examined heather from a regularly burned moor got figures which suggested even a considerably higher feeding value. The value of heather on a hill grazing may be said to depend on a number of factors, the relative amount of green shoots on the heather plants, the accessibility of these green shoots to sheep throughout the winter and the relative proportion of other grazing plants which are at the disposal of the stock.

In order to induce heather plants to provide the desired amount of young shoots the heather is burned periodically. The older a plant gets the less, generally speaking, is the proportion of young shoots produced. Ultimately the plant may produce so small a proportion of green shoots that it is no longer grazed by sheep. Old heather, however, need not necessarily be valueless for grazing since constant cropping tends to induce a fresh growth of green shoots, but as a rule, resort must be had to burning to maintain a constant supply of feeding heather. Burning, however, must be carried out with skill and judgment. The ideal to be aimed at is to have heather burned according to a rotation system so that all over the moor patches will be found in varying stages of development. From the sporting point of view burning should be done in strips or patches so as to permit of cover for birds being

<sup>1</sup> *Scot. Jour. Agric.*, Vol. XIX. (1936).

<sup>2</sup> *Jour. Min. Agric.* Vol. XLIII. (1937). The crude protein content of heather was found to vary from 7.10 to 12.93 per cent. according to the season and the age of heather, the higher figure being got from three-year-old heather examined in June, the lower from seven-year-old heather examined in January.

easily accessible. Burning should also be done before the heather gets too old; otherwise the plant dies after burning and fresh heather plants under these circumstances can develop only from seed. As this process is very slow the area remains barren for long periods. During this time bracken or even mat grass invasion may take place and heather gets displaced.

For various reasons burning has been very much neglected in the past. Difficulties associated with the getting of and payment for labour, unsuitable Springs when burning could not be carried out before the close period, and the conflicting ideas between sportsmen and sheep farmers as to how burning should be carried out have all militated against the practice.<sup>1</sup> In *The Grouse in Health and in Disease* it is stated "that at least 75 per cent. of the larger moors examined are insufficiently burned." Since that was written it is probable that the situation has developed for the worse. In the accounts of the parish surveys carried out in the counties of Argyll and Perth<sup>2</sup> reference is made to the inadequacy of the burning.

While the main purpose of burning is to induce the fresh growth of young shoots a secondary but very important purpose is served by rotational burning. Sheep readily graze the young shoots of the young plant, and during periods when the ground is covered by snow the older heather (3-6 inches long) is of the greatest use as it can be "worked" by sheep and indeed may become the main source of nourishment under such conditions. The main value of the heather plant lies, however, not in itself as a food but in its association with other plants. A grazing which is dominated entirely by heather is not held in great esteem by the sheep farmer, but heather in association with other grazing plants may have a very great value, particularly for wintering purposes. In this connection it should be realised that the number of sheep a hill grazing can carry is largely determined by the amount of grazing it affords during the winter and early spring months. For this reason the importance of the correct management of a moor with the object of providing the desired amount of relatively young heather plants in association with other grazing plants during the winter can scarcely be overestimated.

*Drainage.*—Like other measures designed to effect improvement on hill grazings, hill drainage suffered badly from the depression that set in in the eighties. On moorland pastures artificial drainage is effected entirely by open drains and ditches. The effect of such drainage on hill land is threefold. It promotes the growth of sweeter herbage plants on the marshy areas; it lessens

<sup>1</sup> *Report of Game and Heather-Burning Committee, 1921.* The Heather Burning (Scotland) Act, 1926, empowers the Department of Agriculture for Scotland to regulate muirburn on the application of the tenant.

<sup>2</sup> "Agricultural Surveys," *Scot. Jour. Agric.*, Vol. XIV. (1931).

the incidence of mortality through drowning, and it minimises the risks due to such a disease as liver fluke. Scarcity of labour during the war further accentuated the decline in drainage, and although various Government grants since the war have made it possible for the practice to be continued when otherwise it would have been largely dropped it cannot be said that most of the hill grazings in the Highlands are adequately drained. Indeed in many areas the present-day generation are unfamiliar with either the appearance or the use of a hill drainage spade.

Allied to draining was the practice known as irrigation. Although most of the soil in moorland areas is extremely acid in character it frequently happens that waters which arise from springs are alkaline in nature and that if these waters are so directed as to flush acid slopes a much better type of herbage is produced. But even apart from the basic properties in the water, the water itself tends to improve the herbage of dry slopes. The practice of leading this water in irrigation channels so as to flush slopes was probably never much in vogue in the Highland counties, but since the eighties little or no irrigation has been attempted.

*Removal of Lime and Phosphates, etc.*—Considerable prominence has been given to the fact that for every pound of wool produced and for every sheep reared and sold off a grazing a certain loss of mineral matter is incurred. In the report of the Departmental Committee on Deer Forests it is stated that “there was general agreement amongst the witnesses examined on the point that few grazings will now carry so large a stock as they did eighty, or even fifty years ago, the reason being that more has been taken out of the soil than has been returned to it, and the pasture is to that extent exhausted.” Latham,<sup>1</sup> writing in 1883, stated that “our Scottish mountains are undergoing a process of impoverishment,” “being slowly but surely robbed of many fertilising properties, especially of their phosphates, and that to such a degree as (without a remedy) must in course of time render them comparatively unproductive.” Sir J. B. Orr and A. H. H. Fraser<sup>2</sup> calculated that in Argyll the equivalent of 35 tons of lime CaO and the same amount of phosphate were being carried away annually from the grazings. To this loss must be added the removal of lime, potash, etc., from the soil by drainage. On the other side there is the fact that lime and other bases are made available by the weathering of the rocky material of the soil. Professor Hendrick has shown that at Craibstone a considerable measure of compensation is thus provided.<sup>3</sup>

No similar investigation appears to have been made either of

<sup>1</sup> *Trans. High. and Agric. Soc.*, 4th Ser., Vol. XV. (1885).

<sup>2</sup> *Ibid.*, 5th Ser., Vol. XLIV. (1932).

<sup>3</sup> *Ibid.*, 5th Ser., Vol. L. (1938).

the loss of minerals through drainage or of the gain through weathering on the Highland hill grazings. The point to note, however, is that in the absence of a definite balance sheet indicating gains as well as losses of minerals, it would be unwise to generalise on this alleged cause of deterioration. In the Border grazings, where sheep have been present for very long periods, and where on account of the sheep population being much denser than in the Highlands the mineral losses through sales of sheep may be deemed to be heavier, there does not appear to be any marked deterioration of pastures.

This may be illustrated in a broad way by comparing the numbers of cattle and sheep in the counties of Peebles and Selkirk, both of which resemble the Highland counties in having a fairly high proportion of unimproved to improved land. In their case, however, no loss has been incurred through the formation of deer forests, etc., while heather and bracken problems are less in evidence. The following table shows the average number of cattle and sheep in the counties of Peebles and Selkirk for five three-yearly periods.

<i>Three-Year period</i>	<i>Peebles</i>		<i>Selkirk</i>	
	<i>Cattle</i>	<i>Sheep</i>	<i>Cattle</i>	<i>Sheep</i>
*1855-57	7,353	174,873	2,308	140,103
1880-82	5,801	192,902	2,593	164,349
1905-07	7,356	201,574	3,541	185,168
1930-32	7,093	210,452	4,016	190,642
1935-37	7,429	199,341	4,306	189,793

\* The figures for this period are from the Report of the Highland and Agricultural Society of Scotland.

Professor Watson, referring to these two counties, points out that since the period 1893-95 there is no clear evidence of improvement or of deterioration in the grassland output as a whole.<sup>1</sup>

All we can be certain of in this matter is that over most of the Highlands there is and apparently has always been within historical times a considerable dearth of both lime and phosphates in the soil. Whether or not this dearth has been so accentuated by the introduction first of all of sheep to the Highlands and then by the substitution of ewe stocks for wethers as to cause a marked deterioration in the herbage is a matter on which considerable doubt may be expressed.

Another factor which may be considered in connection with the replacement of manurial constituents is that sheep are inclined to impoverish the more fertile parts of a grazing through their habit of grazing on these parts during the day and of resting on the higher and probably less fertile parts at night.

<sup>1</sup> *Trans. High. and Agric. Soc.*, 5th Ser., Vol. L. (1938). The table was prepared before Professor Watson's article was published.

*Invasion of Scrub, Blaeberry and Whins.*—In a survey of the agriculture of a parish in Argyll the reporters drew attention to the spread of scrub over the rough grazings. This had not only a detrimental effect on the grazings of the lower parts of the area but also tended to make herding very difficult. It was stated (1931) that no fewer than 50,000 acres were then under scrub in Argyllshire. Blaeberry is stated to have spread over considerable areas of rough grazing in Perthshire within recent years, while attention was drawn in the surveys, already referred to, to the damage done to grazing by the spread of whins.<sup>1</sup>

*Damage by Rabbits and Mountain Hares.*—When sheep farming was introduced into the Highlands rabbits were practically unknown in many parts of Scotland. To-day they are, with the exception of the rat, the most serious four-footed pest the agriculturist has to contend with and certainly the most serious from the sheep farmer's point of view. In the absence of definite figures it is difficult to estimate the damage done by these animals. It is not unreasonable to suppose, however, that eight fully grown rabbits have probably eaten quite as much food as the average sheep sold off the hill. In this connection it is of interest to note that on one north-country grazing where the annual output of sheep (wether lambs and cast ewes) is under 2000 some 8000-10,000 rabbits are caught in one year. It has also been stated that on one moor in Inverness-shire upwards of 1100 mountain hares were shot in one day in 1896. It is quite probable that in some cases the value of the grazing is depreciated by at least fifty per cent. because of rabbits and hares.

Since the war the policy of controlling their numbers by trapping has to some considerable extent been rendered inoperative by the fact that the returns got from the rabbits did not meet the expense of trapping, carriage to destination, and commission expenses. Even when farmers do try to control numbers their farms are always liable to be invaded from neighbouring lands. Moreover, rabbits not only attach themselves to the best parts of the grazings, but they destroy the better grazing plants. It is commonly asserted that a rabbit destroys far more than it eats.

*Problems connected with Fecundity, Disease and Nutrition.*—Farmers who keep breeding ewes are concerned with the problems of the natural increase and the death-rate of their flocks. Obviously the greater the number of surplus animals that there are to sell the greater, other things being equal, the income. On many Highland hill grazings the number of such surplus animals is comparatively low, owing partly to the breed of sheep kept, partly to the system of management adopted, and partly to the compara-

<sup>1</sup>"Agricultural Surveys," *Scot. Jour. Agric.*, Vol. XIV. (1931).

tively high death-rate experienced. Normally the hill ewe is not expected to rear more than one lamb per annum; nor is she expected to rear more than three or four lambs during her stay-period on the hill. She may produce her first lamb at the age of two years, but in certain counties it is not customary for hill sheep to bear lambs before they are three years old.<sup>1</sup> Ewes are usually cast before they lose teeth. This may be at the age of four or five according to the grazing. Obviously these factors have a pronounced bearing on the relative prosperity of sheep farming and in any study on the decline of sheep on Scottish hill grazings due consideration must be given to them.

The death-rate amongst hill sheep varies with many circumstances, the locality of the grazing, its freedom from certain diseases and pests, etc., its ability to winter sheep comparatively well or badly, and last of all, with the skill and management of the shepherd or owner. On some grazings many sheep are lost through drowning in bogs, through being smothered by snow, through falls from cliffs, through isolation by tides, etc. Certain grazings are notorious for the heavy death-rate caused by such specific diseases as braxy and louping ill. On most grazings a number of sheep die from undiagnosed causes, but which in many cases are undoubtedly due to such hardships as pregnant ewes have to undergo throughout the winter period. Probably few farmers realise that hill-wintered ewes may lose up to one quarter of their body-weight from October to March, while at the same time they are expected to supply nourishment for their unborn lambs. Conversely, it may be remarked, the ewe usually regains all this loss during the remaining six months of the year. Orr and Fraser<sup>2</sup> have provided illuminating figures on this point. On Heft 4 of Garrochoran grazing, Argyll, the average weight of the ewes declined from 86 to 64 lb. in the period October to March. Even when extra feeding at the rate of fully half a pound of concentrated feed a day was given the weights declined by 16 to 17 per cent. It is not surprising, therefore, that on many grazings not only is the mortality rate amongst ewes very high but the percentage of lambs reared and sold is also surprisingly low. At Garrochoran during the year October 1929 to October 1930—the year before any experimental work was commenced—the following figures were obtained:—

Mortality of ewes	-	11·43 per cent.
Mortality of lambs	-	34·2 per cent.
Birth-rate of lambs	-	66·8 per 100 ewes.
Lambs reared	-	43·95 per 100 ewes.

Although these results may be described as abnormally low,

<sup>1</sup> "Agricultural Surveys," *Scot. Jour. Agric.*, Vol. XIV. (1931).

<sup>2</sup> *Trans. High. and Agric. Soc.*, 5th Ser., Vol. XLIV. (1932).



there are apparently large areas where little, if any, better results are obtained. In the surveys already mentioned it is stated that in an Argyll parish the average death-rate was not less than 15 per cent. In a "healthy" Perthshire parish the average annual loss was found to vary from three to five per cent., but on "unhealthy" ground in this parish a loss of 23 per cent. was recorded in one particularly bad year.

In the same way the percentage lambing rate varies very greatly between one area and another. That the low rate calculated for Garrochoran Farm is not untypical of parts of the West Highlands is confirmed by the calculated percentages obtained from the Agricultural Returns of four parishes selected at random from the western parts of the counties of Argyll and Inverness. These gave the following percentage figures—62·7, 64·5, 64·3 and 72·9. In other grazing parishes in the south of Scotland the percentages are seldom below 90.

That the high death-rate may be reduced and the birth-rate considerably increased under certain conditions is clearly indicated by Orr and Fraser,<sup>1</sup> who found that by giving extra feed to the ewes during the winter considerable improvements could be effected actually in the figures quoted by them; the death-rate was halved by giving the ewes about  $\frac{1}{2}$  lb. of concentrated food a day. Unfortunately it could not be definitely stated that, under the economic conditions prevailing at that time, the practice of giving this extra food added anything to the net profit.

While the Highland sheep farmer has thus in the apparent interests of economy to be reconciled to a policy of semi-starvation of his ewes during the winter, he usually draws the line at wintering the ewe hogs at home. These are almost invariably sent away to low ground pastures for wintering. The object of such wintering is a two-fold one. The death-rate usually becomes markedly reduced, while at the same time the sheep are enabled to grow larger frames. The wisdom of this policy is fully vindicated in the figures obtained in connection with Garrochoran farm where the mortality rate was reduced from 20·7 to 6·0 per cent.<sup>2</sup> by sending the hogs away for the winter, while the loss in weight of the home-wintered lots, which varied from 19 to 32 per cent., was changed into a gain of 4 per cent. in the case of the away-wintered lots. Moreover, although the home-wintered lots tended during the following summer to thrive better than the latter, the lee-way was never made up, the home-wintered lots remaining permanently stunted in growth. It was further found that the addition of a concentrate food was not a satisfactory substitute for wintering on lowland pasture. It should be noted, however, that these results appear to be typical only of some of the worst

<sup>1</sup> *Trans. High. and Agric. Soc.*, 5th Ser., Vol. XLIV. (1932).

<sup>2</sup> Fraser, "The Wintering of Ewe Hogs," *Scot. Jour. Agric.*, Vol. XX. (1937).

east Highland grazings. On grazings where much less trying conditions are encountered it may be profitable to winter the ewe lambs at home.

The wide variations which thus exist on grazings between their death-rates on the one hand, and their rates of natural increase on the other, have an important bearing on the profitability of sheep farming; paradoxical as it may seem, it may pay a sheep farmer to reduce his sheep stock in order to increase the numbers as well as the value of his disposable surplus.

*Economic Situation.*—Behind many of the causes leading to the decline in the numbers of sheep in the Highland counties may be traced the effects of an altered economic situation. When sheep farming was first introduced into the Highlands the prices of sheep were low, but expenses were low in proportion. Wight<sup>1</sup> writing in 1784 stated that three- or four-year-old Blackface wethers made at that time from 6s. to 10s. a head, fat ewes 5s. 6s. and ewes with lambs at foot 7s. to 8s. The cash wages of married farm servants were then £3-£4 a year. During the next thirty or ninety years, except for the period of depression following the Napoleonic Wars, prices generally advanced and although expenditure in the shape of outlays for wintering, dipping, wages, &c., rose, profits were, generally speaking, fully maintained. In the earlier days of sheep farming the price of twenty to thirty lambs paid the cash wages of a shepherd. By the seventies of the last century, however, the increases in expenditure had already overtaken the advance in prices. Macdonald writing in 1877<sup>2</sup> stated that wintering expenses had doubled within the ten years preceding that date and drew attention to the fact that even then, what might be termed the golden age of British agriculture, sheep stocks were declining in the county of Ross and Cromarty.

Ominous as the signs then were they gave no indication of the severity of the coming storm which burst on sheep farmers in the eighties and which reached its climax in 1892 when Blackface lambs were selling for one-third of their previous values and cast ewes changed hands freely at from 5s. to 10s. each. The higher lying and most productive grazings were the first to suffer. Many of these could be grazed only by wethers, which, unlike ewes, did not return yearly income in the sale of surplus stock and which, because of the high and stormy nature of their grazings, had often to be partially wintered on low ground. Moreover, the public began to prefer lamb to wether mutton, and the appreciation between the buying price of the wethers as lambs and their selling price two or three years later, which along with the price of the wool constituted the income from keeping this class of sheep, began to diminish seriously. The value of the wool crop of a wether was

<sup>1</sup> *Present State of Husbandry in Scotland.*

<sup>2</sup> *Trans. High. and Agric. Soc., 4th Ser., Vol. VII. (1877).*

at one time reckoned to be sufficient to defray all possible wintering expenses. With a fall in the price of wool and a rise in the cost of wintering the value of the wool clip could by the nineties defray only a small proportion of such expenses.

When prices did fall the price of wethers fell more in proportion than that of other classes of sheep. The keeping of wether stocks became not only relatively but absolutely unprofitable. Economic rents could not be paid,<sup>1</sup> even although economies on such measures as heather-burning, bracken-cutting, draining, etc., were effected. The reduction of expenditure on these items was in fact applied to most grazings and has doubtless resulted in many cases in the deterioration of their grazing value, particularly since the war.

Thus the former wether grazings became in large measure the modern deer forests. In some cases wethers might be replaced by ewes, particularly if the ewes happened to be of a hardier breed. Thus Blackface ewes might replace Cheviot wethers. The net result, however, was that old wethers practically disappeared. Greig and King<sup>2</sup> reckoned the losses in each of the counties of Argyll, Perth and Inverness as over 80,000, and in Ross and Cromarty and Sutherland as over 40,000.

In an attempt to reduce expenditure on wintering many farmers have intentionally reduced the numbers of sheep kept on their grazings so as to provide more food for the remainder in winter. In a report on the agriculture of a Sutherland parish<sup>3</sup> it was stated that one hirsell of a farm was kept clear of sheep all summer and was used along with the arable land of the farm for wintering. This meant that the total number of sheep kept on the farm was appreciably reduced.

In the post-war period the situation tended to become worse largely owing to the comparatively high outlay incurred for wintering and labour in relation to results. Instead of 20 to 30 lambs paying the yearly cash wages of a shepherd it might take anything from 50 to 100 lambs. As already pointed out such improvement measures as heather-burning, bracken-cutting, draining and irrigation were all prejudicially affected by the disproportionate rise in the price of labour in relation to returns. Moreover, the new situation could not be met, as has been the case in so many industries and even in branches of agriculture itself, by the use of labour-saving devices, etc. The industry of sheep farming has indeed benefited by the discovery of cheap and effective means of controlling such diseases as braxy, louping-ill and lamb

<sup>1</sup> Macdonald, writing in the *Trans. High. and Agric. Soc.*, 4th Ser., Vol. XVII. (1887), mentions that in 1886 close on a hundred pastoral farms exclusive of those previously in the owners' occupation were unlet.

<sup>2</sup> *Scot. Jour. Agric.*, Vol. XII. (1929).

<sup>3</sup> *Ibid.* Vol. XIV. (1931).

dysentery and such pests as liver fluke. But this advance in the treatment of disease has in part been countered by an increase in the maggot-fly pest and in the spread of tick-borne diseases into districts where they were previously unknown. Scientific and technical progress in regard to labour-saving machinery, the use of manures and feeding stuffs, plant-breeding, technique of cropping and rotations have contributed little or nothing to the Highland sheep industry. Indeed, it is often the other way round. The motor car has ruined the roads for droving, has introduced the sheep-stealer and has killed thousands of animals.

No review of the economic situation could, however, be complete without mentioning the effect of acclimatisation values. These values admittedly had a beneficial effect on the industry when first introduced, but of recent years it has been repeatedly suggested that their net effect is to lock up a needless amount of capital and thus to decrease the profitableness of sheep farming.<sup>1</sup>

*Effect of Recent Improvements on Temporary Pastures.*—A superficial analysis of the changes in the live-stock population of any county within a limited period is apt to give misleading results unless consideration is given to such factors as the replacement of one kind of stock by another, or the effect of changes in cropping, manuring and general management. Thus the substantial improvements in the stock-carrying capacity of temporary pastures have had a very pronounced effect on the sheep population of certain counties. In Aberdeenshire, for instance, there are now more than double the number of sheep that there were in the period after the war; in Orkney the increase has been still greater, while in each county and especially in Orkney the number of cattle has shown a significant increase. Both counties are favourably placed for showing these increases on account of their containing a very large proportion of temporary pastures. It should, however, be observed that, in the Highland counties previously referred to, the amount of temporary pasture that has been improved, though small in area in comparison with the total area of the county, nevertheless in the aggregate is capable of carrying a significant increase of stock. In the absence of detailed and accurate information it is difficult to estimate the extra numbers carried. Probably they range from 50,000 to 100,000. In this connection it may be interesting to examine the figures for Sutherland, the county where the masking of the

<sup>1</sup> *Report of Committee on Valuation of Sheep Stocks in Scotland, 1934.* The Sheep Stocks Valuation (Scotland) Act, 1937, sec. 1, provides that in all cases of valuation of sheep stocks that are bound to the ground the arbiters shall show the basis of their valuation and state separately the amounts included in respect of acclimatisation and other factors that they have taken into account.

decline by such a factor as the one outlined above would presumably be least. The figures for this county show that the number of sheep has shown very little variation during the past seventy years. The numbers of cattle and horses have, however, declined considerably. It is not unlikely that in this case the probable declines that would have taken place in the sheep population of the grazings have been neutralised partly by the replacement of cattle and horses by sheep and partly by the increases due to the improvement of temporary pasture.

*Review of Situation.*—In reviewing the situation it will be readily appreciated that it is extremely difficult to apportion to each individual factor its true share in the general decline of the sheep population of the Highland counties. Fundamentally the chief cause has undoubtedly been the economic situation. Its repercussions are to be found in such factors as the abandonment of many of the least healthy and most unproductive grazings, the decline in such improvement measures as draining, irrigation, bracken- and scrub-cutting, heather-burning, curtailment of arable farming on marginal land, etc. It is only a partial and very incomplete truth to suggest (as has been done)<sup>1</sup> that the system of farming as practised in the Highlands is dependent almost entirely on the price of sheep. Many factors influence the profitability of sheep farming, the general level of wages, the price that has to be paid for wintering, the amount of wintering and of extra feeding that have to be done, the annual rate of increase and the annual death rate of the stock. It was inevitable that a system which involved heavy outlays in relation to its results should be unable to withstand the effects of the economic blizzard which assailed the industry in the eighties and nineties of last century. Co-temporary with this arose the increased demand for deer forests and hundreds of thousands of sheep, chiefly wethers, were driven away never to return. Although from the point of view of food production the deer forests may be regarded largely as evils, no one would be bold enough to suggest that all the 600,000 sheep displaced by the deer could now be profitably carried on their old grazings. So far from this being the case there are grounds for thinking that a certain proportion of the present-day sheep grazings are uneconomic.

Apart altogether from the economic aspect and its repercussions there is, however, reason to suppose that the stock-carrying capacity of the grazings has declined and that the scientific discoveries that have had so beneficial effects in other spheres of agriculture have done little to stem the tide of decline in Highland sheep farming. It is, however, only reasonable to hope that the recent advances made in regard to the manuring and cropping of

<sup>1</sup> *Report of Departmental Committee on Deer Forests, 1922.*

arable land and temporary pastures, and in the care and management of certain classes of stock, may be applied in the Highland area. It may be profitable, therefore, to discuss some of the ways in which improvement might be carried out.

*Wintering.*—The stock-carrying capacity of Highland sheep grazings is largely determined by their capacity to support sheep during the winter and early spring months. Any improvement, therefore, which permits of increased wintering being done without adding unduly to the expense would confer a great boon on the industry.

Orr and Fraser<sup>1</sup> have examined the problem from the point of view of supplementing the outside ration with concentrates and minerals. The results although in some ways distinctly hopeful did not give a clear indication that they could be applied practicably under the economic conditions prevailing at the time. In any case the feeding of concentrated food like grain to sheep wintered on the hill would appear to be regarded with some degree of apprehension by practical farmers, who consider that sheep so fed do not thrive well during the ensuing summer. In periods of scarcity good meadow hay is regarded as the best supplementary food for hill ewes, then clover hay. It is possible that ensilage may be a suitable supplementary feed for hill sheep, but long-range experiments to determine its full value do not appear to have been carried out.

Stapledon<sup>2</sup> has approached the problem from another angle. Realising that on most hill grazings there are considerable areas of land at comparatively low levels, which may be cultivated, he has shown us how such land may be set aside for the growing of winter feeding crops like hardy green turnips or rape sown broadcast, Italian rye-grass, etc., sown either singly or in combination with one another. In trials of a *purely preliminary nature* carried out at Aberystwyth on poor land 1000-1300 feet above sea level he has found that such an herb as ribgrass grown as a pure crop may compare favourably from a nutritive point of view even with crops of some of the plants named above. Welsh mountain lambs penned on the following pure crops attained the undermentioned live-weight increases in a feeding period of 6-7 weeks.

<i>Plant.</i>	<i>Live-weight increase.</i>
Rape - - - -	approximately 9.5 lb.
*Ribgrass - - -	" 8 "
Hardy greens - -	" 7 "
Italian Rye-grass - -	" 5.5 "

\* One trial only.

<sup>1</sup> *Trans. High. and Agric. Soc.*, 5th Ser., Vol. XLIV. (1932).

<sup>2</sup> Grass Land Conference at Aberdeen, 1938.

While these results can only be regarded as preliminary they are certainly suggestive.

Further trials have been made in the direction of sowing grasses and herbs which are known to have winter-green properties. If pastures thus produced are grazed in the early part of the summer and closed up during the late summer and autumn they provide *in situ* a valuable winter food for grass. It is important, however, that the correct "rest period" be determined otherwise too much "burn" results.<sup>1</sup>

The possibilities of working along these lines have probably received far too little attention during the past century. Dr James Anderson,<sup>2</sup> a noted agricultural writer of the eighteenth century, drew attention to the fact that sheep's fescue (*Festuca ovina*) had the property of remaining winter-green, particularly if the growth had developed during the late summer and autumn. At Aberystwyth, Professor Stapledon has shown that red fescue and certain other grasses and herbs, particularly ribgrass, may provide valuable winter keep if care has been taken to rest them during the autumn after having been hard grazed during the summer. Fagan<sup>3</sup> has shown that some of the herbs like ribgrass and cat's ear are particularly rich in mineral matter. Sandison<sup>4</sup> describes how outwintering of cattle may be accomplished in the northern part of Zetland by resting bent and fescue pastures during the summer and autumn.

Even the marsh thistle (*Carduus palustris*, Linn.) has been suggested by Andrew Linton<sup>5</sup> as being of sufficient importance for keep in the winter to justify its seed being included along with that of ribgrass in the seeds mixture used for sowing down poor hill pasture. Referring to this latter herb he states that while the plant is eaten at all times of the year, in winter sheep take great pains to eat it close to the root. Linton in the same article also refers to the winter-green characteristics of sheep's fescue and states that it is the most valuable grass in the natural herbage of the hill farm. The particular advantage which a plant like sheep's fescue has over the more common and productive grasses is that it can thrive on very poor land and in exposed situations. Being a xerophytic plant it is able to withstand the scorching effects of spells of bare frost better than most other grasses.

*Management of Grazings for Wintering Purposes.*—In the ordinary hill grazing there is a wide variety of plants which in association with other plants have a very distinct value for

<sup>1</sup> "Burn" is the brown or burnt appearance of the leaf of a grass. It is seen in autumn or winter.

<sup>2</sup> *Essays relating to Agric. and Rural Affairs*, 1779.

<sup>3</sup> *Welsh Jour. Agric.*, Vol. VIII. (1932).

<sup>4</sup> *Scot. Jour. Agric.*, Vol. XX. (1937).

<sup>5</sup> *The Grazing of Pastures*. (Geo. Lewis & Co., Selkirk.)

wintering. The green shoots of heather furnish an instance of this. A pure crop of heather may be of comparatively little value; in association with other plants or food of a more digestible nature heather may be of great value. In Strathspey this fact is fully taken advantage of by many farmers who frequently manage to winter one sheep to the acre on high-lying ground partly arable and partly rough. During the day the sheep have voluntary access to the temporary pastures, but in the late afternoon they go back to the rough grazings where they graze on such plants as heather, sheep's fescue and bent. In times of storm, when they are precluded from grazing on the temporary leas, they may be given a small quantity of hay and turnips. It should be noted that in these instances the rough grazings are only very lightly grazed in summer. Excellent results, so far as the sheep are concerned, are obtained, and there would appear to be no grounds for supposing that the grazing or ranging powers of the animals are in any way impaired by the giving of small quantities of hay and turnips during periods of scarcity. A study of this method suggests that the system might be more widely applied. Linton<sup>1</sup> states: "Thus the low-lying lands on a hill farm have a value when grazed along with the hill greatly in excess of their value as enclosures for grazing stock or generally in excess of their value as cultivated land."

It should be noted that under such heavy conditions of winter stocking there may be a danger of the heather plant disappearing. The effect of the system is certainly to diminish the amount of heather present on areas where the extent of heather is less than that of temporary pasture. Areas which previously had been predominantly heather are now predominantly grass.

One of the most valuable of all plants for winter grazing on moorland pastures is undoubtedly the draw moss, otherwise designated hare's tail or cotton grass (*Eriophorum vaginatum*). This plant produces shoots in the early spring at a time when there may be a great scarcity of digestible vegetation. The flower of this plant is called the "moss crop" and both the lower part of the flower and the white bases of the leaf are readily eaten by sheep. During the late spring, summer and autumn months the plant is entirely neglected by sheep. Drainage may destroy the conditions necessary for the growth of this plant and some moors have had their value greatly impaired owing to the fact that they were overdrained. It is interesting to note that, as a result of a recent manurial trial on moss land in East Aberdeenshire, it was found that the amount of "moss crop" was significantly increased as a result of manuring.

It should be noted that many plants which are left untouched

<sup>1</sup> *The Grazing of Pastures.*



by sheep during the summer provide valuable grazing in the early spring. Examples of this are deer's hair grass (*Scirpus caespitosus*) and spret (*Juncus articulatus*). These plants along with wire bent or mat grass (*Nardus stricta*) and broad or flying bent (*Molinia caerulea*) are eaten in the early spring and may help to tide over a very difficult period. Others may be eaten throughout the whole winter, e.g., pry or carnation grass (*Carex panicea*), stoolbent (*Juncus squarrosus*) and bull snouts (*Aira caespitosa*). It has been suggested by Sandison<sup>1</sup> that although some of these plants do not appear under cultivation to respond readily towards giving a more rapid or palatable growth, yet by selection or breeding improved strains may be obtained which will confer great benefits on agriculturists. Sandison mentions that the great woodrush (*Luzula sylvatica*) is eaten by sheep in Zetland. It seems possible too that in the near future much more will be known about the grazing habits of sheep in the winter. Judging from the amount of grazing that is done by moonlight they certainly do not appear to be too discriminating then in their selection of plants and probably eat a great amount of relatively indigestible material. During the day, however, they appear to be more selective in their grazing habits and it is not unreasonable to suppose that a certain proportion of readily digestible material is the complement of the indigestible material grazed.

The management of hill sheep during winter calls for some remarks. Most sheep wintered on the hills lose weight, but no alarm need be felt so long as the sheep are not weakened beyond a certain stage. There is a stage, however, when a weakened sheep many refuse to eat practically any kind of herbage. In other words, it has become "saucy" and seems to have a fixed determination to die of starvation. In order to prevent sheep getting into this condition hand feeding may have to be resorted to, while the thinner ewes should be periodically taken off the hill and put on to special pastures, lambing fields, etc.

It is also important that shepherds should be familiar with the characteristics of the various plants grazed by the sheep and know how the best use may be made of them. The guiding principle which should be adopted is that a mixed diet should be provided. To do so satisfactorily a considerable amount of herding may be necessary.

*Improvement of Grazings as a Whole.*—On the wider issue of improving the grazing for the whole year a considerable amount of experimental work has recently been undertaken. In most instances this work has been directed towards the improvement of certain limited areas, e.g., (a) old in-taken land; (b) areas

<sup>1</sup> *Scot. Jour. Agric.*, Vol. XX. (1937).

which could be ploughed and re-seeded; (c) over-run bracken areas; (d) bog areas; (e) heather areas.

*Methods of Improvement.*—Well managed in-taken land in association with a sheep grazing has a value altogether beyond what it would have, considered by itself. It is important, therefore, that all reasonable steps should be taken to improve the herbage of this land. Various methods have been suggested—(a) manuring; (b) manuring and re-seeding; (c) scratching, manuring and re-seeding; (d) ploughing, manuring and re-seeding.

(a) *Manuring.*—This method depends on the establishment of the wild white clover plant. Once it has been successfully established it adds fertility to the soil and enables better pasture plants to thrive. The method is successful only where the sward is comparatively open as on heavy clays. On matted swards the results are slow and uncertain, owing mainly to the fact that the wild white clover plants, even if they are present, cannot make headway against the competition of the grasses. Moreover, the mat tends to waterproof the land and render the action of the manures inoperative. Good results have been obtained in many Scottish counties by the use of basic slag, mineral phosphates and potassic mineral phosphate. The classic example of such improvement is at Cockle Park, Northumberland, where the process has been highly profitable.

On the question of the choice of manures it cannot be too strongly emphasised that most Scottish soils of the poorer type are seriously deficient in both lime and phosphate. During the process of reclaiming arable land from the rough, large dressings of lime in various forms, e.g., shell lime, marl and shell sand were almost invariably applied as a preliminary measure. Until the acidity of any soil is reduced to the *desired extent* to enable the better class pasture plants to thrive it is unlikely that good results will follow.

It is quite unnecessary, however, for complete neutrality to be brought about. Some of the most valuable British plants tolerate a moderate degree of acidity. Thus wild white clover will flourish in land which is distinctly acid, provided the soil is not impoverished in phosphate and potash, and provided too that such grasses as agrostis, which grow under acid conditions, do not exert too aggressive an effect on the clover. The object to be aimed at is to enable wild white clover to thrive in association with suitable grasses. Advice as to the amount of lime to be applied should be sought either from the Agricultural Colleges or in the case of the North of Scotland area from the Macaulay Soil Research Institute.

Phosphatic manures are as a rule of more importance than lime. In the soil of most hill grazings there is a marked

deficiency of phosphates. The value of a phosphatic manure lies in the fact that while it may not effect a change in the bulk of the herbage it effects great changes in the quality. This is clearly shown by the Cockle Park Experiments where the unmanured plot actually gave a greater yield of dry matter per acre than the manured. The latter, however, gave a threefold increase as compared with the former in live weight of sheep.

On the choice of phosphatic manures some little comment may be desirable. The more acid a soil is the better are the responses made by mineral phosphates and low soluble slags. Watson<sup>1</sup> in an article on Grassland Improvement has drawn attention to this fact. The choice of the phosphate to be used should therefore depend on the following factors, the price per unit of phosphate, the fineness of grinding and the relative degree of solubility in conjunction with the acidity of the soil. It should be noted that the most profitable results are usually obtained when preliminary dressings of ten cwt. and over per acre of slag or ground minerals are applied.

Potash may or may not give a response in manuring soils associated with hill grazings. Some such soils respond readily to potash, others do not. Applications of potassic manures should be considered purely on the merits of each individual case.

In determining what manures should be applied, full advantage should be taken of the facilities for advice available in connection with the Land Fertility Scheme, 1937. In particular the importance of correcting undue acidity in strongly acid soil cannot be overstressed. W. H. Hamilton<sup>2</sup> of Cairns, Midlothian, who has been most successful in improving old in-taken land which was very acid in character, says that "before any real improvement can be effected, either by the application of manures or by breaking up and re-seeding, the lime requirement of the land must be adequately satisfied."

(b) *Manuring and Re-seeding*.—The fundamental principles here are the same as in (a) but in case plants of the desired species are not present in the sward, opportunity is taken to sow the seed of these plants in the hope that they will germinate and establish themselves. The method is suitable to pasture lands where there is a reasonable chance of germination taking place. On bog land areas in Kirkcudbright most promising results have been got.<sup>3</sup> Here, the wintering of ewe hogs of the farm at home is now possible; the number of cattle kept has been greatly increased while the quality of stock kept has been greatly improved. Similar results are being obtained on other farms in Galloway and on some of the peat areas in Lewis, Sutherland and Aberdeenshire.

<sup>1</sup> *Trans. High. and Agric. Soc.*, 5th Ser., Vol. L. (1938).

<sup>2</sup> *Scot. Jour. Agric.*, Vol. XXI. (1938).

<sup>3</sup> Young in *Scot. Jour. Agric.*, Vol. XIX. (1936).

On drier soils this method has not always been successful, owing to the failure of the wild white clover to germinate and establish itself.

Stapledon<sup>1</sup> considers that this method is applicable to cut-over bracken areas. A Bracken Eradication Committee has investigated the method at Rowardennan, Dunbartonshire, and found that it yielded only moderate results. The investigation there is, however, in a preliminary stage.

The question of seeds mixtures will be discussed at the end of this section.

(c) *Scratching, Manuring and Re-seeding*.—This is a development of the previous methods. The underlying idea is to ensure that the wild white clover or other sown seeds will germinate and establish themselves. This method has been widely tried on old pastures in England and Scotland. One of the difficulties is to get a sufficiently effective harrow. Stapledon<sup>2</sup> considers that the most satisfactory implement is a rotary cultivator driven from the power take-off of the tractor. At Carnwath, Ogg has obtained excellent results on bog land by means of a roto-tiller. Recently a large number of other harrows have been tried at various centres in Scotland with varying results according to the type of land where the tests have been made. The chief drawback to some of the harrows used is that they fail to penetrate the surface sufficiently and that the upturned sods are not broken into small enough particles. This interferes with the germination of the seeds. Where the mat is very thick, stock may refuse to graze the harrowed land while the upturned turf may decay very slowly. This happens on land very deficient in lime and it is possible that at some stage or other both liming and burning may be of great benefit. In Orkney a considerable area of heather has been successfully converted into grassland by this method.

(d) *Ploughing, Manuring, Re-seeding and Controlled Grazing*.—By far the most effective method of re-conditioning and improving pasture land is to attempt the immediate establishment of a sward of improved plants. By ploughing up the destruction of the inferior species is attained while at the same time a suitable seed bed for the germination and establishment of the superior strains may be obtained. Great care must, however, be taken to see that the correct conditions for the germination and subsequent establishment of the seeds are present. The importance of controlled grazing has been emphasised by Martin Jones<sup>3</sup> since otherwise the plants of wild white clover and the finer grasses may be repressed. By giving heed to all these considerations Stapledon<sup>1</sup>

<sup>1</sup> *The Land Now and To-morrow*.

<sup>2</sup> *Scot. Jour. Agric.*, Vol. XIX. (1936).

<sup>3</sup> *Emp. Jour. Exp. Agric.*, Vol. I., No. 1 (1933).

has obtained fourfold increases in the stock-carrying capacity of selected parts of hill grazings, previously unbroken by the plough, at altitudes of over 1000 feet.

This method has been tried in many parts of Scotland. The following articles, which are to be found in the *Scottish Journal of Agriculture*, have described the methods used and the results attained:—M'Dougal, "The Improvement of High-lying Grass Land," Vol. II.; "Pasture Improvement on High Land," Vol. VIII.; Ogg, Garst and Macleod, "Reclamation and Cultivation of Peat Land in Lewis," Vols. XIV., XV. and XVI.; "The Improvement of Grazing Lands," Vol. XX.; Kirkwood, "The Improvement of Grass Land by Ploughing and Sowing down direct," Vol. XX.

One of the difficulties in connection with this method is to obtain a sufficiently pulverised and moist seed-bed to permit of the seed germinating and the plants establishing themselves with a reasonable degree of certainty. In other words, it is often difficult to establish a good "take" by this method. Some farmers are of opinion that very early spring sowing is best; others delay sowing until the end of June in the hope that the July rains will ensure the right conditions for germination. This matter has by no means been satisfactorily settled and improvements in the technique of ploughing out and starting afresh may be confidently expected in the near future. The points to be aimed at are complete burial of the old turf, freedom from weeds, a good tilth, sufficient rainfall to germinate the seeds and sufficient plant food in the soil to maintain the young plants in robust health.

Probably some of the most successful results have recently been obtained in places as far apart as Somerset in the south of Great Britain and in Orkney in the north. In both instances the land was ploughed early in winter. At the County Council Farm Institute, Somerset, the turned-over furrows were inverted and subsequently broken up in the following spring with a view to promoting the rapid decay of the turf. By June the pieces of turf had been worked down to such a degree that they could be ploughed under and a suitable seed-bed established. Heavy rolling in the final stages was also a feature of this part of the work. Towards the end of July, after liming and manuring had been carried out the seed was sown in a perfect seed-bed and, the weather conditions being favourable, satisfactory germination was established within a week or two.

In Orkney, where one farmer has reclaimed sixty acres of heather within the past few years, the main features of his recent operations were tractor ploughing with a flat furrow, disc harrowing, sowing the seed at the end of July and applying at least ten cwt. of slag per acre. In much of the reclamation work

presently being carried out in Orkney shell sand is applied at the rate of two tons per acre in addition to the phosphates.

By sowing turnips, rape, etc., broadcast and eating these plants with sheep Stapledon<sup>1</sup> has succeeded in improving the physical condition of the soil. Two such crops may be taken in succession without ploughing up. Hamilton (previously referred to) prefers putting his old in-taken land through a modified rotation before sowing out is attempted. On the question of taking a nurse crop the general opinion is that better results are obtained on the poorer soils if no nurse crop is taken. It should be noted, too, that the straw-yielding varieties of oats make poor nurse crops owing to the shading effect produced. Rape not exceeding 3 lb. per acre may, however, be used as a "nurse." It should, however, be eaten before it shades the young grass and clover plants. Recent work on "poor land" has suggested that the best results are obtained by excluding rape altogether.

*Seed Mixtures to be employed.*—While the importance of sowing the seeds of superior plants can scarcely be overestimated, due regard must be given to the special circumstances under which the seeds are expected to germinate and establish themselves. Thus if seed is merely broadcast on bog lands a large proportion of the seeds will fail to germinate. In such cases mixtures of grass and clover seed cleanings have so far given the best results. Similarly when land is merely roughed up much of the seed sown may be wasted. Regard, therefore, must be given to the question of cost in relation to results. It should be recognised that even when the plough has been employed it may be impracticable to obtain a sufficiently fine seed-bed to justify the use of a high-class seed mixture. Stapledon's work has emphasised the importance of improving the seed-bed and general soil conditions by definite stages. The immediate aim should in all cases be the same—the establishment of the white clover plant. Once this plant is established fertility can be built up and soil conditions generally improved. Land, which in the first instance would be unable to provide suitable conditions for the establishment of better grasses than Yorkshire fog, may ultimately become fit to grow perennial rye-grass. Where, however, there is reasonable hope of a good take being established immediately, it is probably best to employ a good seeds mixture.

*Value of Miscellaneous Herbs.*—Reference has already been made to the grazing value of plants that cannot be classified as either grasses or clovers. Hitherto scientific workers have in the main been apt to overlook the importance of these plants. Even from the point of view of bulk they may compare favourably under certain conditions with the produce of grasses like perennial

<sup>1</sup>*The Land Now and To-morrow.*

rye-grass and cocksfoot. Milton<sup>1</sup> obtained the following comparative yields when growing the following species of plants in drills. The yields are given in lb. per one-hundredth of an acre.

Seeds sown in 1935.	Weight of air-dried material.	
	1936	1937
Ribgrass - - -	77.5 lb.	41.8 lb.
Cat's Ear - - -	24.6 "	21.8 "
Cocksfoot - - -	17.2 "	25.4 "
Perennial Rye-grass -	21.2 "	22.2 "

These results suggest that of recent years we may have overlooked the part which certain miscellaneous herbs play in pasture.

*Bracken Control.*—Considerable advances have recently been made in the methods of cutting and eliminating bracken. That bracken can be controlled by cutting is a matter of general agreement. Spasmodic and half-hearted attempts, however, serve little purpose. Cutting has the effect of starving the root system of the plant, but so strong are the reserves laid up in the root system that cutting must usually be persisted in over a period of more than two years. Professor Hendrick<sup>2</sup> has shown that in some areas the total amount of rhizome may amount to no less than 43 tons of washed material per acre. The reserve of food thus stored away is enormous. Hence the need for persistent cutting year after year until extermination or at least complete control is effected. Sir John Milne Home<sup>3</sup> has stated that badly infested land can be rendered relatively free from the pest in from two to four years. To be effective cutting must be done at the right time, i.e., when the above-ground parts of the plant have been built up from reserves of food taken from the root system and before any stores of new food have been replaced. The first cutting should be done just when the fronds are completely unfurled, i.e., about the end of June, according to the district, and the next six weeks later. The advantage gained by a third cutting in a season is small provided the first two have been carried out at the right stage. When cutting is done only once per season the best time to cut would appear to be about the middle of July.

The hill grazing of Boghall, Midlothian, occupied by the East of Scotland College of Agriculture, has been practically freed from bracken by the combined effects of cutting and grazing with cattle. The crux of the situation is largely one of costs. Mechanical means, however, can now be employed on much of the worst of the bracken-infested land, with a reduction of cost. Braid<sup>4</sup> has sug-

<sup>1</sup> *Welsh Jour. Agric.*, Vol. XIV. (1938).

<sup>2</sup> *Trans. High. and Agric. Soc.*, 5th Ser., Vol. XXXI. (1919).

<sup>3</sup> *Scot. Jour. Agric.*, Vol. IX. (1926).

<sup>4</sup> Braid, Paper read to Royal Society of Arts in *Scottish Farmer*, Vol. XLVI., page 838; see also "The Eradication of Bracken by Cutting," *Scot. Jour. Agric.*, Vol. XVIII. (1935), reprinted as Leaflet No. 69, and other articles by the same author in Vol. XVII. (1934) of the *Journal*.

gested an average figure of about 1s. 6d. per acre for machine- as against 5s. for scythe-cutting. It is probable that more work requires to be done on the question of costs with mechanical cutters, since the figure given above would appear to have been based on the cutting of limited areas and not to relate to the average cost of cutting for the whole farm.

Cutting in itself should not, however, be regarded as a complete method of improvement. Bracken should be regarded as a symptom of mismanagement of a pasture. The bracken pest is frequently worst on those parts of the grazing where the soil is deepest and best.<sup>1</sup> Because of some deficiency in the soil or mismanagement in the grazing the herbage becomes poor and the stock-carrying capacity of the pasture is reduced. It is under such poor grazing conditions that bracken becomes established. It should, therefore, be the aim of the farmer, after he has reduced the incidence of bracken by cutting, to improve the herbage to such an extent that grazing by stock will not only prevent any further increase in bracken but will also tend to eliminate it altogether.

Professor Stapledon<sup>2</sup> suggests that on bracken-infested slopes successful swards may be established by cutting the bracken, manuring, roughing up and seeding. At Cahn Hill,<sup>3</sup> land, which was useless for grazing because of a dense growth of bracken, was transformed into good grazing by ploughing, manuring, seeding and subsequent cutting or topping the pasture. This land in its improved condition grazed 2·6 sheep per acre during the winter and 3·6 sheep per acre in summer. The bracken problem must, therefore, be viewed from two angles, the initial control of the bracken by cutting and the prevention of its recurrence by taking steps to improve the herbage to such a degree that the land becomes effectively grazed by stock. In most instances the making good of the phosphate deficiency in the soil was of the greatest assistance towards this end, but lime and potash may also both be required.

*Bogland Areas.*—A great deal of the best of the old in-taken land associated with hill grazings is to-day practically worthless through being over-run with rushes and other aquatic plants, which are comparatively useless for grazing purposes. Although rushes are associated with wet land it should not be assumed that improvements are impossible without under-drainage. It has been repeatedly shown that, if effective steps are taken to control the growth of the rushes and improve the conditions under which

<sup>1</sup> In Wales it used to be said that land which could grow bracken could be valued in gold, land where gorse and furze grew in silver, and heather covered land in copper.

<sup>2</sup> *The Land Now and To-morrow.*

<sup>3</sup> Griffith in *Welsh Jour. Agric.*, Vol. XIV. (1938).



grazing plants will grow, rushes may be eliminated without under-drainage even under seemingly impossible conditions. Without under-drainage Cruickshank, Cruden Bay, has transformed rush-infested grassland into first-rate pastures. The North and West of Scotland Colleges of Agriculture have demonstrated how rush growth may be controlled. At Cockle Park rushes have disappeared on the slagged portions of certain plots which have no underground drainage system. At Aberystwyth Professor Stapledon has shown how rushes may be increased or repressed by the control of the grazing. There it has been found that the more land gets infested with rushes the wetter it becomes. On the other hand, the greater the quantity of palatable and digestible herbage damp land is encouraged to grow, the drier it becomes. This can be largely explained by the fact that much of the water which otherwise would be surplus is evaporated off during the process of transpiration. The preliminary steps in treating such land are to rid the land of as much surplus moisture as may be possible by surface drainage, mole drains, etc., to cut and keep on cutting the rushes, to apply phosphates and where necessary to sow the seeds of wild white clover.

But even bogland areas scattered throughout the grazings and producing nothing but white bent, deer's hair grass, bog myrtle and spret have great possibilities in the way of improvement. Possibly because of the damp condition of such land seeds of wild white clover, etc., germinate readily and, provided the manures necessary for growth have been applied, surprisingly good results may be obtained. At Auchinleck,<sup>1</sup> Newton-Stewart, the good results obtained by manuring and sowing cheap grass seed mixtures have been obtained only on this class of land. On dry land the young seedlings of grass and wild white clover appeared to have been unable to establish themselves. Similar results were obtained by Ogg and Macleod in Lewis.

*Heather Areas.*—The improvements effected on heather land are usually so self-evident that little attempt has ever been made to record the effects on any particular area. Heather is a plant which lends itself particularly to control. By moderate burning old heather may be transformed into useful material. By over-burning the whole plant may be killed, in which case invasions of bracken or mat grass become possible. Heather may be killed out also by excessive grazing or even by tramping. The practice of "flushing" is harmful to heather. It is very sensitive to any approach towards neutrality in the soil and can thrive only under distinctly acid and comparatively dry conditions.

Yet by burning great improvements can be effected. On a moor in Renfrewshire an improvement in the output of stock by

<sup>1</sup>Young in *Scot. Jour. Agric.*, Vol. XIX. (1936).

washed or blown on to the fringes, has pronounced fertilising properties. Such patches are not, however, confined to roadways. They occur all over the grazing, on old cultivated patches, along the sides of rocky outcrops and at the base of boulders and bushes. Their formation is no doubt assisted by the treading, grazing and manuring of the sheep. The partiality of sheep for resting on dry and sheltered spots which are easy of access may lead to increased manuring. This in its turn may lead to the development of a superior type of herbage and this again to closer cropping, thereby inducing the growth of prostrate and low-growing plants like the finer fescues, wild white clover and such herbs as ribgrass, yarrow, daisy and plants of the hawkweed family. On such patches the type of herbage is invariably mixed. It may consist of such grass as bent, Yorkshire fog, the finer-leaved fescues and crested dogstail, interspersed with plants of wild white clover and such herbs as those detailed above. In the best patches the sward is always closely grazed, indicating that it is extremely palatable to sheep. A chemical analysis of such pasture reveals the fact that it is both protein- and mineral-efficient. Yet alongside such patches the herbage may be mainly composed of one particular species of plants, e.g., heather (*Calluna*), bent (*Agrostis*) and flying or white bent (*Molinia*). On a Sutherland pasture examined in June 1938 less than one per cent. of one area was grazed. The ungrazed portion was composed of bog myrtle and *Molinia*. Outwardly there appears to be little or no difference in the type of soil between the grazed and ungrazed patches. The fact remains, however, that no matter how much grazing there may be elsewhere, the grazed patches are invariably very closely eaten. How to induce the creation of more and larger patches is a problem which should appeal to the imagination of both the scientist and the practical farmer.

*Breeding Problems.*—It is clearly desirable that live stock should be suited to their environment. For the poorest grazings in Scotland, Blackface sheep are used. But even within the limits of a breed certain types may be produced which are better able to withstand adverse conditions than other types. It has been repeatedly pointed out that the policy of breeding superior animals from the point of view of mutton production has detracted from their hardiness. In an article on the Wintering of Hill Sheep<sup>1</sup> Scott states that the improvement effected in both Cheviots and Blackfaces “has meant a certain loss of hardiness” and “that the sheep are more difficult to winter.” Sandison<sup>2</sup> has recently discussed this matter from the point of view of his own experience in Zetland. He arrived at the conclusion that it was useless to

<sup>1</sup> *Trans. High. and Agric. Soc.*, 4th Ser., Vol. XVIII. (1883).

<sup>2</sup> *Scot. Jour. Agric.*, Vol. XVIII. (1935).

try to improve the mutton-producing qualities of his sheep unless he provided for commensurate improvements in his herbage. Failing to do this he bred from the type of sheep that were best suited for the conditions of his district. The softer types of sheep were culled from his flock; the hardier types were selected to breed from. Figures relating to the wool clip and the mortality rate in the case of both ewes and ewe hoggs indicate that considerable improvements were effected and suggest that breeding on these lines would be a fitting substitute for the policy of using rams, bred under lowland conditions, on mountain ewes. Other sheep farmers who have followed the same methods have found that although the immediate results, as indicated by prices, were disappointing, the ultimate results justified the policy.

*Wintering Problems.*—It seems possible that in the future our present-day ideas about wintering sheep on the grazings may have to be revised. The serious decrease in body weight, the high mortality rates experienced, and the poor lambing percentages obtained on many of the grazings provide striking reasons for improvement. It is still an open question whether or not this can be got by such means as the better utilisation of the plants growing on the hills, the provision of a certain amount of low ground grazing, access to specially grown crops or specially saved areas, and supplementing the roughage of the hill with a concentrated and digestible food like dried young grass or ensilage. Sheep farmers would welcome any improvement provided it were economical and provided too that the grazing habits of the sheep were not in any way impaired.

*General.*—In Scotland there are some twelve and three-quarters million acres of rough grazing land (including deer forests), practically all of which is in the unimproved condition it was a century ago. Not only so, but in the Highland counties considerable deterioration appears to have taken place during this period and at a time when marked improvements were being made in raising the yields of arable crops including temporary pastures. While doubtless in this vast extent of hill land there are wide areas where no economical improvement seems possible, there is a case for endeavouring to improve a certain proportion of this land. Our soil and climate enable us to grow vegetation on most of the land surface. Our problem is not so much how to grow plants as how to encourage the growth of certain species of plants and how to utilise these to the best advantage. The time is ripe for such investigations. In many directions we can utilise the results of the discoveries made by the agricultural engineer, the plant breeder, the chemist and the bacteriologist and can profit by the example of those scientists and practical men who have already shown us how to put some of these discoveries into practice.