Robert Hart RH

THE MACAULAY INSTITUTE FOR SOIL RESEARCH

ANNUAL REPORT

1939-40

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Craigiebuckler, Aberdeen.

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The Institute, which was founded in 1930 with the aid of generous benefactions from Mr. T. B. Macaulay, LL.D. of Montreal, is engaged on research in soils and plant nutrition. It is the national centre for soil research in Scotland and, in conjunction with the University of Aberdeen, facilities are given for post graduate research work. The main lines of investigation deal with soil surveys, soil fertility and drainage, peat and soil organic matter, forest soils, reclamation and spectrographic and mineralogical studies applied to soils.

STAFF

Director	W.G.Ogg, M.A., B.Sc.(Agr.), Ph.D.
Soil Fertility and Advisory Work	A.B.Stewart, M.A., B.Sc., Ph.D. Miss A.J.Preddy, M.A. E.G.Williams, B.Sc., Ph.D. H.G.M.Hardie, A.I.C.
Soil Survey	A.Muir, B.Sc., Ph.D. R.Glentworth, B.S.A.(Manitoba).
Peat and Soil Organic Matter	G.K.Fraser, M.A., B.Sc.(For.), D.Sc. M.R.F.Ashworth, B.A., B.Sc.
Geology	R.Hart, B.Sc., Ph.D.
Spectrographic Department	R.L.Mitchell, B.Sc., Ph.D. Miss A.M.M.Davidson, M.A., B.Sc. R.O.Scott, B.Sc., A.R.T.C., A.I.C.
Lysimeter Studies	H.D.Welsh.
Secretary	Miss E.C.Forrest, M.A.

The programme of work at the Macaulay Institute was modified at the outbreak of war, and, during the past year, October 1939 to September 1940, attention has been concentrated chiefly on advisory work and on problems of immediate importance. In consequence, the time devoted to certain other lines of work has had to be curtailed and some investigations have been postponed.

Soil Fertility investigations have been continued, particularly on lime and phosphate problems. Survey has been curtailed and the Survey Department is assisting with sampling and advisory work and examination of forest soils from areas where felling is in progress. The Spectrographic Department has been carrying on investigations on minor elements in relation to plant and animal diseases and assisting with advisory work.

The peat investigations and work on soil organic matter have been continued with particular reference to composting, and additional horticultural experiments have been undertaken. The reclamation work at Carnwath has been completed and the reclaimed land is now being farmed by the Department of Agriculture for Scotland. The peat work in Lewis has been curtailed and only a few pasture improvement experiments continued.

As in previous years, there has been close collaboration between the Institute and the Scottish Agricultural Colleges, the Rowett Institute, the University of Aberdeen and the Forestry Commission. Joint work is also being carried out with the Animal Diseases Research Association. In conjunction with the Geological Survey of Great Britain a study is being made of the lime resources of Scotland, the analytical work being done at the Institute.

The work of the Institute can be grouped under the following headings:

1. Soil Fertility and Advisory Work.
2. Peat Soils and Soil Organic Matter.
3. Soil Survey.
4. Spectrographic Investigations.
5. Soil Mineralogy.
6. Studies on Soil Drainage.

SOIL FERTILITY AND ADVISORY WORK

Advisory Work

The Institute undertakes the testing of soils on behalf of farmers, and any farmer in the North of Scotland can have this done, free of charge, on application to the North of Scotland College of Agriculture or the Macaulay Institute.

On account of the urgent need for increased food production and the desirability of using the available supplies of fertilizers to the best possible advantage, farmers have been urged to make full use of these facilities. In sampling a soil care must be taken to ensure that the sample is thoroughly representative of the area in question. A sampling-instructions leaflet, covering the main points to be observed, was drawn up for the benefit of farmers and others in a position to undertake soil sampling work. Copies of this leaflet, together with supplies of forms for field notes and sample bags, were issued to the War Executive Committees for distribution to interested farmers. In addition details were given in short articles in the various local newspapers issued in the North of Scotland. The major portion of the soil sampling work has been done by members of the staffs of the Institute and the North of Scotland College of Agriculture, but a considerable number of farmers have undertaken the sampling of their own soils.

During the year 2560 samples of soil have been examined and relative advisory reports issued on the treatment likely to be most suitable for the areas in question. These samples have been drawn both from ordinary arable land and from old grassland which is being ploughed up. From the results obtained with these soil samples a comparison is being made of the lime, phosphate and potash supplies of old grassland as compared with arable rotation land in the North of Scotland. From the results so far obtained the general position appears to be roughly as follows:

Lime: Less than 10% of the samples examined have satisfactory lime contents and over 40% are in need of heavy dressings of lime. These figures vary with the type of soil, the rock from which it is formed and so on. Soils formed from acid igneous rocks, for instance, are generally more acid and lower in lime and phosphate, but richer in potash, than soils formed from basic igneous rocks. The

low percentage with satisfactory lime contents occurs in both rotation land and old grassland.

Phosphate: In arable rotation land only about 20% of the soils have satisfactory phosphate contents and about 25% are in need of heavy dressings. The remainder are in need of more phosphate than they customarily receive. In old grassland the position is relatively much worse; about 60% of the soils are either very low or low, about 30% slightly low and only about 10% satisfactory.

Potash: In regard to potash supplies the position is more satisfactory than it is in respect of lime and phosphate. In rotation land, although only about 25% of the samples have really satisfactory potash contents, the majority of the remainder are only slightly low. Whereas phosphate deficiency is much more pronounced in old grassland than in rotation land, the opposite holds for potash. In old grassland well on to 60% of the soils have satisfactory potash contents and most of the remainder are only slightly low.

In addition to the foregoing general advisory work on agricultural soils, advisory and experiment work on liming and manuring has also been continued in Forestry Commission Nurseries, and further data are being obtained on the lime and manurial requirements of different seedling species. Advisory and experiment work has also been continued in certain areas under large scale fruit production. Results with raspberries emphasize the importance for this crop of adequate potash supplies in the soil; on moderately acid soils raspberries have also responded to the application of medium dressings of lime.

General Soil Fertility Investigations

(a) Experiments with Lime and Phosphates: In the spring of 1939 a series of experiments was arranged in connexion with the Government Land Fertility Scheme. In these the principal aims were to study the effects of varying quantities of lime and phosphate, particularly basic slag, on the yield and composition of ordinary rotation crops and on soil properties. These experiments, which were laid down at six centres in the North of Scotland, have been continued. Lime generally had little effect in the season following its application, but in the second season yield increases of the order of 20% to 40% followed the application of lime to acid

soils. Even in the first season, when there was little effect on actual yield, there were increases in the lime contents of the produce with increases in the dressings of lime applied. With phosphate, yield increases over the control of anything up to 60% were obtained. In the season following application superphosphate was, if anything, slightly superior to a high soluble basic slag supplying an equivalent amount of phosphoric acid; in the second season superphosphate and basic slag both showed marked residual effects, and basic slag was, if anything, slightly superior to superphosphate. The results generally support the view that there is little to choose between superphosphate and basic slag in which 80% or more of the phosphate is soluble in citric acid. The effects of the different treatments on the composition of the produce and on the properties of the soil are being studied.

(b) Phosphate Fixation: A special study is being made of the problem of phosphate fixation i.e. the process resulting in the conversion in the soil of readily soluble or available phosphate into forms which are largely insoluble or unavailable. This is a problem with important practical implications as it has a direct bearing on the question of the utilization of phosphates added in fertilizers. About 250 samples of soil were taken from manuring experiment plots at the North of Scotland College of Agriculture farm at Craibstone. Analytical work on these samples, however, has had to be postponed in favour of other work of a more pressing nature. The major portion of the phosphate fixation work is meantime being carried out on the soil from one of the Land Fertility Scheme Phosphate Experiment centres, which, according to the field experiments, is markedly deficient in phosphate. Varying amounts of different phosphates, with lime in addition in some cases, have been intimately mixed with representative quantities of the soil, filled into large earthenware pots and sunk into the ground in the open to permit the fertilizers to react with the soil under controlled conditions approximating closely to those obtaining in the field. Samples of the soil are being taken periodically and subjected to analyses designed to show the changes which are taking place. The investigation is not sufficiently advanced to permit of definite conclusions being drawn, but preliminary results indicate that ordinary methods of extraction fail to reflect adequately the changes which are taking place, particularly in so far as residual value of the added phosphate is concerned.

As a preliminary to the above investigation a study has been made by Dr.E.G.Williams of the colorimetric estimation of phosphate with the aid of a photoelectric absorptiometer. Special attention has been paid to estimations in acetic acid extracts of soils as used for routine advisory purposes, and it has been found that, with suitable concentrations of reagents, the phosphate in such extracts can be estimated rapidly and accurately without pretreatment of the extract. Details of this work will be published shortly (10).

(c) The Composition and Manurial Value of City Refuse Dust: In many cities the cleansing departments, whose principal concern is the disposal of refuse, pass the refuse through a 5/16 or 3/8 inch screen after glass, metals, etc. have been removed. In Scotland there is available well over 50,000 tons of this screened refuse every year. In view of the abundance of the material available and of its possible increasing importance for war time agriculture, a series of experiments has been undertaken with screened refuse dust from the City of Aberdeen in order to obtain further information on its composition and manurial value. A report on the results obtained will be prepared and submitted to the Agricultural Research Council. The principal results may be summarized as follows:

Composition: On a weight basis the dust compares favourably with farmyard manure except as regards potash in which it is very low. There is, however, in addition a wide range of substances present in the dust. Some of the minor or trace elements present might be of value in certain soils but their availability has not yet been established. Spectrographic determinations have shown the presence of the following amounts of trace constituents:

Refuse Dust: Trace Constituents - parts per million

Cobalt	80	Lithium	2000
Nickel	200	Rubidium	300
Tin	30	Barium	5000
Lead	300	Strontium	5000
Zinc	2000	Chromium	600
Zirconium	100	Copper	300
Vanadium	300	Germanium	30
Molybdenum	10	Gallium	20
Silver	1	Yttrium	30
Beryllium	30	Lanthanum	30
Manganese	3000	Thorium	10

Field Results: From experiments on grassland, which was cut for hay in 1940, it is concluded that the refuse dust has only a limited manurial value. In some instances there were harmful effects from dressings of 10 tons per acre. Even where a yield increase was obtained there was a tendency for this to be brought about by an increase in cocksfoot at the expense of other species, with the result that a coarse hay was obtained. The cost of transport limits the use of this material to relatively short distances from where it is produced.

(d) Crushed Biotite Schist as a Source of Potash: In view of its possible value as a source of potash in war time, experiments have been conducted with crushed biotite schist from Aberdeenshire. An experiment involving comparison of the following treatments on an unlimed soil of pH 5.8 and on the soil limed to pH 6.5 was made on an area under turnips in 1940:

1) Control - no potash.
2) 100 lb. per acre potash (K_2O) in K_2SO_4.
3) 50 " " " " " " crushed biotite schist.
4) 100 " " " " " " " " " .
5) 250 " " " " " " " " " .

Relative yield figures for the turnip crop in the season following the application of the dressings may be summarized as follows:

Treatment	Relative Yield	
	Unlimed	Limed
1	100	119
2	138	146
3	112	122
4	123	131
5	125	137

From these figures it will be seen that biotite schist has a certain value as a source of potash, but in both the unlimed and limed soil 100 lb. per acre K_2O from sulphate of potash is appreciably superior to $2\frac{1}{2}$ times this amount of K_2O from the schist. As against this, lime plus the heavy dressing of biotite gives a useful response similar to that obtained with sulphate of potash in the absence of lime. One of the main difficulties is to obtain a material with a percentage of potash sufficiently high to make it worth grinding. The

sample with which the experiments are being conducted contained only 3% K_2O; this meant that a dressing of approximately 74 cwt. biotite schist per acre had to be applied in order to obtain 250 lb. K_2O per acre. For such a dressing grinding and transport costs per acre are necessarily high. These might be justified if no other source of potash were obtainable and if the residual value proved to be high. The experiment is being continued in order to obtain information on the latter point. From the preliminary results, however, it would appear that at present other materials such as bracken, seaweed, etc, are probably more worthy of consideration as sources of potash than biotite schist.

(e) Borax in Relation to Disease in Potatoes and Swedes: With the potato crop, particularly on light sandy soils, trouble has been experienced in several districts as a result of sprain, internal rust spot or net-necrosis. In recent years too, considerable difficulty has been experienced with the turnip crop throughout the North of Scotland. Root-fly attack, dry rot and raan in swedes all appear to have been involved to varying extents. With a view to obtaining information on the part, if any, played by boron deficiency in these particular problems, experiments have been conducted in conjunction with the Botany Department, North of Scotland College of Agriculture with different quantities of borax on (a) potatoes and (b) swedes at centres where disease normally occurs in these crops. Final results from these experiments are not yet available, but in the preliminary results obtained with the potato crop there does not appear to be any significant trend, and boron deficiency does not appear to be involved in the soils in question. With the swedes under experiment there was very little disease and no evidence of boron deficiency. It is of interest to note that applications of borax up to 60 lbs. per acre were without effect on the yield of either potatoes or swedes, but heavier dressings of borax had depressing effects on the yields of both crops.

(f) Soil Properties in relation to the Occurrence of Grass Sickness in Horses: A paper on this subject will appear shortly (13). This work was undertaken in collaboration with the Animal Diseases Research Association with a view to finding out whether a relationship existed between soil properties and the incidence of grass sickness. From a comprehensive examination of the soils on 63 farms in

Aberdeenshire, where cases of grass sickness occurred, it does not appear that there is any direct relationship between soil properties and the incidence of the disease. The soils examined, however, all fall into the class of acid soils and in very few could the addition of lime be considered unnecessary from the general agricultural standpoint. In view of the relatively widespread acidity in the soils examined the possibility of a relationship between the occurrence of grass sickness and soil acidity is not excluded.

(g) Cobalt Manuring and Pining in Stock: Early in 1940 two manuring experiments, each with cobalt at widely differing rates of application, were laid down on farms in Ross-shire, where pining in stock due to cobalt deficiency occurs. Manuring with cobalt is effective in increasing the cobalt content of pasture, and from these experiments it was hoped to determine the minimum amount of cobalt as a fertilizer likely to be necessary as a practical remedial measure for the disease. On the basis of preliminary results obtained early in the season, a manurial dressing containing cobalt was later applied to half of a six acre field, and in the two portions of this field a controlled grazing experiment with lambs was carried out by the Animal Diseases Research Association. An account of the preliminary results obtained in this joint work will be published shortly (12). From the soil and herbage analyses and from the striking difference between the batches of lambs on experiment, it is concluded that pining in lambs due to cobalt deficiency can be cured and prevented by top-dressing the herbage with a cobalt-rich fertilizer at the rate of 2 lbs. cobalt chloride per acre. The experiments are being continued in order to obtain information on the duration of the beneficial effects of cobalt manuring, and on the relative merits of frequent light or infrequent heavy dressings.

PEAT SOILS AND SOIL ORGANIC MATTER

Peat Reclamation in Lanarkshire - the Carnwath Experiment

In exploring the possibilities of the undeveloped resources of the areas in the South of Scotland where unemployment was most acute, the late Sir Arthur Rose, Commissioner for the Special Areas in Scotland, decided to carry out an experiment on the reclamation of moorland which in this region is very extensive and poorly utilized. Woodend and Blackgate mosses near Carnwath in Lanarkshire were chosen for the experiment. Altitude: 700 ft. above sea level. Rainfall: 35 to 40 ins. per annum.

The peat belongs to the Eriophorum (with Calluna and Sphagnum) type of Moorland or Moss group and the surface layers are much more fibrous than those of the Scirpus type found in Lewis. The depth varies from 15 to 25 ft. and the surface vegetation is mainly Calluna vulgaris, Eriophorum vaginatum and species of Sphagnum and other mosses. These peat mosses were very soft and wet and their only use was to provide a small amount of inferior grazing for sheep for a short time in summer. Their agricultural value was negligible.

Work was commenced in 1936 and completed in 1938. An area of 250 acres was fully reclaimed and about the same area partially reclaimed as improved grazing land.

Most of the fully reclaimed land has meantime been put under grass and part of this has been cut for hay in 1939 and 1940. In 1939 the average yield of hay was nearly 1½ tons per acre with a maximum of over 2 tons in some areas. Very good pasture has been established. Small areas of potatoes and other crops have been tried and yields of silage at the rate of 10 tons per acre obtained.

Various experiments on draining, manuring, liming and grass-seed mixtures have been carried out but at the suggestion of the Department of Agriculture for Scotland some of these have been discontinued.

The cost in the fully reclaimed area was £22 per acre, but as this includes liming, manuring and seeding, normal farming operations which should not properly be charged against reclamation, a deduction of about £7 could probably

be made, bringing out the cost of reclamation at £15 per acre. In this experiment all the workers except the foreman were previously unemployed, and if allowance were made for this, the actual cost to the State did not exceed £7.10.0 per acre. Accounts of the reclamation have been published (1,2).

In order to obtain information as to the agricultural value of the reclaimed land it is being farmed by the Department of Agriculture for Scotland.

Peat Reclamation in Lewis

The Macaulay Farm has been leased to a dairy farmer since February 1939, but the Institute has reserved the right to carry out experiments on any part of the farm and has retained a portion of the land for pasture improvement work.

On the fully reclaimed areas of the farm unsatisfactory drainage and lack of roads have been a severe handicap from the commencement. The drainage on part of the land has been improved during the past few years, but the work has had to be discontinued for the duration of the war. The pasture improvement experiments and a small drainage experiment have been continued on a modified scale.

The work in Lewis has shown that Scirpus peat can be reclaimed successfully but drainage is more difficult and costly on this than on certain other types.

On areas with a good slope, the moorland can be converted into good grazing land at a moderate cost. Probably more would be done by crofters in increasing their acreage of arable land and in improving the moorland grazings were it not for the regulations of the Crofters Act.

Peat and Compost Investigations

An experiment on some of the water relationships of peat as soil or as a soil constituent: The experiment consisted of wetting to saturation equal volumes of various peats, of mixtures of some of these with soil and sand, and of soil and sand alone and allowing these to dry in pots over a period of some months, during which loss of moisture determinations were made.

It was found that the greatest water-holding power was possessed by finely ground, dark coloured raised moss peat. Next to this were fine-leaved sphagnum peats and then coarse-leaved sphagnum peats. These retain about twice the volume of water retained by sand or from one third to one half as much again as that retained by an average loam. The more strongly decomposed and coarsely ground peats are slightly inferior to the coarse-leaved sphagnum peat.

Mixing peats into a normal loam in the quantities usually adopted in horticultural practice does not increase to any marked degree the water-holding power of the loam, although they increase that of sand to a considerable degree.

The rates of evaporation from the peats show the same general order except that well-decomposed phragmites peat resembles a sphagnum peat rather than coarsely ground cotton-grass peat. In peats, drying is relatively more rapid at the surface and slower below the first few centimetres, whereas in soil and sand the rate of drying is more regular from top to bottom of the pot; with mixtures of soil or sand and peat the most notable and unexpected result is that the addition of peat, especially in quantities of 1 part of peat to 3 parts of soil, produces more rapid drying of the soil throughout its depth i.e. the main effect of the peat was increased aeration.

Routine growth tests on peat, using peat (a) as a constituent of a seeding compost and (b) as a soil by itself. A series of 11 different peats was used as the peat constituent of seeding compost with 2 parts loam, 1 part peat and 1 part coarse sand, together with the appropriate manure[1]. The results showed that for making up seed composts coarse-leaved sphagnum peats are undoubtedly the best types and that the quality within the type seems to depend on the degree of decomposition and compaction of the peat (i.e. its age). Fine-leaved sphagnum is not satisfactory. The older and more strongly decomposed peats not derived chiefly from sphagnum are not so good and "hill" peat derived chiefly from heather is, like fine-leaved sphagnum peat, not satisfactory.

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[1]These and other seeding and potting composts are prepared, unless otherwise specified, on the lines indicated in "John Innes Composts for Pot Plants" (The John Innes Horticultural Institute, London. April, 1940.).

Used by themselves the sphagnum peats are not satisfactory, germination is poor and the plants weakly as compared with those growing on more compact peats, of which Lewis (scirpus) peat was the best.

The plants from the composts in this experiment were transplanted intopotting composts containing the same type of peat as that of the seeding compost.

On the average the plants from the slightly decomposed coarse-leaved sphagnum peats were better, but there was little to choose between the types. The Lewis peat compost actually gave the best result by weight, while the fine-leaved sphagnum peat gave results definitely inferior to the others.

A pot-culture test of the Mitscherlich type was carried out on cottongrass peat from Aberdeenshire. Tomatoes were used as the crop. The test was a failure, because after a period of satisfactory growth (up to two flower trusses) all the plants developed signs of special nutrient deficiency, loss of green colour, development of purple veins and poor general growth. This could not be counteracted by additions of minor nutrients and the experiment had to be abandoned. It had shown that the maximum major nutrient requirements of the plants had not been reached even with additions of major nutrients above the quantities used as complete nutrient in Mitscherlich work.

Larger scale tests on peat as soil and as a soil constituent:
(a) In the first experiment tomatoes were grown under glass in small plots of potting composts made up with peat on the John Innes scheme. The results showed that little variation was caused in the growth of tomato plants by the various peats used, although the crops were distinctly improved by the addition of peat. The peat-treated soils were improved by 50% in fruit and 20% in total dry matter. Sphagnum peats were some 10% inferior in their plant weights and 20% in their fruit production to cottongrass peats, while the phragmites peat was intermediate.

(b) A market garden experiment was laid out with the following variations:

(1) Soil without peat.

(2) Soil with coarse sphagnum peat - soil 4 parts, peat 1 part.

(3) Soil with cottongrass peat - soil 4 parts, peat 1 part.

(4) Soil with cottongrass peat - soil 1 part[1], peat 6 parts.

(5) Cottongrass peat only, with manurial dressing equivalent to (4).

Taking No.(2) as 100 the following were the relative returns in crop (green matter) and fruit:

	(1)	(2)	(3)	(4)	(5)
Crop	52	100	120	123	120
Fruit	77	100	104	120	88

These figures show that the cottongrass peat with a little soil added was at least equal as a medium of growth to the soil with peat added, while the addition of either sphagnum or cottongrass peat improved the soil. The cottongrass peat with artificials was only slightly inferior to the same peat with soil added, a good result in part due to the use of soil-raised transplants and partly to the extension of the plant roots to the adjacent soil. Where, in another experiment, weaker dressings of artificials were used in the same peat the plants grew very slowly and gave extremely poor returns.

Compost trials: Various composts were tested as soil constituents in place of leaf-mould or dung and as far as the results in general showed anything it appeared that the kind of compost is of less importance than the nutrient contained in it. On the other hand, town refuse dust (after heating with or without materials like beech leaves and peat for four months) produced poisoning effects on horticultural crops grown in boxes.

A series of composts is under preparation from garden refuse and weeds, with peat added as a means of obviating

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[1]This proportion of the rich soil used was calculated to give, when mixed with peat, a well-balanced compost.

loss of nitrogen. The effect of nutrient content in promoting decomposition is being studied in this series, as well as the effect of the nature of the materials.

The study of changes taking place during composting: During the year detailed "Waksman" and nitrogen fractional analyses have been carried out on the materials produced during the course of composting of various peats and other materials with dried blood. Part of this work has been carried out by Mr. Ashworth and has been submitted and accepted as a Thesis for the degree of Ph.D. An account of his work is in preparation for publication (14). From the other work of a similar kind the chief conclusions reached are that the Waksman procedure does not give much information as to the nature of the changes observed during the composting of peat, that the data of the "proximate analyses" are only a first approximation in the grouping of soil organic matter and that in materials like dried blood and peat composts the principal changes in composition are the nitrogenous changes. The methods of proximate analyses seem to throw more light on these than on the changes in the non-nitrogenous organic matter. Similar analyses and total analyses (nutrient content) have been carried out on a number of peats, composting materials and composts.

A beginning has been made on the investigation of the soil organic matter by methods other than those of proximate analyses i.e. along the lines of the Springer methods.

SOIL SURVEY

The work of the soil survey department for the year consisted in extending the surveys of two areas on which work has been started in previous years, and in carrying out investigations on forest areas for the Forestry Commission.

A. Aberdeenshire.

The survey of the soils of the Insch basic igneous mass by Mr.R.Glentworth was completed and a beginning made with the adjoining rock areas. The Insch mass falls on two 1" Ordnance Survey Maps (Regular Edition) Nos.76 and 86, and the area surveyed covers some 100 square miles.

The average elevation of the terrain is about 300 ft. in the eastern part and rises to about 800 ft. in the western districts, with some hills rising above 1000 ft.

The general plan of the work was to survey the area, mapping the various soil types established (by field and laboratory studies) and then to correlate these types with fertility data obtained by collecting and analyzing as large a number as possible of the surface soils.

In an attempt to cut down the number of place names generally required under the British system when dealing with arable soils, the system of classification which was used in Manitoba by Mr.Glentworth (J.H.Ellis, Sci.Agric., 1932, 12, 338) was gradually adapted to local conditions and made to conform as far as possible to the present British system. The scheme is shown in the following table, with an example.

Soil Zone	Soil Suite	Soil Series	Associates
Brown Earth	Insch (Basic igneous rock)	Insch (Till)	Insch Oromorphic, Phytomorphic, etc.
do.	do.	Pitcaple (Gravel)	Pitcaple Oromorphic, etc.

The zone (or major world group), suite and series are already recognized. The associates are soils derived from similar parent materials, but under local variations in drainage, for example. The oromorphic series are normally excessively drained, whereas the phytomorphic soils are well drained (and in normal years would give the best crops). The hydromorphic soils are badly drained or suffer from excess of water somewhere in the profile. Intermediate series can be introduced, such as phytohydromorphic, in which the upper horizons are well drained, but ground water does occur fairly near the surface. Soil types (i.e. textural varieties within a series) and soil phases (stoniness, etc.) are also recognized.

The soils: Since only small areas, usually of the oromorphic series, remain uncultivated, virgin profiles are not easy to obtain for all the series. As a whole, however, the soils overlying the basic igneous rocks have developed a brown earth profile with only slight variations in the composition of the clay fraction, but almost without exception showing a considerable rise in exchange capacity and base status in the lower horizons.

The granitic and slate soils are podzolized when uncultivated, and even when under cultivation a relic of the former ferruginous B horizon is often in evidence. As might be expected the syenite and Old Meldrum granitic gneiss areas have soils that are not so strongly podzolized, and the cultivated soils have brown earth characteristics.

Insch suite: The soils of this suite are all developed on parent materials derived from basic igneous rocks. Within the suite are a number of series which represent the various kinds of parent material, for example the Insch series covers the soils derived from till, the Pitcaple series covers those derived from the gravels at Pitcaple and so on.

Insch series:

(a) Insch oromorphic associate: This associate is usually of a loamy texture and the surface soil some 5 - 7 inches deep on light, open, thin drift. The surface is often bouldery and the soil is uncultivated as a rule, whins and broom being the most prominent plants in the vegetation.

(b) Insch phytomorphic associate: (i) shallow phase: This is loam to fine sandy loam of less than 10 inches in

depth overlying a coarse sandy to fine sandy buff subsoil. It is an unfavourable soil for crop production in a dry season. (ii) intermediate phase: This is a rich brown fine sandy loam of 10-12 inches over a fine sandy buff subsoil. It is average land and responsive to treatment which largely determines its value. (iii) deep phase: This is a warm brown fine sandy to very fine sandy loam of 16-30 inches depth over a fine sandy to very fine sandy subsoil. It forms excellent land, but oats after lea tend to lodge. It seems to be associated invariably with village sites e.g. Insch, Towie, Clatt, etc.

(c) Insch phytohydromorphic associate: These are soils with a freely drained A horizon and ill-drained ferruginous B horizon. They have a relatively low organic matter content. Two types: heavy clay loam and a light to fine sandy loam.

(d) Insch hydromorphic associate: These bear a mossy A horizon, have a high watertable and the subsoil is of a blue-green to grey colour.

Pitcaple series: Two associates are recognized within this series: (a) Pitcaple oromorphic associate - shallow soils suffering from excessive drainage and (b) Pitcaple phytomorphic associate - deep well-drained soils.

Urie series: The soils of this series are derived from alluvium. The first terrace has phytohydromorphic soils of a somewhat heavy texture, and the second terrace has phytomorphic intermediate to deep soils of a clay loam texture. The profile characteristics are those of a brown earth soil.

Insufficient data have been obtained on the soils of the rock areas on the perimeter of the Insch mass, but it seems likely that it will be possible to classify them in a similar manner.

B. Argyllshire.

The survey of the Ardgartan Forest, which forms the northern part of the Argyll National Forest Park, was continued. The survey is planned on the lines of that carried out for the Bin and Clashindarroch Forests in Aberdeenshire. As would be expected from the situation of the area, it differs markedly in almost all respects from the Aberdeenshire one, although the soils of Ardgartan have certain

genetic affinities with those in the eastern district.

The Ardgartan Forest lies at the north end of Loch Long on its western shores. The topography is very complex. Although glaciation has affected the land surface, post-glacial landslips had been widespread and rejuvenated the area to a marked extent and obliterated some of the effects of glaciation. The geology of the forest is simple: micaceous schists occupy most of the area. These pass into more siliceous schists and greywackes at the southern end. In the north there is an area of diorite, most of which lies at high altitudes; there are some basalt dykes.

A considerable stretch of the lower slopes bordering Loch Long carry a rather scrubby oakwood which appears to have been more extensive in the past and which had evidently been exploited for iron-smelting at one time. The oak passes into scrubby birch with increasing elevation in Glen Loin. Although a brown earth or "mull podzol" soil is found in the oakwood on well-drained deep drift slopes, there are quite a number of heath and wet-heath types on flat sites and in hollows. A variety of slightly gleyed podzol occurs on flat spots, and peaty flush with abundant Myrica Gale is common. Clearing of the oak on the well-drained brown earth sites has resulted in a Pteris-Holcus type of vegetation.

Podzolized soils are not very common. Morainic knolls are usually podzolized, but almost always carry a peaty surface. A few of the apparently podzolized soils within the enclosed part of the Forest seem to have been gley (surface water) before enclosure. Peat gley podzolized soils are much more widespread and occur under various vegetation types.

There is a great variety of gley types. In the oakwood a common gley soil bears a Deschampsia caespitosa flush vegetation which seems to persist to a large extent after felling, although some of the sites with this type may never have borne woodland. Juncus articulatus flush on a humose gley (sometimes almost peaty) is often encountered. A Molinia flush (with or without Myrica) on a peaty gley soil is probably the commonest gley in the unenclosed and recently enclosed parts of the Forest. On enclosure Erica tetralix and Calluna become prominent in this type and the organic surface layer becomes much more fibrous. Large areas of deep peat are not extensive. Within the plantable area, that at Argyll's Bowling Green is the largest. This part of

the area has been longest enclosed and the vegetation is typical of the West Highland blanket moss (Scirpus peat).

Forestry Sample Plots

Two areas were visited in connexion with the studies on forest sample plots. In Middle Speyside the plots at Curr Wood, Broomhill were examined and sampled. During the visit a rapid reconnaissance survey of the district was made. The district is an interesting one on account of the widespread occurrence of sand and gravels and areas of almost natural pine forest. The soils on the gravels are principally of the podzol type and some very well developed examples were seen. On till at higher elevations a greater variety of types occurs. Podzols, peaty podzols and various gley types are all found. Near Aviemore on the steep slopes of Craigellachie creep brown earths occur under birch-juniper scrub.

The other sample plots examined and sampled were at Murthly, Perthshire. Oakwood seems to have been extensive here and relics are still to be seen, both on the hill slopes and on gravelly river terraces. The soils under such vegetation appear to show the beginnings of podzolization, there being a very thin bleached layer under the thin litter layer. The rest of the profile is typical of the brown earth type. The change from oak to larch has resulted in very little change in the appearance of the soil.

War Felling Research Project

This was instituted in an attempt to collect data on the relation between tree growth and soil conditions in areas where extensive felling is now taking place. A number of areas in the Borders, and a few in Perthshire and Aberdeenshire were visited, tree measurements and soil data being collected. Insufficient data have been obtained so far for any definite conclusions to be stated.

A Survey of Scottish Limestone Resources

In co-operation with the Geological Survey of Great Britain, the Institute is making a study of Scottish limestone resources. The Geological Survey is carrying out the field work, i.e. collection and description of limestones, while the Institute is making analyses of the samples.

A number have already been analyzed and data are to be issued as wartime pamphlets by the Geological Survey (18, 19, 20). It is hoped to issue eventually a memoir on the limestone resources in Scotland. Analyses of certain economic minerals, e.g. phosphate deposits, have also been made on behalf of the Geological Survey.

SPECTROGRAPHIC INVESTIGATIONS

The work carried out in the department during the year can be divided into two sections: routine analysis, by the Lundegårdh flame emission spectrographic method, of solutions and soil extracts, principally for advisory purposes; and research analysis, by arc emission methods, of the trace element constituents of soils and plant materials.

The work by the flame emission method has been restricted more and more to the routine determination of potassium for the soil advisory department, and at present it is confined to this and occasional determinations of the alkali contents of limestones, in connexion with the survey of the limestone resources of Scotland. As a result of this concentration on one cation, while rather more plates are being produced, the total number of analyses per annum must be smaller, since only one cation instead of three or four is being determined per plate. In the earlier part of the year, research investigations into the exchangeable cations in forest soils, for the soil survey department, into the cation contents of peats, and into those of soils on which grass sickness in horses occurred, were carried out as in previous years.

As most of the work carried out was of a routine analytical character, little new can be said regarding the technique of the flame emission method. It has been completely standardized and is functioning satisfactorily. Some difficulty was encountered in the determination of potassium in the hydrochloric acid extracts of ignited peats, abnormally rich in calcium, but the effect was principally in the chemical extraction process. Treatment with 1:4 hydrochloric acid did not in some cases extract as much K_2O as did N/2 acetic acid. A preliminary extraction with 10-15 ml. 10% acetic acid followed by ignition and extraction by hydrochloric acid, eliminated this discrepancy, which was probably due to the high calcium content of the ashes.

An investigation has been made of the possibilities of the Ramage Flame Method as modified by Steward and Harrison, but the results obtained were not so satisfactory as those obtained by the Lundegårdh method. The method involves the introduction into an oxy-coalgas flame of a filter paper spill carrying 0.05 ml. of soil extract. Personal factors enter into the process in the folding of the spill and the rate of introduction into the flame, and it was found that equal accuracy was obtained with quadruplicates by the Ramage

process and duplicates by the Lundegårdh technique. As a result the cost of a single determination is substantially greater by the former process. Suitable concentrations were worked out for the determination of several cations, including sodium, potassium, lithium, rubidium, caesium, calcium, magnesium, strontium, iron, cobalt, nickel, copper, lead, chromium and manganese. An account of this work will be published shortly (17). In most cases, however, the determination of trace elements in soils is impractical by this method, just as it is by the Lundegårdh method, and recourse must be made to a sensitive arc method.

The determination of the trace elements in soils by the cathode layer arc method, developed by Mannkopff and Peters in Göttingen, was commenced during the preceding year. This method has now been modified somewhat to suit the problems encountered in soils, and satisfactory quantitative determinations are being made. Much of the work on this method has been carried out by Miss A.M.M.Davidson and Mr.R.O.Scott. A method has been worked out utilizing the iron present in the soil as an internal standard, despite the fact that it may vary in content from 2-15% or even more. This technique involving a variable internal standard has been used for the determination of cobalt, nickel, chromium and copper in soils and has been confirmed by colorimetric determinations of these cations. The normal soil contents of these elements vary from one or two up to a thousand or more parts per million. Calibration curves have been obtained also for tin, lead, silver, molybdenum, vanadium, zirconium, yttrium and lanthanum.

The method depends on the fact that working curves for any cation with standards of varying iron contents are parallel, so that a correction curve for varying iron content can be constructed, and the results obtained from one standard working curve, provided the iron content of the sample is known. For soils, the determination of the iron content is straightforward, as adequate amounts of material are available, but for chemical concentrates and precipitates where only a few milligrams are available for the spectrographic determination and the determination of the amount of iron in the sample, an accurate colorimetric method had to be worked out. It has been found that a salicylic acid method is suitable, and the effects of various interfering substances have been investigated. In particular it has been shown that the visual interference of titanium can be eliminated with suitable filters, and that the method is applicable to either ferrous or ferric iron.

In the colorimetric determinations of cobalt and chromium, an interference effect of chromium on cobalt was observed, and a simple method of separation, involving precipitation of cobalt with sodium hydroxide in the presence of sodium peroxide, was adopted. The determination of chromium in soils using diphenylcarbazide has been investigated.

Accounts of the general cathode layer arc method (covering over 30 elements) by R.L.Mitchell (6), and of the Variable Internal Standard Method by A.M.M.Davidson and R.L. Mitchell (7) have been published. That of the Colorimetric Determination of Cobalt and Chromium is in the press (8) and an account of the Colorimetric Estimation of Iron by R.O.Scott is in preparation (16).

In general it can be said that the year's results show that the spectrographic method is more convenient and just as precise as chemical methods for the determination of the total content of trace constituents, such as cobalt and chromium, in soils. The determination of the "available" or easily soluble portion of the trace constituents has been under investigation and results for cobalt so far obtained are interesting. This work has been carried out in conjunction with an investigation of soils on which sheep and cattle are liable to pine, and the effect on the soil and pasture of incremental dressings of cobalt is being studied. In the spectrographic determination of the cobalt content of pastures and of acetic acid extracts of soils, preliminary chemical concentration is essential and suitable methods are being investigated.

Other small investigations have included the spectrographic study of refuse dust, salt licks, seaweed meal and similar materials of agricultural interest.

Spectrographic carbons have previously been obtained from Germany, but as this supply is now unavailable, it has become necessary to find an alternative source of suitable electrodes. Negotiations are in process with a British supplier and it is hoped they will be in a position to supply carbons in quantity at a reasonable price in the very near future. During the year the only major piece of spectrographic equipment purchased has been a Hilger photoelectric spectrum line microphotometer, which has been employed with success in the variable internal standard method previously mentioned.

SOIL MINERALOGY

The study of the mineralogical composition of soils and soil parent materials from eastern Scotland has been continued. The parent materials of the cultivated soils of Scotland are in the main glacial drifts and the complex nature of these deposits gives rise to difficulties in distinguishing soil types. As an aid to soil studies an investigation of the parent materials of soils in Kincardineshire has been made (21). These are drifts from three glaciations. The mineral composition of the fine sand fractions of the boulder clays has been determined and by this means the boulder clays, though they show colour similarities, are shown to be distinct in their composition. They also differ from the soil parent materials (boulder clays) of south-eastern Scotland, previously investigated, in that their content of ferro-magnesium silicate minerals is much higher generally. This is due to the fact that in the North-east the ice has been mainly moving over a belt of metamorphic and igneous rocks while in the South-east sedimentary formations contributed largely to the glacial deposits. Also the connexion between the underlying rock and the drifts above them are obscured in the North-east by the incorporation of material from earlier in later drifts.

The examination of the mineral composition of soils, parent materials and rocks in connexion with soil surveys and advisory work has been carried out.

The X-ray apparatus obtained by a grant from the Agricultural Research Council is being used in an investigation of the mineralogy of soil colloids. This material is the clay fraction of the soil (0.002 m.m. equivalent diameter). Single crystals from such material are not large enough to be used so that in the X-ray examination the powder method and the method of ordered aggregates must be used. From the X-ray diagram a number of reflexions are obtained and these are characterized by their position, width and relative intensities and are expressed as lattice spacings.

Various silicates of the layer lattice type, the clay minerals, form the main constituents of all soil colloids so far investigated. Specimens of clay and other minerals were obtained and standard X-ray diagrams made for purposes of comparison. Such minerals as quartz, kaolinite, halloysite, montmorillonite, beidellite and mica have been used.

Optical determinations of refractive index and double refraction have also been made.

STUDIES ON SOIL DRAINAGE WATER

Lysimeter investigations have been in progress since 1919 at Craibstone, the Experimental Farm of the North of Scotland College of Agriculture, near Aberdeen, on a light granitic soil of glacial origin.

The lysimeters are three in number, each one-thousandth of an acre in area, and contain soil and subsoil of a total depth of 40 inches enclosed in their natural condition without being broken up or seriously disturbed in any way. Lysimeter No.1 has been continuously unmanured since 1914; Nos.2 and 3 are manured from year to year, and both receive the same manuring with the exception that No.3 receives a dressing of lime each rotation. Dung is given to Nos.2 and 3 with the turnip crop. They are cropped in the ordinary seven course rotation of the district, and were constructed to measure the amount of rainfall which percolates through an arable soil, and to measure the effects of manuring and liming on the drainage and the amounts of manurial and other constituents removed from the soil.

A description of the lysimeters and their construction, together with preliminary results, is published by Hendrick in Trans. High. & Agric. Soc., 33(1921) 56-79. Further results appear in papers by Hendrick, and Hendrick and Welsh in Trans. High. & Agric. Soc., 42(1930) 1-27, 44(1932) 86-96, 46(1934) 202-223, and 50(1938) 184-202.

A considerable amount of colloidal and coarsely dispersed material appears in the drainage, varying in amount from month to month, and from year to year. This is removed by filtration through a membrane filter and the amount is determined. Papers by Hendrick and Welsh on the nature and composition of this material are published in Trans., III Int.Cong.Soil Sci., I(1935)293-295 and Trans., II Com.,Int.Soc.Soil Sci.,A(1938) 60-67.

The crop on the lysimeters during the period October 1939 to September 1940 was third-year pasture. No.1 was unmanured; Nos.2 and 3 each received sulphate of ammonia at the rate of 6 cwt. per acre in dressings of 1½ cwt. applied in March, May, June and August. The crop was cut at intervals, the cuttings being collected and weighed. The results for the period, expressed as pounds per acre, are presented in Tables I to V, and may be summarized as follows:

Drainage: About 56% of the rainfall came through this soil as drainage water during the period. In the three winter months, December to February, drainage was a little more than the recorded rainfall, and this was due to the melting of the drifted snow on the lysimeters during January and February; about 56% came through during the three spring months, 30% in the summer and 56% for the remaining months.

Nitrogen: The nitrogen found in the drainage of No.1 was principally in the form of nitrates, whilst only one-third of the amount appeared as ammonia. In the drainage from the lysimeters receiving sulphate of ammonia, nitrogen as ammonia was lost in slightly less quantity than that appearing as nitrates, and the totals lost by Nos.2 and 3 were almost double those coming away from the unmanured No.1. There was considerable variation in the proportion of ammoniacal nitrogen from month to month.

Lime: Fair quantities of lime were removed in the drainage, especially from Nos.2 and 3 which received sulphate of ammonia, No.3 losing a little less than double that from the unmanured No.1.

Potash: The loss of potash from the three lysimeters was very similar, though the amount from No.3 was slightly higher. The losses were very small.

Phosphate: Mere traces of phosphate were found in the drainage during the period.

Colloidal suspended material: This material was leached out irregularly and varied greatly in amount from month to month. By far the greatest amount was removed during the month of July when an excessive rainfall following upon two or three months of little discharge resulted in a greatly increased flow of drainage. At the beginning of the period when the volume of drainage was high the amount of suspended material was considerable, and diminished as the drainage flow decreased. The rapid melting of accumulated snow in February gave rise to greatly increased drainage flow and the amount of suspended material in it also increased and persisted until the end of April when the liberation of drainage diminished. In every month the drainage from No.1 contained more suspended material than that from either Nos.2 or 3, and taken over the whole period the amount was about three times that in either of the others.

TABLE I

RAINFALL AND DRAINAGE
1st October 1939 to 30th September 1940.

	RAIN inches	DRAINAGE inches			DRAINAGE Per cent of Rainfall		
		1.	2.	3.	1.	2.	3.
October	5.09	3.02	3.05	3.08	59.3	59.9	60.5
November	4.01	2.93	3.29	2.94	73.1	82.0	73.3
December	1.88	1.76	1.96	1.90	93.6	104.2	101.1
January	2.04	0.99	1.18	1.05	48.5	57.8	51.5
February	2.78	4.00	3.82	3.55	143.5	137.4	127.7
March	3.03	2.07	2.11	1.97	68.3	69.6	65.0
April	2.53	1.67	1.72	1.69	66.0	68.0	66.8
May	1.62	0.30	0.26	0.24	18.5	16.0	14.8
June	0.68	traces	traces	traces	-	-	-
July	8.47	3.35	3.28	3.28	39.6	38.7	38.7
August	1.975	0.03	0.04	0.01	1.5	2.0	0.5
September	2.435	0.37	0.27	0.42	15.2	11.1	17.2
TOTAL	36.54	20.49	20.98	20.13	56.1	57.4	55.1

TABLE II

AMMONIACAL AND NITRATE NITROGEN IN THE DRAINAGE WATERS
1st October 1939 to 30th September 1940.
Pounds per acre.

	Lysimeter 1			Lysimeter 2			Lysimeter 3		
	Amm.	Nit.	Total	Amm.	Nit.	Total	Amm.	Nit.	Total
Oct.	0.10	0.21	0.31	0.18	0.29	0.47	0.20	0.41	0.61
Nov.	0.06	0.17	0.23	0.19	0.27	0.46	0.18	0.27	0.45
Dec.	0.04	0.09	0.13	0.10	0.15	0.25	0.11	0.17	0.28
Jan.	0.02	0.05	0.07	0.05	0.08	0.13	0.06	0.09	0.15
Feb.	0.09	0.19	0.28	0.18	0.25	0.43	0.19	0.29	0.48
Mar.	0.04	0.09	0.13	0.09	0.12	0.21	0.10	0.15	0.25
Apr.	0.04	0.07	0.11	0.07	0.10	0.17	0.08	0.13	0.21
May	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.03
June July	0.08	0.16	0.24	0.13	0.18	0.31	0.15	0.27	0.42
Aug. Sep.	0.01	0.02	0.03	0.01	0.02	0.03	0.02	0.03	0.05
TOTAL	0.49	1.06	1.55	1.01	1.47	2.48	1.10	1.83	2.93

TABLE III

SOLUBLE CONSTITUENTS REMOVED IN THE DRAINAGE WATERS
Pounds per acre.
1st October 1939 to 30th September 1940.

	Lys	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May to July	Aug. to Sep.	Year
Sol. solids	1	48.59	48.02	29.56	15.39	78.28	29.76	16.60	57.48	10.58	334.26
	2	80.24	75.09	48.26	26.23	79.69	44.20	34.74	82.07	8.28	478.80
	3	108.48	80.31	45.67	23.77	80.46	37.63	34.63	85.95	7.93	504.83
I. I. of sol. solids	1	19.44	18.89	5.84	5.07	29.94	10.51	6.70	13.93	1.36	111.63
	2	15.63	18.76	5.51	8.28	22.53	11.09	8.86	16.44	1.19	108.29
	3	22.31	12.80	7.05	7.64	29.61	11.37	8.86	19.82	1.54	212.00
SiO_2	1	7.03	5.75	2.88	1.91	5.44	5.33	4.05	10.03	0.62	43.04
	2	9.28	5.38	3.54	2.55	4.03	4.00	4.59	9.90	0.70	43.97
	3	7.05	5.71	3.98	2.29	5.07	5.55	5.55	6.52	0.79	42.51
SO_3	1	4.81	2.86	3.23	1.21	16.00	4.61	2.68	6.87	0.86	43.13
	2	28.39	23.70	12.54	5.64	13.49	11.28	8.35	21.43	2.13	126.95
	3	38.54	21.51	11.20	3.34	11.22	7.62	5.73	17.39	3.34	119.89
P_2O_5	1										
	2										traces
	3										
CaO	1	5.86	6.96	3.89	2.22	12.32	4.52	3.74	8.26	1.06	48.83
	2	11.83	14.18	7.51	3.83	12.58	7.20	5.31	12.56	1.94	76.94
	3	19.91	9.04	7.01	4.50	14.29	7.14	5.14	14.35	2.31	83.69
MgO	1	2.62	3.04	1.28	1.01	4.85	1.56	1.85	5.01	0.48	21.70
	2	4.52	4.31	2.30	1.10	5.14	2.24	2.27	4.13	0.37	26.48
	3	5.36	3.65	2.18	1.63	4.96	2.35	1.98	4.69	0.62	27.42
K_2O	1	0.77	1.30	0.97	0.42	0.92	0.51	0.55	1.04	0.11	6.59
	2	0.88	1.12	0.44	0.57	1.19	0.51	0.53	1.08	0.20	6.52
	3	1.78	1.96	0.68	0.33	1.52	0.73	0.55	1.03	0.11	8.69
Na_2O	1	7.91	9.74	5.64	2.35	13.09	4.43	3.45	10.38	1.32	58.31
	2	11.72	12.63	6.59	3.26	12.32	6.68	5.58	12.30	1.50	72.58
	3	12.32	9.41	6.94	2.95	9.50	5.07	4.61	10.84	1.32	62.96
Cl	1	6.28	11.64	6.06	3.41	23.66	6.81	5.03	7.51	0.64	71.04
	2	5.95	12.74	7.03	4.03	21.38	7.55	5.29	5.43	0.33	69.73
	3	3.19	8.79	6.37	3.41	18.34	6.59	5.16	5.11	0.51	57.47
Cl as NaCl	1	10.40	19.22	10.03	5.62	38.95	11.26	8.30	12.42	1.03	117.23
	2	9.81	21.07	11.61	6.65	35.40	12.47	8.74	8.86	0.55	115.16
	3	5.29	14.53	10.56	5.66	30.24	10.87	8.48	8.46	0.81	94.90
Total N	1	0.31	0.23	0.13	0.07	0.28	0.13	0.11	0.26	0.03	1.55
	2	0.47	0.46	0.25	0.13	0.43	0.21	0.17	0.33	0.03	2.48
	3	0.61	0.45	0.28	0.15	0.48	0.25	0.21	0.45	0.05	2.93

TABLE IV

MATERIAL IN SUSPENSION IN THE DRAINAGE WATERS
Pounds per acre.
1st October 1939 to 30th September 1940.

	Dried at 105°C			Loss on Ignition		
	1	2	3	1	2	3
October	71.32	8.82	8.86	9.24	1.28	0.81
November	17.54	5.86	6.52	2.42	0.90	0.79
December	7.34	2.16	2.24	0.75	0.33	0.42
January	4.76	1.78	1.63	0.68	0.20	0.13
February	9.39	8.89	6.63	0.79	0.90	0.81
March	7.56	4.59	5.29	0.84	1.12	1.10
April	10.07	6.57	6.70	1.54	0.84	0.95
May	1.63	0.64	0.99	0.20	0.07	0.11
June & July	84.78	35.80	29.76	7.58	3.37	3.28
Aug. & Sep.	5.51	1.69	2.97	0.66	0.20	0.31

TABLE V

CROP 1940. PASTURE.
Weights per acre.

	Date cut	Lysimeter 1		Lysimeter 2		Lysimeter 3	
As cut	30 May	69 cwt.	8 lb.	73 cwt.	82 lb.	72 cwt.	62 lb.
	29 Jul.	23 "	30 "	41 "	53 "	34 "	68 "
	2 Sep.	17 "	69 "	16 "	95 "	15 "	68 "
	Total	109 cwt.	107 lb.	132 cwt.	6 lb.	122 cwt.	86 lb.
Dry Matter (at 105°C)		Grasses	Clovers	Grasses	Clovers	Grasses	Clovers
		cwt. lb.	cwt. lb.	cwt. lb.	cwt. lb.	cwt. lb.	cwt. lb.
	30 May	14 46	- 100	13 17	- 103	15 13	- 18
	29 Jul.	5 42	- 86	7 104	- 74	8 103	- 19
	2 Sep.	3 111	- 63	3 92	- 47	3 109	- 14
	Total	23 87	2 25	24 101	2 0	28 1	- 51
		Total		Total		Total	
	30 May	15 cwt.	34 lb.	14 cwt.	8 lb.	15 cwt.	31 lb.
	29 Jul.	6 "	16 "	8 "	66 "	9 "	10 "
	2 Sep.	4 "	62 "	4 "	27 "	4 "	11 "
	Total	26 cwt.	0 lb.	26 cwt.	101 lb.	28 cwt.	52 lb.
% Dry Matter	30 May	22.15		19.09		21.06	
	29 Jul.	26.41		20.72		26.06	
	2 Sep.	25.31		25.15		26.29	
	Total	23.64		20.30		23.18	
% of clovers (on dry weight)	30 May	5.81		6.53		1.05	
	29 Jul.	12.55		7.71		1.88	
	2 Sep.	12.35		9.89		3.11	
	Total	8.55		7.43		1.60	

PUBLICATIONS

Issued during the year:

1. "The Reclamation of Moorland. Pt. II. Reclamation Experiments in Scotland." By W. G. Ogg and I. M. Robertson. (Emp. J. Agric. VIII. pp. 56-64. 1940.)

2. "The Reclamation of Peat Land in Lanarkshire." By W. G. Ogg and I. M. Robertson. (Scot. J. Agric. XXIII. pp. 56-62. 1940.)

3. "Soils and Vegetation of the Bin and Clashindarroch Forests." By A. Muir and G. K. Fraser. (Trans. Royal Soc. Edin. LX. Pt. I. No. 8. 1939-40.)

4. "Vegetation Survey of Waste Land in relation to the Establishment of Woodlands (with special reference to the North-east of Scotland)." By G. K. Fraser. (Forestry. XIV. pp. 59-70. 1940.)

5. "Some Forest Soils of the North-east of Scotland and their Chemical Characters." By A. Muir. (Forestry. XIV. pp. 71-80. 1940.)

6. "The Spectrographic Determination of Trace Elements in Soils. I. The Cathode Layer Arc." By R. L. Mitchell. (J. Soc. Chem. Ind. LIX. pp. 210-213. 1940.)

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