THE FERTILISER ASSOCIATION OF IRELAND

"Trends in Soil Fertility in the Republic of Ireland"

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TRENDS IN SOIL FERTILITY IN THE REPUBLIC OF IRELAND

The use of lime and fertilisers has been commonplace in Ireland for almost thirty years now with steady growth through the fifties and sixties but disturbing episodes of stop-go during the seventies. Despite this recent uncertainty, more than £1.5 billion (1981 prices) has been spent on soil fertility in the past ten years so it seems valuable to ask "how fares the land" at this time. A survey of our soils which was carried out in March-April 1981 provides the opportunity to comment on this and look at progress over the years. In this presentation we shall comment mostly on lime, phosphorus and potassium as these tend to leave residues in soils and can be monitored but we will also refer to nitrogen and briefly to sulphur.

Method for 1981 Survey

Soil samples 0-10 cm were taken at locations at the corners and the centres of the 10 kilometre squares of the national grid, except where these occurred over 600 ft or in forests, cities, etc. Peats were included. A total of 1,083 samples were taken and as each sample represents on average 12,350 acres all the samples would represent a total of 13,375,000 acres distributed as follows:

Table 1: Intensity of Sampling

Farming System	No. of Samples	Area Represented
Peats	192	2,371,200 acres
Old Pasture	644	7,953,400 acres
New Pasture	86	1,062,100 acres
Tillage	111	1,370,850 acres
Not classified	50	617,500 acres

If we include the unclassified samples as pasture the total pasture represented would be 9.6 million acres and total pasture plus tillage 11.0 million acres. The ratios and total numbers are therefore within 10% of the expected values and are accepted as satisfactory. Peat samples would only represent peats below 600 ft. O.D. The samples were analysed for pH, lime requirement, phosphorus and potassium at Johnstown Castle.

LIME

Introduction

Following intensive use of lime in the mid-nineteenth century its use declined markedly from 1880 onwards and during the period 1934-1951, when the Lime Subsidy Scheme operated, a total of 0.1 million tons of lime per annum was used. An improved Ground Limestone Scheme was introduced in 1951 and usage quickly rose to 1 million tonnes in 1955. It can therefore be taken that the modern practice of liming based on chemical analysis, dates from the early fifties and it is therefore of interest to review progress after thirty years.

Three main surveys have been carried out on the lime status of our soils

1. That of Walsh, Ryan and Kilroy (1) based on advisers' soil samples, January 1957
2. A random survey from Old Pastures by Brogan (2) in 1964
3. A random survey in 1981 covering old pastures, new pastures, tillage and peat reported here.

Complete data is not available to give a full assessment of the effects of lime over the years, e.g. amounts of lime used each year are known from Department of Agriculture records but not the amounts used on pasture although some data is available from the Fertiliser Use Surveys of An Foras Talúntais (3). Nevertheless, broad relationships and trends are obvious which are useful in deciding future strategy.

Results

Average pH of mineral soils = 6.1.

Average lime requirements of mineral soils = 2.7 t/acre.

The frequency distribution of lime requirement values from mineral soils from the 1981 survey can be compared directly with samples from the advisory services for 1979.

Table 2: Frequency Distribution of Lime Requirement Values

	% in each category					
t/ac lime	0-1.0	1.1-2.0	2.1-4.0	4.1-6.0	6.1-8.0	8.1-10.0
1981 Random	32.3	15.8	26.5	18.3	5.4	1.7
1979 Advisory	26	39	23	9	2	1

There was a higher proportion of acid soils in the random survey than in the advisory samples e.g. 25.4% of random samples needed more than 4.0 t/ac compared to only 12% of advisory samples. This is a measure of the bias in advisory samples towards the better farms. A simple interpretation of the average lime requirement of 2.7 t/ac is that 32 million t of lime are required to correct soil acidity in the 11.9m acres of arable land in the country. However, if this was applied immediately no further lime would be required for approximately 10-15 years and it is more appropriate to estimate annual amounts of lime needed.

There was considerable variation around the average values with pH varying from 4.2 to 8.1 and lime requirements varying from 0 to 10 t/ac on mineral soils but a good deal of the variation was related to farming system, soil type or region.

The survey of 1964 was on a random basis of sample selection but was confined to old pasture so it can be compared to the old pasture in the 1981 survey. Within this period the average pH of old pasture rose from 5.86 to 5.94 while the average lime requirement fell from 3.8 t/ac to 3.2 t/ac. Total lime use for the 17 years was 26 million tons or 1.5 t per acre and 0.13 t per acre per annum. Fertiliser Use Survey data (2) indicate that use on old pasture was probably less than 0.1 t/ac/annum over the period and it therefore appears that losses of lime through leaching or crop removals must have been less than this amount. Such a low rate of loss would reflect the acid nature of such soils. Where the soil was at a higher pH the loss of lime would probably be greater.

In an attempt to define these trends more precisely the relationship between the rate of lime used in each county 1964-1981 and the change of pH in old pasture in each county over the period was studied. The relationship is illustrated in Fig. 2 and although not very precise it was statistically significant. It indicates that the counties where more than 0.2 t/ac/annum of lime was used showed increases in pH on the old pasture. These were also counties of high proportions of tillage so the rate of lime used on old pasture would probably have been less than 0.15 t/ac/annum. The trend line indicates zero pH change, i.e. maintenance dressing at 0.07 t/ac/annum but if a correction is added for tillage as above, this might be as high as 0.09 t/ac/annum.

Kerry was separate from the main trend in that a reasonable rate of lime was applied at 0.13 t/ac but nevertheless the average pH fell. Perhaps the high rainfall in Kerry accounts for some of this anomaly. In Meath the pH increased by 0.375 units for a moderate use of lime at 0.09 t/ac/annum. Such a high rate of increase would not be welcome in a high molybdenum area but the experimental error may have exaggerated the result.

Effect of Nitrogen Fertiliser on loss of lime

It is known that nitrogeneous fertiliser can acidify the soil. The most common form used in Ireland, i.e. ammonium nitrate 27.5% N contains approximately 20% of ground limestone as filler and this neutralises most of the acid generated. However, if there was a general change to urea or ammonium sulphate as sources of nitrogen and if nitrogen usage continued to increase, the lime needed to neutralise the acidity generated could possibly reach 0.7 million tonnes for 0.5 m tonnes of nitrogen (4).

Molybdenum

The estimates and calculations quoted above refer to the correction of soil acidity but there are extensive areas in the country where the soil levels of molybdenum are undesirably high (see areas B, C, D and E of Fig. 3), and liming may aggravate the negative effects of this on livestock. The lime status should be brought to a moderate rather than a high value in these areas and the lime requirement should be reduced by 3.0 t/ac on such soils. As 10.5% old pasture soils have been classified as high (greater than 0.5 ppm Mo) this would reduce the total lime requirement referred to by 3.0 million tonnes from 32 million to 29 million tonnes.

Poor soils

The most acid areas in the north and west are associated with regions dominated by extensive cattle farming and wet soils. Obviously the rate of progress will be slow in such areas especially as lime is a rather longer term investment than other fertilisers. Some years ago with more favourable cattle prices farmers responded by using more fertiliser and increasing production in these areas, so it is expected that with favourable economic circumstances the old pastures in these areas would be limed as they are in the south and east.

Projections for the future

The tillage and new pasture systems are already at a reasonable status and progress has been obvious. Demand for lime from this section will drop to a maintenance rate of less than 0.4 million tonnes per annum, probably within the next five years.

Rates less than 0.1 t/ac/annum on old pastures, i.e. 1 million tonnes per annum will lead to the status quo or a decline in pH. A modest rate of progress would be to apply a further 0.5 million tonnes per annum to the old pastures to continue the gradual improvement of the previous thirty years. A total annual usage of 2.0 million tonnes ground limestone per annum seems a modest target. Rates less than 1.5 million tonnes per annum will lead to an increase in acidity.

Effects of Lime on Grassland

In view of the obvious neglect of the liming of permanent grassland some of the evidence for its beneficial effects are included here. There were three main series of experiments.

1. Grazing observations 1949-1954. Forty four trials on the effect of lime on new pasture were observed by agricultural advisors over five years. Positive effects on palatability and earliness of growth were recorded on thirty six sites with no effect observed on eight sites.

2. Cutting Trials 1975-1979. Nine experiments were carried out in this period three at Johnstown Castle and one each at Ferns, Dundalk, Ballintubber, Kilmuckridge, Castlecomer and Abbeyfeale. The site at Abbeyfeale showed no response but the other eight showed increases in grass yields of tonnes per acre of dry matter as follows: 1.2, 1.8, 0.6, 0.6, 0.4, 0.6, 0.8, 0.6. As the experiments were carried out at zero nitrogen these increases were 20% or higher on yield of unlimed plots. The soil types ranged from medium to very heavy textures with no sandy soils included.

3. A grazing experiment at Ferns, Wexford 1976-1979. In this instance the initial pH was 5.3 on a very old permanent pasture with virtually no ryegrass. Application of 3 tonnes of lime/acre increased stocking capacity by 20% in the first year and by 100% in the fourth year of the experiment. This rather dramatic result may not be achieved on all old pastures but it does show that grassland can respond under grazing as well as under cutting conditions.

The various trials referred to were carried on for a minimum of 4 years and one trial lasted 11 years. All showed that the effect of lime lasted a long time and when it is costed over say 10 years it is very good value but this will not be obvious if it is only evaluated over a short period.

Farming Systems

Table 3: Average pH and lime requirement for different systems

	pH	Lime Requirement
Old Pasture	5.9	3.2
New Pasture	6.4	1.6
Tillage	6.7	1.2
Peat	5.0	7.4* (2.0)

*Needs correction — see below.

New pastures and tillage have a very similar lime status and are apparently in the same rotation. Separate maps of the location of these samples showed a strong correspondence between them with the new pastures somewhat more scattered than the tillage sites. The two types are shown together in the one map in Fig. 1. It is obvious that they are dominantly located in the East Cork, Wexford/Carlow and Dublin/Louth regions and that the majority of samples require only maintenance dressings of 0 to 1 tonne/ac of lime with very few fields needing 4 t/ac or more. The frequency distribution of lime requirement for new pasture and tillage combined is shown in Table 4.

Table 4: Frequency distribution for new pasture and tillage

	% Samples in each category					
t/ac lime	0-1.0	1.1-2.0	2.1-4.0	4.1-6.0	6.1-8.0	8.1-10.0
	54.3	20.3	19.8	3.5	1.5	0.5

Old pastures included a much higher proportion of acid soils as shown in Table 5.

Table 5: Frequency distribution of lime requirement values on old pastures

	% Samples in each category					
t/ac lime	0-1.0	1.1-2.0	2.1-4.0	4.1-6.0	6.1-8.0	8.1-10.0
	25.3	13.8	28.6	23.3	6.8	2.2

Thirty-two percent of old pastures required more than four tonnes of lime/acre while only five percent of new pastures and tillage were in this category. Even within the system of old pastures, however, the lime status was not evenly distributed throughout the country but the areas in the north and west were more acid while the south and east had a higher lime status. Fig. 1. Shallow limestone soils near Galway City were exceptional and obviously have a high natural pH while in the South East areas around the Castlecomer plateau where soils are heavy and wet are still acid. A good deal of the soil in Wexford and Carlow, i.e. the Clonroche and Borris soil series is based on acidic shales or granite and this was apparent in the 1957 and 1964 surveys (2) but such influence has now been largely obscured, obviously by liming. The average lime requirement in the northern acid region (Monaghan-Mayo) outlined in Fig. 1 was 3.7 t/ac; in the south west (Clare-Kerry) 4.6 t/ac; in the mid-west (Roscommon-Limerick) was 3.9 t/ac and near Castlecomer was 3.1 t/ac while the south-east/midlands/Galway area needed 1.3 t/ac. Farmers have been liming old pasture where this is based on good, well-drained soil and especially where it is in a region with a strong tillage influence but they have not been liming old pastures where the farming is based on cattle and sheep and where many of the soils are wet.

Peat

Peat soils are obviously very acid with an average pH of 5.0 and a range from 3.9 to 7.7. However the optimum pH on peat soils for most crops is 5.3-5.5 compared to 6.5 to 6.8 on mineral soils so the laboratory measurement of lime requirement which is shown in Table 3 to average 7.4 t/ac for peats should be corrected to approximately 2.0 t/ac. Obviously very little of this peat is used in agriculture but experiments have shown that it has considerable potential and acidity would be one of the limiting factors.

Trends over time

Data which is available from 1957 quoted by Walsh, Ryan and Kilroy is, unfortunately, not very comprehensive as it was collected before the advent of the computer. Nevertheless, some important points can be drawn from it. Some 62% of samples were below pH 6.0 in 1957 but only 51.6% were in this category in 1981. More particularly in the counties Cork, Waterford, Wexford, Wicklow, the percentages of samples at pH 5.5 or less (equivalent to lime requirements 5 t/ac or greater) were 24, 26, 30, 44 respectively. Today, this category would account for less than 10% in those counties.

PHOSPHORUS

The value of phosphorus in increasing yields of grassland and other crops has been widely accepted and quite spectacular responses can be observed at deficient sites. It is also appreciated that fertiliser phosphorus leaves residues after one year's cropping and may build up in the soil with regular dressings.

Current levels of phosphorus in our soils are shown in Table 6.

Table 6: Frequency of Phosphorus Levels — Mineral Soils

	% in each category			
ppm P	0-3.0	3.1-10.0	10.1+	Avg.
Random 1981	47	38	15	5.4
Advisory 1979	37	44	19	6.0

The same bias that appeared in the lime tables is obvious in Table 6 where the advisory samples are slightly higher than the random samples.

Again, as expected, the phosphorus status of tillage soils was higher than those on permanent grass Table 7.

Table 7: Frequency of Phosphorus Levels

	% in each category			
ppm P	0-3.0	3.1-10.0	10.1+	Avg.
Tillage	36	35	29	7.6
Perm Grass	52	38	10	4.7

In the early 1950s more than ninety per cent of soils had values less than 1.0 ppm P and although the overall average has been increased to 5.4 by 1981 nevertheless the influence of soil type still persists. (See Fig. 4). This is obvious in the relatively high values corresponding to soil No. 33 around Galway city which is not an area of high fertiliser use and the persistent low values in Wexford, an area of relatively high fertiliser use. Apart from the area near Galway, levels in the north and west are generally low. Within the Northwestern region, thirty per cent of the samples from old pasture has values of 1 ppm or less and would be expected to show yield increases with fertiliser phosphorus of 20% or more.

Statistics on amounts of phosphorus used per county are not as readily available as for lime so it was not possible to calculate the relationship between the amount of phosphorus used and the change in soil phosphorus level. However, it is clear that average usage of phosphorus on permanent pasture from 1964-1981 was less than 10 kg/ha but yet the average soil level rose from 3.2 ppm to 4.7 ppm in that period. This indicates that for the intensity of farming on the permanent pasture over this period — 2 acres per livestock unit — 10 kg P/ha was greater than the amount lost in crops, animals or drainage water. More intensive agriculture would probably lead to higher losses.

POTASSIUM

Potassium deficiency can have dramatic effects on yield and quality of crops and grassland and yields of 40% of potential have been recorded in experiments in Ireland. As in the case of phosphorus the use of potassium fertiliser can leave residues which build up in the soil but losses of soil potassium can be much higher than for phosphorus especially with silage and soil potassium levels can therefore fluctuate quite widely.

Current values for potassium in our mineral soils are shown in Table 8.

Table 8: Frequency of Potassium Levels — Mineral Soils
% in each category

ppm K	0-49	50-74	75-99	100+	Avg.
1981 Random	16	21	20	42	93
1979 Advisory	17	18	17	47	103

The difference between the random survey and the advisory samples is relatively small which implies that intensive farmers are not using much more potassium than average. Farming systems also showed very minor influences on soil potassium levels. In fact, levels in tillage soils were lower than those on permanent pasture probably due to the recycling of dung and urine under grazing, Table 9.

Table 9: Soil Potassium Levels for Different Systems

Permanent Grass	93
New Grass	100
Tillage	85

Evidence not available from this survey but available from the advisory samples shows that the most important effects of management are those between cut and grazed grassland, with values after silage significantly lower than those after pasture.

Despite the increases in silage making however, the overall trend in soil potassium levels is upward Table 10.

Table 10: Trends of Soil Potassium Levels — Permanent Grassland (cut and grazed)

1956	50 ppm K
1964	76 ppm K
1981	93 ppm K

Average usage over this period has been less than 25 kg K/ha on permanent grass and obviously this has been more than the total losses from the system at the level of stocking — 2 acres per LU — used. This is not to diminish the importance of replacement of potassium after silage as fertiliser or manure on individual farms.

Soil type and geological origin had a marked effect on soil potassium as shown in figures 5 and 6. The pattern is more striking on the tillage soils possibly because recycling under grazing may blur the soil differences. It is clear that soils of limestone origin, especially those running in a band from Meath through Kildare to Laois, maintain low levels of available potassium even when well fertilised. Potassium fixation was described on some of these soils more than thirty years ago but it is of interest that the effects persist desite so much use of fertiliser in the intervening years. Patterns in permanent grassland are more complex but in general limestone soils are again low while those infuenced by granite, shale or sandstone are relatively high in potassium. A combination of intensive silage cutting on limestone soils is very sensitive to potassium deficiency.

NITROGEN

Unlike lime, phosphorus or potassium, nitrogen fertiliser leaves virtually no trace in soil so the survey method described here gave no information on the nitrogen status of our soils. Nevertheless, there are some trends over the years which are worthy of comment.

Because the N/PK ratio has increased over the yerom 0.5 in 1972 to 1.29 in 1981 some questions have been raised about an imbalance arising between the various nutrients. This is not likely to cause any problems or disorders for many years to come. Grassland dominates the overall demand for fertiliser in Ireland. At low stocking rates clover is an adequate source of nitrogen but phosphorus and potassium are required to support good growth of clover. We could say that zero fertiliser nitrogen is required at this stage of development and the N/P and K ratio would be zero. As a farmer intensifies his production he will substitute nitrogen for clover but will not require much extra fertiliser P or K since grass can thrive with lower concentrations of P and K than clover. At high stocking rates the N/P and K ratio may rise to 4.0 but there is nothing alarming about this and the grassland will be adequately treated with P and K if the manure or slurry is returned.

Brogan (1971) estimated that a national herd of 9.0 million livestock units would require a nitrogen usage of 340,000 tonnes. Lee and Diamond made two estimates of 191,000 tonnes at a low stocking rate of 8.0 million L.U.s and a high figure of 812,000 t at 9.7 million L.U.s. These apparently contradictory estimates are all quite compatible with the expected pattern of development of nitrogen usage with stocking rate as shown in Fig. 9. We can expect a relatively sharp rise in livestock units as nitrogen usage is increased initially but this rate of increase will diminish rapidly as the higher rates are used. Up to

1974 the rate of nitrogen usage was related to the size of the national herd in close agreement with the curve in Fig. 9. But since that time livestock numbers have fallen back while nitrogen usage has continued to rise. Obviously these two numbers should be in better balance. Nitrogen usage on grassland in Ireland is still relatively low being less than 50 kg N/ha compared to approximately 90 kg N/ha in the U.K. or 250 kg N/ha in Holland so there is obviously further scope for the use of extra nitrogen combined with increased livestock numbers.

SULPHUR

Sulphur has only been commercially considered as a fertiliser nutrient within the past two years. Significant responses have been measured under grazing conditions as well as in cutting experiments and it appears that up to thirty per cent of our soils are affected. It is important that sulphur should only be applied to light soils and particularly not to soils high in molybdenum.

SUMMARY

Some progress has been made in correcting soil acidity in the Republic of Ireland over the past twenty years especially in the South and East and on areas of new pasture and tillage. However, permanent grassland in the north and west increased in aciditv over the same period. Nationally more than 1.0 million tonnes of lime would be needed to maintain the status quo on permanent pasture.

Average levels of phosphorus and potassium have increased steadily through the fifties and sixties but have stabilised in the late seventies. Permanent grassland especially in the north and west is low in phosphorus but potassium values are relatively high on permanent pasture but low after hay or silage. Soil type still affects levels of soil phosphorus with the limestone soils tending to be high while the Clonroche soil in Wexford is below average. Potassium values show the reverse, in that limestone soils are low while soils based on granite are high.

Nitrogen usage is still low but has been increasing steadily and is now somewhat ahead of equivalent stocking rate. No special problems of N/PK balance are envisaged in the future nor are there any signs of a sudden breakdown of soil fertility with present systems of farming.

Sulphur fertilisation if used carefully should improve the fertility of up to 30% of our soils.

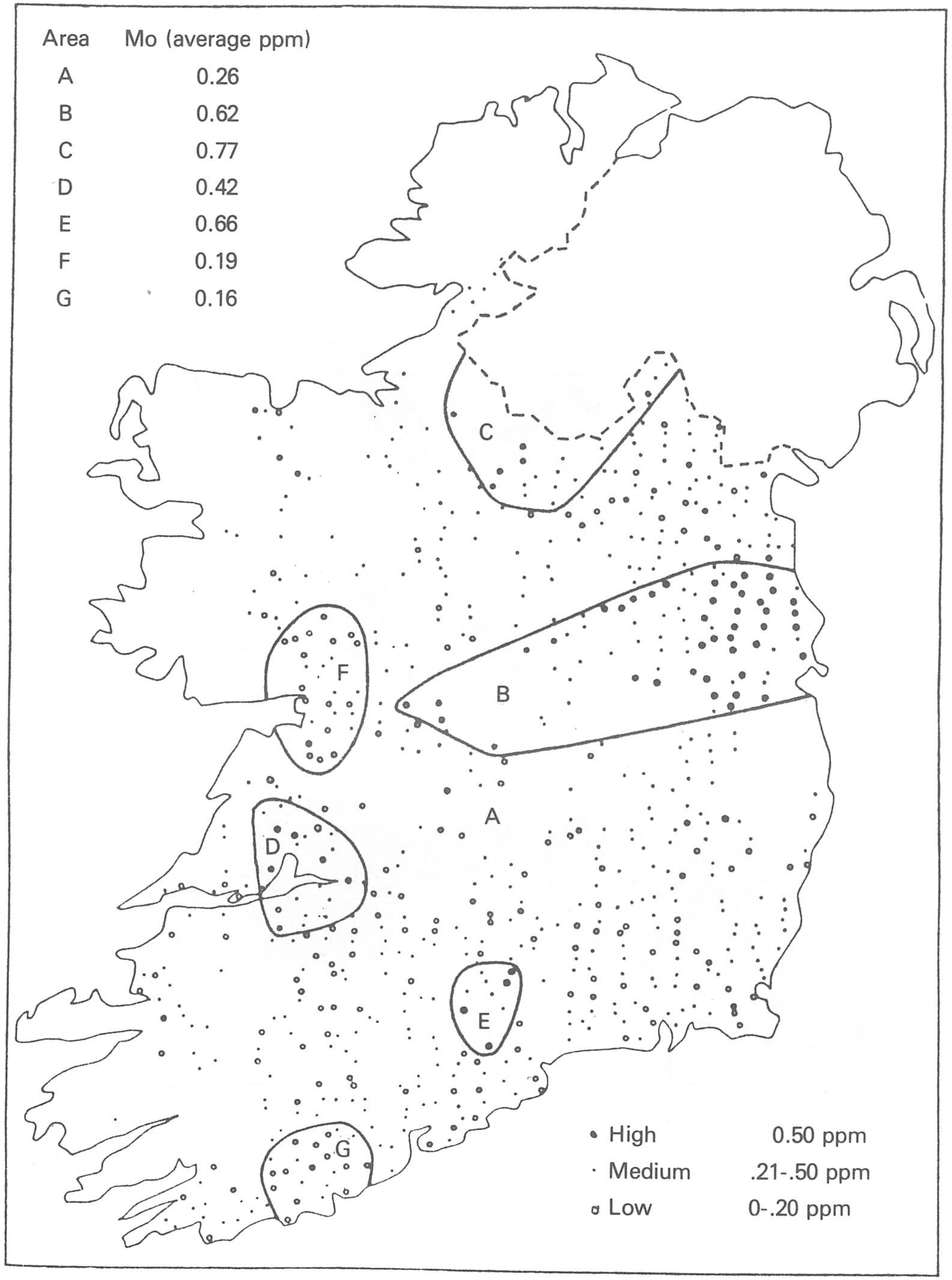

Fig. 3: Geographical distribution of molybdenum levels in Irish pasture soils

Fig. 4: Old pasture

Low phosphorus status

Fig. 1: Old pasture

Low lime status

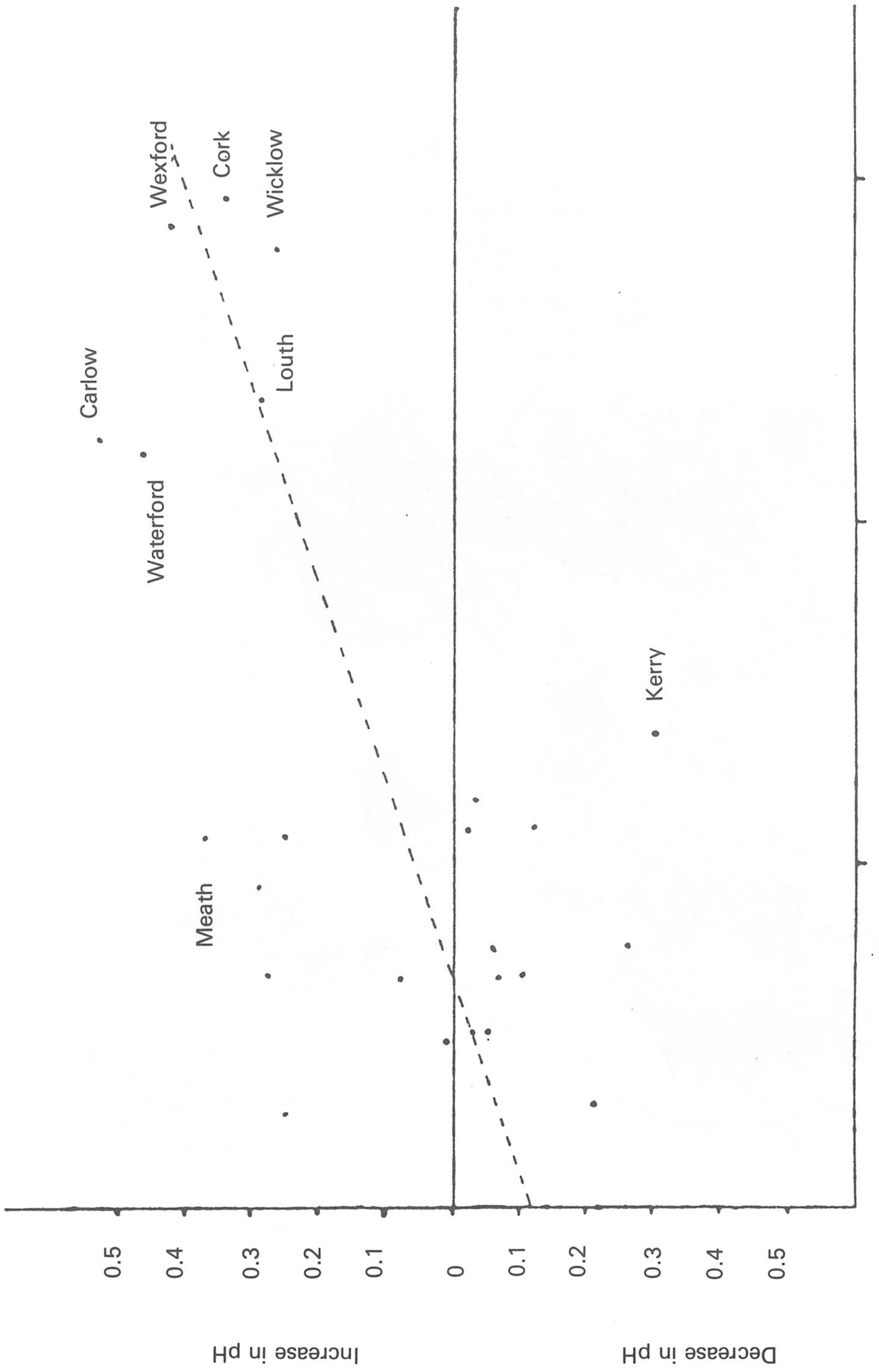

Fig. 2: Change in pH of Old Pasture v Lime use per acre per annum for each county — 1964-1980.

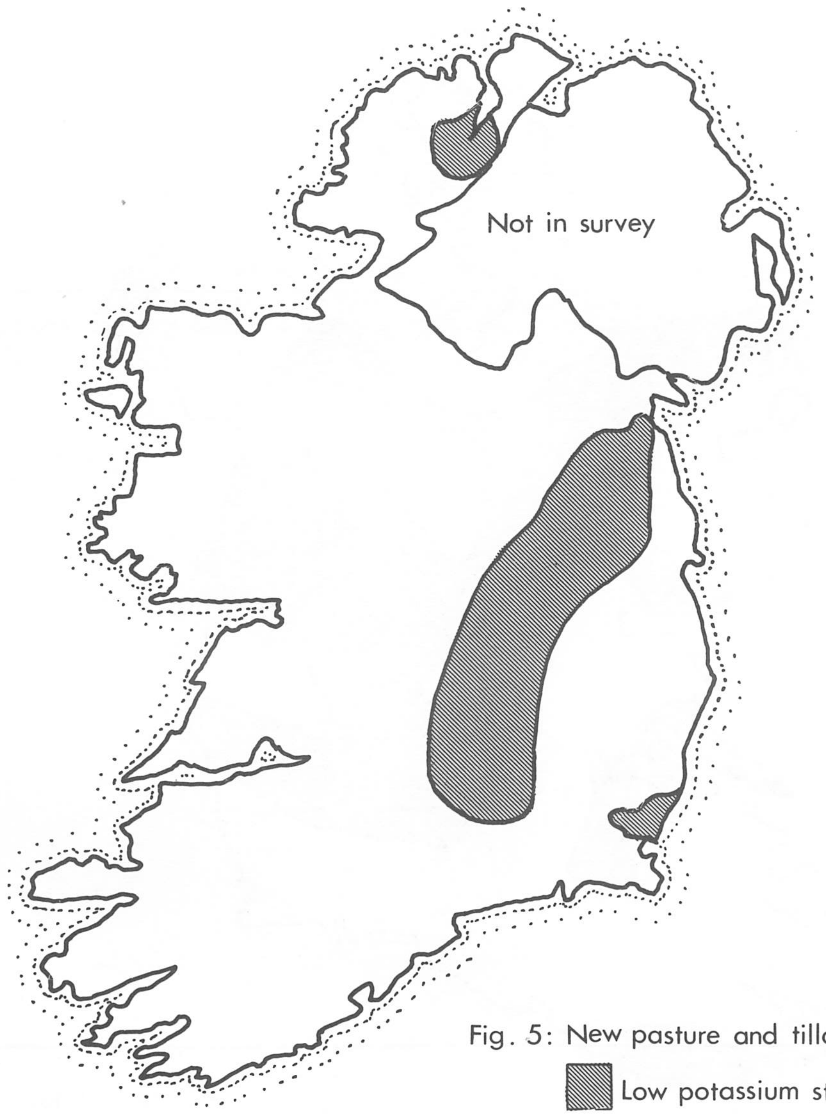

Fig. 5: New pasture and tillage

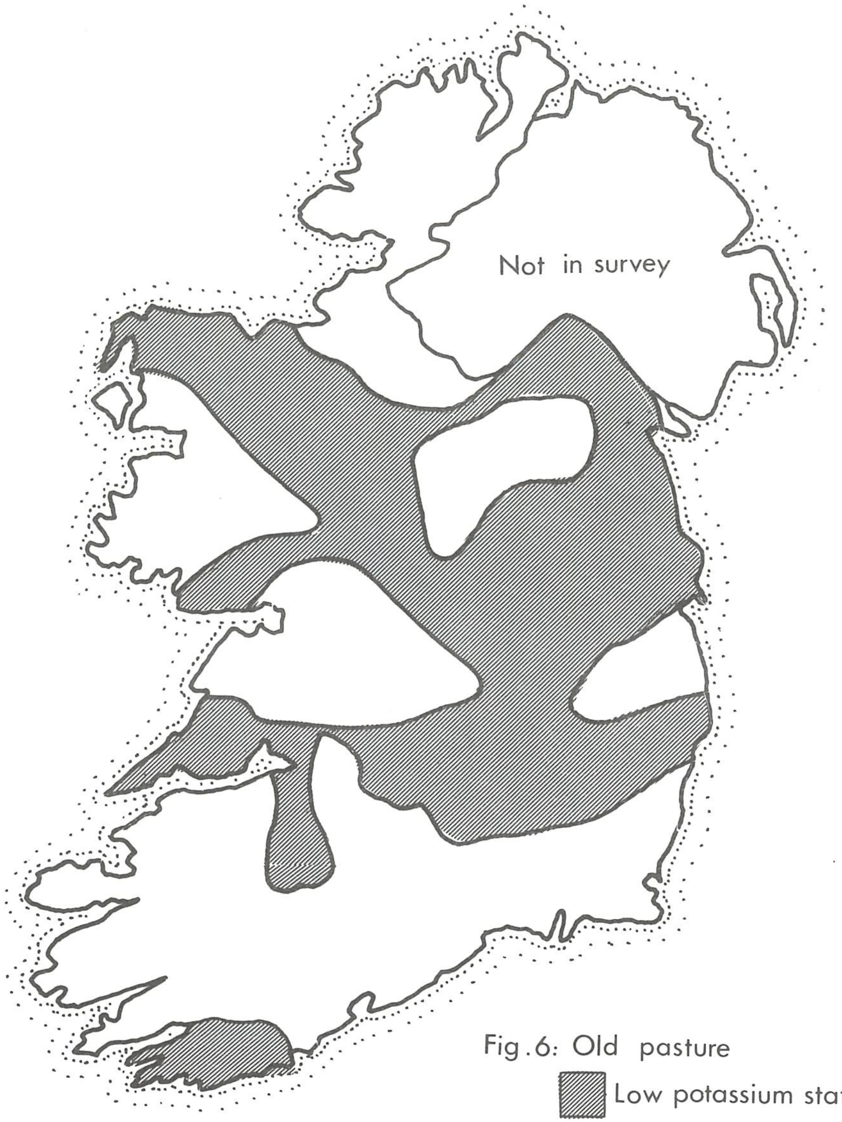

Fig. 6: Old pasture

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