THE FERTILIZER ASSOCIATION OF IRELAND

RECENT DEVELOPMENT IN TRACE ELEMENTS IN IRISH AGRICULTURE

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AGRICULTURE IN THE IRISH ECONOMY 1970 – 1990

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RECENT DEVELOPMENTS IN TRACE ELEMENTS IN IRISH AGRICULTURE

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Trace element deficiencies are occurring with increasing frequency in grassland and in arable crops. The deficiencies which occur most frequently in grassland and affect livestock are copper deficiency, cobalt deficiency, selenium deficiency and iodine deficiency. Copper, selenium and iodine deficiencies can affect sheep, cattle and horses, including bloodstock. Cobalt deficiency affects sheep mostly. In arable crops the main trace element deficiencies are boron, manganese, copper and zinc deficiencies. The crops which are sensitive to boron deficiency are beet, brassicae, carrots and celery. Manganese deficiency affects cereals, sugar beet and peas. Copper deficiency affects cereals and sugar beet and zinc deficiency is most common in cereals. The most recent developments which have occurred in the area of trace element research are as follows:

1) New investigations which show differences in uptake and utilisation in soil and in the plant of different species of the same trace element.
2) The influence of the soil organic matter on the uptake of trace elements by plants.
3) The influence of major elements, in particular nitrogen on trace element uptake by plants.
4) Method of application of trace elements and the issues which will affect future developments in methodology, especially the environment and human nutrition.
5) New developments in selenium application.
6) New information on boron deficiency.

There has been an increase in interest in the importance of trace elements in human nutrition in the past decade. The hazards which heavy metals present for human health are well known. More recently some important research work done particularly in Scandinavia and in the United States have shown that an imbalance or deficiency of trace elements can cause problems in human health. Some investigations in trace elements in foodstuffs have also been carried out here in Ireland.

Trace Elements Speciation in Soils

For more than 50 years scientist have been investigating the most suitable extractants for trace elements in soils. As a result of many years of experimentation extractants such as EDTA, DTPA, calcium nitrate and quinol have been shown to reflect with acceptable accuracy the amounts of trace elements which are taken up by crop plants. Until relatively recently the importance of the different soil fractions in the uptake of trace elements by plants was not clearly

understood but research in recent years has shown that certain soil fractions are critical in the transfer of trace elements from the soil to the plant. Most of this work has been carried out in the past 20 years (Kirk et al., 1985; Pickering 1986; Campbell et al. 1988).

The most common approach to the identification of important soil fractions with regard to trace elements is the use of sequential extraction. This method involves extraction of a number of trace elements of different mobilities and solubilities with extractants of increasing strength using the weaker ones first and a strong extractant finally (Viets, 1962). Many sequential extraction procedures have been developed. Attempts are being made at present by a group of expert laboratories commissioned by the EC to standardize methods and procedures within the EC. Johnstown Castle laboratories are involved in these investigations. Each extractant used must be specific with regard to the soil fraction which is extracted. Consequently great care must be taken to ensure that the correct procedures are followed during extraction. Relatively small differences in extractant concentrations can give inaccurate results. In practice few of the extractants used are fully specific. Sometimes a change in the sequences of the extractants can improve the technique. A typical extraction sequence is shown in Table 1. The most easily extractable trace elements are those that are free in the soil water. These are extracted by hot water. The soil boron which is taken up by plants is measured by this method (Sillanpaa, 1982). The exchangeable trace elements are those that are loosely held on soil particles or on the soil organic matter. Most of the trace elements other than boron which are taken up by plants are in the exchangeable form. Heavy metals are also taken up by plants in the exchangeable form. Carbonates and hydrous oxides of iron and manganese also carry a relatively high proportion of plant-available trace elements. Apart from the soil organic matter the residual material is coarse textured and does not carry any available trace elements.

Table 1: Possible sequential extraction procedures for soils.

Fraction	Extractants
Free Moisture	Hot Water
Exchangeable	Potassium Nitrate, Magnesium Chloride, Ammonium Acetate
Carbonates	Acetic Acid, Sodium Acetate, EDTA
Hydrous Oxides	Hydroxylamine Hydrochloride, acid Ammorium Oxylate. Sodium Dithionite, Sodium Citate + Sodium Bicarbonate.
Organic Matter, Sulphides	Hydrogen peroxide, EDTA
Residual	Aqua Regia (Nitric/Sulphuric/Hydrochloric Acid)

Soil Organic Matter

The soil organic matter is a more complex soil fraction and has a more important role in the availability of trace elements than was at first thought. The capacity of the soil organic matter to absorb and store trace elements is much greater than that of the soil itself varying from 125 to 250 ml/100 g compared with 10 to 80 ml for different clay minerals in various soil types (Lucas, 1982). This is shown in Table 2.

Table 2: Cation exchange capacity of soils and soil phases.

Soil Type	Cathion Exchange Capacity (me/100g)
Sandy loam	10
Medium loam	30
Heavy loam	40
Organic Matter	
Undecomposed	125
Decomposed	225

Investigations by Ducarior et al. (1988) have shown that by far the greatest amounts of exchangeable trace elements are carried on the soil organic matter. Moreover, organic matter has an important role as an intermediary in the transfer of trace elements from clay minerals to the plant roots. Some trace elements are highly dependent on the soil organic matter as an intermediary, others less so. For example, zinc may become virtually non-transferable in the absence of organic matter but a large part of the exchangeable copper will transfer directly from the clay fraction to the plant roots and its availability, to the plant is less dependent on a high soil organic matter content. It follows that soils which are subject to continuous tillage and organic matter depletion such as light textured cereal soils are more likely to be deficient in trace elements than soils under permanent pasture which have a relatively high organic matter content. The organic matter content of some zinc deficient soils in Co. Louth in 1985 and 1986 was less than two per cent. The zinc deficiency symptoms were most severe in the soil with the lowest organic matter content.

Trace Element Speciation in Plants

Recent investigations have shown that the form in which a trace element occurs within a plant affects its function and its bioavailability. Kickens et al. (1981) have shown that trace elements are carried about the plant as relatively simple organic complexes. When entering in a non-complexed form these elements are immobilized on the wall of the xylem tubes and remain so until complexed by an organic ligand. These organically-complexed trace element species are more readily absorbed and transferred within the plant. Recent investigations at Johnstown have shown that an extract from grass was 3-5 times more potent as a source of selenium than sodium selenite (Verkleig and McNaeidhe 1992, Fig 1).

The selenium concentration in the washed samples was 5 times greater following

treatment with the grass extract compared with the inorganic salt. Similar results were obtained by Trelease et al. (1942) and by Ferrandon and Chamel (1988). These results show that organically bound selenium has greater bioavailability than the inorganic salt. Livestock which feed on fresh grass will tolerate lower selenium concentrations than those feeding on concentrates. To meet animal requirements the selenium content in forages should be higher than 0.1 ug/g-l (Schwartz and Foltz, 1957) but a concentration of 0.25 ug/g-1 is recommended for concentrates. Easily available organically complexed trace elements are linked with amides, amino acids or proteins. Plants hormones may also be involved.

<u>The effect of major elements on trace element uptake</u>

All of the major elements exert an influence on the availability of trace elements to plants. Interactions between phosphorus and zinc and between potassium and boron have been known to occur but those involving nitrogen occur most frequently and are well documented. Fleming (1988) has shown that nitrogen application can increase the uptake of copper, zinc and selenium in pasture herbage. A series of investigations carried out in the field and in the glasshouse using soil with low zinc concentrations showed a complementary interaction between zinc and nitrogen. Nitrogen is less effective in promoting crop growth and increasing crop yield when soil zinc concentrations are low. In cases where soil zinc was adequate or high heavy nitrogen dressings caused cereal crops to lodge but lodging did not occur where soil zinc concentrations were low. The results of these investigations is shown in Table 3. In the investigations which were carried out at Johnstown Castle the results showed that the interaction between the nitrogen and the trace elements which were investigated were complementary but this complementary interaction can lead to the development of deficiency symptoms in situations where the concentrations of copper, selenium or zinc are low in the soil. This type of deficiency is described as an induced deficiency.

Table 3: The effect of zinc and nitrogen application on the grain yield of winter barley Panda.

Treatment	%Lodging	Grain Yield t/ha
Nitrogen 90 kg/ha	34	6.00
Zinc^{+} sulphate 5.0 kg/ha		
Zinc sulphate 5.0 kg/ha	16	6.49
Nitrogen 90 kg/ha	24	4.53
Control	–	2.83
S.E.		1.09

METHOD OF APPLICATION OF TRACE ELEMENTS

In crops trace elements may be applied to the soil or to the foliage. In cases of chronic deficiency it is recommended that copper and boron should be applied to the soil. Zinc may also be applied to the soil but manganese is ineffective as a soil application and should be applied to the foliage. In cases of acute deficiency foliar application is recommended and there is often a preference for this method of application on the basis that the amounts applied are smaller and the response is more rapid. In pasture the method of application is also dependent on the element is question and on the soil type. From 90 to 95% of animal feed comes from fresh or conserved herbage and an adequate concentration of the important trace elements in herbage is essential for animal health. Soil application of copper is recommended for cattle, sheep and horses except where the soil molybdenum is high. Soil application of cobalt is recommended except where the total soil manganese concentrations are high. In cases where the above two conditions are not met direct treatment of the animal is recommended. Selenium and iodine deficiencies have heretofore been controlled by direct treatment of the animal. All these methods of treatment are being reviewed at present for the following reasons:

1) Environmental
Strict new environmental standards are being drafted at EC level in relation to chemicals used in agriculture. Some critical permissible concentrations in soils and in plants have already been defined for some major elements and heavy metals. The rates of application and the dosages for animals will be restricted by law in the future due to the risk of carry-over into the human food chain.

2) Bioavailability
Recent research work has shown that certain species of trace elements are more bioavailable than others. The increase in uptake of selenium from a perennial ryegrass extract has already been mentioned in this paper. Vitamin E and selenium fulfill complementary roles in preventing disorders in livestock and the high content of vitamin E in young herbage may be responsible for the prevention of selenium deficiency at herbage concentrations which are often well below the critical concentration of 0.1 mg/kg selenium (Price, 1989). Investigations by Singh (1991) have shown that uptake of selenium in the selenate form is greater than uptake in the selenite form. Due to the limitations which will be imposed on the concentrations of trace elements which can be applied these trace elements should be applied in the most bioavailable form.

3) Human nutrition
In recent years the importance of trace elements in human nutrition have been highlighted as a result of the advancement of knowledge in this area of science. The importance of iron in the human diet is well known. Previously trace element deficiency was considered to be prevalent mainly in third world societies. However, in recent years zinc has been shown to have an influence on the incidence of stress in urban societies in the United States of America, copper/zinc ratios are important in the prevention of heart disease and selenium has been shown to have anticarcinogenic properties in humans (Underwood, 1977). The method of application can affect the availability of these trace elements to humans.

4) Persistence
With the exception of boron and iodine trace elements are persistent in soils and excessive applications can result in a build-up towards toxic concentrations. The availability of trace elements is related to soil conditions such as soil pH, moisture content and temperature. There is an increased interest in the manipulation of soil conditions in order to maximise the uptake of certain trace elements by plants. The increase in the soil zinc concentrations at 10 sites in Louth and Meath as a result of foliar applications of zinc sulphate is shown in Table 4. Application of copper sulphate at 2 kg/ha as a foliar spray on peat soil did not increase the soil copper concentration significantly but the incidence of copper deficiency symptoms was reduced (Table 5). Continuous foliar application of copper can lead to copper toxicity. In French vineyards which had been converted to pasture grazing animals suffered severe copper toxicity symptoms. The vines had been sprayed with copper sulphate solution to control leaf diseases. Continuous application may not affect the soil trace element concentrations especially in highly absorptive soils but added amounts of trace elements may become available to the plant when desorption occurs and trace elements are released from the soil to the soil water. Such flushes may be brought about by changes in the soil moisture, temperature or chemistry. Increased activity of microorganism, synchronized release of root exudates or lime and fertiliser application may also cause trace element flushes to occur.

Table 4: Concentrations of zinc in soil treated with a single mineral zinc sulphate spray over 3 and 5 years.

Period of Application	Rate/ha	Soil Concentration (mg/kg)
Before Application	-	1.5
3years	5.0 kg	2-7
5 years	5.0 kg	3.1

Table 5: Concentration of copper in a peat soil treated with copper sulphate at 2.0 kg/ha over 5 years.

Year	Rate	Soil Copper (mg/kg)	Deficiency
1980	2.0 mg/kg	1.4	+
1981	2.0 mg/kg	1.5	–
1982	2.0 mg/kg	2.1	–
1983	2.0 mg/kg	2.2	–
1984	2.0 mg/kg	1.7	–

Where trace element application is necessary the method of application which leads to the least increase in soil or plant concentration should be practiced. The effect of soil moisture content on the uptake of trace elements from soil is well known. Trace elements are taken up in the soil solution and when the soil is dry uptake by plants is reduced. The mechanism by which molybdenum is more available in wet soils has been described by Fleming (1988). Copper and manganese are less available to the plant when the soil is dry. Zinc deficiency is more severe in cereals and in maize when the soil temperatures are low. The effect of season on trace element uptake is shown in Table 6.

Table 6: The effect of seasonal rainfall on trace element uptake in winter barley in June.

Year	Rainfall (May) (mm)	- - -Soil Concentration - - - B	Cu	Mn	Zn	- - Foliar Concentration - - B	Cu	Mn	Zn
1989	6.4	0.91	3.7	84	2.1	34	5.1	51	19
19990	37.4	0.88	3.6	91	2.4	82	7.4	111	27

Soil application of selenium

Investigations were started in 1989 on the application of selenium to the soil. The purpose of these investigations was to study the effectiveness of this method and to assess the advantages, if any, of soil applied selenium over subcutaneous injection. Selenium levels in the blood, in the herbage and in the milk was assessed. The selenium concentration in the herbage before treatment was less than 0.1 mg/g and this was regarded as being below optimum. In 1989 and 1990 selenium concentrations in pasture, in silage, in milk and in the blood of dairy cows was increased by the application of 25 g/ha elemental selenium to the grassland. In 1991 there was no increase in the selenium concentrations in the herbage but the selenium levels in the blood was increased. Selenium blood levels were increased by subcutaneous injection of medium to longterm persistence. The main advantage of soil application was the reduction in handling of the livestock. No penning or movement of the animals was necessary as the treatment was applied to the pasture. A number of trace elements can be applied simultaneously using this method.

Boron Deficiency

Boron deficiency affects clover, sugar beet, fodder beet, turnips, mangolds, swedes, kale, horticultural brassica crops, celery and carrots. It is not essential for animals or humans. Boron is among the most water soluble of all trace elements and is easily leached from the soil by rainfall. On this account it is applied annually in some of the above mentioned crops as a soil application. Until recently a soil application of 3-4 kg/ha of elemental boron was considered to be adequate for all boron sensitive crops.

However, boron deficiency symptoms have occurred in swedes, sugar beet and celery following a 4 kg/ha application at sowing. In 1991 sugar beet showed symptoms of boron deficiency at five out of six inspected sites. In swedes all five sites inspected had boron deficient roots. Boron deficiency does not occur in each year but is dependent on weather conditions and soil type. Heavy rainfall in winter will leach the residual boron from the soil. Heavy rainfall in summer following the application of the boron will leach much of the recently applied boron. Heavy showers will leach larger amounts of boron than light continuous rainfall. A high soil pH and drought will also lead to boron deficiency. Boron uptake is very much reduced at a high soil pH. The available soil boron is carried in the soil moisture and boron uptake is reduced during periods of drought. Leaching of boron is greater in free draining, light textured soils. A soil application of 4 kg/ha elemental boron may not be adequate in a light textured calcareous soil when heavy rainfall in the early to mid-summer period is followed by drought in late summer and it may be necessary to apply some foliar sprays. The number of foliar sprays which are necessary depends on the boron concentration in the soil and on weather conditions. When the boron concentration is 1.0-1.5 mg/kg a foliar spray of solubor at 4 kg/ha should be applied at the 6-8 leaf stage of beet, mangold and swede crops. A second foliar spray should be applied when very dry weather occurs in July and August. The most suitable time to apply this spray is immediately before the drought breaks. When the soil boron concentration is greater than 1.5 mg/kg the spray at the 6-8 leaf stage may be omitted but the later spray should be applied in dry conditions. When the soil concentration of boron is less than 1.0 mg/kg the application of both foliar sprays is recommended and an additional spray may be necessary depending on weather conditions.

Future Developments

Future developments in trace element technology will be strongly influenced by environmental restrictions enforced by EC law. In the heavily industrialized parts of continental Europe contamination of soil and ground water by heavy metals and disposal of metal contaminated waste such as sewage sludge, mine tailings and industrial waste are recurring problems. Regulations controlling the concentrations of heavy metals in the environment are already in force or are being drafted. Due to the central European experience there will be a strong emphasis on the dangers of environmental pollution rather than on the problems caused by deficiency. Consequently, any future developments in the area of trace element research must take into consideration the dangers of environmental pollution. The development of new trace element products must therefore be concentrated on environmentally benign materials in order to gain sanction under the new regulations. Low concentrations of these products must be used and consequently such products must be highly efficient. Due to the perceived risk of pollution and the high cost of obtaining clearance synthetic products are not the most suitable for development. The emphasis is more likely to be on natural products which can be developed with the minimum use of additives and minimum processing. Such products are chemically complex and difficulties are often encountered with investigations on the mode of action and on the pathways of the different chemical interactions.

More emphasis will be placed in future on creating the soil conditions which favour a low risk of trace element deficiency. This may involve the use of grass more frequently in the rotation to increase the soil organic matter, the use of animal waste and other organic material and a reduction in the use of nitrogen. At present, proposals have been put forward at EC level to restrict the levels of nitrogen in soil water to 50 mg/kg. Adjustment of the soil pH to the correct value is also an advantage.

In these days of static or falling commodity prices and of increasing costs a serious attempt must be made to carry out economic studies of the various methods of trace element application while simultaneously considering the environmental implications. There are several schools of thought on this subject. Some scientists believe that soil application however economical and trouble free should not be permitted due to the risk of trace element build-up. Others consider soil application to be the best option on the basis that the plant can transform the trace element into a form which is biologically more available to the animal and the human.

New, more environmentally acceptable sources of trace elements must be identified. Mechanical rather than chemical processing of raw materials is more acceptable in this regard. Investigations are required on different raw materials such as minerals from rocks, ores and the byproducts of mining operations. The trace element content of different rock formations are well known but the trace element content is more often than not insufficient to justify processing as a source of a trace element for agricultural purposes. The processing and development of biological sources of trace elements should be considered as a realistic option. Trace elements are more available in the biological form and smaller quantities can be used to control deficiencies. Investigations should also be carried out on the relative efficiency of the various biological forms as this can lead to a reduction in the amount of trace element applied.

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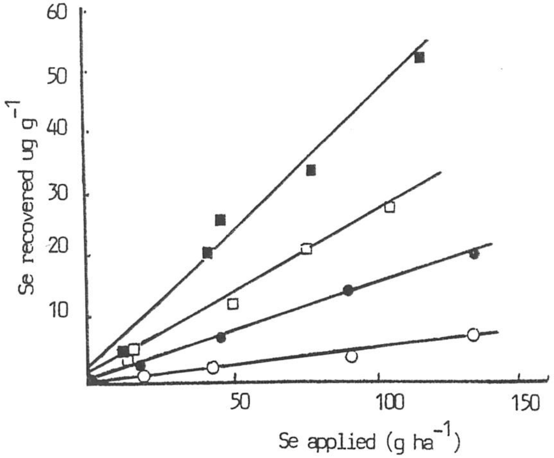
Fig. 1: The relationship between the amount of biological and inorganic selenium applied and recovered.



Organic, not washed	y = 0.4561x + 07325, R = 0.9867
Organic, washed	y = 0.2708x + 1.7021, R = 0.9541
Inorganic, not washed	y = 0.1 622x + 0.011, R = 0.9613
Inorganic, washed	y = 0.0456x + 0.1787, R = 0.885

AGRICULTURE IN THE IRISH ECONOMY 1970 TO 1990

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Summary

The agri-food industry is more important within the Irish economy than it is in other EC countries. This is especially true in its contributions to net earnings from exports. Its growth rate has been one of the highest in the EC since 1970 but has tended to fall relatively in the 80s. High levels of productivity gains have been recorded in both the use of labour and land. Real income to the sector has however not matched increases in output. This derives principally from the fact that the real prices of output have fallen substantially. In addition it has happened despite the high levels of FEOGA transfers to the Irish exchequer since EC entry. While total Irish exchequer expenditure has increased substantially exchequer expenditure on agriculture has declined by 75 per cent. Increases in output and income on individual farms mirror the picture which is shown by the aggregate national statistics. Large changes in farm practices have taken place over the past 18 years. These changes underly the changes in productivity shown above.

Part I

The Agriculture Industry in Perspective

The performance of the Irish Agricultural industry has received much attention since Ireland's entry into the EEC. This is understandable given the importance of the agricultural industry in the total economy. Agriculture in Ireland represents a greater percentage of the total economic activity than it does in other EEC countries. Table 1 shows the percentage of total employment who work in agriculture and the percentage of the GDP which is derived from agriculture in the EEC countries for the year 1988-89. Ireland, with 15.1 per cent of its total employment in agriculture is exceeded only by Greece and Portugal. It derives 10.9 per cent of its GDP from agriculture and is more heavily dependant on this industry than any country with the exception of Greece.

These figures probably understate the contribution of the agri-food sector to the Irish economy. Brendan Riordan of Teagasc has shown that because of its low input content, high FEOGA transfers and lack of any profit repatriation, approximately 40 per cent of net income earned from exports derives from the agri-food industry. There is evidence that it has remained at the 40 to 50 per cent level in all years since EC entry. While gross non-food exports have increased significantly their benefit to the economy has been minimised by large imports of raw materials and high repatriation of profits out of the country. E Henry of ESRI in an Input/output study shows that up to 300,000 people within the economy derive some or all of their income either directly or indirectly from the agri-food industry.

Rate of growth

The rate of growth of the agricultural industries of the EEC countries in the decades 1970 to 1980,1980 to 1990 and the whole period from 1970 to 1990 is shown in Table 2.

Irish agriculture grew at a similar rate to that of the Netherlands between 1970 and 1980. Both of these had a faster growth rate than the other countries over that period. In the period 1980 to 1990, however, Irish agriculture grew by the lower rate of 1.7 per cent per annum. This was a slower rate of growth than that of Denmark, Netherlands and Belgium/Luxembourg. In the whole period 1970 to 1990 Netherlands had the fastest growth rate with Denmark next. Ireland's growth rate was third but was slower in the 80s in comparison with the 70s. This reflects a decline in the impact of EEC membership on the growth of the Irish agricultural industry in the latter period.

Table 1: Agriculture in the EEC 88-89

Country	% of Total Employment Agriculture	% of GDP from Agriculture
Ireland	15.1	10.9
U.K.	2.2	1.4
Denmark	6.0	3.8
France	6.4	3.2
Germany	3.7	1.6
Netherlands	4.7	4.2
Belgium	2.8	2.2
Luxembourg	3.4	2.3
Italy	9.3	4.1
Greece	26.6	16.4
Spain	13.0	5.1
Portugal	18.9	5.2

Source: Eurostat

Table 2: Index of Growth in the Volume of Gross Agricultural Output per annum

	1970-1980	1980-1990	1970-1990
Ireland	3.5	1.7	2.6
Netherlands	3.4	2.6	3.0
France	2.6	0.3	1.5
U.K.	2.4	1.3	1.7
Italy	2.2	0.4	0.9
Denmark	1.8	3.9	2.9
Belgium/Luxembourg	1.4	1.9	1.7
Germany	1.2	1.3	1.2

Source: 1981 and 1990 FAO Production Yearbook Volumes 35 and 44

Table 3: Output per Worker for the Different Enterprises from 1970 to 1990

	1970	1990	% Change
Agricultural Labour Force (000)	276	155	-44%
Total acres of agricultural land per worker	48.48	77.42	+78%
Output milk per worker (gallons)	2377	7763	+227%
Output cattle per worker (No.s)	5.25	12.6	140%
Output cereals per worker (tons)	3.67	14.1	284%
Output pigs per worker (No.s)	7.55	16.4	117%
Output lambs per worker (No.s)	5.09	28.2	454%
Index of volume of gross agricultural output per worker	100	304	204%

Source: Central Statistics Office

Productivity

The change in the volume of physical output per worker between 1970 and 1990 is shown in Table 3.

A feature of the Irish agricultural industry which it shares with other developing agricultural industries is the rapid decline in its labour force (44 per cent between 1970 and 1990). When this is combined with increases in gross output, large increases in productivity result (Table 3). These vary from an increase in output per worker of 454 per cent in lambs, 284 per cent in cereals, 227 per cent in milk, 140 per cent in cattle to 117 per cent in pigs between 1970 and 1990. Gross agricultural output per worker increased by 204 per cent over the same period.

Table 4: Composition of Value of Irish Agricultural Output and percentage increase 1970 and 1990

	1970 IR£m	1970 %	1990 IR£m	1990 %	% Change
Cattle	808	31.2	1238	38.5	+53
Sheep	113	4.3	144	4.5	+27
Pigs	310	11.9	176	5.5	-43
Poultry	136	5.3	99	3.1	-27
Milk	604	23.3	1042	32.4	+73
Cereals	211	8.1	167	5.2	-21
Total (incl. Stock Change)	2598		3216		+24

Source: C.S.O.

Composition of Output

Table 4 shows the composition of Irish Agricultural Output for 1970 and 1990. In 1970, 58.8 per cent of output was grass based in the form of the produce of the dairycow, cattle and sheep herds. In 1990, this had increased to 75.4 per cent mainly due to large increases in milk and cattle output in the intervening period.

This is further exemplified in Table 4 which shows the real value of output in 1990 values for 1970 and 1990. While the total value of output increased by 24 per cent the real value of output of milk and beef increased by much more, 73 per cent and 53 per cent respectively. At the same time the real value of pigs, poultry and cereals declined by 43, 27 and 21 per cent. The fall in value of output arose from a decline in real prices. The volume of output actually rose in all three enterprises but not enough to balance the fall in real prices.

Table 5: Livestock units, ha's crops and stocking rate 1970 and 1990

	1970	1990
Total number LUs	4590	6293
Ha's of crops	460	384
Stocking rate ha/LU	0.96	0.71
Stocking rate LU/ha	1.04	1.41
Increase in stocking rate		+36%

Source: C.S.O.

Stocking Rate

Total number of livestock units increased from 4590 to 6293 between 1970 and 1990. At the same time the number of hectares of crops declined from 460 to 384. This resulted in a change in stocking rate from 0.96 ha per LU (1.04 LU/ha) to 0.71 ha per LU (1.41 LU/ha) in 1990 or 36 per cent increase in stocking rate.

Change in output compared with Income

An interesting comparison between the growth in the volume of gross output and the change in aggregate real income is shown in Figure 1 for the period 1970 to 1990. The growth in gross agricultural output was steady in that period at a rate of 2.5 to 3 per cent per annum. Aggregate real income in contrast has varied widely and does not show any marked relation to the growth in output. There are two distinct periods. In the 70s income growth was higher than output growth but after the spectacular fall in real incomes in the 1978 to 1980 period, aggregate real income was near or below the level of 1970 during the 1980s. The exceptions were 1988 and 1989.

The question arises as to why there is such a difference between the growth in output and the changes in incomes.

Figure 2 shows the development of the real prices of input and output over the period. It shows that, while both sets of prices moved in parallel, input prices were in general lower in the seventies and higher in the eighties than output prices. It also gives an indication why 1972, 73 and 78 were such good years in farming with output prices much higher than input prices. The most significant fact about Figure 2 is that real output prices fell substantially from 1978 onwards. This fact, together with the relatively higher real input prices from then on, had an effect on the fall in real incomes during that period shown in Figure 1.

Figure 3 shows the growth in the volume of inputs relative to the volume of gross output from 1970 to 1990. The message from Figure 3 is that while the volume of output and input increased in parallel the volume of inputs increased at a faster rate in the late 70's and has maintained that increase since. Therefore some of the decrease in real income relative to the change in gross output is due to an increase in the volume of inputs relative to the volume of output.

Table 6: Percentage of Income Decline relative to Output due to Real Prices and volume 1970 to 1990

% Change due		
	to Volume	17%
	to Price	83%

When the figures are examined however it is confirmed that the predominant influence (83%) on the decline in real agricultural income relative to the increase in the volume of gross agricultural output is the fall in the real prices of output (Table 6). The increase in the volume of inputs is responsible for the other 17 per cent.

FEOGA Refunds and Direct Payments to Farmers

The level of income to farmers is also influenced by FEOGA refunds which are payments made to the Irish exchequer. Most of these payments take the form of either payments for products which are put into intervention or export refunds for products which are exported outside the community. They therefore influence the price of these products and without them prices would have fallen to a greater extent than has already happened.

Some of these refunds are paid directly to farmers in the form of headage payments in the disadvantaged areas or as premia for cattle or sheep.

Figure 4 shows the real value of FEOGA refunds to Ireland together with the direct payments to farmers net of levies for the years 1973 to 1990. FEOGA refunds have been significant in all years since 1973. They were over £1000m in the late seventies and in all years since 1985. Direct subsidies net of levies to farmers have not been very significant in the seventies apart from 1974. They have increased in significance however since 1982. They promise to be of even more significance in the future given that the CAP reform proposals have been approved.

Irish Exchequer Expenditure

Since 1972 Ireland has developed a total national debt of £26,000m. It is of

interest therefore to look at how the expenditure on agriculture by our own national exchequer has developed in that period Figure 5 shows total real expenditure by the Irish exchequer in comparison with exchequer expenditure on agriculture. The most obvious fact demonstrated by Figure 5 is that while total real government expenditure increased dramatically (88 per cent) Irish exchequer expenditure on agriculture has decreased equally dramatically (75 per cent).

Changes on Individual Farms

The following tables use data from the National Farm Survey to look at changes in individual farms.

Table 7 shows real value indices of output costs and income for 1990 assuming 1972 = 100 for the average of all farms in comparison with the average of full-time farms. Full-time farms had bigger increases in output and costs between 1972 and 1990. They also achieved higher levels of increases in family farm incomes in the same period.

In the period 1972 to 1990, for all farms and full-time farms, the real value of costs, especially fixed costs, increased faster than that of either gross output or gross margins. At the same time, the real value of output costs and margins also increased faster than the real value of family farm income.

Table 7: Real value index numbers for 1990 (1972 = 100) for full-time farms in comparison with all farms

	All farms	Full-time farms
Gross output	161	260
Variable costs	235	391
Gross margin	136	217
Fixed costs	275	437
Total costs	252	410
Family farm income	92	146

Source: National Farm Survey, Teagasc

An index of the change in the real value of the various items that make up the total of direct costs between 1972 and 1990 is shown in Table 8 (1972 = 100). Miscellaneous other costs, which include silage additives and polythene, show the highest rate of increase with crop protection being next. Expenditure on both are approximately six times higher in real terms in 1990 compared with 1972. The index of machinery hire 255 in 1990 (1972=100) shows the next highest increase. Purchased meals and fertiliser, which make up nearly two thirds of direct costs, have increased by approximately 100 per cent over the period.

An examination of the changes in the real value of the individual items that make up the fixed costs between 1972 and 1990 is shown in table 9 (1972 = 100). The index of interest on borrowings @ 1335 (1972 = 100) is the item which has increased most in the period resulting from a big increase in borrowings to finance the capital investment which took place over that period. This is further reflected in the increase in the index numbers of building maintenance to 908, upkeep of land to 519 and machinery operating expenses to 415 in 1990 compared to 100 in 1972.

The decline in the index of other fixed costs to 86 per cent of the 1972 figure is due to the fact that rates on agricultural land are no longer payable.

Table 8. Index of Direct Costs in 1990 (1972=100)

Purchased meals	215
Fertiliser	196
Crop protection	595
Seed	169
Machinery hire	255
Transport	150
Livestock expenses	236
Other	616
Total	**235**

Source: National Farm Survey, Teagasc

Table 9. Index of Fixed Costs in 1990 (1972=100)

Con-acre	269
Machinery operating	415
Building maintenance	908
Upkeep of land	519
Car, telephone, electricity	272
Hired labour	124
Interest	1335
Other	86
Total	**275**

Source: National Farm Survey, Teagasc

Table 10 shows the changes in the adoption of selected farm practices associated with grassland between 1974 and 1988, Frawley (1985). These changes show quite a dynamic industry with increases of 48 per cent in the number of farms making silage, 46 per cent in the installation of running water in farmyards and of approximately one third in the important grassland management practices of nitrogen on early grass, controlled grazing and resting land in wintertime.

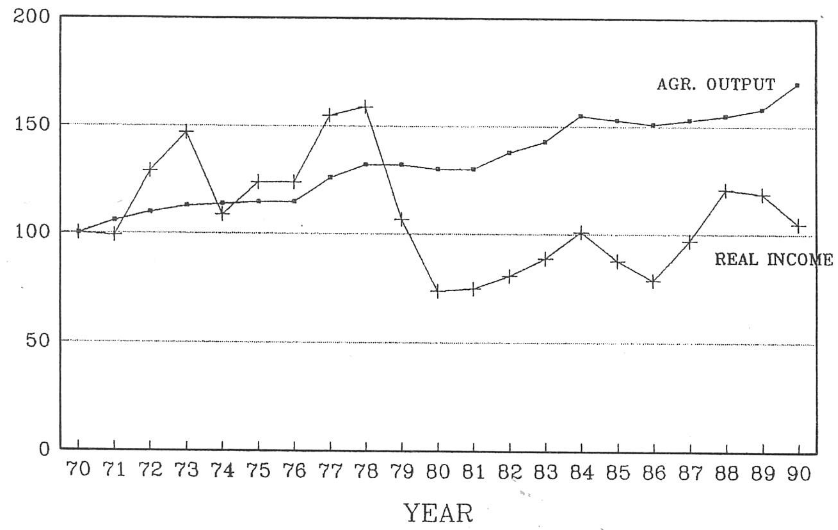
Approximately 90 per cent of farmers now use fertiliser on grassland and have both electricity and water installed in their farmyards. Approximately two thirds of farmers make silage and use nitrogen on early grass. Just over half use controlled grazing and rest land in winter time.

Table 10: Adoption of grassland practices 1974 and 1988

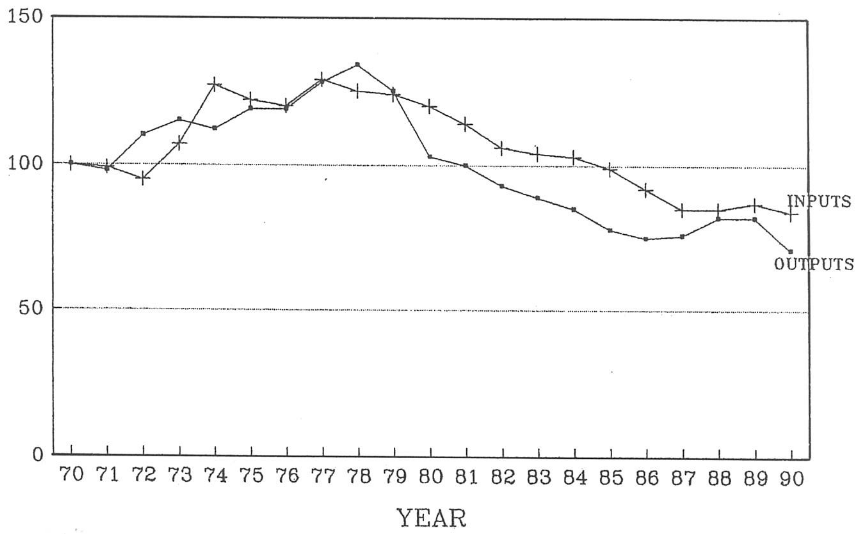
Practice	1974	1988	Change
Fertiliser on grazing	77	90	+ 13
Nitrogen on early grass	33	65	+ 32
Controlled grazing	24	53	+ 29
Land rested	22	56	+ 34
Making silage	22	70	+ 48
Land re-seeded	-	34	-
Electricity in yard	57	90	+ 23
Water in yard	43	89	+ 46

Source: J Frawley, Teagasc

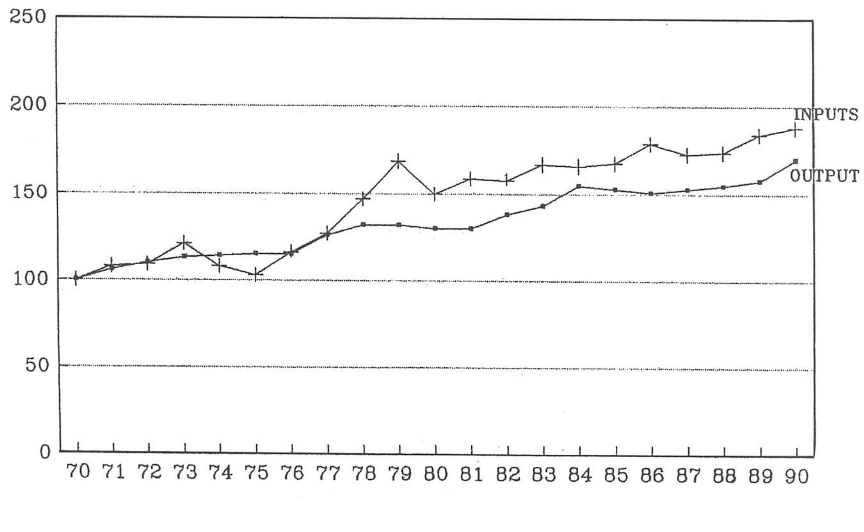
INDEX OF VOLUME OF GROSS AGRICULTURAL OUTPUT AND INDEX OF REAL INCOME 1970–90



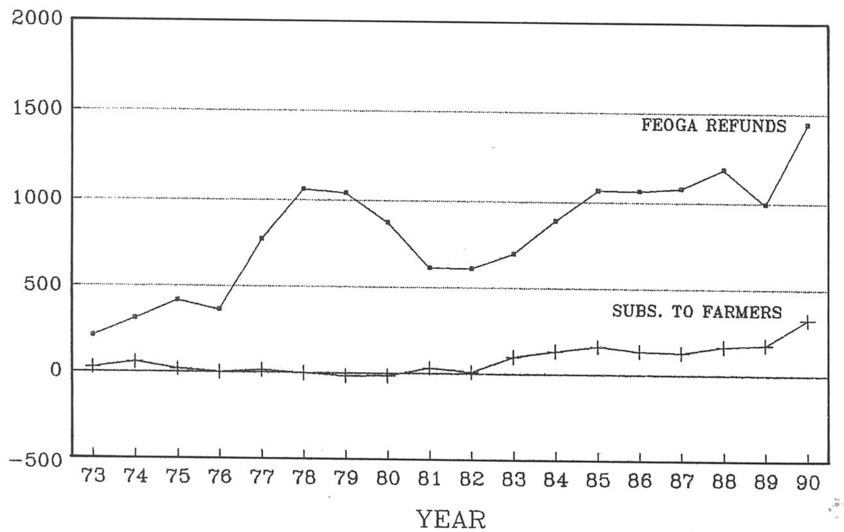
INDICES OF REAL PRICES OF OUTPUTS AND INPUTS 1970–90



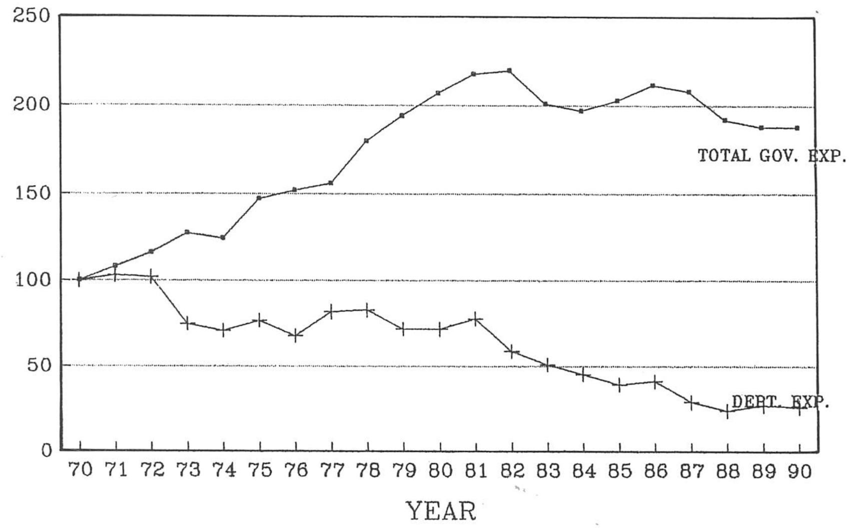
VOLUME INDEX OF AGRICULTURAL OUTPUTS AND INPUTS 1970–90



REAL VALUE (1990) OF FEOGA REFUNDS AND DIRECT SUBS. TO FARMERS NET OF LEVIES



INDICES OF TOTAL GOVERNMENT EXPENDITURE AND DEPT. OF AGRIC. EXPENDITURE



Comparison of Farms in the Disadvantaged Areas v those in Ireland as a whole using FADN data

Until 1992, 58 per cent of the agricultural land in the Republic of Ireland was in the disadvantaged areas as specified by Directive 268 of the EC. This area comprised all the area west of the Shannon plus West Cork and Kerry in the south west and the counties along the border with Northern Ireland in the north east. In 1992 the disadvantaged areas were extended to incorporate more of the land area in the east and south of the country. The following analysis is based on the pre 1992 disadvantaged areas.

Table 1 shows family farm income for all farms in Ireland in comparison with the similar figure for all farms in the west (roughly equivalent to the disadvantaged areas). Average income per farm in the west region is IR£4672 compared with IR£6682 for Ireland as a whole. This is approximately 30 per cent of a difference; 20 per cent of this can be assumed to be due to the difference in farm size at 26.3 ha UAA in Ireland in comparison with 21.0 ha in the west. The rest of the difference can be largely explained by the difference in land quality which is lower in the western region. In addition the western region has a lower proportion (25 per cent) of high profitability dairy, field crops and 'other' systems than the country as a whole (34 per cent) which would also help to explain some of the difference in income **(Table 2).**

Table 1: Family Farm Income compared with farm size UAA for all farms in Ireland and the West

	Ireland	West	Index West (Ireland = 100)
Income	IR£6682	IR£4672	70
Farm size	26.3	21.0	80

Source: National Farm Survey, Teagasc

Table 2: Percentage of Farms in Each Farm System for all farms in Ireland and the West

	Percentage in Ireland		
	Ireland	West	Percentage in West
Dairying	18.4	8.6	14.3
Cattle	46.5	31.6	52.7
Dairy/Cattle	12.4	6.3	10.5
Mainly Sheep	17.1	13.2	22.0
Dairy/Tillage	0.2	0	0
Drystock/Tillage	2.7	0.2	0.3
Field Crops	2.3	0	0
Other Systems	0.5	0.1	0.2
All Systems	100.0	60.0	100.0

Source: National Farm Survey, Teagasc

Table 3 shows gross output, costs - direct and fixed, gross margin and income per ha for all farms in Ireland and the West. It shows that while output is 26 per cent lower, both direct and fixed costs are lower by 32 per cent. At the same time calculation of stocking rate shows 1.21 LU/ha in the west in comparison with 1.46 LU/ha in Ireland as a whole, i.e. a difference of 17 per cent This results in income per ha being 13 per cent lower in the west than in Ireland as a whole. The conclusion is that, the quality of the land resources is lower in the western region which results in a more restricted enterprise mix, lower stocking rate and lower gross output in the western region. However, lower fixed and variable costs on the western farms help to counteract these disadvantages.

Table 3: Average Output, Costs and Income per ha for all farms in Ireland and the West IR£

	Ireland IR£	West IR£	West Index (Ireland = 100)
Gross output	777	577	74
Direct costs	282	191	68
Gross margin	490	386	79
Fixed costs	240	164	68
Income	254	222	87

Source: National Farm Survey, Teagasc

Another factor which helps to maintain income on farms in the disadvantaged areas in the west is the fact that they receive a higher level of subsidies than the farming community of Ireland as a whole (Table 4).

Table 4: Grants and Subsidies per ha for all farms in Ireland and the West by system IR£

	Dairying	Cattle	Dairy/ Cattle	Mainly Sheep	Dairy/ Tillage	Drystock tillage	Field Crops	Other	All
	IR£	IR£	IR£	IR£	IR£	IR£	£	IR£	IR£
Ireland	15.8	67.2	34.4	162.5	12.8	71.5	23.2	66.7	65.8
West	20.0	74.6	36.1	154.7	-	82.2	-	-	84.3

Source: National Farm Survey, Teagasc

Systems involving cattle and sheep have the highest levels of subsidy. On average the level of subsidy per ha is higher in the west by IR£18.5.

Table 5: Average number of Labour units available per farm in comparison with total standard labour units used per farm for all farms in Ireland and the West

	Ireland	West
Family	1.1	1.0
Total	1.1	1.0
Standard labour-units	0.8	0.5

Source: National Farm Survey, Teagasc

Table 5 shows the average number of labour units available on all farms in Ireland and in the western region compared with the average number of standard labour-units utilised on these farms. Two messages arise from table 5:

(a) Nearly all labour available is family labour. This is especially true of the western region.

(b) Labour utilisation is low on all Irish farms where 0.8 of the 1.1 labour units available is gainfully employed. Under-utilisation of labour is even more of a problem on western farms where 0.5 of the 1.0 labour units is utilised.

Table 6: Average Output Costs and Income per Standard Labour unit for all farms in Ireland and the West IR£

	Ireland IR£	West IR£	West Index (Ireland = 100)
Gross Output	25530	24218	95
Direct Costs	9279	8002	86
Gross Margin	16251	16216	100
Fixed Costs	7899	6872	87
Income	8888	9506	107

Source: National Farm Survey, Teagasc

Table 6 shows gross output costs (direct and fixed) and income per standard labour unit utilised on all farms in Ireland and in the western region. The message that arises from **Table 6** is that the productivity of utilised labour on farms in the western region compares favourably with that of Ireland as a whole. The detailed figures show a marginally lower gross output per standard labour unit in the western region balanced out by lower costs and resulting in a 7 per cent higher income per labour unit in the western region.

As in the case of return to land the return to labour is also influenced by the extent to which farmers in the west region receive higher levels of grants and subsidies **(Table 7).**

Table 7: Grants and Subsidies per standard labour unit for all farms in Ireland and the West by system IR£

	Dairying	Cattle	Dairy Cattle	Mainly Sheep	Dairy/ Tillage	Drystock Tillage	Field Crops	Other	All
	IR£	IR£	IR£	IR£	IR£	IR£	IR£	IR£	IR£
Ireland	346	3025	837	7717	304	2558	893	910	2175
West	478	3903	853	8630	-	3023	-	-	3528

Source: National Farm Survey, Teagasc

Subsidy per standard labour unit is £1353 higher in the west than in Ireland as a whole. But for this, income per labour unit in the west, as shown in Table 6, would be 8 per cent lower than that in the rest of the country.

Therefore part of the reason that incomes in the western region do not lag further behind those in the rest of the country is that grants and subsidies arising out of EC policy decisions are higher in the west Any discussion of the future competitiveness of these areas will have to take into account how secure these transfers from the rest of the community are.

In summary, farmers in the disadvantaged areas have poorer quality resources and less land, under-utilise their labour resources to a significant extent, have a higher dependence on State transfers and consequently have lower family farm income than the average of all farms in Ireland. They do, however, generate at least as high an income per utilised standard labour unit as the average of all farms in Ireland. They do this through lower costs and by virtue of the fact that they receive a higher level of State transfers.

Table 8: Income per ha and index of same for all farms and full-time farms in Ireland as a whole and the Western Region

	Dairying	Cattle	Dairy Cattle	Mainly Sheep	Dairy/ Tillage	Drystock Tillage	Field Crops	Other	All
	IR£	IR£	IR£	IR£	IR£	IR£	IR£	IR£	IR£
All-Farm Ireland	446	134	333	183	339	198	221	667	254
Full-time Farm Ireland	460	185	333	194	339	222	225	682	321
Index (All Farms=100)	103	38	100	106	100	112	102	102	126
All Farms West	383	151	306	191	-	140	-	-	222
Full-time Farms West	400	180	307	213	-	-	-	-	292
Index (All Farms West=100)	104	119	100	115	-	-	-	-	132

Source: National Farm Survey, Teagasc

An examination of full-time farms (defined as those who utilise more than 0.75 labour units on their farms) is shown in the following paragraphs. The rationale for this examination is that future development of farms, which are not utilising their existing resources to the full, should be in the direction in which existing full-time farms have developed.

Table 8 shows income per ha for all farms and full-time farms, both in Ireland as a whole and in the western region, for the various systems of farming. An index of the income per ha for full-time farms for both areas (all farms = 100) is also shown.

All full-time farms show a 26 per cent higher income per ha than that of all farms for Ireland as a whole. For the western region full-time farms show a 32 per cent higher income per ha than all western farms.

Within each individual enterprise, apart from the cattle enterprise, the difference between income per ha on all farms and full-time farms is much less than the overall difference. Increased efficiency within enterprises therefore contributes only marginally to the higher income per ha on full-time farms.

Table 9 tries to elucidate some of the reasons which underlie the higher income per ha on full-time farms for Ireland as a whole and for the western region. The first reason is that full-time farms utilise the available labour more fully than all farms with 6 per cent over-utilisation on all full-time farms in Ireland as a whole and 7 per cent under-utilisation on western full-time farms. In contrast, labour under-utilisation is 27 per cent on all farms in Ireland as a whole and 50 per cent on all farms in the western region.

A similar picture emerges in the case of land. Stocking rate is more intensive on full-time farms, 1.44 in Ireland as a whole and 1.68 in the western region, compared with 1.69 and 2.04 respectively for all farms.

Table 9: Intensity of use of Resources of all Farmers compared to full-time farms for Ireland and Western Region

	% Under-utilisation of available labour	Stocking rate AC/LU	% of Farmers in intensive enterprises
Ireland			
All farms	-27%	1.69	31.5%
Full-time farms	+ 6%	1.44	69.8%
West			
All farms	-50%	2.04	25.0%
Full-time farms	- 7%	1.68	75.3%

Source: National Farm Survey, Teagasc

Similarly a higher proportion of full-time farms have high gross margin enterprises such as dairying, sugar beet, potatoes and farmyard enterprises such as pigs and poultry, 69.8 per cent in Ireland as a whole and 75.3 per cent in the western region compared with 31.5 and 25 per cent respectively for all farms.

The conclusion which suggests itself from these figures is that full-time farmers have a higher income because they utilise their resources more fully and efficiently and concentrate on higher gross margin enterprises than the average of all farmers.

The corrollary of this is that farmers whose future competitiveness is most at risk are those who are under-utilising their resources. Given the recent CAP reform decisions, expansion in conventional enterprises is not possible. The result is that, in order to more fully utilise the resources available to the farmer, alternative farming systems or off-farm employment or both are necessary.

PART III

Some Social Characteristics*

The following tables show the social characteristics of farmers in Ireland as a whole. Further analysis is necessary to show the social characteristics of farmers in the disadvantaged areas. It is not expected that there will be major differences. Table 1 shows that 63 per cent of farm operators are married with 31 per cent single and less than 6 per cent widowed or separated. Farm operators are predominantly male - 96 per cent, as is shown in Table 2. Table 3 shows that approximately one third of farm operators are over 60 and nearly 57 per cent are over 50. Only 21 per cent are under 40. Twenty two per cent have an off-farm job - Table 4, most of these on a part-time basis. Table 5 shows that 49 per cent of farm operators have primary education only, 20 per cent have secondary, 18 per cent agricultural and 11 per cent other vocational education. Less than 2 per cent have third-level education. Table 6 shows that the level of education is age related, with 75 per cent of those having primary education only being over 50 years old. At the same time a predominance of those with second and third level education are in the under 50 age group. Just under 31 per cent of farm operators have contact with the advisory service. This has declined in recent years with a decline in the number of advisers Table 7.

Table 1: Marital Status

	%
Married	63.17
Single	31.13
Widowed	5.29
Separated	0.41

Table 2: Farm Operator

Male	Female
96.43	3.57

Table 3: Percentage of Farmers in Different Age Categories

Age	%
20-29	6.01
30-39	15.10
40-49	22.09
50-59	24.02
60-69	25.27
70-79	7.37
80-89	0.15

**Data derived from a survey by Dr. Jim Frawley of Teagasc Rural Economy.*

Table 4: Employment Status of Farm Operator

	%
Full-time farming	78.17
Off-farm job:	
Part-time	19.21
Full-time	2.62

Table 5: Formal Education

	%
Primary	49.01
Secondary	19.74
Vocational	10.58
3rd level	1.78
Agricultural education	17.91

Table 6: Age/Education

Age	Years 20-49	Years 50 +
Primary	24.99	75.01
Secondary	75.86	24.14
Vocational	78.67	21.33
Third level	57.69	42.31
Agricultural education	67.90	32.10

Table 7: Advisory Contact

	%
Yes	30.94
No	69.06

Part IV

Analysis of Alternatives

Given the large surpluses of agricultural commodities and future increases in productivity in agriculture it seems that less resources will be needed in future to produce EC food requirements. In addition, recent decisions on the reform of the CAP have imposed effective quotas on nearly all conventional enterprises. These decisions have also given a fillip to the long-term deterioration in the real prices of output from these enterprises. This has implications for the future competitiveness of many farm businesses especially in the disadvantaged areas of the community.

It is therefore important that consideration be given to how these surplus resources could be utilised with special reference to the possibility of their use for producing alternative enterprises which would enable these farms to be competitive. The contribution to competitiveness of the existing agricultural enterprises compared to that of possible on-farm alternatives should be the focus of any such investigation. At the moment there is no large-scale market for the output of many of these alternatives. Increases in output of these commodities could have the effect of reducing their prices. It is therefore necessary that the output from these systems is valued at moderate prices. Any conclusions on the future widespread use of the output of these alternative enterprises therefore depends on the development of markets to absorb this increased output.

The objective of the following calculations is to find out the optimum plans for average farms in Ireland as a whole and in the disadvantaged areas in Ireland. Linear Programming is judged to be the most suitable technique for this exercise.

Monoperiod LP is in widespread use in agriculture to provide optimum plans for farms. It is admirably suited to optimising the generation of income from enterprises which have an annual cash flow which most agricultural enterprises have. A problem arises in relation to the longterm enterprises since they are multi-annual.

They use large amounts of resources e.g. capital and labour in one period of one year and none for many years after that. Their cash flow characteristics are such that they generate large cash deficits over a number of years and later large cash surpluses when the crop is harvested some years hence. The use of discounted cash flow techniques to establish an annuity per ha gets over the latter problem to some extent. A discount rate of 10 per cent was used in this exercise. The problem of the uneven use of resources could not be satisfactorily solved by averaging out the use of resources over all years. To overcome these problems a multiperiod Linear Programming model could be used to complement the investigation carried out by the monoperiod model.

The objective in the selection of farms for study is that they would represent the type of farms and farming systems in the region from which they come. In Ireland two farms were chosen, one representing Ireland as a whole and one from the disadvantaged areas of the west and north. Each farm represents a system of farming which is prevalent in the specific region, i.e. cattle and sheep.

The source of the data for each farm was the National Farm Survey which is carried out nationwide by Teagasc, the Agriculture and Food Development Authority. This survey forms part of the EC FADN network. A total of approximately 1500 farms selected on a stratified random sample basis are included in the survey. Data from the average of farms representing the various systems of farming in each region was judged most suitable.

The farm data used was an average of the typical cattle and sheep farms in Ireland as a whole and in the disadvantaged areas. Reliable data, especially for labour and machinery requirements of certain enterprises, is not available and has had to be estimated.

The classification of farms into farming systems is based on EC farm typology methods. While systems of farming do not vary much as between the disadvantaged areas and the rest of the country, systems based on dairying and crops are more likely to be found in the east and south while systems based on cattle and sheep predominate in the disadvantaged areas of the north and west. However, most systems occur in all areas.

Farms are classified according to the proportion of a standard gross margin which comes from the main enterprise after which the system is named e.g. a specialist cattle farm will have at least two thirds of its standard gross margin coming from cattle. Similarly, with sheep farms.

Since cattle farms are found in all areas and, since these farms are more likely to have low incomes and under-utilised resources, a farm was chosen representing an amalgamation of the weighted average cattle farm for both the eastern region and for the disadvantaged areas which are represented by the western region.

The resources and constraints of each of the farms used were the average over the whole region of the physical and financial data of the farms in the cattle system. The representative farms are therefore a composite of all farms and not a specific individual farm. These farms therefore represent a variety of farm sizes, land types, levels of efficiency and levels of capital and labour which are involved in the cattle and sheep systems.

Results. *(The results quoted here derive from preliminary work done for an EC funded project which has U.K. French and Greek participants).*

Objective1: To highlight some of the main issues which will contribute to the future competitiveness of farms in Ireland

Objective 2: To derive some figures on the contribution to competitiveness of:

(a) Improvements in efficiency of existing enterprises

(b) Alternative enterprises

Example Farm

Chosen **1:** Average cattle farm from FADN Ireland-Eastern region

2: Average cattle and sheep farm from FADN Ireland-Western region

Resources Available

Cattle Farm Eastern Region

Land 56 ac.
Rough grazing 6 ac.
Capital (fixed) IR£15,000
Labour 1.0 labour units (family)
Quota livestock 25 LU

Cattle Farm Western Region

Land 38 ac. Rough grazing 29 ac. Capital (fixed) £11,200
Labour 0.9 labour units Quota livestock 15.1

Objective Maximise gross margin per farm given the resource constraints. Both capital and labour constraints can be overcome by borrowing or hiring at a pre-determined price.

Table 1: Cattle Farm Eastern Region

	Moderate Efficiency	High Efficiency	Moderate Efficiency plus Alternatives	High Efficiency plus Alternatives
Gross margin	100	124	165	187
FF Income	100	138	204	239

Tables 1 and 2 show the potential improvements in gross margin and family farm income which is theoretically available through making better use of the available resources. The figures for gross margin and family farm income are presented as indices in the tables. Table 1 shows that, for the average cattle farm in the East, improving the efficiency of the existing enterprises without adding any other enterprise, increases gross margin by 24 per cent and income by 38 per cent. The addition of alternative enterprises at conservative levels of profitability raises gross margin by 65 per cent and income by 104 per cent at moderate levels of efficiency for existing enterprises. The equivalent figures for the farm, if the efficiency of existing enterprises are improved and alternative enterprises are added, are an 87 per cent increase in gross margin and a 139 per cent increase in income.

Table 2: Cattle Farm Western Region

	Moderate Efficiency	High Efficiency	Moderate Efficiency plus Alternatives	High Efficiency plus Alternatives
Gross margin	100	127	203	233
FF income	100	141	257	301

Table 2 shows that, on the average cattle farm in the disadvantaged areas, improving the efficiency of existing enterprises without adding any other enterprise increases gross margin and income by 27 per cent and 41 per cent respectively. The addition of alternative enterprises at conservative levels of profitability raises gross margin and income by 103 per cent and 157 per cent respectively at moderate levels of efficiency for existing enterprises. The equivalent figures for the farm, if the efficiency of existing enterprises are improved and alternative enterprises are also added, are a 133 per cent increase in gross margin and a 201 per cent increase in income.

The conclusion to be reached from these figures is that the competitiveness of both farms can be substantially improved by a combination of:

(a) increases in the efficiency of existing enterprises

(b) utilising the presently under-utilised basic resources of land, and more especially labour, to nearer their economic potential through the introduction of alternative farm enterprises

Table 3 shows the returns per unit of land labour and fixed investment for all of the alternative enterprises and for conventional enterprises at intensive and extensive stocking rates.

Since the farms used in the exercise have a relatively small area of land and have surplus labour, enterprises which give a high return to land will be favoured by the model. It will also favour those enterprises which do not require high levels of capital investment which has to be borrowed at high interest rates.

Increasing income on farms will involve utilising the surplus labour and intensifying the use of land by increasing the efficiency of existing enterprises and introducing alternative enterprises since conventional enterprises are capped by quota.

Major alternative enterprises favoured by the model include soft fruit, apples, tree nurseries and mushrooms, together with minor enterprises such as free-range layers and turkeys for the Christmas market. Major question marks arise in relation to available markets if a major expansion were to occur in any of these enterprises Other enterprises are less profitable in Irish conditions but, under the assumptions used, any or all of them could find favour with individual farmers under specific sets of circumstances.

Given the lack of job opportunities off farm and the under-utilisation of the labour resource on farm, highlighted earlier, progress on most farms can mainly be achieved through improving the efficiency of existing enterprises and introducing suitable alternatives.

The success of such a strategy will depend on:

(a) the skills and knowledge being available on farms to introduce and manage new enterprises

(b) the marketing expertise being available. to sell the new output.

	ALTERNATIVES		
fixed RETURN	Per acre IR£	Per Hour IR£	Per IR£10 Inv. IR£
Mushrooms	-	3.33	57.1
Strawberries	755	3.36	12S.8
Apples	940	5.88	50.8
Tree Nursery	1619	2.98	38.1
AG Tourism	-	5.59	10.7
S.R. Forestry	50	15.15	200.00
Pigs	-	6.42	15.4
Milking Goats	409	1.93	26.3
Rabbits	-	4.23	20.6
Conv. Forestry	40	13.10	160.00
Sport Horses	72	2.48	8.6
Deer	254	3.23	14.4
Free Range Layers	-	1.25	48.1
Turkeys	-	1.25	-

	CONVENTIONAL		
Per acre RETURN	Per Hour IR£	Per IR£100 fixed IR£	Inv. IR£
Calf to Beef	249	9.97	49.80
Dairy Cows	475	8.14	57.00
Ewes	275	7.86	55.00
Suckler Weanlings	225	12.6	52.50
Suckler Beef	184	10.49	40.40
Extensive calf to beef	190	10.8	54.00
Extensive suckler weanlings	166	13.6	57.00
Extensive suckler beef	137	12.5	48.00

MAGNESIUM IN IRISH AGRICULTURE: A REVIEW

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Introduction Magnesium (Mg) is an essential element in the life cycle of plants and animals, including humans. In animals, Mg is found in teeth and bones and is a constituent of a large number of enzyme systems, especially those associated with oxidation of foods and transfer of energy. In plants, Mg is an essential constituent of chlorophyll, the green pigment that enables plants convert solar energy to carbohydrates in photosynthesis. In plants, Mg is also required in a wide range of energy transfer reactions and in synthesis of proteins. Supply of adequate Mg from soil to plants, and from plants/feedstuffs to animals is therefore an important aspect of crop and animal production. This paper gives a general over-view of soil-plant Mg behaviour, and describes such information as is available relating to Mg behaviour in the Irish context.

Magnesium Utilization by Plants Crop plants absorb essential nutrients, including Mg, from the solution phase of the soil. Nutrients enter roots and are simultaneously translocated to shoots, participation / involvement of the nutrient in

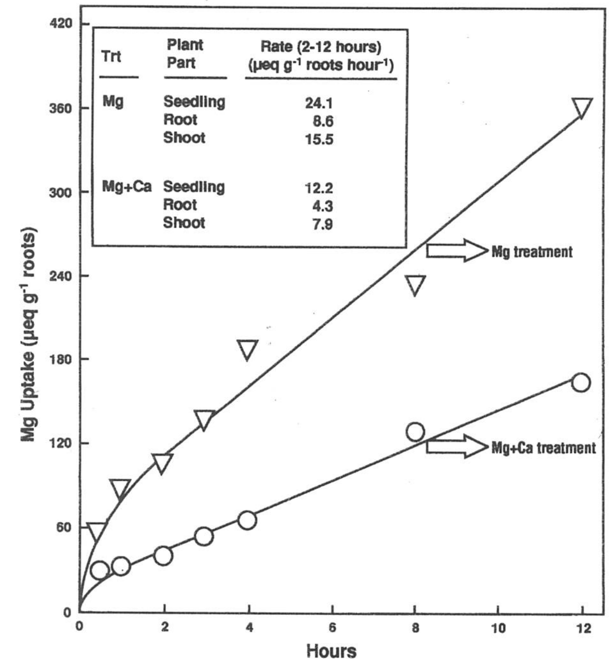

Figure 1. Uptake and distribution of Mg by Perennial ryegrass seedlings (adapted from Morgan and Jackson, 1976).

metabolic reactions occurring in each plant part during the actual uptake process. Maintenance of adequate concentrations of nutrients in the solution is via the solid materials of the soil (clay and organic matter), with or without fertilization.

Many of the details of Mg utilization by crop plants derive from experiments that use nutrient solutions rather than soils. Such studies show that uptake of Mg by perennial ryegrass in the absence of possible interactive effects becomes linear after a few hours (Figure 1), reaching a 'potential' uptake rate of 24.1 μeq g^{-1} roots $hour^{-1}$. Concurrent presence of calcium (Ca) in the solution however, caused Mg uptake to be reduced to 12.2 μeq g^{-1} roots $hour^{-1}$, the effect of the Ca being to reduce the Mg content of both roots and shoots, and each to the same extent (50%).

It can be reasonably assumed that the main features of the results shown in Figure 1 would not apply to all possible conditions involving ryegrass, Mg and Ca. Thus, the rate of Mg absorption, its distribution between roots and shoots, and the effect of Ca on each of these processes is likely to change with such variables as age of plant, relative size of roots and shoots, light intensity, ambient temperature and concentration of Mg and Ca in the root medium. Some of these effects are demonstrated in Figure 2 which refers to winter wheat grown at two levels of Mg (0.4 and 4.0 mM $MgSO_4$), three root zone temperatures (10°, 15° and 20°C) and three combinations of ammonium (NH_4): nitrate (NO_3) in the nutrient solution (10:0, 5:5 and 0:10 mM ratio). The results may be summarized as follows: (a)

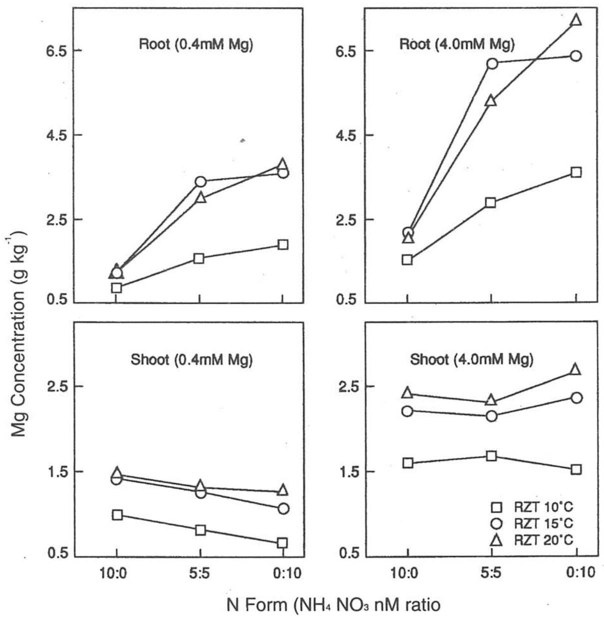

Figure 2. Effect of N form and root zone temperature (RZT) on Mg concentration of roots and shoots of wheat supplied with 0.4 or 4.0mM $MgSO_4$ (adapted from Huang et al., 1990).

significantly larger amounts of Mg accumulated in roots and shoots when growth was carried out at the higher Mg concentration (b) there was a marked effect of the NH_4:NO_3 ratio on the pattern and magnitude of response of the plants to the Mg treatments and (c) Mg concentrations of roots and shoots were significantly lower at 10° than at 15° or 20°C.

Numerous reports are available which indicate an antagonistic effect of increasing potassium (K) supply on the Mg content of crop plants (Hossner and Doll, 1970; Ologunde and Sorensen, 1982; Rahmatullah and Baker, 1981; Rehm and Sorensen, 1985). Solution culture, and soil culture experiments in which recovery of roots was possible, suggest that the effect of the K is to reduce Mg movement from roots to shoots rather than reducing Mg uptake by the roots (Ohno and Grunes, 1985). Further insight into this well documented interaction is provided by the data in Figure 3 which show strong negative correlations between the K concentration of young wheat roots and the proportion of total plant Mg present in the shoots (i.e., percent translocation). These results are of particular interest because here, the range of values for K content of the roots arose, not from variation in K supply, but from variation in the NH_4:NO_3 ratio of the nitrogen (N) treatment that was applied.

Finally, it is worth emphasising that root activity and nutrient uptake generally are highly dependant on the oxygen (O_2) concentration of the soil atmosphere. The results in Figure 4 highlight this dependence for Mg concentration in annual ryegrass that was grown at a range of soil O_2 levels and at two night temperatures. Other data (Elkins et al., 1978) confirm the antagonistic effect of lowered soil O_2 content on concentration of Mg in forage, as well as showing similar effects of soil drainage status (an index of O_2 tension) on Mg content of tall fescue (Figure 5).

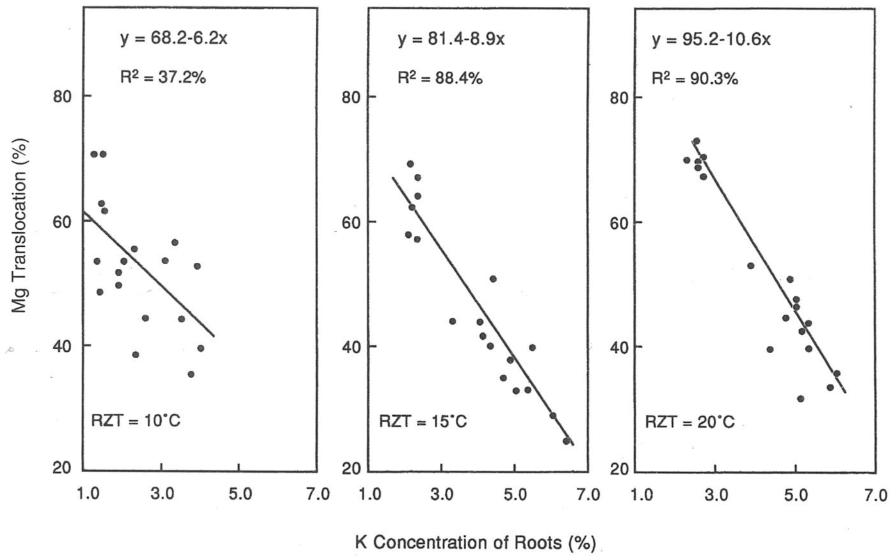

Figure 3. Relationships between Mg translocation and K concentration of roots of wheat plants at three root zone temperatures (adapted from Huang et al., 1990).

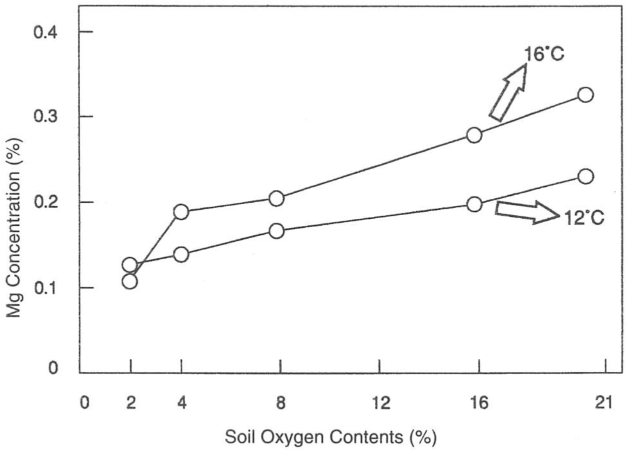

Figure 4. Effect of soil oxygen content and night temperature on Mg concentration of ryegrass (after Elkin and Hoveland, 1977).

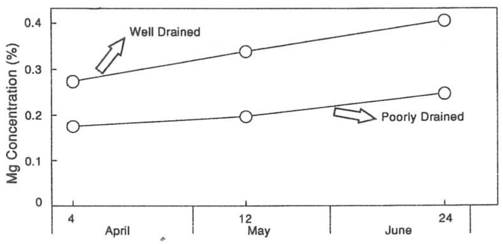

Figure 5. Effect of soil drainage status on Mg concentrations of Tall Fescue forage (after Elkins et al., 1978).

The foregoing observations suggest that the capacity of crop plants to accumulate Mg is regulated by a complex combination of soil physical and chemical properties. In such circumstances, it is extremely difficult to optimize conditions for Mg utilization except by ensuring adequate levels of available Mg in the soil (possibly through Mg supplementation) and hoping that the effects of the various antagonisms will be minimal. This approach pre-supposes that the yield and/or Mg concentration of crops in the field will respond to differential supplies of Mg in the soil. Reference to the following sections however show that such responses do not invariably occur.

Tillage Crops There are few published references to problems of Mg deficiency in tillage crops in Ireland and it can be reasonably assumed that Mg nutrition is not a problem except under very acid soil conditions and / or where the soils are sandy in character. Neither of these conditions however has been quantified. Examples of cases in which deficiency has been reported are French beans grown in peat (O'Sullivan et al., 1972) and sugar beet in a mineral soil (Blagden, 1970), each corrected by use of $MgSO_4$. In contrast, Brogan and Noonan (1980) found no

significant effect of $MgSO_4$ (soil dressing or spray) applied to sugar beet and barley on a site with exceptionally low available Mg (20 mg kg^{-1}). At present, response of tillage to Mg fertilization of soils with more than 50 mg kg^{-1} available Mg (Index 3 and higher) would be regarded as unlikely except for root crops (Anon., 1986). However, as far as can be ascertained, a yield response of tillage crops (including roots) to Mg supplementation has never been demonstrated in Ireland.

Grassland Aside from extreme cases of Mg impoverishment in soil (Blagden, 1971; 1972) there is no evidence in Ireland that grassland production is limited by Mg supply. Nevertheless, Mg nutrition of grassland is an important issue because of the apparent connection between dietary intake of Mg as reflected in herbage Mg concentration, the quantity of ingested Mg that is absorbed into the blood stream, and the possibility of occurrence of grass tetany where blood serum Mg concentration is not maintained at an optimum level. In Southern Ireland, the incidence of tetany between September and March, and from turn-out to mid-summer, is estimated to be 5% and 2-3% respectively (Rogers, 1992). In Northern Ireland, a survey based on blood samples from 646 dairy herds (6345 cows) and 728 suckler herds (6979 cows) revealed that 5% of dairy cows and 15% of sucklers were 'deficient' in Mg, with a further 12% and 28% respectively being in the 'marginal' category (Rice et al., 1985). This work also showed that while the highest incidence of the 'deficient' and 'marginal' conditions occurred in September, there were many instances of deficiency in July and August.
Although a distinct causal relationship between herbage Mg content and occurrence of grass tetany has never been established, maintenance of minimal concentrations of Mg in pasture is generally considered to be advantageous in controlling development of the condition. In this context, it has been suggested that hypomagnesaemia will not occur when herbage Mg concentration is greater than 0.2% (Elkins and Hoveland, 1977; Every, 1981; Wright and Barber, 1984;

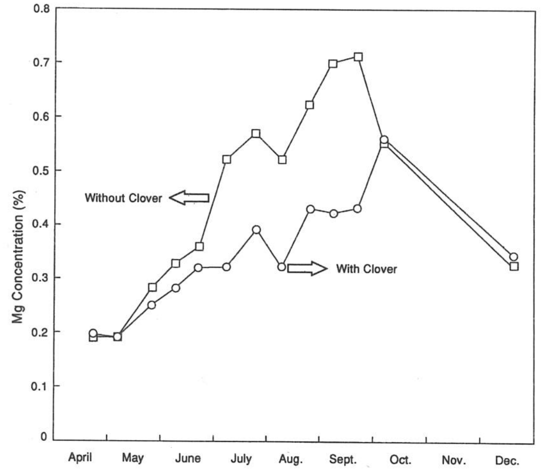

Figure 6. Seasonal variation in Mg concentration of Perennial ryegrass grown with and without clover (adapted from Fleming, 1966).

Grunes et al., 1970; Huang et al., 1990). Implicit in this suggestion is that this concentration of Mg be maintained throughout the period that the herbage or its products is being consumed.

Seasonal variation in Mg content of perennial ryegrass in Ireland has been characterized by Fleming (1966) and Fleming et al. (1975). Under conditions of frequent defoliation, Mg concentration increases from Spring through late Summer (Figure 6). Under cutting conditions, or where there is extensive grazing however, there is a tendency for Mg content to decrease over the course of the season (Fleming 1966; Fleming and Culleton, 1985). Attention is drawn to the lack of effect of presence of clover on the pattern of Mg accumulation (Figure 6) although there was clearly a large negative effect of the legume on the actual concentration of Mg achieved in the grass.

The rather high values for herbage Mg content shown in Figure 6 are not commonly found and therefore many attempts have been made to increase herbage Mg levels by treating soils with various forms of Mg 'fertilizers'. Results from one such study in Ireland are shown in Table 1. Treatments were applied in Spring and the acid soils (pH 5.7 - 6.3) initially contained 40 - 50 mg kg^{-1} available Mg. In the year of application, the highly soluble kieserite resulted in significant increases in Mg content, but there was little effect of this treatment in the second year. In contrast, the poorly soluble limestone source showed largest effect in the second year.

Table 1. Mean Effect of Kieserite (16% Mg) and Magnesian Limestone (13% Mg) on Mg Concentration (% d.m.) of Pasture1/

Date	Control (Zero Mg)	Kieserite (100 kg ha^{-1} Mg)	Magnesian Limestone (650 kg ha^{-1} Mg)
June 1973	0.19	0.26	0.21
August 1973	0.21	0.27	0.25
September 1973	0.32	0.38	0.41
May 1974	0.15	0.17	0.21
June 1974	0.22	0.25	0.34
August 1974	0.21	0.24	0.34
October 1974	0.22	0.23	0.34

1/ After Fleming et al. (1975)

In Northern Ireland, Stevens and McAllister (1985) studied the response of soil (pH 6.2) and pasture (perennial ryegrass / white clover) to magnesian limestone and calcined magnesite. The limestone was applied at 3277 or 6554 kg ha^{-1}, and the magnesite (619 or 1238 kg ha^{-1}) to supply the same amounts of Mg as the limestone treatments. Plots were harvested in early June, late July and late September (Harvests 1, 2 and 3 respectively) in each of the following ten years. The results showed that all treatments significantly increased available Mg content of the soil. The treatments also increased Mg concentrations in the herbage, representative data for which are given in Table 2 for the higher rate of Mg

fertilization. In absolute terms, however, the magnitude of the increases were quite small and were not commensurate with the corresponding increases in soil Mg content. For the experiment as a whole, the overall mean annual increase in herbage Mg content was in the range 0.02 - 0.04% and in only eighteen of the 104 treatments did Mg concentration equal or exceed 0.2%, all of which were found at the final September harvest. Essentially similar conclusions can be drawn from the work of McConaghy et al. (1963) and others viz., that soil applications of Mg cause only minor increases in herbage Mg concentration.

Table 2. Response of Herbage Mg Content (% d.m.) to Application of Magnesian Limestone and Calcined Magnesite (Representative Data)1/

Years After Mg Application	Harvest No.	Control (Zero Mg)	Magnesian Limestone (6554 kg ha^{-1})	Calcined Magnesite (1238 kg ha^{-1})
2	1	0.10	0.12	0.14
	2	0.14	0.16	0.20
	3	0.19	0.21	0.27
6	1	0.11	0.14	0.14
	2	0.13	0.18	0.16
	3	0.14	0.21	0.19
10	1	0.08	0.12	0.11
	2	0.11	0.17	0.15
	3	0.15	0.18	0.17
Annual Mean (N = 26)		0.13	0.17	0.17

1/ After Stevens and McAllister (1985)

Table 3. Mean Annual Range of Values for Concentrations of Soil and Herbage Mg in Farm Survey 1/ 2/

Parent Material	Soil Series / Soil Name	Available Soil Mg (mg kg^{-1})	Herbage Mg Concentration (% d.m.)
Alluvium	Boyne Valley	115 - 197	0.15 - 0.18
Basalt	Coleraine	187 - 281	0.16 - 0.19
Granite	Borris	134 - 385	0.17 - 0.21
Limestone	Dunboyne	103 - 243	0.14 - 0.15
	Elton	159 - 269	0.15 - 0.17
	Rathowen	94 - 432	0.14 - 0.22
Sandstone	Leitrim	136 - 191	0.15 - 0.18
	Strancally	82 - 192	0.17 - 0.19
Shale	Castlecomer	129 - 308	0.16 - 0.17
	Clonroche	102 - 336	0.19 - 0.30

1/ Morgan (1992)

2/ Work kindly sponsored by Irish Fertilizer Industries

Current Information In 1988-1989, a survey of the Mg status of farms was carried out in Ireland (Morgan, 1992). The farms chosen were representative of four soil series / names and six soil parent materials. Each series was represented by four farms to give a total of forty farms. Soil and herbage samples were collected every second month, commencing in November 1988 and finishing in September 1989. Farming activity ranged from intensive dairy production to extensive beef production. In a parallel pot experiment, the responsiveness of Mg concentration in perennial ryegrass to supplementation with 'soluble' and 'insoluble' sources of Mg was studied in two soils (Dunboyne and Strancally) that were included in the field survey. The following were the salient observations from these studies:

Table 4. Mean Annual Mg Concentrations and Numbers of Samples with ≥0.20% Mg [1/2/]

Soil Series / Soil Name	Mean Annual Herbage Mg Concentration (% d.m.)	Number of Individual Herbage Samples With ≥0.20% Mg (% d.m.)
Boyne Valley	0.17	4
Coleraine	0.17	4
Borris	0.19	10
Dunboyne	0.14	0
Elton	0.16	2
Rathowen	0.16	2
Leitrim	0.16	3
Strancally	0.18	8
Castlecomer	0.17	1
Clonroche	0.24	19

1/ Morgan (1992)
2/ Work kindly sponsored by Irish Fertilizer Industries

(a) all farms contained adequate available soil Mg (Table 3), mean annual values ranging from 82-192 mg kg^{-1} for the farms on Strancally to 187-281 mg kg^{-1} for the farms on Coleraine.

(b) highest values for herbage Mg content were found on Clonroche with a mean annual range of 0.19 - 0.30%. Lowest concentrations of herbage Mg occurred on Dunboyne, where the mean annual range was only 0.14 - 0.15% (Table 3).

(c) overall yearly average concentrations of Mg ranged from 0.14% (Dunboyne) to 0.24% (Clonroche), the remaining soils producing herbage with yearly mean values of 0.16 - 0.19% (Table 4).

(d) only small numbers of individual herbage samples in the survey equalled / exceeded 0.20% Mg concentration (Table 4). Clonroche ranked highest, nineteen of its twenty four samples satisfying this criterion. At the other extreme no herbage from Dunboyne, and only one sample from Castlecomer, equalled / exceeded 0.20% Mg.

(e) there was no significant correlation between Mg content of herbage and any measured parameter of soil fertility, including available soil Mg content.

In the pot experiment examining herbage response to Mg supplementation,

(a) adding Mg to the soils had no effect on % Mg at the first harvest.

(b) supplementation with 'insoluble' Mg after each harvest did not increase % Mg at following harvests, regardless of application rate.

(c) supplementation with 'soluble' Mg after each harvest only increased Mg concentration at the higher rate of application, and then only at the fourth and/or fifth harvests.

(d) there was essentially no difference between 'insoluble' and 'soluble' Mg in responses of herbage Mg concentration, regardless of rate of supplemental Mg.

(e) although the values for % Mg obtained in the pot study were higher than those found in herbage grown on corresponding soils in the field survey, such changes in Mg concentration as did occur were extremely small and of little practical significance.

Conclusions Available evidence does not suggest that Mg nutrition is a general problem for crop production (including grassland) in Ireland. Such concern as has been expressed about Mg nutrition relates to grassland, and specifically to the apparent connection between herbage Mg content and occurrence of grass tetany. The 'safe' concentration of herbage Mg (i.e., the content above which grass tetany will not occur) has been suggested to be 0.2%.

Results from the farm survey outlined here (Tables 3 and 4), as well as other published information (Table 2), suggest that this 'safe' value is not likely to be routinely exceeded. Although many soil properties alter Mg concentrations in plants, they do so in negative ways (Figures 1-5). Likewise, while nutrient solution experiments show that Mg concentration of plant tops can be increased by increasing the concentration of Mg in the root medium (Figure 2), this is not necessarily the case under field conditions. Evidence for this conclusion is (a) the consistently high values for available soil Mg without correspondingly high values for % Mg in associated herbage (Stevens and McAllister, 1985; Table 3) and (b) the lack of significant response of herbage Mg to Mg fertilization, whether this be a long-term assessment in the field (Table 2) or a short-term pot experiment employing different rates of application of 'soluble' and 'insoluble' sources of Mg (cf. previous section).

It is possible that herbage Mg concentrations under our conditions are held 'low' through the combined influences of antagonistic soil factors (e.g., high Ca or K) and/or because grass species have a limited capacity to absorb and translocate Mg. Either way, it would appear that more subtle approaches than have been used so far are required in order to elevate Mg concentrations to higher levels than are usually encountered.

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