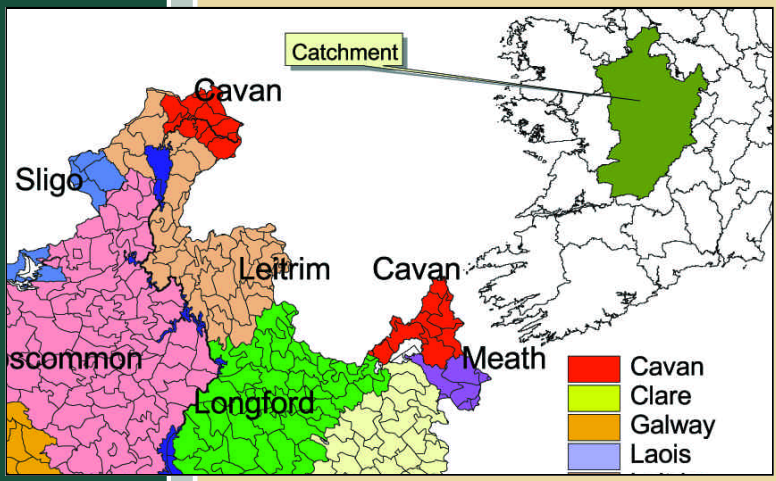
END OF PROJECT REPORT

PROJECT 4496

VISUAL ENVIRONMENTAL DATA ON SOILS AND LANDUSE



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VISUAL ENVIRONMENTAL DATA ON SOILS AND LANDUSE

END OF PROJECT REPORT

ARMIS 4496

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SUMMARY

- This project was established to develop a computer based system to view, manipulate and store data on soils, environment and land use in electronic map form for environmental decision support. It was designed to produce new information, charts and maps by combining features from the captured data, and to develop networking systems to allow exchange of data with other Teagasc centres, local and national government and the EU. The current report presents maps and tabular data of particular relevance to the environment. It includes information and maps on the total stocking density of livestock in different parts of Ireland. This is relevant to the nutrient loadings that soils and the environment are subject to from normal farming operations. It also includes maps and tabular information on phosphorus and potassium levels in soils and the recommended manure and fertiliser application given by Teagasc for grassland and cropping on these soils.

  In addition, it also describes and illustrates with tables and maps, a computerised programming approach for mapping phosphorus and potassium levels in soils at a detailed level by using the farmer's address to locate samples at townland or DED level.

INTRODUCTION

- Project 4480 was established to develop a computer based system to view, manipulate and store data on landuse and the environment. It is an extension of Project 4104, which has already been published as the End of Project Report: "Enhancing and visualising data on soils, land use and the environment" under the headings:
  - Map Presentation of National Census Information,
  - Capturing Digital Soil Information,
  - Thematic Maps derived from Soil Survey Information.
- The primary task in developing the computer based system further was to review the additional sources of information, both maps and tables, that would be used to continue the development of an information system of linked digital and tabular data. This report reviews and illustrates the findings and outputs under the headings:

  Changes In Livestock Numbers 1970 – 1991

  National Soil Lime, P And K Levels And Fertiliser Usage

CHANGES IN LIVESTOCK NUMBERS 1970-1991

Detailed Soil P And K Mapping At Catchment Level

- The Central Statistics Office kindly made the 1970, 1980 and 1991 Irish Agricultural Census data on crops and animals available as a text file (Central Statistics Office, 1994). The data were converted to dBase compatible form and linked into the GIS map coverage of District Electoral Divisions (DEDs), of which there are approximately 3100 in the Republic of Ireland with an average area of approximately 24 km^2. They are called DEDs because their most frequent use within the country is as the management unit for national and local elections.

- The names and boundaries of district electoral divisions (and other larger administrative units) have been published in map form by the Irish Ordnance Survey Office (1935, revised 1961). There have been several revisions of DED code numbers since then, with a major change in codes and changes in some boundaries in 1991 (Central Statistics Office, 1994, Coulter et al (1998).

- Thus each record or row of data represented the agricultural information within a DED. The GIS process allowed geographical relationships to be established between the boundaries of each DED in the maps and the agricultural census records in the database. The records were processed to produce the total calculated livestock units of cows and replacements, other cattle and sheep.

- The stocking rates for cows and replacements, other cattle and sheep and the overall rates were calculated by dividing the number of livestock units in each DED by the total area of the DED as measured on the map. This does not reflect the stocking rate from a grazing point of view as the geographic area may include unutilised rough grazing, rock outcrop or even small water bodies. However, it was necessary to use the total areas to allow accurate comparisons across years because there was a difference in the basis for calculation of utilised agricultural area in the 1991 census compared to the earlier ones (Central Statistics Office, 1994). This makes the mapped stocking densities less meaningful agronomically, although there may be some environmental justification for dividing the total livestock units by the geographic

area to obtain the livestock density as this reflects the stress or loading on the whole area, rather than just one part of the DED.The formulae used to compute the stocking density for each of the livestock enterprises: cows and replacements, other cattle and sheep were given in Coulter et al (1998); and are repeated in equations (1) - (3). The overall livestock densities for each year is given by equation (4) and illustrated in Figures 1-3 for cows and replacements, other cattle and sheep. In each of the equations, the denominator 'area' is the total mapped area of the DED in hectares as previously stated. This area thus includes all utilised and non-utilised land in the DED whether grassland, tillage or rock etc. This is necessary in order to allow strict comparison between the same areas in different years.

Cows and Replacements Stocking Density:

$$SD_c = [a + b + c + (d + e) \times 0.7] / \text{area}, \quad (1)$$

where SD_c is the cows and replacements stocking density, a = number of dairy cows, b = other cows, c = bulls for breeding, d = dairy heifers in calf, e = other heifers in calf.

Other Cattle Stocking Density:

$$SD_o = (a + b \times 0.7 + c \times 0.4) / \text{area}, \quad (2)$$

where SD_o is the stocking density of other cattle, a = cattle > 2 years old, b = cattle 1-2 years and c = cattle < 1 year.

Sheep Stocking Density:

$$SD_s = (a \times 0.23 + b \times 0.21 + c \times 0.17) / \text{area}, \quad (3)$$

where SDS is the sheep stocking density, a = number of rams, b = ewes and c = other sheep.

The overall stocking density SD is given by:

$$SD = SD_c + SD_o + SD_s \quad (4)$$

Horner et al (1984) used similar coefficients to account for the national herd of 7.1 million cattle livestock equivalents in 1980. This broke down as 39.5% breeding cattle, 40.6% dry cattle, 9.3% cattle under 1 year old and 9.4% sheep.

Table 1: Total livestock density* over the years 1970-1991, averaged by province in LU/ha.

Province	Geographic Area	Livestock Density LU/ha in *Census Year*		
	km²	**1970**	**1980**	**1991**
Connaught	17137	0.64	0.71	0.78
Leinster	19073	0.88	0.96	1.15
Munster	24016	0.82	0.97	1.07
Ulster	8014	0.55	0.66	0.77
Overall	68240	0.76	0.86	0.98

* In Tables 1-5, the livestock census in LUs (livestock units) may be obtained by multiplying the livestock density by the geographic area in km² multiplied by 100 to bring it to hectares.

Overall Livestock Densities Table 1 gives a provincial summary of the changes in overall livestock density estimated from the agriculture census taken in 1970, 1980 and 1991. There has been an upward trend in livestock density over the period since 1970 and this is clearly evident in Figures 1-3 which show that the overall increase in the livestock density is generally observed in all areas.

Fig. 1 : Total Livestock Density (Census 1970)

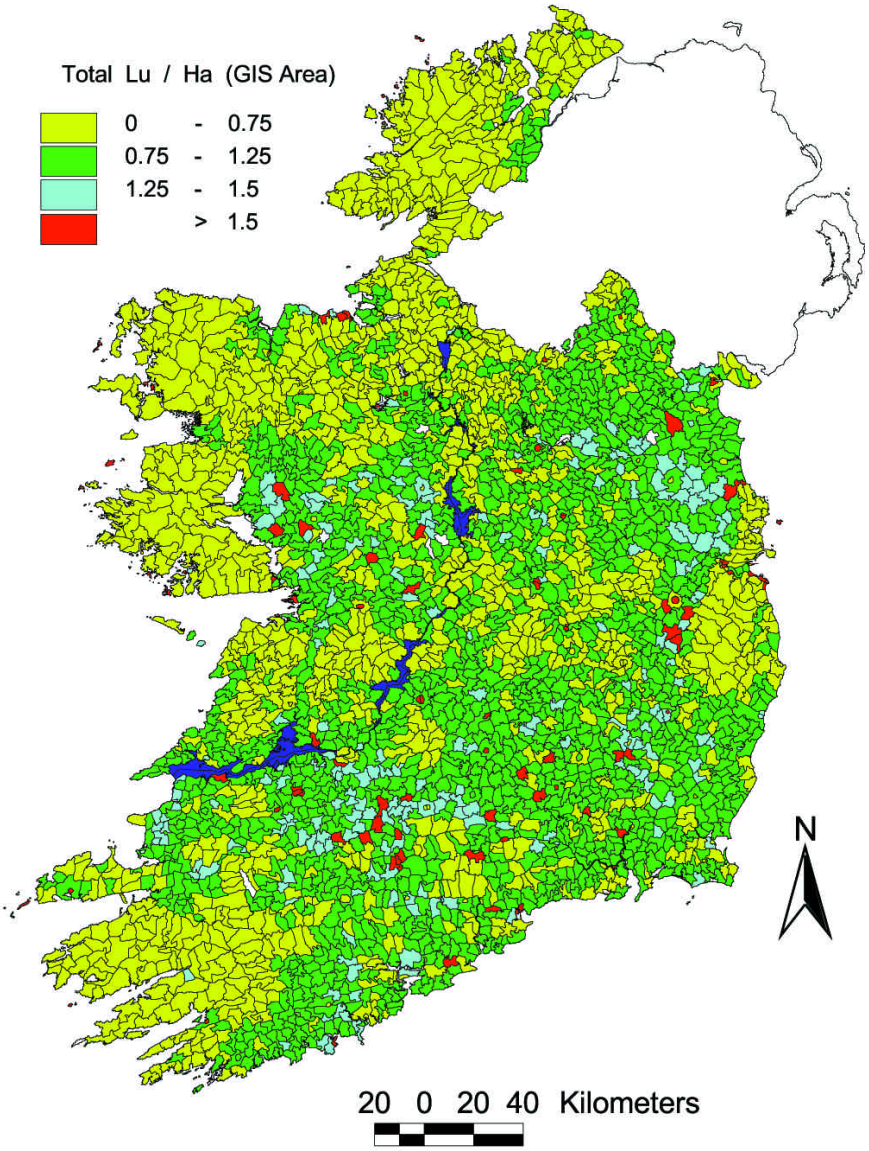

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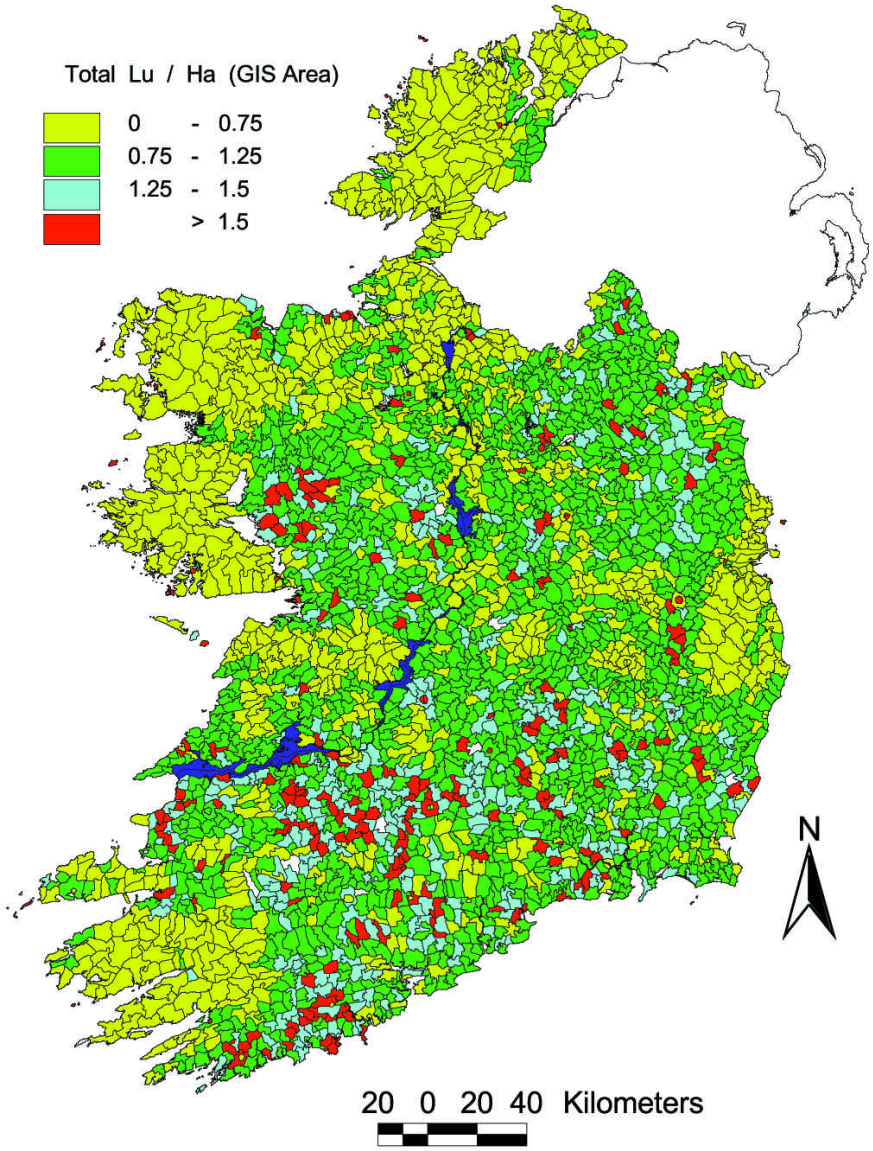
Table 2 shows the estimated livestock density changes on a county basis. With the exception of County Dublin, all counties show an

Table 2: Total livestock density over the years 1970-1991, averaged by county in LU/ha.

County	Geographic Area	Livestock Density LU/ha in **Census Year**		
	km²	**1970**	**1980**	**1991**
Carlow	897	1.02	1.05	1.49
Cavan	1912	0.83	0.97	1.04
Clare	3191	0.71	0.80	0.82
Cork E.R.	4014	0.94	1.12	1.27
Cork W.R.	3299	0.72	0.95	1.08
Donegal	4810	0.36	0.42	0.56
Dublin	363	0.81	0.69	0.73
Galway	5881	0.69	0.74	0.90
Kerry	4725	0.58	0.68	0.82
Kildare	1691	0.90	0.87	0.99
Kilkenny	2064	0.95	1.12	1.38
Laois	1723	0.81	0.94	1.11
Leitrim	1527	0.56	0.63	0.58
Limerick	2733	1.06	1.22	1.19
Longford	1042	0.76	0.89	0.91
Louth	824	0.90	0.89	1.08
Mayo	5491	0.51	0.58	0.63
Meath	2302	1.17	1.12	1.35
Monaghan	1292	0.84	1.06	1.17
Offaly	1992	0.70	0.86	0.96
Roscommon	2444	0.84	0.94	0.94
Sligo	1794	0.67	0.72	0.76
Tipperary N.R.	1991	0.88	1.04	1.19
Tipperary S.R	2250	1.00	1.12	1.29
Waterford	1813	0.82	1.00	1.16
Westmeath	1798	0.89	0.99	1.03
Wexford	2354	0.91	1.05	1.36
Wicklow	2023	0.63	0.69	0.93
Overall	68240	0.28	0 26	0.22

Fig 2 : Total Livestock Density (Census 1980)



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increase in density over the years.

- In order to explain the uniform increase in overall livestock density it is necessary to review the stocking density of cows and replacements, other cattle and sheep, in recent years. These were discussed in detail in Coulter et al (1998). However, Tables 3 – 5 summarise the changes in cows and replacements, other cattle and sheep livestock densities at provincial level.

- Table 3 shows that with the exception of Munster, the density of cows and replacements decreased in all provinces between 1970 and 1980 and again between 1980 and 1991. In Munster, there was an increase between 1970 and 1980 and a subsequent decrease to 1991. Examination of more detailed data (Table 13 in Appendix 1) shows that, with the exception of County Clare in which there was a uniform decrease, this trend was apparent at county level. Examination of cows and replacements numbers at DED level (Coulter et al, 1998) showed that the declines were most

Table 3: Cows and replacements livestock density over the years 1970-1991, averaged by province in LU/ha.

Province	Geographic Area	Livestock Density LU/ha in *Census Year*		
	km^2	1970	1980	1991
Connaught	17137	0.18	0.10	0.06
Leinster	19073	0.26	0.22	0.20
Munster	24016	0.38	0.43	0.36
Ulster	8014	0.21	0.18	0.14
Overall	68240	0.28	0.26	0.22

apparent in those geographic areas where the smallest herds were most concentrated.

- In contrast with cows and replacements, the livestock density of other cattle increased greatly over the years 1970 – 1991 with the largest increase apparent in Connaught between 1970 – 1980, followed in this case only by a small contraction. The increase in the beef livestock density was observed in Coulter et al (1988) for almost all DEDs where the expansion in the beef sector was

Table 4: Livestock density of cattle other than cows and replacements from 1970-1991, averaged by province in LU/ha.

Province	Geographic Area	Livestock Density LU/ha in *Census Year*		
	km^2	1970	1980	1991
Connaught	17137	0.32	0.50	0.47
Leinster	19073	0.50	0.64	0.65
Munster	24016	0.39	0.49	0.58
Ulster	8014	0.28	0.40	0.43
Overall	68240	0.39	0.52	0.55

attributed to a decline in the dairy sector, particularly in Connaught. More detailed data at county level is given in Table 14 in Appendix 2.

- With the exception of Ulster, provincial sheep stocking densities decreased between 1970 and 1980 and then increased markedly to the 1991 levels (Table 5). This is in marked contrast to cows and replacements in Table 3, which showed uniform decreases and to other cattle (Table 4), which showed uniform increases. The

Fig 3 : Total Livestock Density (Census 1991)

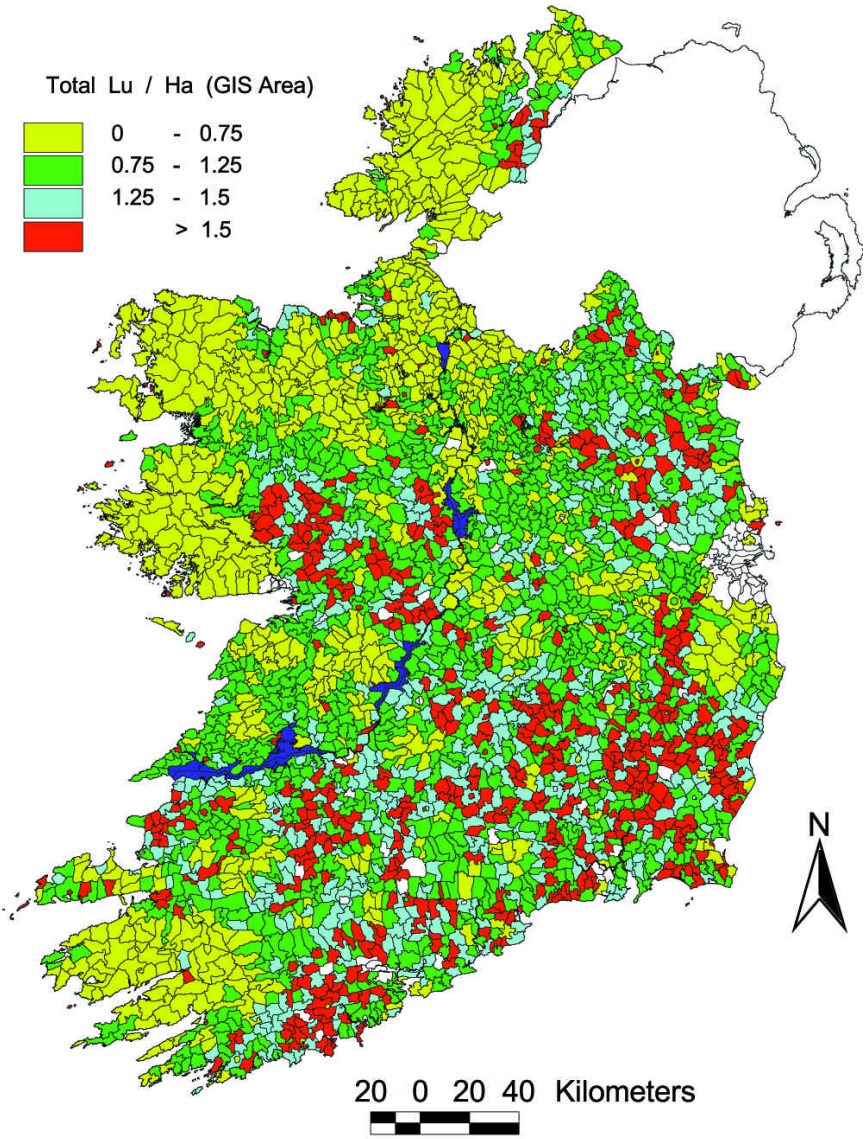

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Table 5: Sheep livestock density over the years 1970-1991, averaged by province in LU/ha.

Province	Geographic Area	Livestock Density LU/ha in *Census Year*		
	km^2	1970	1980	1991
Connaught	17137	0.14	0.11	0.24
Leinster	19073	0.13	0.09	0.30
Munster	24016	0.05	0.04	0.14
Ulster	8014	0.06	0.07	0.20
Overall	68240	0.10	0.08	0.22

increases between 1980 and 1991 are very striking and are apparent in every county (Table 15 in Appendix 3) and in almost every DED in the country (Coulter et al, 1998).

- It is thus clear that overall stocking density is a composite effect of many factors that have affected cows and replacements, other cattle and sheep stocking levels. In many cases, the increases between 1970 and 1980 are smaller than between 1980 and 1991 (Tables 1 and 2). This is due to the increases in other cattle compensating for the drop in cow numbers. In some counties, particularly the Munster counties, there were large increases in the period 1970 to 1980. This was caused by the combination of increases in both dairy and beef cattle with minimal changes to very low sheep livestock densities at that time.

- In all counties there were increases in overall densities between 1970 and 1991. This was due mainly to large increases in cattle other than cows and their replacements and also a large increase in sheep in the 1980-1991 period. There were relatively smaller decreases in cows and replacements for the whole period.

NATIONAL SOIL LIME, P AND K LEVELS AND FERTILISER USAGE

- Maps showing the average lime requirement of soil samples and the mean values for P and K over the years 1993 – 1997 are shown in the following pages. In addition, the nutrient advice issued by the Soils Laboratory at Johnstown Castle for the 1997-1998 season is also given in map form. These national maps show the element status averaged within 100 km^2 squares according to the national grid for the period 1993-1997. Each grid-square on the map is a 10 x 10 km square based on the national grid and represents the mean of between 3 and 940 soil samples (150 on average). The number of samples per grid-square is illustrated in Figure 4, which shows that only 15 squares out of a total of 845 have no information. The soil samples received by the laboratory are reasonably representative of farmland in the country as a whole. Farmers at all levels of fertility have their soils analysed periodically. With poorer farmland this may be in order to improve fertility while, with the better land, farmers wish to economise on inputs when the fertility is already high enough. However, analysis costs money so farmers in some of the poorer regions make less use of soil analysis as evidenced by the location of the grid squares with very little fertility information.

Fig 1 : Soil Samples Analysed 1993 - 1997

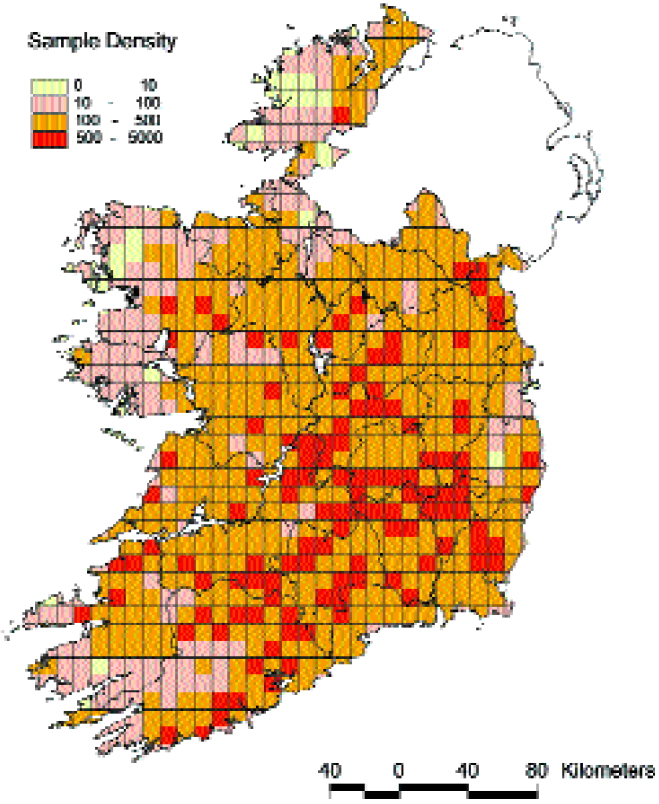
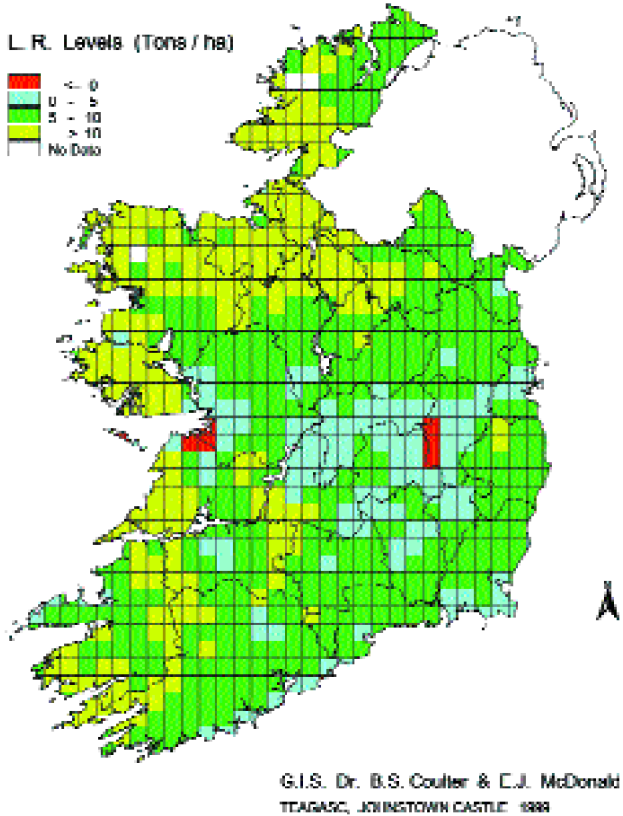


Fig 5 : Mean Lime Requirement in Soils 1993 - 1997



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- The index breakpoints for soil analytical values of P & K are shown in Table 6 together with the interpretation of nutrient requirement for optimal cropping, as used for grassland. There is no index system for lime requirement and the maps drawn in use the arbitrary breakpoints of greater than 10, 5.1 - 10, 0.1 – 5 and 0 or less t/ha as shown in Table 6.

Table 6: Index system and soil test range for soil lime requirement, phosphorus and potassium.

Element Index	Lime*t/ha	P mg/l	K mg/l	Interpretation of P and K Index	
1	> 10.0	0.1-3	1-50	Treatment Reponse:	Definite
2	5.1 -10	3.1-6	51 - 100		Likely
3	0.1 - 5	6.1-10	101 -150		Transition
4	0 or less	>10	> 150		Tenuous

* Lime Reguirement does not have an index system as such, but these levels are used on maps in Figures 4-5.

- The mean values for lime, P and K by province are given in Tables 7 – 9. The number of soil analysis results that go to make up each value is very large.

  There are 206311 values overall, and the numbers in Connaught, Leinster, Munster and Ulster are 31732, 79849, 83183 and 11547 respectively,

LIME REQUIREMENT

- The national variation in lime requirement is illustrated in Figure 5 and the provincial averages are given in Table 7. Most of the variation can be explained on the mineral soils, by farming system, soil type and region. The more acid soils in the west, northwest and southwest of the country are due mainly to the presence of old unlimed pastures and peat soils. The grassland in this area is dominated by extensive cattle farming and wet soils.

- The lower lime requirement average in the midlands, the east and the south is most likely to be associated with soil type. In the midlands, the soils are mostly derived from limestone. In the east and south, the soils are well suited to tillage crops and were well limed in the past.

Table 7: Average lime requirements in t/ha for the provinces: 1993-1997.					
Lime Requirement					
Province	**Mean**	**Percentage of Samples with LR Values**			
	t/ha	***≤ 0***	***0-5***	***5.1-10***	***>10 t/ha***
Connaught	8.2	8.5	20.2	35.5	35.8
Leinster	5.5	13.8	33.9	35.3	17.0
Munster	7.3	8.0	28.3	34.5	29.3
Ulster	9.0	2.3	20.1	37.0	40.6
Overall	7.3	10	28.7	35.1	26.2

PHOSPHORUS

Available Phosphorus (P) in Soils

- The distribution of available phosphorus levels in Irish soils is illustrated in Figure 6 and a provincial summary is given in Table 8. Many of the high phosphorus regions can be explained by either the type of land use, or by the properties of the soils found in the area. High levels in Louth, east Dublin and south east Wexford (Leinster) are due to a combination of soil type effects and extensive tillage farming. High levels in east and north Cork are due to a combination of intensive dairying and tillage on very good soils. In northwest Kerry, a combination of tillage on light textured soils gives elevated phosphorus levels while in west Clare and south Galway tillage on shallow calcareous soils is the most likely explanation. High levels in Carlow, Laois and south Kildare is associated with intensive tillage on limestone derived soils while the high phosphorus region in Cavan, within the rather low Ulster region, is probably due to the intensive poultry and pig enterprises in this county.

Table 8: Average soil phosphorus contents in mg/1 for the provinces: 1993-1997.

Phosphorus					
Province	**Mean**	***Percentage of Samples with P Values***			
	mg/l	***0-3***	***3.1-6***	***6.1-10***	***>10 mg/l***
Connaught	7.7	21.0	33.9	22.6	22.5
Leinster	8.2	20.8	33.5	22.1	23.7
Munster	8.2	16.4	33.7	25.2	24.7
Ulster	6.3	27.9	38.8	19.4	13.9
Overall	7.7	19.4	34	23.3	23.3

- An interesting feature of the map is that most of the grid squares have phosphorus levels above 6mg/l. If the map could be drawn with 1950 data, most of the squares would have been in the 0-3 category. Indeed many of them would have had no information since soil testing was then in its early stages in Ireland and very few soils were sent for analysis. The increase in soil analysis was very influential in improving the fertility of our soils.

Fig 6 : Mean Phosphorus in Soils 1993 - 1997

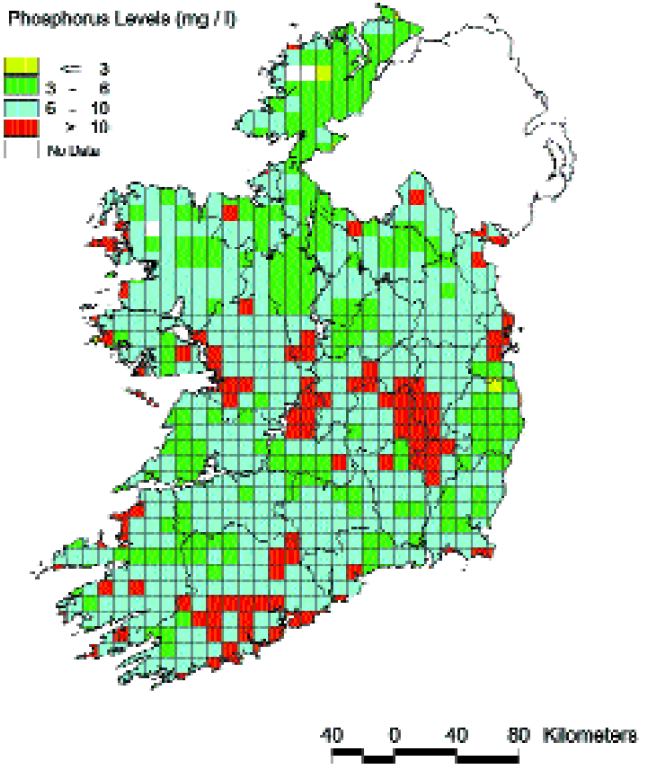
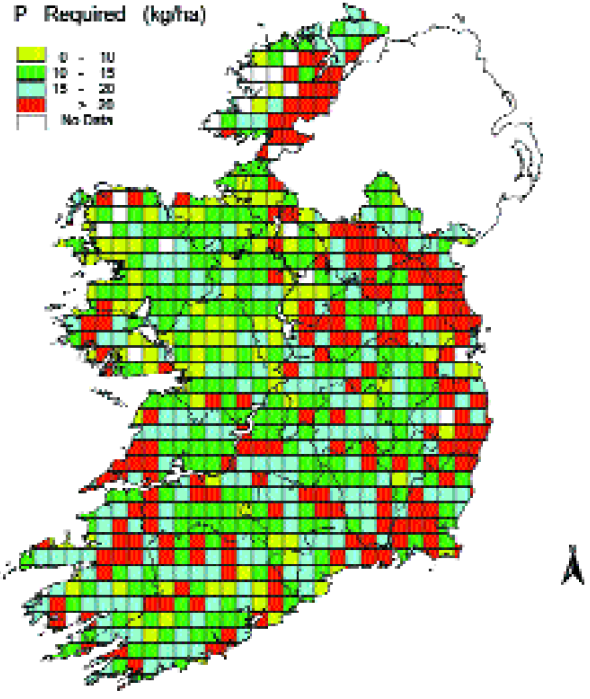


Fig 6 : Total P Nutrients Advised May '97 - April '98
(Fertiliser and Organic Manure)



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Total P Nutrients Recommended for Grassland

- The phosphorus fertiliser advice for optimum crop growth on grassland soils, based on soil analysis by the laboratory at Johnstown Castle over the period May 1997 to April 1998, is illustrated in Figure 7. The P required by crops can be supplied either by fertiliser P and/or by slurry and organic manure. The advice given by the laboratory depends on the soil test results, the crops grown and the stocking rates. It also assumes that the P in the slurry will be used effectively. The laboratory advice or recommendation on which the map is based assumes that animal manure will be applied to the silage ground at the rates specified by the farmer or at an assumed rate of 33,000 litres per hectare of silage if no information is given.

Fig 8 : Phosphorus Supplied by Organic Manure
(1997 / 1998)

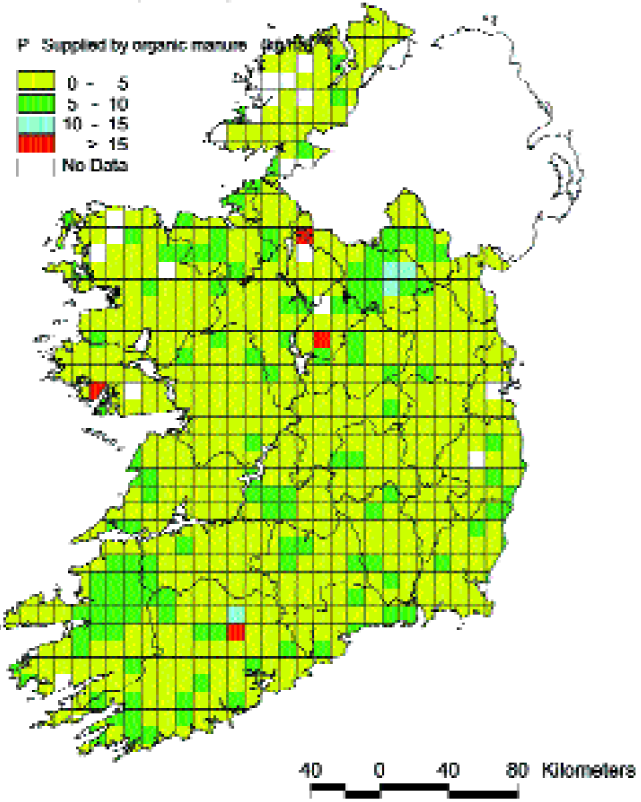
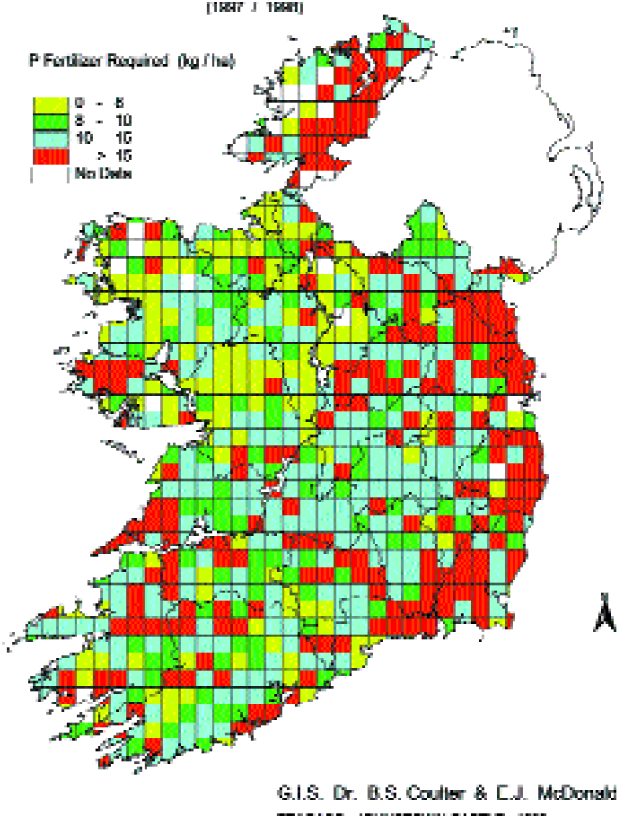


Fig 9 : Phosphorus Fertiliser Required
(1997 / 1998)



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Phosphorus supplied by organic manure

- Figure 8 shows how much of the P recommended for grassland based on soil analysis can be supplied by organic manure. The information was calculated from information supplied by the farmers and their advisers when submitting the soil samples. Thus, the total nutrient application rates advised by the laboratory are based on the soil test and the information supplied. They are dependent on the number and type of livestock, the amounts of concentrates imported to the farm and the length of the winter housing period. The average estimated amounts are illustrated in Figure 8. The data mapped, is the amount of the nutrient advised that was supplied by organic manure. Nutrients supplied in excess of requirements were not used for the maps. Thus areas where there were low requirements of nutrients are shown as areas of low nutrient supply by organic manure.

- Those areas of medium or high supplies of P from organic manure received much of the P from nearby of pig and poultry enterprises, and at the same time had a high P requirement. In intensive dairy areas, the use of concentrate feeds for high yielding cows made a small contribution.

- Figure 8 shows that the greatest amounts of P supplied by organic manure are concentrated in North Kerry, North Cork and Sligo/East Donegal; and these correspond main with high livestock density areas (including pigs). There is another contiguous area of high values in Cavan/Monaghan, this corresponds to an area of high stocking densities allied with heavy densities of pig and poultry production.

Mineral Phosphorus Fertiliser Required

- Figure 9 shows the amount of mineral fertiliser P advised for crops. This was calculated in the laboratory by subtracting the organic manure contribution from the total P nutrients required. Greater amounts of fertiliser P were required in the east of the country because of relatively low soil P, higher stocking rates, farming systems using low levels of concentrates and the absence of large scale pig and/or poultry enterprises. The map shows considerable variation in utilisation of organic manure throughout the country. In some areas, such as north Monaghan, Leitrim and Limerick, pig and poultry farms are important sources of the P supply for grassland while in most others, manures from dairy and drystock contribute much of the P requirements for grassland.

POTASSIUM

Available Soil Potassium (K) Levels

- The geographic distribution of potassium levels, illustrated in Figure 10, shows that the level of K reveals the influence of specific physical variables. The areas showing low soil K content, (the national average for all samples is 108 mg/l) are strongly coincident with areas where the solid geology is limestone. Potassium fixing soils frequently form under this limestone influence. Fixation occurs when available K is rendered unavailable by interaction with clay minerals, and is associated with the drying-out of these soils. This may explain why the eastern counties Dublin, Kildare, Laois, Meath and Offaly (Leinster in Table 9) have lower soil K and more green areas than the wetter western counties. This is apparent also in Table 9 where Ulster and Connaught (north and west) show higher K values than the rest of the country.

Table 9: Average soil potassium contents in mg/1 for the provinces: 1993-1997.

Potassium					
Province	**Mean**	***Percentage of Samples with K Values***			
	mg/l	***0-50***	***51-100***	***101-150***	***> 150 mg/l***
Connaught	120	10.0	34.8	28.5	26.7
Leinster	107	17.1	37.2	24.8	20.9
Munster	104	17.2	39.0	24.8	19.0
Ulster	122	10.9	32.9	28.0	28.2
Overall	113	14.7	36.6	26.1	22.7

- The remainder of the country shows a variety of geological influences, particularly Old Red Sandstone, Ordovician Shale and Granite. Samples taken from peaty soils may give high K readings, but these are not classified as high agronomically because they do not have the K reserves of mineral soils. High soil K is also found in tillage areas where sugar beet, potatoes and vegetable crops are grown, except where there is K-fixation. Fertiliser use has had a considerable impact on soil K test values over the entire country. The average value of tested soils is now around 108 mg K/l; in 1954 it was 22 mg/l.

Fig 10 : Mean Potassium in Soils 1993 - 1997

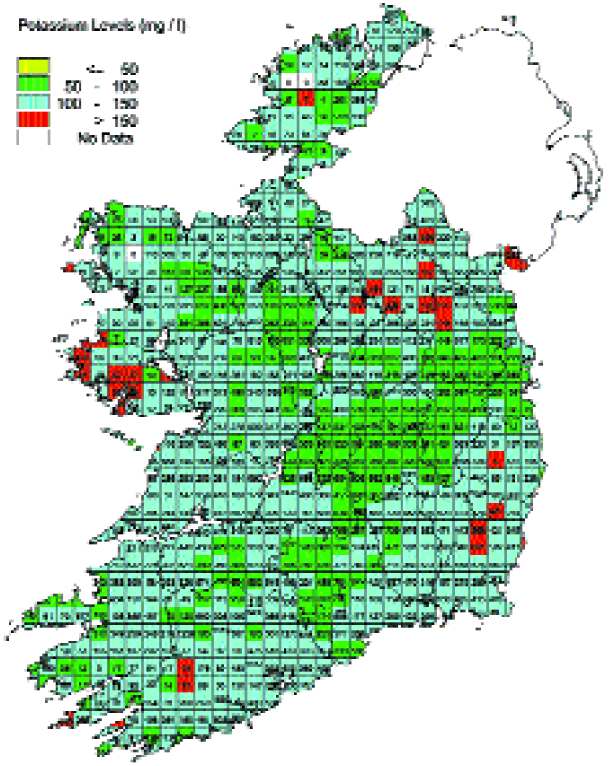
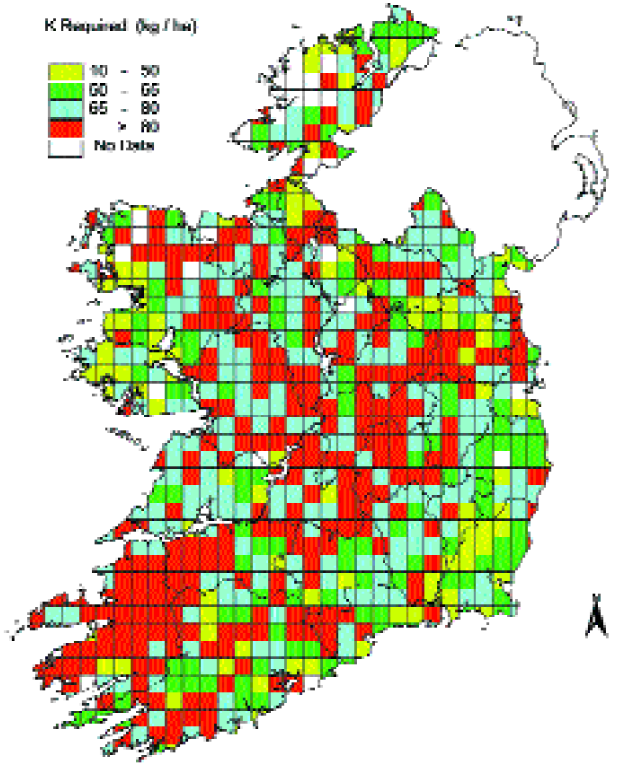


Fig 11 : Total K Nutrients Advised May '97 - April '98
(Fertiliser and Organic Manure)



40 0 40 80 Kilometers

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Potassium fertiliser advice for grassland

- The potassium fertiliser advice for optimum crop growth on grassland soils, based on soil analysis by the laboratory at Johnstown Castle is illustrated in Figure 11 for the period May 1997 to April 1998. This map is inversely related to Figure 10, that is, areas with the greater total K advised rates correspond with those areas with lower mean K in soils. Thus soils in West Wexford, West Galway/Mayo, North Donegal and North Meath/South Cavan tend to have very low K requirements while a considerable part of the country has very high K requirements. The amounts of K removed from the soil by grassland farming are relatively low when all the organic manure generated by the ruminant livestock is returned to the silage and hay areas. In some cases farm management considerations such as transport distances and limited accessibility prevent the return of organic manure and hence a requirement for extra fertiliser K in hay and silage fields.

Potassium supplied by organic manure

- The amount of animal manure estimated to be available to grassland assuming that all of the animal manure produced in over wintered cattle is applied to the silage ground is given in Figure 12. It suggests that in those areas where the K supplied by organic manure was highest, extra silage was required because of high stocking rates and longer winters.

Mineral Potassium Fertiliser Required

- Figure 13 shows fertiliser K application rates recommended by the laboratory in addition to animal manure. It represents the difference between total K requirement and the amount supplied by organic manure. In most of the country, the amounts of fertiliser K required are low, even though the soil K levels for the same areas are also fairly low. This reflects the large quantities of K that are available in slurry or FYM. Thus, the map highlights the value of K in manures, and shows that if organic manures are not recycled properly, the cost of fertilising grassland will be much higher. The fertiliser K application rates advised by the laboratory were highest in areas of low soil K. Intensive pig and poultry areas showed the lowest levels of requirement for fertiliser K.

Fig 12 : Potassium Supplied by Organic Manure
(1997 / 1998)

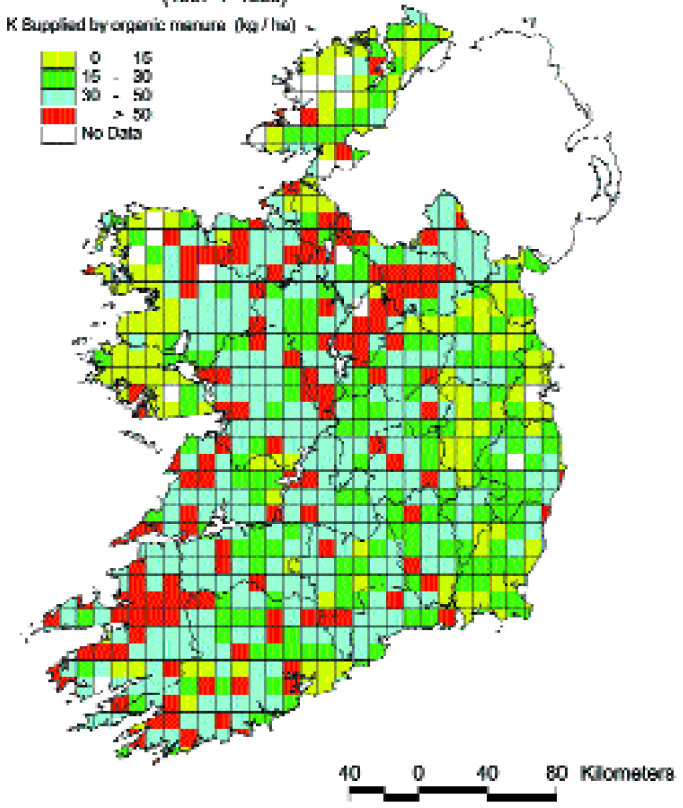
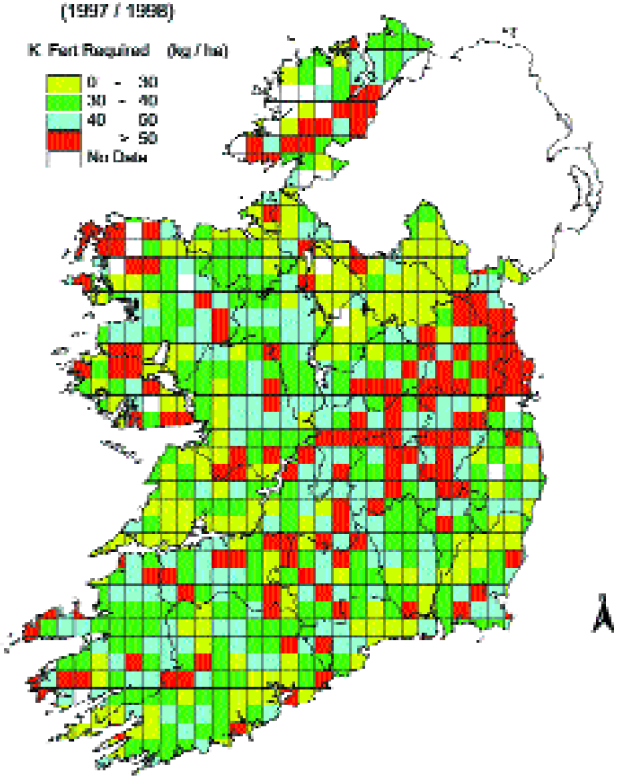


Fig 13 : Potassium Fertiliser Required
(1997 / 1998)



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DETAILED SOIL P AND K MAPPING AT CATCHMENT LEVEL

- The mapping of soil analysis results and recommendations in the last section was based entirely on knowledge of the location of the soil sample. From about 1965, this location, or geo-reference was obtained by advisors and samplers from a specially printed map showing 10 km x 10 km squares on the national grid. While this has enabled some very useful maps to be produced (e.g. the previous section in this report and in Nutrients and Trace Element Status of Grassland Soils in Coulter et al, 1999), the discrimination between areas is not accurate enough for many purposes. In particular, there is a national need to provide detailed soil nutrient maps of river catchments, maps useful for this purpose would require area discrimination at least at the level of a DED which have a typical area of 24 km^2.

- Recently, the Soil Laboratory at Johnstown Castle has requested that soil samplers use the system of 'Land Parcel Identification Numbers' (LPIN) produced by the Irish Department of Agriculture and Food to geo-reference the samples instead of the former 10 km grid squares system. This system is very precise as LPIN codes identify an area the size of a large field. It uses a code in two parts, the first part consists of a letter followed by 5 numeric digits; the second part consists of up to 5 numeric digits. The letter identifies the county and the next three digits specify the district electoral division (DED) within the county.

- The final two digits of the first part specify the townland code within the DED. A townland is a bounded, named and mapped subdivision of the DED, with an area between 10 and 1000 ha which is mainly used for postal delivery purposes. There are approximately 54,000 townlands in Ireland and a rural DED may contain from 3 to 90 townlands within it.

- The next 5 digits of the LPIN specify the land parcel within the townland. The LPIN will become a very precise and valuable aid to mapping, but is not yet used to an adequate extent to provide sufficient coverage for mapping. Many advisors and samplers, who do not know the full LPIN, can provide the first four digits of the code. This identifies the DED in which the sample lies and as the area of a DED is about 24 km^2, this is consequently much more accurate than the previously used grid squares, which have an area of 100 km^2. Using one of these code systems, mapping of soil analytical parameters will be possible as the locations and boundary lines of DEDs, townlands and LPINs are available from the Ordnance Survey Office in Dublin.

A computer program for address geo-referencing

- Irish postal addresses do not contain a zip code making it difficult to obtain geographic co-ordinates (geo-reference) for data, based only on the location address. In general however, the addresses of farms often contain the name of the nearest town or village. Daly and Mills (1999) produced a fairly detailed map of soil phosphorus levels by linking the farm address of the samples to a GIS database of town and village names and locations. They achieved a match with about 50% of the samples. Examination of unsuccessful matches and introduction of alternative spellings for many of the commonly used names in the address fields extended this to 66%. However, there may be an uncertainty in location if only town and village names are use for geo-referencing as postal address sometimes contain a town name which is used for postal sorting and may not be near to the farm or even in the same county.

- A computer program was written in Foxpro database language to determine the appropriate townland, town or DED for a large number of farm addresses contained in a database table. In order to design the most effective program, a sample of typical farm addresses from the River Shannon region was examined. This showed that most of the addresses contained townland names and sometimes, but not usually the name of a town or village.

- A database table was constructed with a record for each townland and town in the study area. A program was written which used the strategy of comparing each of these records in turn to the list of farm addresses to determine if the farm address contained the townland or town in question. Since each townland or town record would be compared with every farm address, it was likely that multiple occurrences of concurrence or 'hits' would occur. It was thus necessary to prioritise the type of hit and record all the hits and their priority in the farm address record as they occurred.

- The program was designed to follow 5 logical steps or 'passes' as detailed in the following paragraphs. These demonstrate the types of hits that were catered for in the program and the action taken.

Pass 1: Full townland name found in address

Action: The address record is flagged as having had unique agreement and the town land name, townland code and DED name and code (taken from the townland record) are stored in the farm address record. Details of the action are recorded in a memo file attached to the address record in case there are multiple hits due to ambiguity of the townland records.

Pass 2: First word of townland name found in address

Action A: If the address record is not flagged as having already had unique agreement, the townland name, townland code and DED name and code (taken from the townland record) are stored in the farm address record.

Action B: If the address record is ***already*** flagged as having already had a unique agreement hit, the townland name, townland code and DED name and code in the address record are left unchanged.

In either event, details of the action are recorded in a memo file attached to the address record.

Pass 3: Town or village name found in address

Action A: If the address record is ***not*** flagged as having already had unique agreement, the town name and code and DED name and code (taken from the townland record) are stored in the farm address record.

Action B: If the address record is ***already*** flagged as having already had a unique agreement hit, the townland name, townland code and DED name and code in the address record are left unchanged. Because townland records are stored in the table before town/village name records, this will give automatic priority to townland names.

In either event, details of the action are recorded in a memo file attached to the address record.

Pass 4: First word of DED name found in address

Action A: If the address record is ***not*** flagged as having already had unique agreement, the DED name and code (taken from the townland record) are stored in the farm address record and the townland name and townland code are left blank.

Action B: If the address record is ***already*** flagged as having already had a unique agreement hit, the townland name, townland code and DED name and code in the address record are left unchanged.

In either event, details of the action are recorded in a memo file attached to the address record.

Pass 5: No townland, town or DED found in address but DED code given with sample

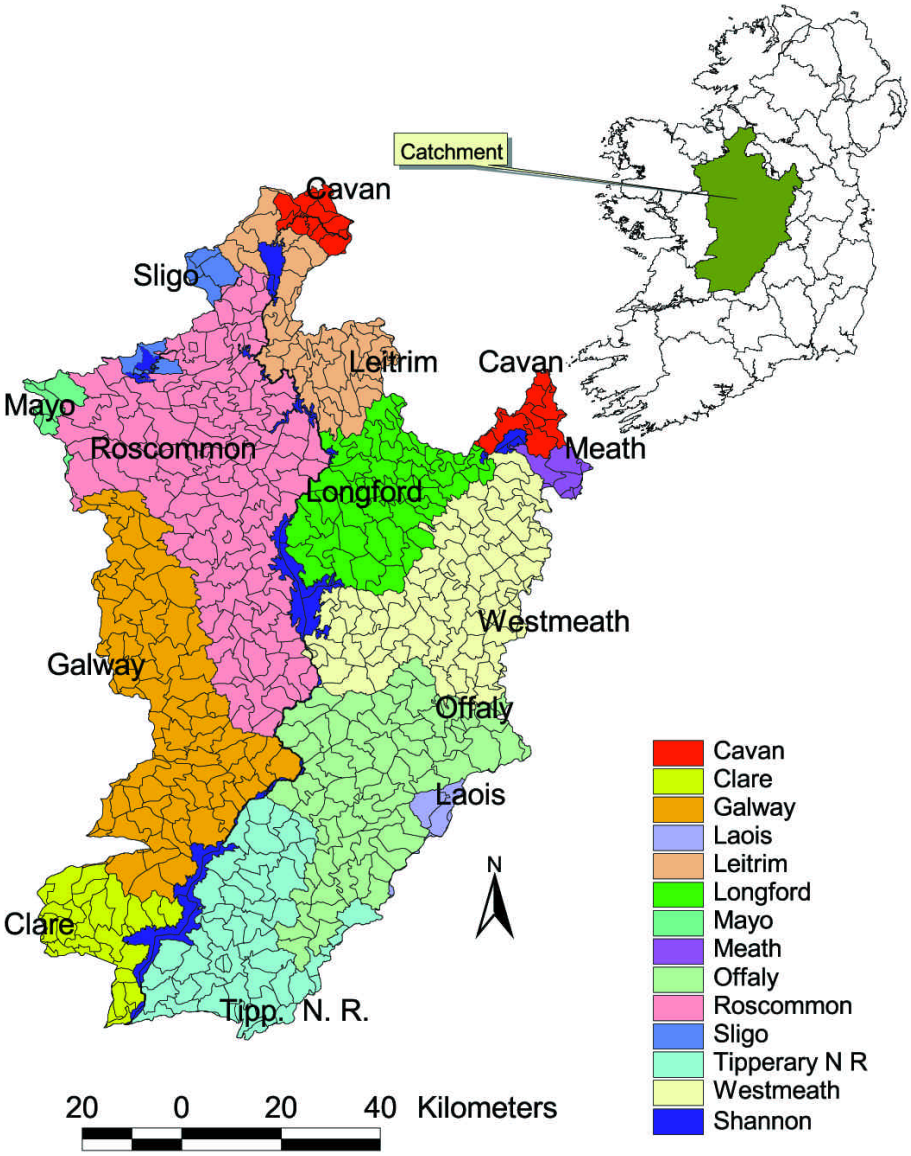
Action A: If there has been no other kind of hit, the DED name and code (taken from the database table of all DED codes) are stored in the farm address record and the townland name and townland code are left blank.

Action B: If there has been any kind of address hit, the townland name, townland code and DED name and code in the address record are left unchanged.

Procedures and Methods

- Generation of a detailed database and map of soil P levels for townlands and DEDs of the Lough Derg/Lough Ree catchment system was used to test the computer program. A database table was obtained which contained the townland names, townland codes, DED names and codes and the names and codes of towns and villages for each county with land in the Lough Derg/Ree catchment. The boundary of the catchment and names and extent of the 12 counties contained within it are shown in Figure 14. To cut down on computer processing time, only townlands and DEDs within the catchment boundary of each county were included.

Fig 14 : Counties Included in Derg-Ree Catchment



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- A database table of soil sample results for the years 1997-1998 was also prepared. This included only sample results that either had a farm address or a DED code for the location of the soil sample if it was available. In some counties, a large percentage of samples did not have sufficient address information to allow address geo-referencing. The County Agricultural Officers kindly arranged for this address information to be supplied.

- A trial run of the program was run in order to test the effectiveness of the different steps in the address geo-referencing process. The database tables were restricted to the counties Sligo and Roscommon to speed up the test. The program was instructed to stop after each pass so that the accumulated number of hits registered after each pass could be enumerated. The number of hits recorded after each step of the process is given in Table 10.

Table 10: Recorded hits in geo-referencing process for soil samples for Sligo and Roscommon

Program Step	Logical Process used in Program	Hits	Success Rate %
Pass 1:	Full townland name found in address	1371	43
Pass 2:	First word of townland name found in address	1431	45
Pass 3:	Town or village name found in address	1968	62
Pass 4:	First word of DED name found in address	2434	76
Pass 5:	No information in address but DED code available	2481	78

- The table shows that the greatest success was obtained from the full townland name (43%) with an additional 2% obtained by allowing a match with just the first word of the name. The full town/village name was very useful too in that it contributed a further 17% to the success rate. Use of the DED name added 14% to the address matching.

- Several precautions were taken by the program to prevent false matching. If the first word of a DED name corresponded with a county name, the DED name was not used in the matching process. Equally, the names of county towns were not used in the towns/villages table.

Validation of the geo-referencing process

- The memo file attached to each farm address record shows the program history in deciding from which townland or DED a sample address is derived. Tables 11 and 12 show typical farm addresses and the program steps before the final choice is made. Because the address in Table 11 contained a full townland name, the program did not search the town and village names for a matching record. On the other hand, the address in Table 12 did not contain a townland name so the town/village names were utilised to deduce the DED from which the sample originated.

- The automatic geo-referencing process was checked by examination of the memo file and comparing the townland/DED arrived at by manual coding with that deduced by the computer program. The agreement was found to be over 90%. As a further check, those soil analysis records that included full DED location and had a full farm address were examined after automatic geo-referencing. The

Table 11: Typical decision path in checking the townland database during geo-referencing a farm address containing a townland name.

Result	**Farmer: CURRAGHBOY; ATHLONE; CO. ROSCOMMON**
Hit I - DED found **Hit 2 - DED found** **Hit 3 - DED found** **Hit 4 - DED found** **Hit 5 - townland found** **Decision:** ***Townland=Curraghb***	Townland; DED Name ***oy*** ***DED=Rockhill*** ***MONKSLAND;ATHLONE WEST RURAL*** ***BELLAUGH;ATHLONE WEST RURAL*** ***DOOVOGE; ATHLONE WEST RURAL***

Table 12: Typical decision path during geo-referencing a farm address containing a town name.

Result	**Farmer: FOUR ROADS; CO. ROSCOMMON**
Hit I - Town found **Decision: Town=Four**	Town; DED Name ***Roads DED=Lismara*** ***FOUR ROADS; LISMAHA***

agreement was found to be excellent.

Results and Discussion

- When the computer program was found to give reliable results, it was rerun using the full table of townlands and DEDs in all the counties in the Lough Derg/Ree catchment. The process took over 12 hours of processing time on a fast computer and yielded a memo file over 200 MB in size. However, more than 84% of the soil records were successfully geo-referenced.

- In order to plot the data, a new table was produced giving the mean P and K in DEDs in the Derg/Ree catchment. This table was linked to a map of DEDs in the catchment and maps of the P and K fertility of the catchment were produced by ArcView GIS techniques (Figures 15 and 16).

Fig 15 : Derg - Ree Phosphorus Levels

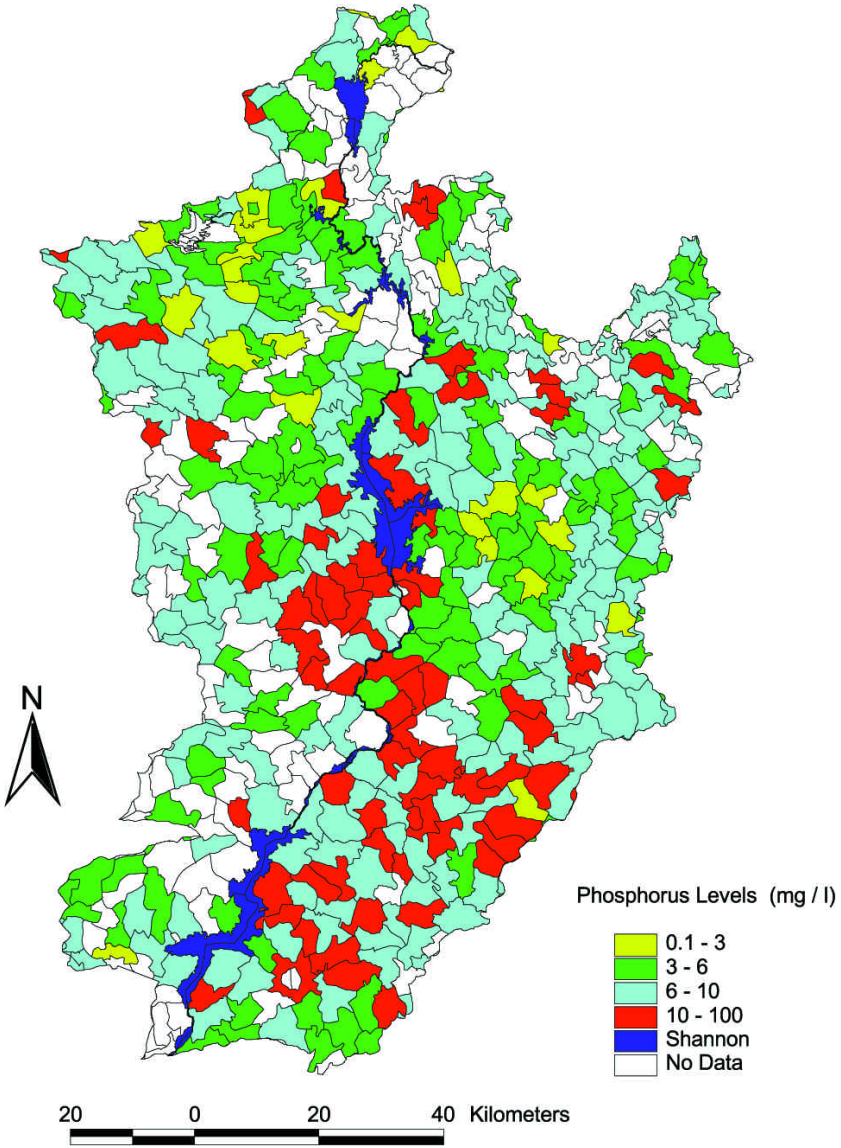

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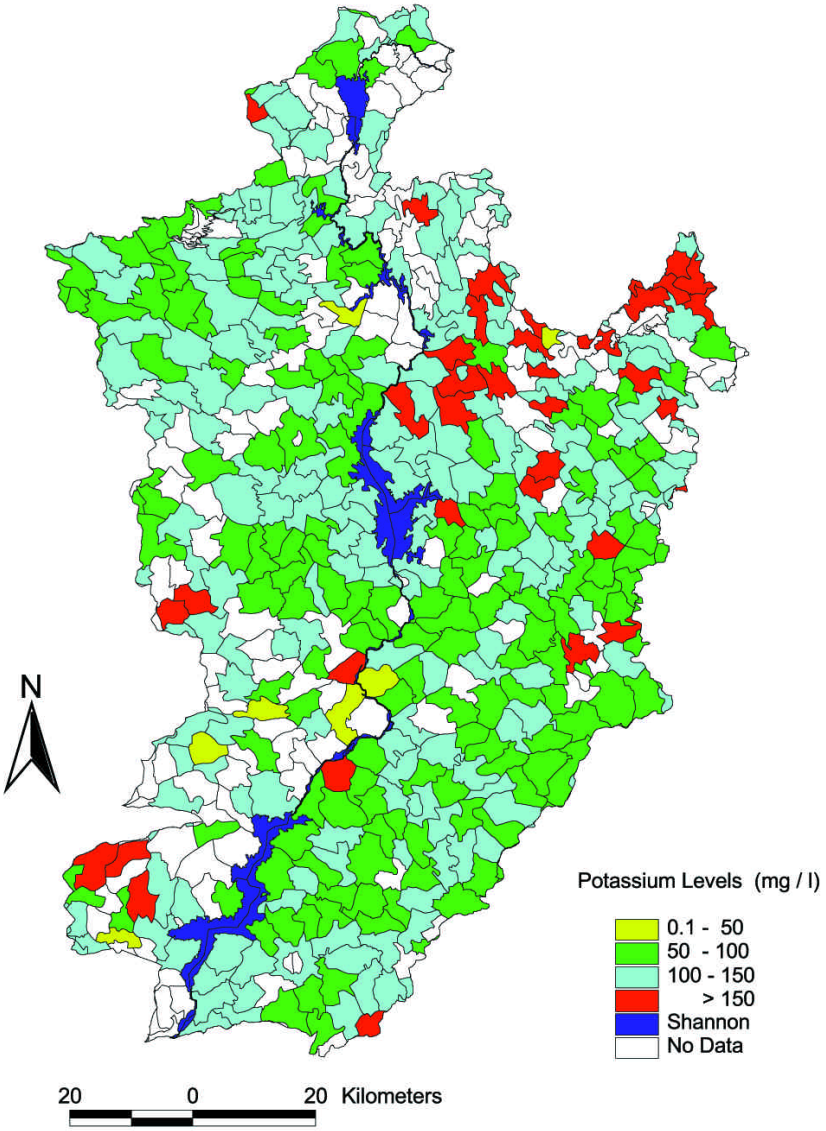
Fig 16 : Derg - Ree Potassium Levels



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- Figure 15 shows the average soil P levels for the catchment. Some of the DEDs are blank. These are areas from which no soil samples were received. The P level in most of the catchment is above 6 mg/l i.e. at soil P index 3 or 4. The highest levels appear to be mainly associated with mineral fertiliser P loading of soil from grassland and crops, together with organic P loading of soils by animals grazing in the area (B. Coulter, unpublished information and Duggan, 1999).

- Figure 16 shows the average soil K levels for the catchment. Again, areas from which no soil samples were received are blank. The K level in 50% of the catchment is above 100 mg/l i.e. at soil K index 3 or 4. This is above the national average. The highest levels appear to be mainly associated with organic K loading of soils by animals grazing in the area (B. Coulter, and P. Duggan, loc cit).

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We wish to thank Mr Gerry Brady of the Central Statistics Office, Skehard Road, Cork for supplying data for the national agricultural census in machine readable form. We also wish to thank the CAOs in the counties within the Lough Derg/Ree catchment for supplying farm address information for the soil samples. We are grateful to Mr Pat Duggan of the Lough Derg and Lough Ree Catchment and Monitoring Project for geographic information concerning the catchment.

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APPENDIX 1: COWS & REPLACEMENTS STOCKING DENSITY BY COUNTY

Table 13: County Estimates of cows and replacements stocking density* over the years 1970-1991 in LU/ha

County	Province	Geographic Area km^2	Livestock Density: Cows/Replacements LU/ha		
			1970	1980	1991
Carlow	Leinster	897	0.27	0.18	0.17
Cavan	Ulster	1912	0.37	0.36	0.25
Clare	Munster	3191	0.29	0.23	0.16
Cork E.R.	Munster	4014	0.47	0.59	0.53
Cork W.R.	Munster	3299	0.37	0.46	0.40
Donegal	Ulster	4810	0.11	0.06	0.04
Dublin	Leinster	363	0.20	0.13	0.11
Galway	Connaught	5881	0.16	0.10	0.07
Kerry	Munster	4725	0.30	0.32	0.26
Kildare	Leinster	1691	0.23	0.16	0.13
Kilkenny	Leinster	2064	0.33	0.38	0.34
Laois	Leinster	1723	0.28	0.25	0.22
Leitrim	Connaught	1527	0.24	0.09	0.04
Limerick	Munster	2733	0.58	0.64	0.51
Longford	Leinster	1042	0.27	0.18	0.10
Louth	Leinster	824	0.28	0.23	0.21
Mayo	Connaught	5491	0.16	0.09	0.06
Meath	Leinster	2302	0.29	0.27	0.26
Monaghan	Ulster	1292	0.36	0.40	0.33
Offaly	Leinster	1992	0.19	0.14	0.13
Roscommon	Connaught	2444	0.20	0.10	0.04
Sligo	Connaught	1794	0.22	0.14	0.09
Tipperary N.R.	Munster	1991	0.32	0.37	0.30
Tipperary S.R.	Munster	2250	0.41	0.45	0.37
Waterford	Munster	1813	0.35	0.44	0.38
Westmeath	Leinster	1798	0.20	0.15	0.13
Wexford	Leinster	2354	0.32	0.31	0.28
Wicklow	Leinster	2023	0.19	0.15	0.13

*In Tables 13 -15, the livestock census in LUs (livestock units) may be obtained by mutiplying the livestock density by the geographic area in km^2 multiplied by 100 to bring it to hectares.

APPENDIX 2: STOCKING DENSITY OF CATTLE OTHER THAN COWS & REPLACEMENTS BY COUNTY

Table 14: County estimates of stocking density of cattle other than cows and replacements over the years 1970-1991 in LU/ha

County	Province	Geographic Area km^2	Livestock Density: Cattle LU/ha		
			1970	1980	1991
Carlow	Leinster	897	0.44	0.63	0.66
Cavan	Ulster	1912	0.44	0.59	0.67
Clare	Munster	3191	0.39	0.55	0.60
Cork E.R.	Munster	4014	0.43	0.52	0.64
Cork W.R.	Munster	3299	0.30	0.44	0.52
Donegal	Ulster	4810	0.16	0.26	0.25
Dublin	Leinster	363	0.52	0.50	0.40
Galway	Connaught	5881	0.31	0.49	0.51
Kerry	Munster	4725	0.22	0.28	0.35
Kildare	Leinster	1691	0.53	0.63	0.55
Kilkenny	Leinster	2064	0.52	0.68	0.81
Laois	Leinster	1723	0.48	0.66	0.73
Leitrim	Connaught	1527	0.29	0.49	0.40
Limerick	Munster	2733	0.48	0.57	0.64
Longford	Leinster	1042	0.49	0.72	0.69
Louth	Leinster	824	0.50	0.57	0.62
Mayo	Connaught	5491	0.25	0.40	0.37
Meath	Leinster	2302	0.73	0.78	0.79
Monaghan	Ulster	1292	0.47	0.66	0.76
Offaly	Leinster	1992	0.46	0.68	0.65
Roscommon	Connaught	2444	0.49	0.74	0.63
Sligo	Connaught	1794	0.37	0.51	0.48
Tipperary N.R.	Munster	1991	0.51	0.65	0.75
Tipperary S.R.	Munster	2250	0.53	0.63	0.73
Waterford	Munster	1813	0.39	0.50	0.61
Westmeath	Leinster	1798	0.61	0.79	0.71
Wexford	Leinster	2354	0.43	0.58	0.59
Wicklow	Leinster	2023	0.23	0.35	0.35

APPENDIX 3: SHEEP STOCKING DENSITY BY COUNTY

Table 15: County estimates of sheep stocking density over the years 1970-1991 in LU/ha

County	Province	Geographic Area km^2	Livestock Density: Sheep LU/ha		
			1970	1980	1991
Carlow	Leinster	897	0.32	0.24	0.65
Cavan	Ulster	1912	0.03	0.03	0.12
Clare	Munster	3191	0.03	0.02	0.06
Cork E.R.	Munster	4014	0.05	0.03	0.09
Cork W.R.	Munster	3299	0.04	0.05	0.16
Donegal	Ulster	4810	0.09	0.11	0.26
Dublin	Leinster	363	0.15	0.09	0.21
Galway	Connaught	5881	0.22	0.15	0.32
Kerry	Munster	4725	0.07	0.09	0.21
Kildare	Leinster	1691	0.13	0.08	0.31
Kilkenny	Leinster	2064	0.09	0.06	0.24
Laois	Leinster	1723	0.05	0.03	0.17
Leitrim	Connaught	1527	0.04	0.05	0.15
Limerick	Munster	2733	0.01	0.01	0.05
Longford	Leinster	1042	0.03	0.03	0.12
Louth	Leinster	824	0.12	0.09	0.25
Mayo	Connaught	5491	0.10	0.09	0.20
Meath	Leinster	2302	0.16	0.08	0.30
Monaghan	Ulster	1292	0.02	0.01	0.08
Offaly	Leinster	1992	0.06	0.04	0.18
Roscommon	Connaught	2444	0.15	0.11	0.27
Sligo	Connaught	1794	0.08	0.07	0.19
Tipperary N.R.	Munster	1991	0.06	0.04	0.15
Tipperary S.R.	Munster	2250	0.06	0.05	0.19
Waterford	Munster	1813	0.07	0.05	0.17
Westmeath	Leinster	1798	0.09	0.05	0.19
Wexford	Leinster	2354	0.17	0.17	0.49
Wicklow	Leinster	2023	0.21	0.19	0.45

CARTRON;ATHLONE WEST RURAL
CURRAGHBOY; ROCKHILL

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