Ir. J. agric. Econ. rur. Sociol. 8: 73-95, 1980

PRINCIPAL COMPONENTS ANALYSIS OF CHANGES IN AGRICULTURAL PATTERNS IN THE REPUBLIC OF IRELAND, 1950–1971

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ABSTRACT

Many changes occurred in agricultural patterns in the Republic of Ireland between 1950 and 1971. Changes in general land-use patterns, crop acreages, livestock numbers, farm size distributions and levels of mechanization are discussed in this paper. The emphasis in the paper is on examining by principal components analysis the intercorrelations between 27 indicators of change. The principal component was identified as describing the trend towards intensification and consolidation in agriculture, which displayed marked east-west contrasts. Other components identified related to persistence of traditional tillage practices and trends in particular crop and livestock patterns. The spatial pattern of scores on these components was more complex. To conclude the study a grouping procedure has been used to collapse the individual patterns for each component onto a single map that highlights the complexity of regional patterns of adjustment in agriculture. The paper also serves to illustrate the usefulness of principal components analysis and cluster analysis for summarizing large data sets.

INTRODUCTION

The role of agriculture in the Irish economy declined considerably between 1950 and 1971. Its share of the national total decreased from 40% to 25.5% of employment and from 64% to 38.5% of value of total exports. Significant changes occurred in many aspects of agriculture; in general land-use patterns, crop acreages, livestock numbers, farm size distributions and levels of mechanization. Many of these trends have already been described and accounted for (1, 2). These studies have highlighted the regional deviations from the national trends. In a recent study, Higgins (3) used the shift and share technique to analyze the regional deviations in the changes that had taken place between 1954–1973 in relation to particular crop and livestock enterprizes. In his study, the change in each enterprize was examined separately. In contrast, the purpose of this study is to explore the inter-relations between changes in many aspects of agriculture and to attempt to identify some independent dimensions of change. These dimensions will be extracted from a large data set through principal components analysis. Since this technique does not seem to have been widely used previously with agricultural data, a further purpose of this paper is to examine the usefulness of the technique as a tool of description in this

area. Following on the identification of the independent dimensions of change scores will be computed for each county. These will be used as input to a clustering algorithm that will produce a multivariate regionalization of Irish counties.

METHODOLOGY

The technique of principal components analysis (PCA) has been widely described (4, 5, 6, 7, 8) and used (9, 10, 11) over the last 20 years. Basically, the technique collapses an original set of N intercorrelated variables onto M orthogonal axes or components where M is less than or equal to N. The variables are related to the components by component loadings. The following is a brief outline of the procedures involved in applying this technique. For each county i measurements are taken on a number of variables j. The data are summarized in a matrix $X = (x_{ij})$ where x_{ij} is the measure of variable j in county i. PCA transforms X into a matrix $Y = (y_{ij})$ of uncorrelated component scores where y_{ij} is the score of county i on component j. The transformation is achieved as follows:

(a) A correlation matrix $R = (r_{ij})$ is formed from X. This highlights the degree of interdependency between the variables.

(b) By normal matrix orthogonalization procedures R is rewritten as:

$$R = E.\,\Lambda.\,E^T \tag{1}$$

where $\Lambda = (\lambda_{ij})$ is a diagonal matrix of the eigenvalues of R, $E = (e_{ij})$ is a square matrix of the associated eigenvectors and T denotes the transpose of a matrix.

(c) From E and Λ a square matrix of component loadings, C, is derived,

$$C = (c_{ij}) = (e_{ij}).\,(\lambda_{ij})^{0.5} \tag{2}$$

The elements of the matrix C are the correlation coefficients between the i^{th} variable and the j^{th} component. The elements are known as component loadings and satisfy the following conditions:

$$\sum_j c_{ij}^2 = 1 \tag{3}$$

$$\sum_i c_{ij}^2 = \lambda_j \tag{4}$$

Equation 3 ensures that the total variance of each variable is preserved and equation (4) states that the total variance is apportioned between the components according to the magnitude of the eigenvalues of the correlation matrix. The interpretation of the components follows from examination of the c_{ij}'s.

The final step in the transformation procedure is to relate the components back to the original data points, to achieve a matrix of component scores, $Y = (y_{ij})$. The required transformation is:

$$Y = (y_{ij}) = (x_{ij}).\,(e_{ij}). \tag{5}$$

The elements y_{ij} are the scores of each county on each component. The scores on each component have a mean of zero, a variance equal to the eigenvalue of the component and are uncorrelated with the scores on any other component.

Data

A series of 27 indicators of agricultural change were obtained from the annual agricultural census to provide data for the study. The indicators chosen included measures of change in general land-use patterns, individual cropping patterns, livestock numbers, farm size distributions and levels of mechanization. The choice of variables was limited to what was available from the census. Nevertheless, the 27 variables reported on in this paper (Table 1) represent a subset of an original set of 39 variables (1). The choice of variables to be discarded (Appendix A) was made from an examination of the correlation matrix which showed that some variables had very similar correlation patterns (therefore, repeating the same information) and a few had very weak correlations (i.e. those with very little information content). The percentage change 1950–71 in each of the variables was computed and used as input data.

A detailed discussion of the trends represented by the 27 variables is not possible in

TABLE 1: Variables used in the analysis

Percentage change 1950–71 in,	
1. Proportion of total area under corn crops,	CORN
2. Proportion of total area under root[1] crops,	ROOTS
3. Proportion of total area under pasture,	PASTURE
4. Acreage of wheat,	WHEAT A
5. Proportion of corn acreage under wheat,	WHEAT P
6. Proportion of corn acreage under oats,	OATS P
7. Proportion of corn acreage under barley,	BARLEY P
8. Yield per acre of wheat,	WHEAT Y
9. Yield per acre of oats,	OATS Y
10. Yield per acre of barley,	BARLEY Y
11. Proportion of roots acreage under potatoes,	POTATOES
12. Proportion of roots acreage under sugar beet,	BEET
13. Yield per acre of beet,	BEET Y
14. Proportion of milch cows in total cattle numbers,	P COWS
15. Proportion of 3 yr. olds or over in total cattle numbers,	AGED CLE
16. Proportion of 1–2 yr. olds in total cattle numbers,	YOUNG CLE
17. Total sheep population,	SHEEP
18. Total pig population,	PIGS
19. Total poultry numbers,	POULTRY
20. Total number of horses and ponies,	HORSES
21. Proportion of all holdings between 1–10 acres,	TINY HOLS.
22. Proportion of all holdings between 50–100 acres,	MED HOLS.
23. Proportion of all holdings over 100 acres,	LA HOLS.
24. Density of combine harvesters/1000 acres corn crops,	COMBINES
25. Density of tractors/1000 acres arable land,	TRACTORS
26. Number of milking machines/1000 milch cows,	MILKMACHS
27. Number of males engaged in agriculture,	MALES

[1] Root crops include sugar beet, fodder beet, mangels, turnips, potatoes and other vegetables

the space available here. However, the trends represented by each of the variables have been discussed in detail and accounted for by the author in his dissertation (2). Maps have been prepared of the regional variations in each trend, copies of which can also be obtained from the author.

The principal trends in general land use related to the area under crops and pasture. Between 1950–71 the total acreage of pasture and hay increased by 785,000 acres, or 8%, as a result of a decline in the acreage of crops and through drainage and reclamation of marginal areas. The greatest expansion of pasture land occurred in Galway, Clare, Mayo, Offaly, Monaghan and especially Donegal. In contrast, the proportion of the total land area under pasture decreased in all the counties along the east coast, and also in Kildare, Carlow and Cork. The decrease in Louth and Dublin was largely due to urbanization while in most of the other counties it was due to expansion of the cereal crop acreage. Overall, the percentage of the total area of the Republic under crops declined from 10.75% to 7.7%. The principal trends and regional variations have been discussed in (1). Briefly, there was a decline of 13% and 45% in the proportion of the total land area of the state under cereals and root crops, respectively. The decline in cereal acreage was most marked in Connaught, Ulster, West Munster and counties Laois and Offaly. Significant increases in cereal acreage occurred in the counties along the east and south coast. The most significant change that occurred was in the relative proportions of the three main cereals grown. Oats was replaced by barley as the dominant cereal, in terms of acreage grown. However, this trend did not occur all over the island, oats still being the dominant cereal in a greatly reduced cereal acreage in the western counties. Like oats, wheat has declined in importance in all counties except Louth, Meath, Wicklow and Carlow. The increased popularity of barley was due mainly to the increased demand for concentrated feedstuffs that resulted from expansion of the total livestock numbers. Other reasons were the shorter growth season required by barley and its higher yields. The spatial variations in the transition to barley reflect variations in climatic and edaphic conditions as well as variability in levels of mechanization and farmers' knowledge of the crop (1). Most of the decline in the root crop acreage resulted from cutbacks in the cultivation of potatoes and fodder crops such as mangels and turnips. These cutbacks were offset to some extent by expansion of sugar beet cultivation in South Leinster and Munster. The decline in the cultivation of potatoes was relatively greater in the south east than elsewhere.

Over the period 1950–71 the number of livestock units increased by an average of just over 2% per annum (3). The rate of increase varied from 0.54% per annum in Leitrim to 3.44% per annum in Wicklow, with Dublin being the only county which showed a decline. Total cattle numbers increased by 42%. The rate of increase varied considerably from less than 20% in Donegal and Leitrim to over 60% in Laois, Offaly, Wexford, Galway and Monaghan. The most significant trend was in the composition of the cattle population. The proportion of the total number that were classified as milch cows, heifers in calf or 0–2 year olds expanded while there was a reduction in the proportion of store cattle, especially those over 3 years old. The general trend then was towards dairying and away from cattle

fattening. The movement towards dairying was strongest in the midlands and the south east where dairying was not previously well established. In contrast to the trend in most counties there was a decline in the proportion of milch cows in the cattle population of Dublin and the northwestern counties of Donegal, Sligo, Leitrim, Roscommon and Mayo.

The trends in total sheep, horses and ponies, pigs and poultry numbers were also examined. Total sheep numbers increased by 75% the largest increases being in Kildare and the remainder of East Leinster. The lowest rates of increase were in Cork, Kerry, Limerick and Clare. There was a national decline of 70% in the number of horses and ponies used for agriculture, largely as a result of the diffusion of tractor technology. However, some of the greatest declines were in Leitrim, Roscommon, Cavan, Donegal, Monaghan and Longford. These were counties where many small holdings ceased to be economically viable on their own. In these areas the decline in the number of horses was due more to structural reorganization in agriculture than to the spread of tractor technology.

The pig population of the country expanded by 137%. The expansion of the pig population was closely linked to the increased cultivation of feeding barley (1). In the 1950's when feeding barley was being promoted, it was hoped that many barley growers would become pig producers also. This did not always happen, but it resulted in a considerable trade within Ireland between barley growing regions and the pig producing regions. The keeping of poultry was traditionally a farmyard enterprise undertaken on a small scale by the womenfolk. In the 1960's there emerged a number of specialised poultry farms. The traditional farmyard enterprise lost its importance (12). As a result, the total number of poultry in the country declined by 37% over the period. An increase occurred only in Carlow, Kildare, Wicklow, Limerick and particularly Monaghan.

The changes in Irish agriculture have not been confined to crop and livestock patterns only. Important changes have also taken place in the distribution of farm sizes and the levels of farm mechanization. In 1950, 55% of the agricultural holdings in the state were less than 30 acres, while only 25% were greater than 50 acres. By 1970 the corresponding figures were 47.5% and 31%, respectively. The consolidation and enlargement of holdings was most evident in the west and particularly the northwest. Despite the progress achieved in this region, many serious problems remain.

The level of farm mechanization is influenced by a number of factors including general quality of the agricultural resource base, size of farms and dominant agricultural enterprises. Three indices of mechanization which related to tractors, milking machines and combine harvesters were used in this study. The level of mechanization was very low in 1950 since there were only 0.88 tractors per 1000 acres of arable land, 3.86 milking machines per 1000 milch cows and 0.49 combine harvesters per 1000 acres of cereals. At the same time, the spatial distribution of each of the new forms of technology was highly uneven. For example, the number of tractors per 1000 acres of arable land ranged from 0.13 in Leitrim to 3.52 in Dublin, the number of milking machines per 1000 milch cows ranged from zero in Leitrim to 3.37 in Dublin and the number of combine harvesters per 1000 acres of cereals ranged from 0.03 in Donegal to 1.46 in Kildare. By 1970 the

overall levels of mechanization had increased considerably and the amount of variation in the spatial distributions had also been greatly reduced. The coefficient of variation decreased from 81% to 33% for the tractor distribution, from 86.6% to 63% for the milking machine distribution and from 96% to 78% for the distribution of combine harvesters. Variables 24, 25 and 26 measured the changes in these forms of agricultural machinery.

For this study the geographical unit of measurement has been the county since data were not available for smaller administrative units in 1950. This is unfortunate because data at county level have serious limitations arising from the great variety of physical and socio-economic conditions found within some counties. Despite these difficulties it was felt that the study would be worthwhile by highlighting the broad regional trends. County Dublin has been excluded from the analysis reported here. This decision was taken after a preliminary PCA showed that Dublin was an anomalous region exhibiting changes in many variables that were opposite to those recorded in other counties (2, 8). Finally, the reasons for the choice of 1950–71 as the study period have been given in a previous paper (1) and need not be repeated here.

RESULTS AND DISCUSSION

The Principal Components Analysis was performed on the 27 x 27 matrix of Pearson r correlation coefficients[1]. An inspection of the matrix showed that two-thirds of the 351 correlations were greater than 0.4 which is the critical level of 0.05 significance, if the measurements are considered to be based on independent and random samples from the counties. This showed that overall there was a high degree of intercorrelation between the variables. The eigenvalues and explained variances of the principal components are set out in Table 2.

The first two components account for almost half of the total variance, while 80% of it is accounted for by the first six components. In the next section an attempt will be

TABLE 2: Eigenvalues and explained variances

Component	Eigenvalue	Percentage variance	Cumulative percentage
1	8.77	32.48	32.48
2	4.61	17.07	49.55
3	2.91	10.78	60.33
4	2.25	8.32	68.65
5	1.74	6.46	75.11
6	1.46	5.40	80.51
7	1.20	4.47	84.98
8	0.86	3.19	88.17
9	0.76	2.80	90.97

[1] The correlation matrix was used instead of the variance-covariance matrix because of the large differences in variance between the variables.

made to interpret each of the components that account for at least 5% of the total variance. The identity of the components is obtained by examination of the component loadings which are set out in Table 3.

TABLE 3: Component loadings

Var.	Comp. 1	Comp. 2	Comp. 3	Comp. 4	Comp. 5	Comp. 6	Variable
1.	0.882	−0.089	−0.186	0.127	0.101	0.086	Corn
2.	0.680	0.090	−0.099	−0.106	0.615	0.047	Roots
3.	−0.686	−0.038	−0.088	0.227	0.338	0.008	Pasture
4.	0.803	−0.300	−0.267	0.005	−0.177	0.025	Wheat A
5.	0.365	−0.708	0.015	−0.227	−0.360	−0.074	Wheat P
6.	−0.933	0.162	−0.094	−0.125	−0.087	0.080	Oats P
7.	−0.339	−0.603	0.054	0.608	0.221	−0.112	Barley P
8.	−0.485	−0.288	−0.124	0.490	−0.519	0.121	Potatoes
9.	0.237	0.517	0.166	0.115	0.108	−0.665	Beet
10.	0.732	0.197	0.245	0.268	−0.158	−0.317	Wheat Y
11.	0.587	0.393	0.139	0.199	−0.279	−0.084	Oats Y
12.	0.474	0.150	−0.255	0.491	−0.329	−0.121	Barley Y
13.	0.116	0.733	0.306	0.044	0.032	−0.427	Beet Y
14.	0.229	0.642	−0.181	0.078	−0.009	0.522	Horses
15.	0.614	−0.091	−0.439	−0.301	−0.114	−0.110	P Cows
16.	−0.310	0.120	0.787	−0.057	−0.260	0.229	Aged cle
17.	0.495	−0.160	−0.726	−0.261	−0.263	−0.003	Young cle
18.	0.447	−0.412	−0.397	−0.447	0.080	−0.158	Sheep
19.	−0.166	−0.684	−0.020	0.434	0.418	−0.030	Pigs
20.	0.281	−0.448	0.206	−0.323	−0.045	0.062	Poultry
21.	0.745	−0.165	0.133	0.343	0.156	0.236	Tiny hols
22.	−0.770	0.015	−0.312	−0.269	−0.290	−0.256	Med hols
23.	−0.782	−0.336	−0.135	−0.265	−0.082	−0.169	La hols
24.	0.697	−0.370	0.338	−0.179	−0.015	−0.145	Combines
25.	0.231	−0.769	0.467	−0.191	0.068	−0.115	Tractors
26.	0.555	−0.143	0.649	−0.023	−0.258	0.241	Milkmachs
27.	0.445	0.565	−0.185	−0.363	0.110	0.232	Males

Component One

The first component has high positive loadings from corn crops, root crops, acreage and yield of wheat, combine harvesters, number of milch cows, milking machines and 1–10 acre holdings. There are high negative loadings from pasture, proportion of oats in cereal acreage and number of holdings greater than 50 acres. The component, then, is describing the general trend of correlations resulting from areas with

- highest rates of increase in proportion of land under corn crops, yield per acre of wheat, combine harvesters, number of milch cows and milking machines;
- lowest rates of increase in proportion of land under pasture and proportion of farm holdings greater than 50 acres;

- lowest rates of decrease in proportion of land under root crops, acreage of wheat, and 1–10 acre holdings;
- highest rates of decrease in proportion of cereal acreage under oats.

The counties with this overall trend score highest on the component. The highest score was recorded for Wicklow while the lowest was for Leitrim (Table 4). Fig. 1 shows that the region with the highest scores included counties Carlow, Wexford, Wicklow, Kildare and Meath.

TABLE 4: Component scores by county

County	Comp. 1	Comp. 2	Comp. 3	Comp. 4	Comp. 5	Comp. 6
Carlow	10.380	−2.098	−0.364	−2.645	2.089	−0.346
Kildare	9.206	−0.008	−1.719	−2.012	0.746	1.797
Kilkenny	6.043	−0.219	−0.143	−0.789	0.799	0.208
Laoighis	3.350	−1.267	0.076	−2.252	2.036	−0.741
Longford	−5.534	−1.104	−4.213	1.301	−1.688	−0.454
Louth	7.602	−3.047	0.581	1.418	−3.118	−1.417
Meath	11.193	−1.489	−5.124	1.973	−3.594	1.409
Offaly	3.673	0.462	−1.934	−1.093	1.525	−0.501
Westmeath	7.034	2.554	−3.636	2.533	−1.345	−0.480
Wexford	10.036	−2.259	0.452	−3.089	1.626	−1.068
Wicklow	11.264	−1.861	−0.646	1.126	1.424	−0.038
Clare	−5.192	6.667	−0.063	0.678	0.613	1.764
Cork	6.994	2.232	4.788	1.022	0.341	−0.014
Kerry	−0.633	5.179	6.963	1.154	−0.341	1.367
Limerick	−1.516	2.567	6.141	1.112	−2.041	0.934
Tipperary	3.144	0.793	1.131	0.560	0.434	0.455
Waterford	3.569	2.288	0.750	0.435	−0.118	0.562
Galway	−3.192	5.773	−2.479	0.401	0.873	1.001
Leitrim	−19.101	0.191	−2.004	−3.428	0.290	1.588
Mayo	−11.376	4.557	−1.393	−0.093	0.266	−0.330
Roscommon	−7.246	8.245	−0.030	−0.133	−0.441	−5.446
Sligo	−14.499	0.005	−1.810	−1.019	−0.394	1.042
Cavan	−9.528	−8.720	1.318	−1.949	−1.884	−0.483
Donegal	−10.921	−9.555	0.173	7.165	3.900	−0.355
Monaghan	−4.750	−9.886	3.185	−2.378	−1.996	−0.456

Contributing equally to component one are the counties with precisely the opposite characteristics; highest rates of increase in proportion of land under pasture and proporation of all holdings greater than 50 acres; lowest rates of increase in yield per acre of wheat and density of milking machines; lowest rates of increase and some decreases in density of combine harvesters and number of milch cows; highest rates of decrease in corn and root crop acreages, wheat acreage and 1–10 acre holdings; lowest rate of decrease in proportion of cereal acreage under oats.

The counties with these overall characteristics have large negative scores on the component and are found along the West Coast, especially in the north-western counties of

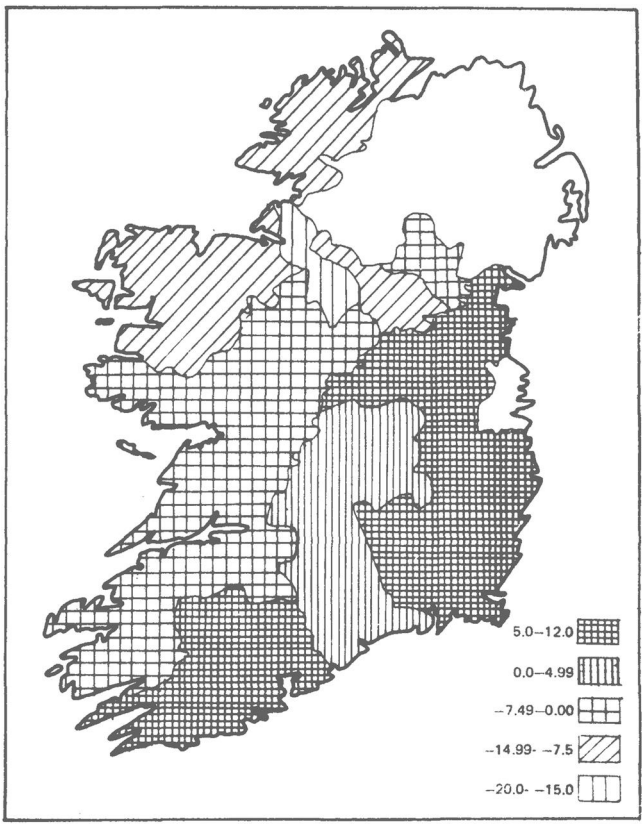

Fig. 1: Scores on Component 1.

Leitrim, Mayo, Sligo, Cavan and Donegal. Counties Kerry and Limerick have scores very close to zero which indicate that they are exhibiting either near mean values for the variables loading highly on the component or they have some characteristics that score positively, while others score negatively on the component.

The first component then, which accounts for almost one-third of the total variance, may be broadly interpreted as an "intensification of agriculture" component. The positive aspects of this trend were most marked in east Leinster which is probably the most progressive agricultural region in the country. This viewpoint is supported by some on-going research into the diffusion of agricultural machinery across the country. The eastern region was characterised by increasing emphasis on dairying and cereal production with much mechanisation and improvement in wheat crop yields, the proportion of land under root crops and wheat acreage not declining in importance as much as in other areas, a very low increase in pasture and a heavy decline in the already small proportion of the cereal

acreage under oats. In contrast, the west, north-Connacht in particular, has tended to move towards pasture, with a concomitant lower emphais on mechanisation. The variables relating to size of holdings have an interesting relation to this component. Relative increases in holdings larger than 50 acres have been lowest in the intensive east, highest in the less intensive west; decreases in 1–10 acre holding were least in the east, greatest in the west. This reflect the fact that the land holding structure in the east of the country has been stable for most of this century, but that in the west there has been a large amount of consolidation in progress, with the creation of larger, more viable holdings. Agriculture has become more progressive and more intensive in all counties, but the nature of the progress shows marked east/west contrasts.

Component Two

The second component has high positive loadings from yield and acreage of sugar beet, horses and males employed in agriculture and highest negative loadings from the proportions of wheat and barley in the total cereal acreage, the change in the pig population and the change in the density of tractors. Therefore, the general trend being described results from

- highest rates of increase in proportion of root crop acreage under sugar beet and yield per acre of sugar beet:
- lowest rates of increase in the proportion of barley in the total cereal acreage, the total pig numbers and the density of tractors;
- highest rates of decrease in the proportion of wheat in the total cereal acreage;
- lowest rates of decrease in the number of males engaged in agriculture and the number of horses and ponies used for agriculture.

The spatial distribution of scores on the trend are listed in Table 4, and shown in Fig. 2. They range from 8.25 in Roscommon, to –9.89 in Monaghan. The highest scores are found in a block of counties along the western seaboard extending from Mayo south to Kerry, and including Galway, Roscommon and Clare. The counties that most strongly exhibit trends which are opposite to those in the counties listed above are those with the largest negative scores, Monaghan, Donegal and Cavan. Therefore, this component divides the traditional western counties into two blocks. The buffer counties between these two blocks are Sligo and Leitrim, both of which have scores very close to zero, suggesting that the mean values for the trend described by the component are found in those counties. The remainder of the country divides into two major zones, one of which represents counties with negative scores and includes all the counties along the east coast plus Kildare, Laois, Kilkenny and Longford. The remainder of the country is characterised by moderately large positive scores indicating that the trend reflected by the component is not as strong in these parts of the country as in Connacht and Clare.

It is rather difficult to provide a label that adequately describes the trend represented by this dimension of agricultural change which accounted for 17% of the total variance. The variables that load highly on the component suggest that it represents some of the

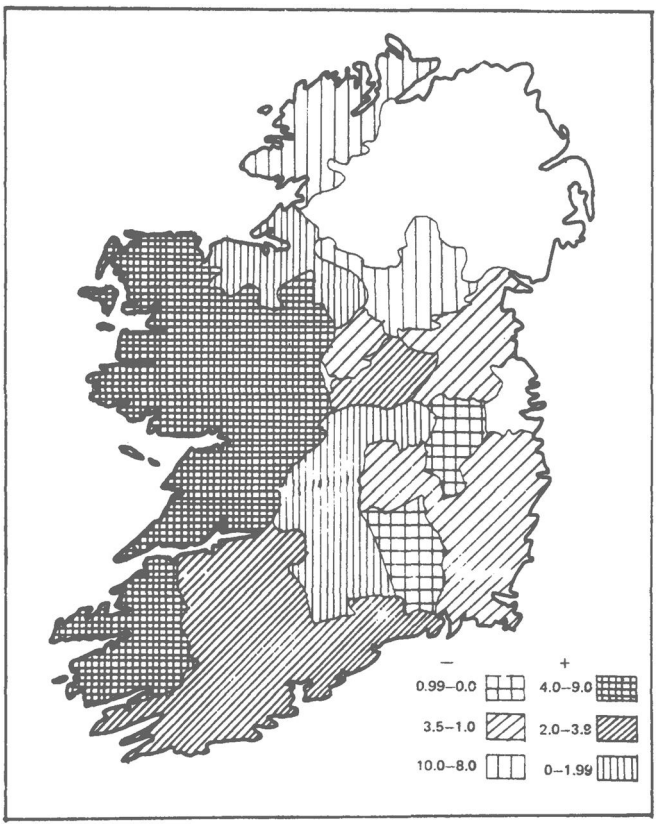

Fig. 2: Scores on Component 2.

changes that occurred in relation to traditional tillage farming. The negative aspects of the trend were most evident in the western counties, extending from Mayo south to Kerry, which contain some of the poorest agricultural land in the country. This region was characterised by a relatively slow shift away from manual and horse labour to the tractor, a low increase in the barley share of cereals, a high decrease in the already small share of the cereal land under wheat, a relatively small increase in total pig numbers and a very high rate of increase in the previously very small portion of the root crop acreage under sugar beet and the previously very low sugar beet yields. Therefore, there was a great reluctance in this region to change from the traditional labour intensive pattern and to embark on commercial enterprises such as pig production and barley growing. The only positive change that did occur was in relation to sugar beet production. While the relative changes in this respect were very substantial, it must be remembered that in absolute

terms these changes were not very significant. In contrast, the three Ulster counties, Cavan, Monaghan and Donegal, have experienced considerable increases in levels of mechanisation, total pig numbers, especially in Donegal, and proportion of cereal acreage under barley. The proportion of cereal acreage under wheat increased in Cavan and Monaghan. Furthermore, in contrast to the counties south of Mayo, the production of sugar beet virtually disappeared from the Ulster counties. In the remainder of the country it is evident that the propensity to change was greatest in the counties of east Leinster, with the reluctance to change generally increasing westwards.

In summary, the strength of component two, which represents the reluctance to change from traditional tillage farming, varies considerably between counties. The reluctance pattern shows marked east-west contrasts, but allied with these are very important north-south contrasts within the traditional western region.

Component Three

The third component which accounts for 10.8% of the total variance has high positive loadings in the change in the proportion of all cattle that are over 3 years old and the change in the number of milking machines. The only high negative loading is in the change in the proportion of all cattle that are one to two years old. Clearly, this component relates to changes in livestock numbers. It broadly reflects the general trend towards more dairying in all counties outside of Connacht. This has given rise to an increase in the proportion of younger cattle and a decline in the proportion of older ones. The number of milking machines per 1000 milch cows has increased most in the counties where this trend has been strongest.

The spatial distribution of the scores on the component is shown in Fig. 3. The importance of the dairying tradition in the south-west is clearly evident. The tradition is also evident in the northern dairying belt centred on Monaghan and Cavan. The change to younger cattle and mechanised dairying has been least in Longford, Westmeath and Meath. There has been a strong tradition of cattle fattening in these counties which is only being slowly altered. The remainder of the map again highlights the general reluctance to change throughout most of Connacht, and for this particular dimension, the way the reluctance has spread eastwards to Offaly and Kildare. In summary, the livestock component of change highlights the contrasts between the dairying and cattle fattening parts of the country.

Component Four

This component accounts for 8.3% of the total variance and has high positive loadings on proportion of barley in total cereals acreage, proportion of root crop acreage under potatoes, barley yield and total pig numbers. The largest negative loadings occur in relation to change in the total sheep numbers. Thus the areas which score highly on the component have had large increases in the proportion of the cereal acreage under barley, the proportion of the root crop acreage under potatoes, the total pig numbers and rather low increases in sheep numbers. These trends were most manifest in Donegal. The lowest

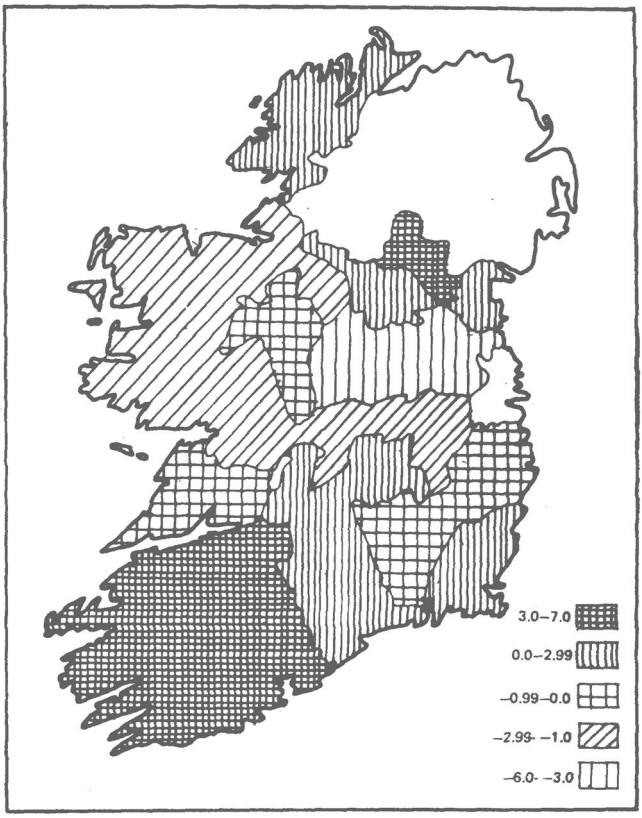

Fig. 3: Scores on Component 3.

score was for County Leitrim, which was the only county to experience a decline in the proportion of barley in the cereal acreage. Further examination of the distribution of scores shows that large negative scores are found in Carlow, Kildare, Laois, Wexford and also in Cavan and Monaghan (Fig. 4). In the former group of counties these scores result from the relatively small increase in the proportion of barley in the cereal acreage in this region where barley growing was already well established by 1950, the above average decrease in the proportion of the roots acreage under potatoes due to competition from sugar beet, and the above average increase in sheep numbers in these counties. The scores are not as high as in Leitrim because they are offset to some extent by relatively large increases in total pig numbers.

The large negative scores in Cavan and Monaghan arise for other reasons. On the one hand, these counties experienced large increases in the proportion of barley and total pig numbers. On the other, the proportion of the roots acreage under potatoes actually

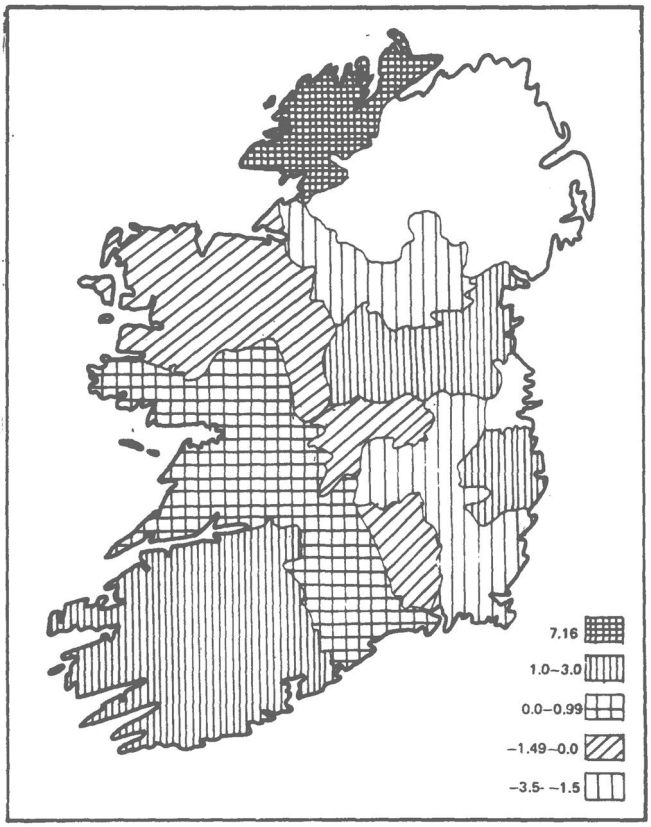

Fig. 4: Scores on Component 4.

increased in these counties, while there was a decrease in most other counties, the increase in sheep numbers was above average and especially in the case of Monaghan there was a very large increase in poultry numbers when again there was a decrease in almost every other county. Relatively large positive scores are also found in Louth, Meath, Westmeath, Longford, Wicklow, Kerry and Limerick. In most of these counties the scores result from the relatively substantial switchover from oats to barley as the main cereal crop, in the case of Louth, Meath and Wicklow the increase in the share of the root crop acreage under potatoes, while in Wicklow and Westmeath there were large increases in total sheep numbers.

The component is simply labelled change in barley, potatoes and sheep because of the variables that load highly on it. It would seem that the pattern of increase in sheep numbers coincides with the cropping patterns, rather than being part of the same process.

This is borne out by the very low correlations between the sheep variable and the other two, in both cases it was less than 0.3. The spatial pattern of scores on this component which is independent of those examined so far is very complex showing contrasts between east and west Munster, north and south Leinster, and north and south Connacht.

Component Five

This component accounts for 6.46% of the total variance and has a high positive loading on root crops and a large negative loading on potatoes. Therefore, high scores on the component are associated with counties that experienced a small decrease in the proportion of their total area under root crops and a large decrease in the proportion of the root crop acreage under potatoes. Clearly, then, this is a root crop component.

The highest score was in Donegal. Contrary to expectation the proportion of the root crop acreage under potatoes increased considerably in this county. The high score in the county was due to the slightly above-average decline in the area under root crops and the relatively very high increases in total pig numbers which is another variable that correlates strongly in a positive direction with this component. Large positive scores occurred also in the south-east and in counties Laois and Offaly where there was a large decrease in the area under roots, the proportion of the root crop acreage under potatoes and a relatively large increase in total pig numbers. It seems likely that these trends are more coincidental than part of the same process. In contrast, in north Leinster, Cavan and Monaghan (Fig. 5) where there were above average decreases in the root crop acreage as a proportion of total area, and increases or slight decreases in the share of potatoes in the roots acreage, there were large negative scores, the largest being in Louth. The only other county with a large negative score was Limerick which had the largest decrease in the root crop proportion and a slight increase in the potato proportion. The map of scores for the component, Fig. 5, demonstrates a strong contrast within Leinster between the northern and southern counties, and a large area extending westward from Waterford and Kilkenny northward to Leitrim which exhibited near mean values on the variables that load highly on this component.

Component Six

The final component extracted from the analysis was associated with decline in the number of horses and ponies and increases in the proportion of the root crop acreage under sugar beet. This component accounts for 5.4% of the total variance and again seems to be describing trends that were spatially coincidental rather than causally interrelated. High positive loadings result from low increases in the proportion of the roots acreage under sugar beet and low rates of decrease in the number of horses and ponies. These trends were most evident in the western counties. However, large positive scores occurred also in Kildare and Meath since in parts of these counties there has been a strong tradition of horsebreeding. The largest negative score was in Roscommon, which was due to a very large relative increase in the proportion of the root crop acreage under sugar beet.

The square of a component loading is a measure of the portion of the variance of a

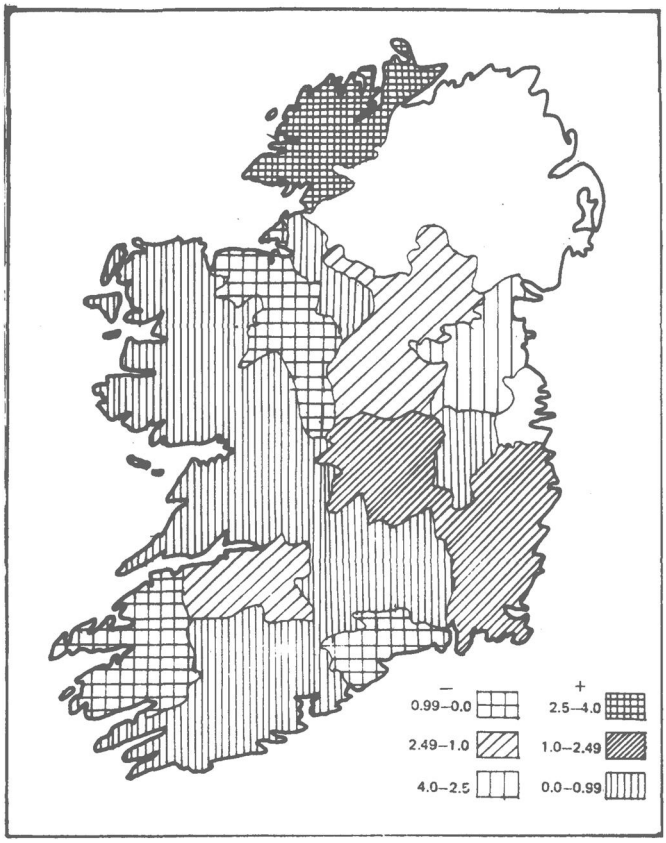

Fig. 5: Scores on Component 5.

particular variable that is accounted for by a given component. Such measures are known as the communalities of the variables. In this study at least 75% of the total variance in 23 of the variables could be accounted for by the first six components. The only variable with a low communality was the poultry one. Only 43% of the variability in the change in poultry numbers could be accounted for by the first six components. An examination of the component loadings matrix shows that component eight was in fact the poultry component. It was not extracted, however, since its eigenvalue was less than unity (Table 2), indicating that the component was accounting for less variance in the data set than one of the original variables. Nevertheless, the cumulative communalities on the other variables suggest that the first six components provide a very satisfactory summary of the total variance in the original data set.

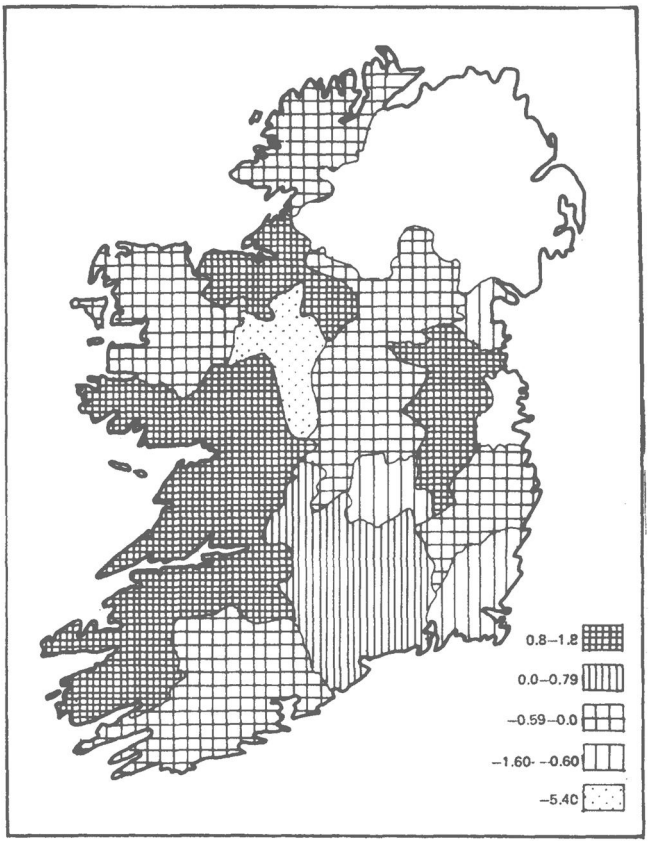

Fig. 6: Scores on Component 6.

REGIONS OF AGRICULTURAL CHANGE

Regions of agricultural change or agricultural adaptation were delineated by clustering the counties on the basis of their scores on the first six components. The technique used was a version of hierarchical cluster analysis developed by Wishart (13) which uses the square of euclidean distance in N-dimensional space as a similarity measure and agglomeration of unweighted centroid clusters as a grouping procedure. The algorithm proceeds in a stepwise fashion to arrive at a solution which minimizes within-cluster distances while at the same time maximising between-cluster distances. This fulfils the objective of the technique, to maximize within-region homogeneity and between-region heterogeneity. The input

data for this part of the study were the unweighted scores on the first six components for each county. These data satisfy the assumptions of the similarity measure. The output from the algorithm consists of a linkage tree of the counties.

Two cluster analyses were performed, one without and one with a contiguity constraint imposed. Since the results from both were almost identical only the solution for the contiguity constrained exercise will be discussed. The linkage tree and associated map of regions are shown in Figs. 7 and 8. There are basically two major regions exhibiting different characteristics of agricultural change. One consists of all Leinster excluding Longford, plus Tipperary, Waterford and Cork. This region is more uniform than the other one as indicated by the value of the maximum squared distance for each region. These were 1.05 for the first region and 2.39 for the second one. However, within each region there are a number of sub-regions (Fig. 8). To help identify the principal characteristics of each region and to facilitate inter-region comparisons the component scores in each region were standardised by taking the ratio of the mean score on each component over the component eigenvalue. The standardised scores are listed in Table 5.

The first two rows of the table contain the mean scores for the two major regions.

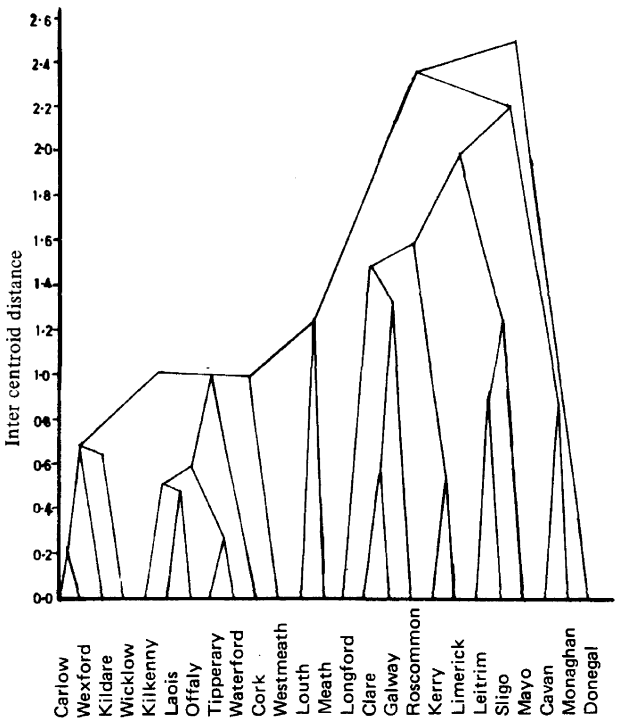

Fig. 7: Hierarchical clustering linkage tree.

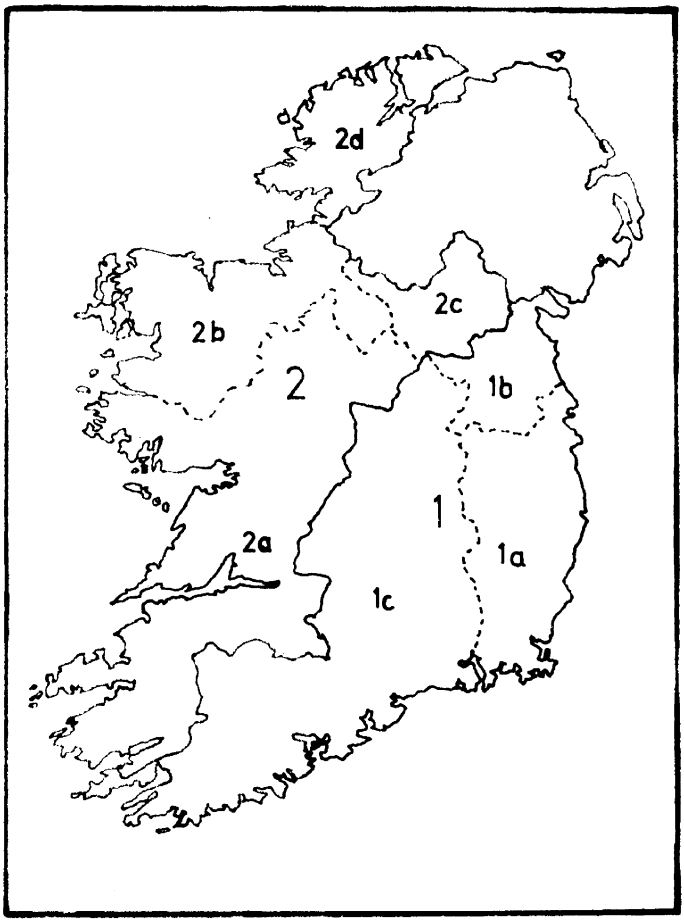

Fig. 8: Agricultural adjustment regions.

The figures demonstrate clearly the importance of the first component which related to intensification of agriculture. It is on this one that the greatest contrast occurs between the regions. Clearly, then, the ability and propensity to intensify production is a major differentiating characteristic between the two principal agricultural regions of the country.

The sub-regions that occur result from variations in the scores on the other components of change.

Sub-Region 1a

This region consists of Carlow, Wexford, Kildare and Wicklow. Its principal charac-

TABLE 5: Standardised component scores

Region	Component 1	2	3	4	5	6
East (1)	0.84	−0.07	−0.16	−0.10	0.13	−0.01
West (2)	−0.81	0.07	0.29	0.11	−0.14	0.01
West 1a	1.19	−0.34	−0.20	−0.75	0.86	0.06
West 1b	1.09	−0.50	−0.80	0.77	−1.96	0.00
West 1c	0.56	0.22	0.15	0.06	0.31	−0.07
West 2a	−0.45	1.00	0.44	0.34	−0.29	−0.10
West 2b	−1.75	0.35	−0.61	−0.69	0.00	0.54
West 2c	−0.83	−2.06	0.79	−0.98	−1.13	−0.33
West 2d	−1.27	−2.11	0.06	3.26	2.28	−0.25

teristics were a very high propensity to modernise and intensify, a relatively small increase in the proportion of the cereal acreage under barley, since barley growing was already well established there by 1950, a relatively substantial switch from potatoes to sugar beet and an above-average increase in total sheep numbers.

Sub-Region 1b

This includes counties Louth and Meath which were also characterised by a high propensity to intensify but nevertheless showed a reluctance to change to dairying, there was an above-average decrease in the root crop acreage as a proportion of total area and contrary to the national trend, there was a slight increase in the proportion of the roots acreage under potatoes. The principal contrast between sub-regions 1a and 1b relates to the change in the importance of potatoes in the roots acreage.

Sub-Region 1c

This is the remainder of the east region. The tendency towards more intensive production was less marked in these counties. The mean scores on the other components are also rather close to zero indicating the transitional nature of this region between the east coast region of greatest change and the least progressive western areas. Naturally, contrasts occur between parts of the sub-region in regard to some components. Those contrasts are highlighted on the component score maps.

Sub-Region 2a

These counties, particularly Kerry and Limerick, contained some of the most progressive parts of the western region. The large positive mean score on component two arises from the general reluctance of farmers in the sub-region to change from manual and horse labour to the tractor, the relatively small increase in the barley share of cereals and in total pig numbers. The score on component three is mostly due to the increased emphasis on capital intensive dairying in Kerry and Limerick.

Sub-Region 2b: This one consists of the north-west counties of Mayo, Sligo and Leitrim.

The sub-region was characterised by a very low propensity to modernise, a high degree of reluctance to switch to dairying and by an abandonment of barley growing in Leitrim.

Sub-Region 2c: Here there was a weak reluctance to change from traditional tillage farming, a high propensity to switch to dairying, a relatively large increase in the barley share of the cereal acreage and in total pig numbers. Furthermore, the potato share of the root crop acreage increased slightly. Despite these changes, the counties still scored negatively on the overall dimension of intensification.

Sub-Region 2d: This is County Donegal which had scores similar to those in Cavan and Monaghan except on components 4 and 5. The principal differences between the counties relate to the very large growth rates in pig numbers and the proportion of barley in the cereal acreage in Donegal.

The regionalisation has shown how local variations on the independent dimensions of agricultural change have combined to produce a number of sub-regions that differ from one another according to the adaptations their farmers have made. The principal spatial contrasts were between the traditional eastern and western regions but within each region there were a number of sub-regions that resulted from more localised variations in some of the relatively less important independent dimensions.

SUMMARY AND CONCLUSIONS

In the two decades between 1950 and 1971 there were many changes in agricultural patterns in the Republic of Ireland. There were decreases in the total cropland acreage, the total number of agricultural holdings and the number of people employed in agriculture. In contrast, there were substantial increases in total livestock numbers and in levels of agricultural mechanization. There were many sources of variation in these aggregate trends. For example, the acreage of some crops declined drastically while that of others increased, the increase in some categories of livestock were much greater than in others, similarly only farm holdings of certain sizes were declining. Added to these many sources of variation were the spatial ones resulting from variations in topography, climatic and edaphic conditions, the demographic structure of the farming population and the rate of transformation of Irish rural society (1).

In this paper, principal components analysis was used in an attempt to unravel the intercorrelations between the many changes that have taken place. Originally 39 indicators of change were measured. Later it was discovered that twelve of them could be discarded without much loss of information. The principal components analysis produced a six-dimensional solution which accounted for over 80% of the variance in the distribution of the indicators that were retained. The solution dimensions or components were independent and each could be given a broad interpretation. The first two components were general ones describing the trend towards intensification and consolidation and the decline of traditional tillage practices. The others described trends in particular crop and

livestock patterns. A grouping procedure was used to regionalise the counties on the basis of similarity of component scores. This collapsed the distributions of the six independent dimensions into a single map providing a simple summary of the complex patterns of variations of agricultural change in the Republic. The pattern emphasises the traditional east-west division of the country, and also highlights some important sources of sub-regional variations.

The technique of principal components analysis used in this paper is primarily a transformation procedure. As such, the results derived are totally dependent on the original set of variables used as input data. Therefore, one would expect that if the original data were altered the results would be different. However, this need not always be the case. At the commencement of the work on which this paper is based a principal components analysis was performed on 39 variables, and at a later stage the same analysis was carried out on a selection of fifteen variables from the original set by Daultrey (8, p. 26–40). The principal components extracted in both of those studies were similar to the ones extracted in this study.

Obviously, a major limitation of this study has been the choice of counties as data measurement bases. This arose because at the time the study was undertaken no data were available at a finer geographical scale for a long time period. However, since the publication of the results of the 1975 agricultural census it might be worthwhile to analyse the changes that have taken place at rural district level between 1960 and 1975. A methodology for such a study has been provided in this paper. In future studies attention could be given, perhaps, to the inclusion of some other indices of agricultural change and to an assessment of the effects of different measurement scales.

In conclusion, this paper has shown that principal components analysis and cluster analysis are useful techniques for summarising both non-spatially and spatially highly intercorrelated data sets. Furthermore, the paper has shown that while the effect of the dominant component of intensification and consolidation was to emphasise traditional east-west contrasts there were other components that highlighted many subregional differences. As a result the regional patterns of adjustment were seen to be highly complex.

ACKNOWLEDGMENT

The author would like to thank Stu Daultrey, U.C.D. for permission to use his computer programs.

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Received July 1979

APPENDIX A: Variables discarded after preliminary analysis

Percentage change 1950–71 in,

1. Proportion of total area under hay,
2. Proportion of total area classified as "other land",
3. Acreage of oats,
4. Acreage of barley,
5. Total number of cattle,
6. Total number of milch cows,
7. Proportion of total cattle aged 2–3 years old,
8. Proportion of total cattle aged 0–1 year old
9. Proportion of total cattle classified as heifers in calf
10. Total number of agricultural holdings greater than 1 acre,
11. Proportion of all holdings between 10–30 acres,
12. Proportion of all holdings between 30–50 acres.