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AGRICULTURE is generally the most important single use of land in any country, and the description and interpretation of the rich variety of agricultural activities have played a major part in writings in both regional and economic geography. Yet, apart from purely impressionistic descriptions, studies in the geography of agriculture have largely been concerned with individual crops or classes of livestock, rather than with the complex agricultural systems of which they are part. There are three important reasons for this situation: first, the fact that in most countries the only available data for any large area are crop acreages and livestock numbers; second, the difficulty of handling the large quantity of data involved in any consideration of the whole range of agricultural activities; third, the problem of relating the different crops and classes of livestock in any objective and meaningful way.

While changes in the kind of data available must largely depend on changes in the attitudes of those government departments which collect agricultural statistics, an important methodological advance towards a solution of the third difficulty was made in 1954 by J. C. Weaver in his study of crop combination regions in the Middle West; but even his pioneer work did not overcome the difficulty of integrating crop and livestock data for the analysis of types of agriculture.[1] The possibility of finding practicable solutions has been greatly increased by the advent of the digital computer, which is ideally suited to the rapid and accurate handling of large bodies of information, particularly where, as in the calculation of crop combinations, a long sequence of complex procedures has to be repeated for each of a large number of areal units. This paper presents some of the results of an attempt to apply a modified version of Weaver's method to crop and livestock data for England and Wales, using the University of London Mercury computer to produce not only crop and livestock combinations, but also combinations of agricultural enterprises.

The Data

Ideally, all studies relating to the geography of agriculture ought to be based on information for individual farms, since the farm is the operating unit; but in most countries, including England and Wales, data are available only for administrative areas. Where farm records are available, the case for using data processing equipment is all the stronger because of the large number of units involved; yet, even with such equipment, necessary preliminary procedures, such as locating the numerous farms and identifying the farm territory,

[1] J. C. Weaver, "Crop Combination Regions in the Middle West," *Geogr. Rev.*, Vol. 44, 1954, pp. 175–200.

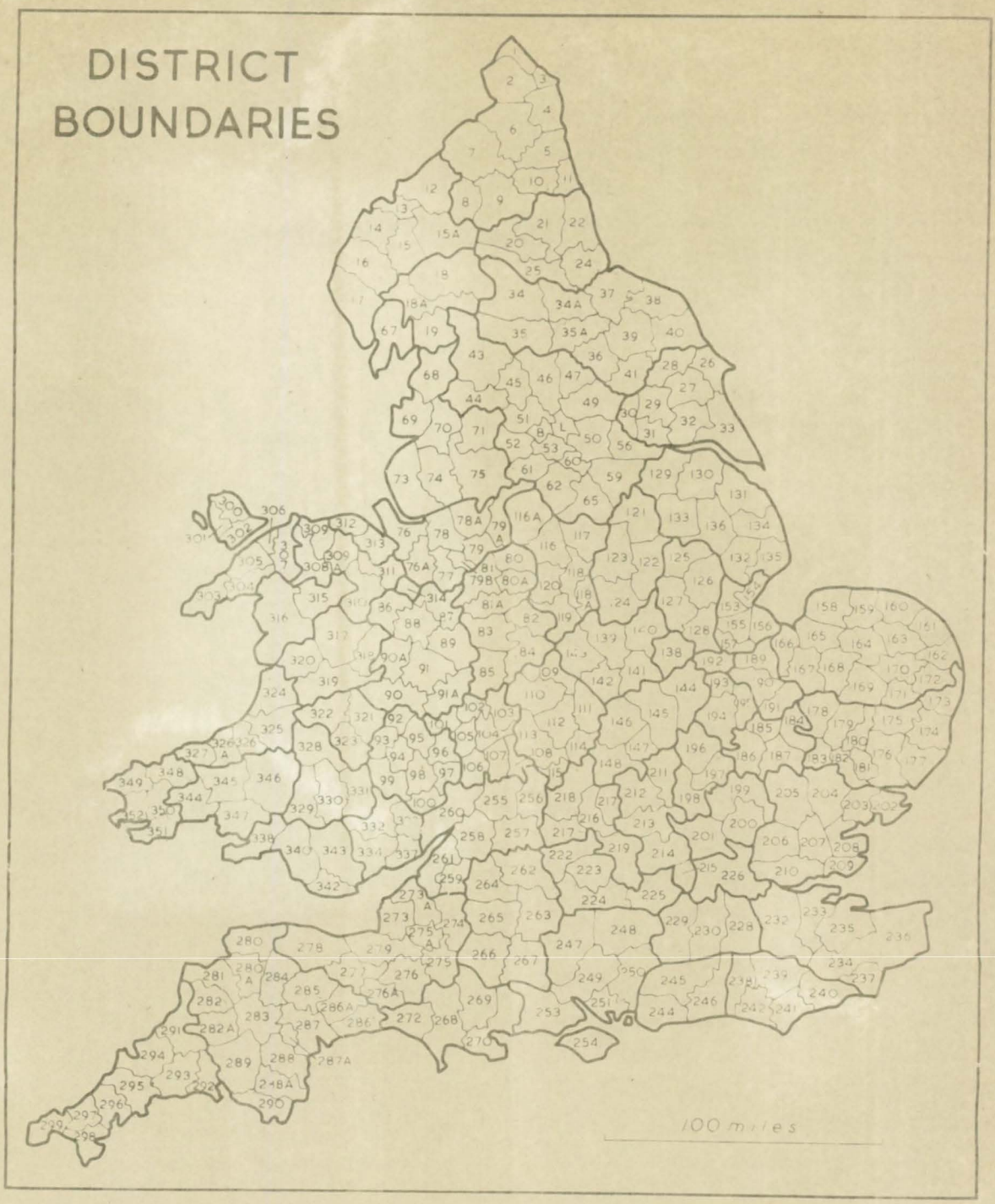

FIG. 1.—National Agricultural Advisory Service Districts.

make the use of farm data difficult except in the study of quite small areas.

In this study, official census data for 1958 for National Agricultural Advisory Service Districts were used. These districts are groups of some 30 or 40 parishes and contain several hundred farms; their boundaries are shown in Figure 1, the county boundaries being indicated by thicker lines. These areas, for which agricultural census data are unfortunately no longer compiled, are not ideal, for they vary considerably in shape and in the variety of types of land they contain; but they are fairly homogeneous in size, nearly 90 per cent falling

in the range 80 to 280 square miles, and some of the smaller districts have amalgamated with their neighbors to make for even greater uniformity. This question of size is important in the application of statistical procedures, for great variation in size may have a considerable effect upon the results, suggesting areal differences which are only apparent.[2] It would have been preferable to have employed a smaller unit, like the parish; but since parishes number over 10,000, show a wide range of sizes, and often contain as great a variety of physical conditions as the districts, the advantages of using them are not as great as might at first appear. Moreover, the fact that all data had first to be extracted by hand from official records and then punched on five-channel paper tape for use by the computer placed a severe practical limit on the amount of data which could be handled.

For each of the 350 districts, there were 122 items of information to be punched, making a total of over 42,000. Since several hundred operations had to be performed on the data for each district, it would have been very laborious to have undertaken the computations by hand. Only two hours of computer time were required for all these computations; and it was estimated that, allowing for preparation of programming, the use of the computer reduced the total time required by more than five-sixths.[3] In future applications of the same computations to other data, the benefits would be very much greater.

CONVERSION FACTORS: CROPS AND LIVESTOCK

Crops and livestock do not occur in isolation on farms: they compete with and complement each other and form parts of farming systems. To examine these complexes, two steps are necessary: crop acreages and livestock numbers must be converted into some common units, so that they can be compared; and some measure of their relative importance must be devised.

Conversion factors raise a question which is too often disregarded in agricultural geography, that of differences in the intensity of agricultural operations. The geographer is inclined, from his interest in land as such, to give great weight to the area occupied by any kind of farming; yet extensive cereal growing or livestock rearing over large areas may be economically far less important than truck farming or intensive poultry production which occupy much smaller acreages. Thus, while at first sight the comparison of different crops presents few difficulties, since they are already expressed in a common unit, acres, this measure disregards the fact that the yield per acre of one crop, say, potatoes is some four times that of another, wheat. The absence of district data for yields makes it difficult to take these variations in the intensity of crop production into account in calculating crop combinations; area has thus been the sole criterion of importance and unweighted acreages have had to be used for purposes of comparison.

While the fact that there is nothing intrinsically implausible about comparing an acre of potatoes and one of wheat obscures the importance of such differences in intensity in crop farming, the impossibility of using numbers alone as a basis for comparing the relative importance of different classes of livestock is at once apparent; for it would clearly be ridiculous to equate, say,

[2] See, for example, J. T. Coppock, "The Parish as a Geographical Statistical Unit," *Tidj. voor Econ. en Soc. Geog.*, Vol. 51, 1960, pp. 317–326.

[3] J. T. Coppock, "Electronic Data Processing in Geographical Research," *Professional Geogr.*, Vol. 14, 1962, pp. 1–4. The estimates given here relate only to that part of the program concerned with the subject matter of this paper.

one hen with one cow. It is necessary, therefore, to convert the various livestock into livestock units. Many sets of factors have been devised, although they do not differ greatly from each other. The commonest approach is to try to equate the various kinds of livestock on the basis of their feed requirements. Difficulties obviously arise over seasonal variations in numbers of livestock kept and the fact that some stock are on farms for only part of the year, but it is impossible to take these into account owing to lack of data. The factors used in this calculation are: horses, 1 livestock unit; cows, bulls, and other cattle two years old and over, 1; other cattle between one and two years old, 2/3; other cattle under one year old, 1/3; breeding ewes, 1/5; rams, 1/10; other sheep, 1/15; sows, 1/2; boars, 1/4; other pigs, 1/7; poultry six months old and over, 1/50; poultry under six months old, 1/200. Although these calculations are simple, they involve over 10,000 separate steps; once the data are available on tape, they can rapidly be computed.

CONVERSION FACTORS: AGRICULTURAL ENTERPRISES

Conversion factors are also necessary for the evaluations of agricultural enterprises. The term "enterprise" here means a branch of farming, such as the growing of crops for sale, the production of orchard fruit, or the keeping of a dairy herd. Some of these enterprises involve only crop production, but livestock generally depend on grazing and, to varying extents, on home-grown fodder crops. To identify the different enterprises and to evaluate their importance it is therefore necessary to convert all the crop and livestock data into common units; for it is clearly impossible to compare numbers of livestock with acreages of crops, or, as Weaver and his associates have noted, to integrate crop and livestock combinations.[4] Where records of farm income are available, the monetary value of the different crops and livestock sold can be used; but, for England and Wales, farm income data are collected from only a small sample of farms, and even this information is available only for groups of farms whose location cannot be accurately determined. There are two alternative sets of factors which can be used to convert the raw material provided by crop acreages and livestock: (1) standard outputs, in which monetary values are ascribed to each crop and class of livestock; and (2) standard labor requirements, in which the annual man-days necessary for each crop or class of livestock provide the common measure. Both sets of standard factors are derived from records of quite a large sample of farms; they measure only standard values, for the actual values are likely to vary considerably from farm to farm. Neither basis is wholly satisfactory, since various arbitrary assumptions have to be made, e.g., about crop disposals, and because each method assumes uniformity of conditions throughout the country. On balance, labor requirements seem the more satisfactory criterion, particularly since they change more slowly than prices. The most debatable aspect of the conversion of acreages and numbers into man-days is the assumption of uniformity, for it is highly unlikely, in view of the marked differences of soil, slope, farm layout, farm size, and farm equipment throughout the country, that labor requirements are the same in all districts. This difficulty might be met by adopting different factors for the various parts of the country; but such a procedure would involve

[4] J. C. Weaver, L. P. Hoag, and B. L. Fenton, "Livestock Units and Combination Regions in the Middle West," *Econ. Geogr.*, Vol. 32, 1956, p. 237.

an equally arbitrary choice of boundaries and might result in sharp discontinuities between adjacent regions. In any case, the significance of any differences in requirements is minimized by the fact that farming in districts in western England and Wales is primarily concerned with livestock and that in eastern England with crops. In further justification, it may be noted that standard labor requirements have been considered sufficiently reliable to form the basis of a statutory scheme for aid to small farmers.

TABLE I

MAN-DAYS PER ACRE OR PER HEAD

Wheat, barley, rye	3.5
Oats, mixed corn	4.5
Pulses for stock	4
Potatoes	20
Sugar beet	17
Turnips, swedes	12
Mangolds, fodder beet	21
Other crops	7
Vegetables, brassicas	20
Vegetables, root	21
Vegetables, pulses	12.5
Other vegetables	40
Hops	100
Small fruit	45
Orchards with small fruit	55
Other orchards	25
Flowers, nursery stock	50
Glass	1320
Bare fallow	0.5
Grass for mowing	2
Grass for grazing	0.25
Dairy cows	15
Dairy heifers	9
Beef cows	4.5
Bulls	7
Other cattle	3
Sows and boars	4
Other pigs	1.2
Upland sheep one year old and over	0.5
Lowland sheep one year and over	1
Other sheep	0.25
Poultry six months old and over	0.3
Poultry under six months old	0.1

The factors chosen for the conversion of crop acreages and livestock numbers into labor requirements were, with some modifications, those proposed in the Small Farmer Scheme and are set out in Table I.[5]

Each crop acreage and the number of each class of livestock had to be multiplied by one of the 33 factors and the results added to give the total labor requirements for each district; the totals were then increased by 15 per cent to allow for overheads, e.g., farm maintenance. With one exception, these calculations were straightforward, though their computation by slide rule or desk calculator would have been extremely tedious. The only complication arose from the necessity of distinguishing between upland and lowland sheep, which are given different labor requirements but are not separately distinguished in the agricultural census from which the primary data were derived. It was decided that, rather than make an arbitrary choice of counties or districts which would be considered upland or lowland, the sheep population for each district would be allocated between upland and lowland in the proportion of the acreage under rough grazing to that under crops and grass; e.g., if 80 per cent of the agricultural land in a district was rough grazing, 80 per cent of the sheep in that district would be regarded as upland sheep and 20 per cent as lowland. This procedure provides an example of the way in which a simple addition to the computer program can provide a more satisfactory basis for applying factors to data already being processed by the computer.

The results of the conversion of crop acreages and livestock numbers to man-days, expressed per 100 acres of agricultural land, are shown in Figure 2. The choice of class intervals on the map has been guided by the assumption that 275 man-days represent full-time employment for one man for one year; the map can thus be read in terms, either of man-days, as on the key, or of men required per year.[6] It can also be regarded

[5] *Assistance for Small Farmers*, Cmd. 553, H.M.S.O., London, 1958.

[6] B. E. Cracknell and H. Palca, "Farm Size and Farm Business," *Agriculture*, Vol. 65, 1959, pp. 593–597.

as a measure of the intensity of agricultural land use in England and Wales. Only in a few parts of the uplands are labor requirements less than one man per 100 acres, over most upland districts between one and two men being needed; in the belt of mixed farming between

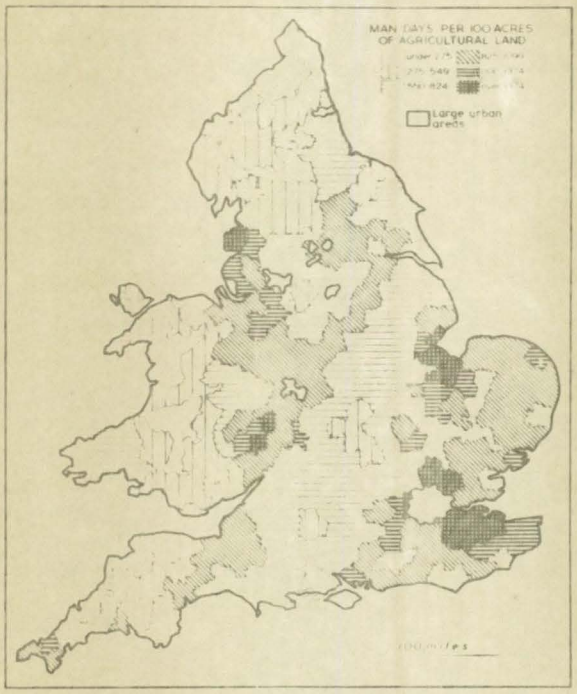

FIG. 2. Distribution of labor inputs.

Lincolnshire and Dorset and in lower areas of the west and north from two to three men are required; while in most districts of arable or dairy farming between three and four men are needed per 100 acres. Higher values are confined to those localities which specialize in the production of fruit and vegetables, the highest values being found in the Fenland and in Kent.

It must be admitted that the further the data depart from the original crop acreages and livestock numbers, the greater the risk of errors of interpretation, although the computer removes the possibility of purely mathematical errors, which might easily arise when a long sequence of tedious calculation is done by desk calculator. It is difficult to devise conversion factors which are equally appropriate everywhere. At least, the use of a computer increases the likelihood of finding satisfactory solutions; for it should not be unduly difficult to program the computer to modify the factors for each district within certain predetermined limits, the actual factors applied depending on, say, distance from some datum district, or on values determined by a number of agricultural indices. The recognition of upland and lowland sheep provides a simple example of such a procedure. In any case, the fact that difficulties arise in measuring differences in stocking or in the intensity of farming does not mean that geographers should rest content with the simple analysis of crop ratios and livestock densities.

METHODS OF GROUPING CROPS, LIVESTOCK AND ENTERPRISES

Assessing the relative importance of different crops, livestock, or farming enterprises may be attempted in a number of ways. In the past it has often been done subjectively, on the basis of knowledge of the area or by superimposing maps showing the distribution of the different crops and classes of livestock. Yet it seems desirable that decisions about the grouping of phenomena should be made as objectively as possible, provided that the results of such objective classifications are neither implausible, nor so complex that they are incomprehensible.

A first, non-quantitative approach to the objective grouping of agricultural data is the ranking of crops, livestock, or enterprises according to their importance; thus it is possible to map all areas with the same leading crop, viz., that with the largest acreage. Such a map would give no idea of the degree of dominance of the leading crop or of the extent of other crops; a refinement might therefore be to map associations

of, say, the same first, second, and third ranking crops, e.g., all areas in which wheat was the leading crop, barley the second, and oats the third. But such an approach would give the same weight to all crops of the same rank, even though they represented quite different proportions of the total. Thus, in one district the leading crop might account for 60 per cent of the crop acreage, the second for 10 per cent, and the third for 5 per cent, while in another the same three crops might account for 26 per cent, 25 per cent, and 24 per cent. Moreover, where many different crops are grown, there is no logical point at which the ranking of crops should cease. What is needed is a method of grouping which takes into account not only the rank but also the actual differences in the extent of each crop.

This may be done in one of two ways. Certain values, or cut-off points which are thought to be significant, are chosen and only those crops, livestock or enterprises which account for percentages lying within the selected ranges are considered. For example, it might be decided that crops with over 50 per cent of the crop acreage would be regarded as main crops and those with between 25 and 50 per cent as subsidiary crops; a district in which oats accounted for 52 per cent, turnips for 26 per cent, and rape for 24 per cent would therefore be defined as a 2-crop combination of oats-with-turnips. Such a procedure has the advantage of being objective, once the critical values have been chosen, and easy to apply; but the choice of values is arbitrary and the method is capable, as the example chosen illustrates, of producing results which conflict with common sense—for this should surely be a 3-crop combination of oats-with-turnips-and-rape.

The alternative is to devise some statistical procedure by which the grouping and selection are made quite objectively in some way which reflects the importance of the component crops, livestock or enterprises. J. C. Weaver's approach satisfies these conditions, for in his method the actual proportions of cropland occupied by the component crops were compared with those in ideal, theoretical combinations, the best fit being established by the method of least squares. His method has been adapted by D. Thomas for the identification of crop combinations in Wales.[7] Their approaches are very similar, but to establish more accurately which theoretical combination the actual proportions of cropland most strongly resemble, Thomas includes the full range of crops under discussion in the calculation of each sum of squares of differences between observed and ideal values, whereas Weaver restricted crops to the number involved in the combination under discussion. Thus, in a district with five crops occupying, respectively, 49, 34, 9, 4, and 2 per cent of cropland, the sum of squares on Weaver's method would be $(50-49)^2+(50-34)^2$; Thomas' method would give a total of $(50-49)^2+(50-34)^2+(9-0)^2+(4-0)^2+(2-0)^2$. It was decided to apply Thomas' approach first to the consideration of crop and livestock combinations and then, by integrating all crop and livestock into appropriate agricultural enterprises, to determine combinations of enterprises. A computer program incorporating a routine for the recognition of combinations was devised by A. Sentance, and could, with slight modifications, be applied equally well to crops, livestock or agricultural enterprises. This was a great benefit, for not only was the calculation of combinations very laborious, but the output from the computer gave a printed record of the successive sums

[7] D. Thomas, *Agriculture in Wales during the Napoleonic Wars*, Cardiff, 1963, pp. 80–81.

of squares and the percentages of the component crops (livestock or enterprises) arranged in descending rank order.

CROP COMBINATIONS

The application of this approach to the different crops in the 350 districts presented few difficulties. Acreages for up to 21 crops were recorded in the census; but it was decided to limit the analysis to the first ten crops in each district, since the remainder rarely accounted for as much as 0.1 per cent of the cropland and a complete analysis would have required more output time on the computer. The principal difficulty

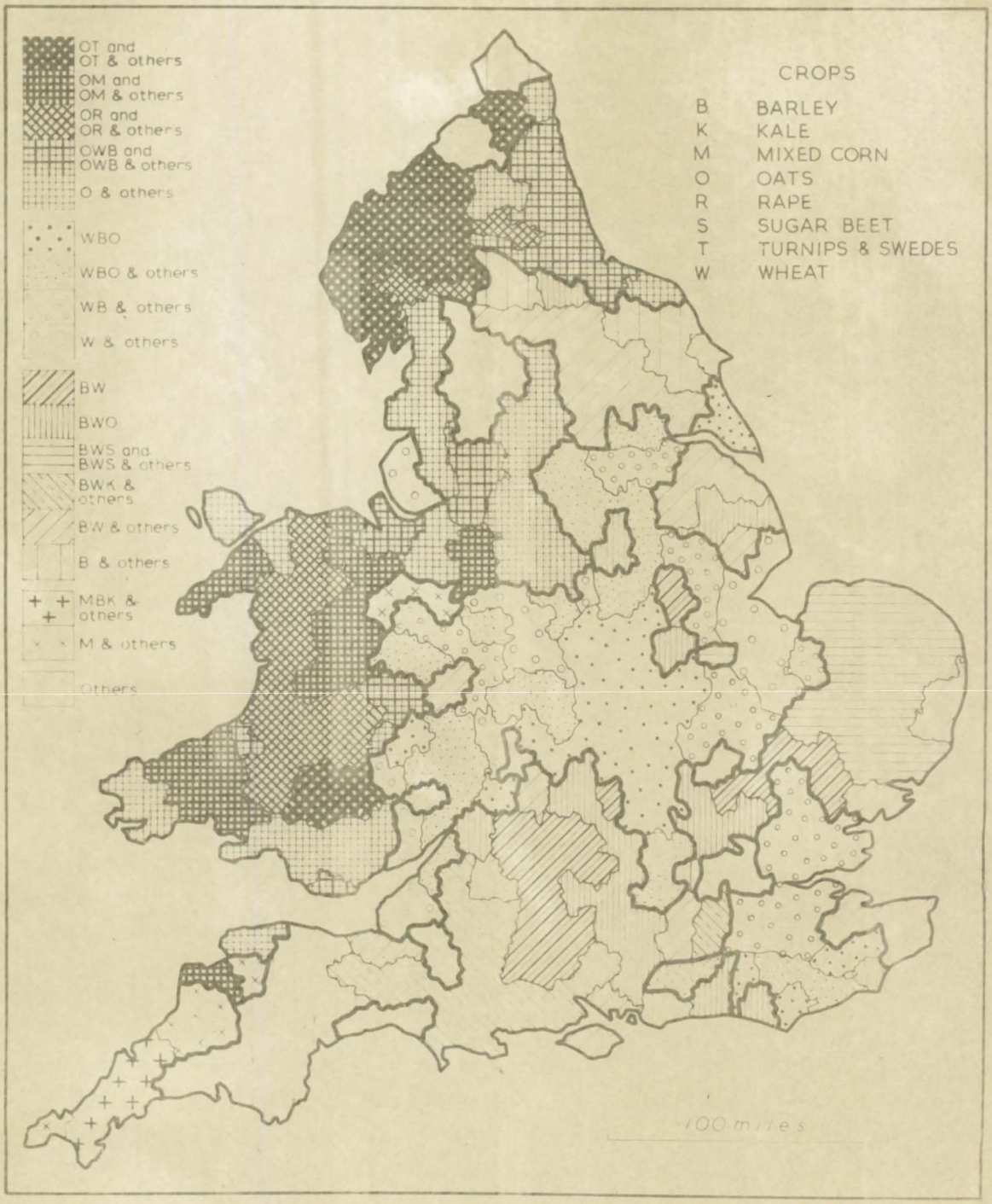

FIG. 3. Number of crops in each combination.

in mapping the results arose over the question of the rank of the crops included in each combination. In Weaver's study, separate maps were made showing the rank of each crop, i.e., of all first ranking, second ranking crops, etc., and rank was then disregarded in identifying crop combinations. Such a procedure worked satisfactorily in a large area like the Middle West where regions were distinguished by different crops; but in England and Wales most crops are widely grown and many of the differences between districts were chiefly related to the rank and acreage of the same crops. For example, whereas over much of the chalkland of southern England the prevailing combination was a 3-crop one of barley, wheat, and oats (in that order), a similar 3-crop combination comprising these same cereals was to be found on the clay areas of the east Midlands in which the rank order was wheat, oats, and barley. To disregard rank would make nonsense of quite strongly-marked regional differences; yet to take it fully into account would result in the preparation of excessively complex maps in which each combination covered only a small area. For mapping purposes a compromise solution was adopted, whereby rank was considered only in the case of the leading crop. Even so, it was not possible to take all crops into account in drawing the map of crop combinations (Fig. 3), especially where there was a long tail of minor crops, or where the combination concerned occupied only a small area; this omission is partly made good by Figure 4 which shows the number of crops in each combination.[8] Shadings have been grouped so that there is a family resemblance between combinations with the same leading crop; areas with the same leading crop are further distinguished by being bounded by a heavy line.

The map of crop combinations shows a number of features. The simplest combinations are to be found in the uplands of Wales and northern England and in south-central England, the most complex in the belt of country lying

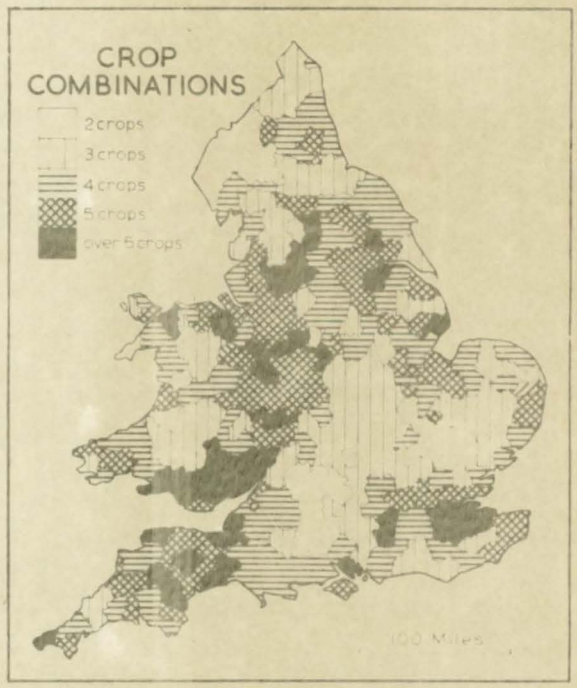

FIG. 4. Crop combinations.

east of the Welsh massif between the Dee and the Severn. In northern England, oats and turnips are the principal crops; indeed, over much of the northwest there is a 2-crop combination of these crops.[9] In Wales, although oats remain the leading crop, rape and mixed corn (in north Wales) and rape and turnips (in south Wales) are the distinctive crops occurring in the combinations. In the southwestern peninsula of England, barley, mixed corn, oats, and kale are the principal crops. In the eastern arable areas most combinations are permutations of barley, wheat, and

[8] For details of the combinations in each district, see J. T. Coppock, *An Agricultural Atlas of England and Wales*, Appendix III, London, forthcoming.

[9] Turnips and swedes are not separately distinguished in the agricultural census; reference to both crops is intended where the word "turnips" is used.

sugar beet, sometimes with vegetables and potatoes; whereas most other areas have combinations largely confined to the cereal crops.

LIVESTOCK COMBINATIONS

The identification of livestock combinations is at once much easier and more difficult than that of crop combinations;

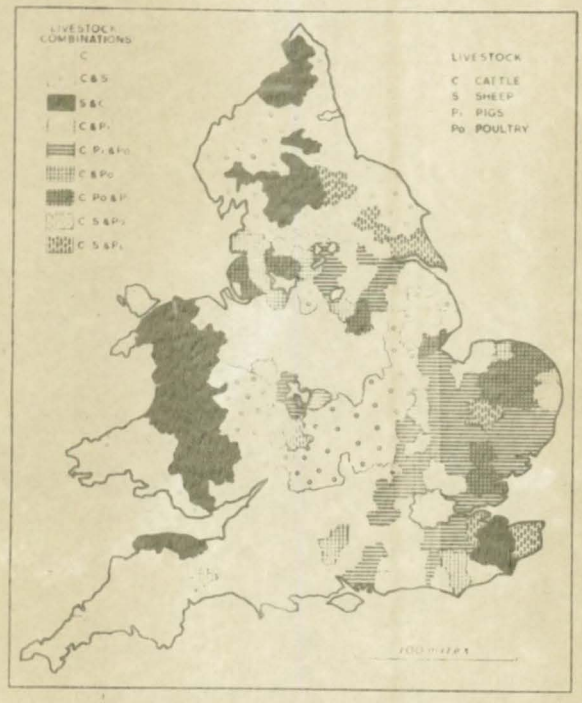

FIG. 5. Livestock combinations.

easier because there are fewer classes of livestock and more complicated because it is necessary to convert all livestock into livestock units before they can be compared. For most practical purposes there were only four classes of livestock, viz., cattle, sheep, pigs, and poultry; the number of horses is now so small that it affected combinations in only two districts (178 and 184) and has been disregarded in preparing Figure 5. As a result, combinations are simple and it is possible to show the component livestock in correct rank order. This is an important advantage, for differences between many combinations, e.g., cattle-with-sheep and sheep-with-cattle, are based purely on rank differences of the same classes of livestock. It will be appreciated that the choice of factors introduces an arbitrary element into the calculations, for somewhat different combinations can be produced by varying the factors; for example, the exclusion of shearling ewes (flock replacements) from the category of breeding ewes results in the relegation of sheep to second place in seven districts.

On the basis of these calculations, the country may be broadly divided into areas dominated by sheep and by cattle, although the fact that many districts in upland counties include both rough hill grazings and improved land in the adjacent lowlands has the effect of minimizing the importance of sheep in the uplands, particularly in the Lake District where only one district in Westmorland (18A) is shown as sheep dominant. In no district do sheep appear as the only livestock in a combination but the combination sheep-with-cattle is found in upland Wales, the northern Pennines, Exmoor, and much of Kent. These regions are surrounded by areas with the combination, cattle-with-sheep; a broad belt of country with this combination also extends from the Welsh border, through the fattening pastures of the Midlands, to Lincolnshire. Over much of the western lowlands of England and southwestern Wales, cattle are sufficiently important to give rise to a combination with only one class, although they are nowhere the only type of livestock. Elsewhere cattle are also the leading livestock, but they are associated in various permutations with pigs and poultry. Areas with these combinations stretch in an arc from Lancashire to Kent, covering the Pennine flanks and East Anglia, with outliers around Birmingham and in western Cornwall; poultry are more important than pigs in Lancashire and Norfolk,

and pigs than poultry in most other areas.

IDENTIFICATION OF AGRICULTURAL ENTERPRISES

Once man-days had been calculated for individual crops and classes of livestock it was necessary to allocate them to appropriate agricultural enterprises before enterprise combinations could be identified. Seven enterprises were recognized, viz., dairy cattle, beef cattle, sheep, cash crops, fruit, vegetables, and pigs and poultry, the last two being treated together because they depend largely on purchased feedingstuffs. In most instances, the allocation of man-days presented no great difficulty, but problems did arise over the distinction between beef and dairy cattle and over the recognition of cash crops. Both issues are important since dairying, cash cropping, and the rearing and fattening of beef cattle are all major enterprises; but here again, the facility with which data already prepared for the computer could be manipulated made it much easier to find solutions.

The difficulty concerning the division of cattle between beef and dairy animals arose because the census data available for 1958 did not distinguish beef and dairy cattle except in the case of cows; it was therefore necessary to apportion the cattle other than cows between beef production and dairying. It was assumed that all male cattle other than bulls should be allocated to beef production and that bulls and all other female cattle should be divided between beef and dairy cattle in the ratio of beef cows to dairy cows. Such a calculation, involving 20 separate steps, would have been very time-consuming by hand.

The difficulty over the recognition of cash crops is more generally relevant. It arose because the produce of many crops is partly sold and partly used on the farm as fodder, the proportion sold varying from region to region; thus, much barley is sold for malting in East Anglia, particularly from areas of light soil, while in many other parts of England the crop is used mainly for home-grown fodder. There are two possible solutions to this problem: either the man-days for all grass and crops can be amalgamated under one head, "cropping"; or an arbitrary decision can be made about which crops are to be considered cash crops. The first procedure, while less arbitrary, has one great weakness; since a large proportion of the land under crops and grass is used for the support of livestock, the allocation of all man-days devoted to crops and grass to "cropping" would exaggerate the importance of crops in the agricultural economy and minimize that of stock. On the other hand, any decision about which crops are cash crops will exaggerate the importance of cropping in areas where much of the produce of these crops is retained for fodder. This difficulty could perhaps be minimized by a procedure similar to that used to distinguish upland and lowland sheep, e.g., the acreage could be divided among cash and fodder crops on the basis of the ratio of tillage to grassland, since the smaller the acreage of tillage the more likely it is that crops will be used for fodder.

In the present study, it was decided that wheat, barley, sugar beet, and potatoes should be regarded as cash crops, vegetables and fruit being treated separately as part of the enterprise "horticulture." Yet even when this choice has been made there remains the problem of allocating all other man-days attributable to crops and grass. If they are either disregarded or treated as a separate enterprise of "fodder crops and grass," such procedures will diminish the relative importance of the livestock

enterprises for which such land is used; if fodder and grass man-days are considered a part of the various livestock enterprises, an equally difficult problem arises of apportioning them among the different classes of livestock. It seemed best to follow this last approach and to try to solve the problem of distribution by allocating the fodder and grass man-days to the beef cattle, dairy cattle, and sheep enterprises according to the nutritional requirements of these classes of stock as expressed in livestock units. Here again the help of the computer was invaluable.

ALTERNATIVE GROUPINGS

With the numerous arbitrary decisions involved in dividing man-days among the various enterprises, it is obvious that different procedures and different factors will produce apparent changes in the pattern of agricultural enterprises. One of the great advantages of using a computer in work of this kind is the ease with which the effects of different factors or procedures can be determined; for once the data have been prepared and the program written, it is a simple matter to substitute one factor for another or to incorporate small modification of procedure. In this study enterprise combinations were calculated in four different ways to examine the effects of different assumptions: Figure 6 shows some examples of the effect of different procedures on the distribution of leading enterprises; similar, but more complex changes arise among the enterprise combinations. In the upper left-hand map, only five enterprises are recognized, beef cattle and sheep, and fruit and vegetables being treated as single enterprises, while all crop and grass man-days are included under cropping. Cropping is thus seen to be the leading enterprise over much of the English lowlands, being replaced by dairying in most western districts. Beef cattle and sheep (mainly the latter) are largely confined to the Welsh uplands and to the northern Pennines and the Border country. There are scattered pockets of horticulture, the main centers being in the west Midlands and Kent, while around the industrial Pennines pigs and poultry are the leading enterprise. In the upper right-hand map "cropping" has been restricted to the selected cash crops, the remaining man-days attributable to crops and grass being treated as a separate enterprise which is nowhere sufficiently important to appear on the map. Fruit, vegetables, sheep, and beef cattle have each been recognized as separate enterprises instead of being grouped, so that there are now eight possible enterprises. On this map, cropping as the leading enterprise is restricted to eastern England, apart from a small pocket in the west Midlands; while the area with dairying as the leading enterprise has expanded to cover most of the remainder of lowland England. The areas dominated by beef cattle and sheep are more extensive, while some new fruit and vegetable areas appear and others disappear.

In the two lower maps the fodder crops and grass man-days have been distributed among the grazing livestock in the manner already described. In the left-hand map five enterprises are recognized; if this map is compared with the corresponding map above it will be seen that, while the horticultural areas are very similar, pigs and poultry are no longer represented, and the areas under both dairying and beef cattle and sheep have been enlarged at the expense of cropping. In the right-hand map, beef cattle, sheep, fruit, and vegetables have again been treated separately, so that there are now seven possible enterprises. This map closely resembles the top right-hand map except that pigs and poultry

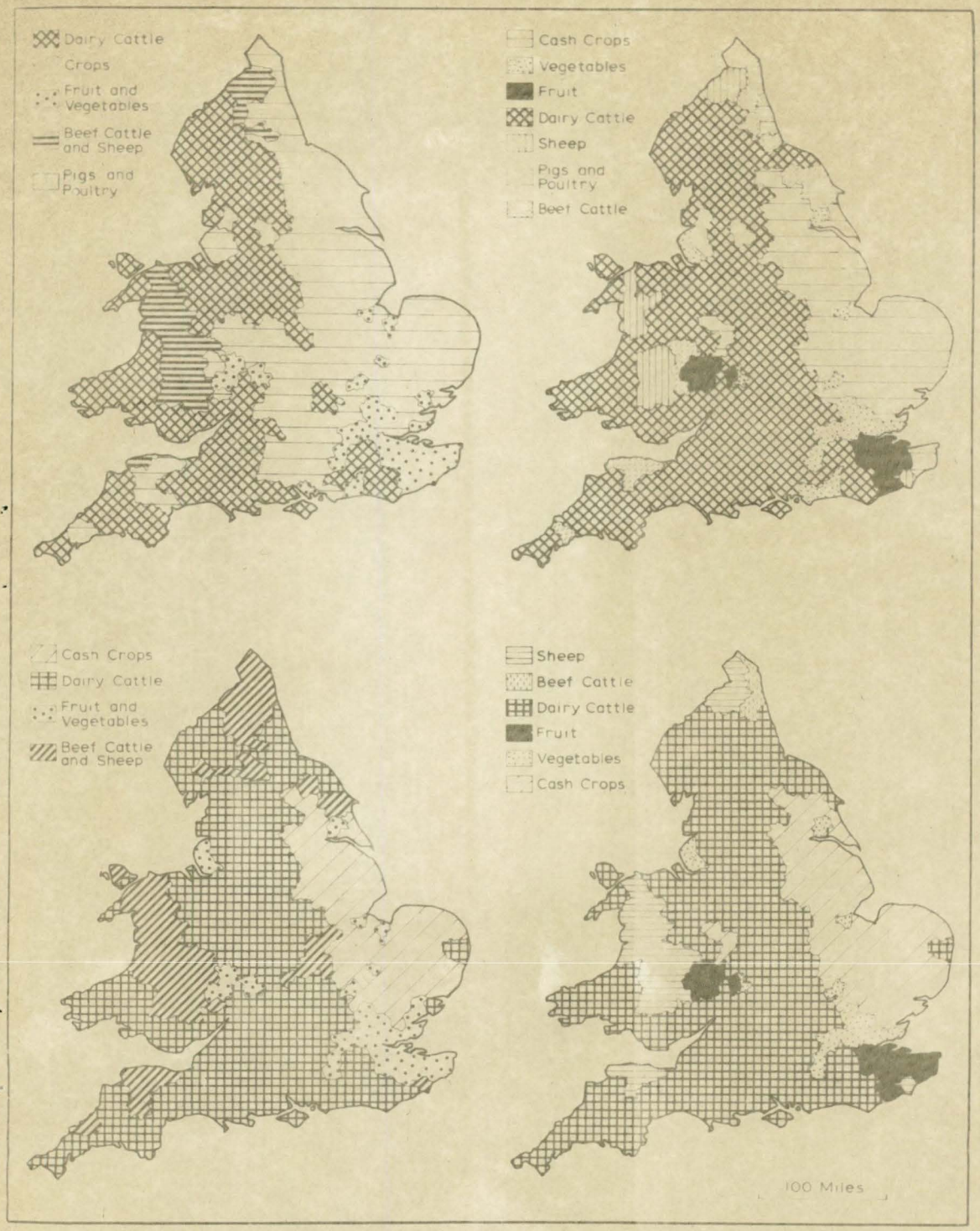

FIG. 6. Alternative groupings of enterprises.

no longer appear, while in some areas beef cattle have been replaced as the leading enterprise by sheep or by cash cropping.

ENTERPRISE COMBINATIONS

In preparing the map of enterprise combinations (Fig. 7) the approach has been that adopted in the bottom left-hand map in Figure 6, viz., using five enterprises, with fodder and grass man-days apportioned among the grazing stock. As with crop combinations, the enterprise combinations have not been given in full on the maps. Enterprises

are shown in rank order, but in combinations with three or more enterprises only the first two are named. Shadings have again been grouped so that there is a similarity between districts with the same leading enterprise, such areas being further distinguished by a heavy line around them.

Only in parts of Wales and northern England are livestock (mainly sheep) sufficiently important to give rise to single enterprise combinations; although this is partly due to the size and shape of districts in hill areas.[10] In most of

[10] The term "livestock" has been used for convenience to describe sheep and beef cattle.

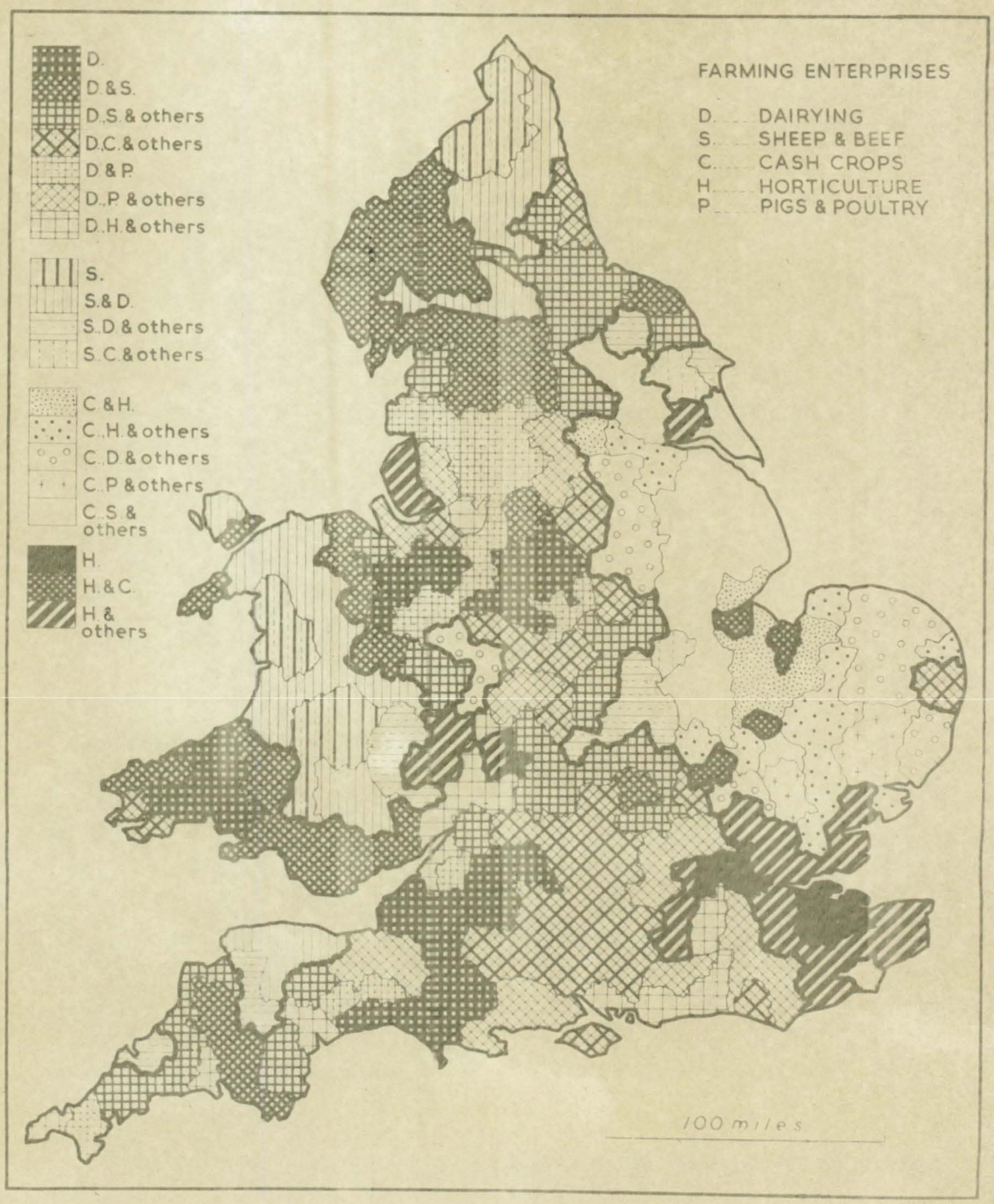

FIG. 7. Enterprise combinations.

the remainder of upland Wales, in the northern Pennines, and in north Devon the keeping of livestock is combined with dairying. Other areas in which livestock enterprises are dominant are the east Midlands, where they are associated with dairying, and the East Riding, where they are combined with cropping. Dairying appears as a single dominant enterprise in lowland Somerset, Dorset, and Wiltshire, in Cheshire and Derbyshire, and in southwestern Wales. The remaining fringes of the uplands are generally mapped as dairying-with-livestock. Most other dairy dominant combinations comprise either dairying-with-pigs-and-poultry, as in Lancashire and Cheshire, or dairying-with-cropping, as in the chalklands of Hampshire and Wiltshire. With one exception, cropping is not sufficiently important to appear as a single enterprise combination, although this is largely due to the fact that field vegetables, which are important crops in eastern England, are included with horticulture. Thus, in the Fenland, the major cash crop area of the country, most districts are mapped as cropping-with-horticulture. The remaining districts of East Anglia are more or less equally divided among three combinations dominated by cropping, with horticulture, dairying, and pigs and poultry respectively as second ranking enterprises. Over most of Lincolnshire, on the other hand, the prevailing combination is one of cropping-with-livestock-and-other-enterprises. Combinations dominated by horticulture are widespread in southeastern England and in the west Midlands, with isolated pockets in southwestern Lancashire, the East Riding, mid-Bedfordshire, and parts of the Fenland.

This map is in no sense a type of farming map, for it is based upon the district totals and not upon individual farm records. Yet many similar problems would arise if farm data were available, for it would be necessary to establish the grouping of different types of farms in much the same way. The map admittedly shows a number of anomalous features, although many of these can be explained either by the shape of the districts or by the values attributed to different enterprises. Thus, the classification of the Lake District as dairying-with-livestock reflects the layout of large districts, each comprising upland rough grazings and lowland plain. The wide zone around London with combinations dominated by horticulture is in part a result of the existence of small but commercially important areas of glasshouse cultivation, as in the Lea valley, and does not give an accurate idea of either the pattern or the intensity of agricultural land use over much of these districts. Similarly, the wide extent of the areas dominated by horticulture in the west Midlands is due partly to the fact that cider and perry orchards, which are not separately distinguished in the agricultural census, have necessarily been given the same weighting as orchards producing culinary and dessert fruit, although this is justified neither by their importance nor by their labor requirements. Owing to the shape and size of the districts, some small but distinctive areas, like the Isle of Thanet, are lost in the districts in which they lie, while the outlines of others are blurred because they extend into more than one district, e.g., the Tamar valley (289 and 292); yet, where such *pays* correspond approximately to districts, as in Romney Marsh (237) and the Fylde (69), their agricultural characteristics are well displayed on the maps.

FURTHER INVESTIGATIONS

Some of the limitations of these maps spring from the coarseness of the mesh provided by the districts, but others

derive from the methods used. There are three possible lines of investigation which could profitably be followed in the search for more adequate procedures. The first concerns the allocation of crops and livestock to different enterprises. The principal limitations here arise in part from inadequacies of the data and in part from uncertain nature of the distinctions themselves, e.g., between beef and dairy cattle; but, while solutions to many of them demand changes in the form of the official data, there is scope for experimentation to see whether more satisfactory empirical solutions might not be devised. For example, calculated numbers of upland and lowland ewes might be compared with those of breeding ewes on which hill sheep subsidies have been paid.

The second possible line of advance lies in improving the techniques by which combinations of crops, livestock, or enterprises are determined. The method used here is least satisfactory in two contrasting situations, the one where the leading crop (or livestock or enterprise) accounts for a large proportion of the total, but not sufficiently large for all other crops to be excluded from the combination, the other where no crop accounts for more than a quarter of the total and there is a long tail of minor crops. In the first case, the technique does not discriminate satisfactorily between dissimilar combinations; for example, cropping in two districts, the one with crops occupying 70.7 per cent, 22.2 per cent and 7.1 per cent of cropland, and the second with percentages of 44.9, 43.5, 7.4, 3.9, and 0.2, is identified in each case as a 2-crop combination, although cropping in the latter district is very much closer to the theoretical 2-crop combination in which both crops occupy 50 per cent of the crop acreage. This theoretical, equal division among the crops comprising the combination is rarely met in practice; what is needed is a method by which such marked differences between leading and second crop can be recognized. In the second case, the technique is too discriminating, separating districts which have very similar crop distributions. For example, a district with percentages of 20.9, 18.1, 12.5, 11.3, 9.0, 6.9, 4.2, 3.7, and 3.5 under the first nine crops has a 7-crop combination, while one with percentages of 20.1, 19.0, 13.6, 12.0, 5.7, 5.6, 5.0, 4.6, and 3.5, has a 9-crop combination, the successive sums of squares of differences being respectively, 7084, 2365, 1167, 628, 396, 310 and 253, and 7221, 2329, 1065, 509, 429, 379, 351, 338, and 337. Clearly, only a small difference in acreage would be sufficient to convert the combination for the second district into a 7-crop combination. It is true, of course, that similar problems arise in any method of classification, but a satisfactory alternative to Weaver's approach which is more discriminating when there are a few high but unequal percentages and less discriminating when there are many low but nearly equal percentages, has not yet been found.

The third direction in which improvements might be sought is in the cartographic representation of these combinations. Bar graphs or divided circles might be used to represent combinations, but when the number of circles or graphs is large they are more difficult to read than are choropleth shadings. The dilemma here is that, while farming patterns are extremely complex, it is possible to show only relatively simple facts in black and white cartography. Greater clarity can be achieved only by greater simplification; even these complex maps are but a pale imitation of the complex reality they represent.

CONCLUSION

This paper has demonstrated the usefulness of data processing equipment in studies of this kind, but the end product has been less satisfactory than might have been hoped from Weaver's maps of the Middle West. In part, this is due to the less regular layout of the administrative areas for which data were available, in part to the greater variety of agriculture within a small area, resulting largely from the wide range of crops and livestock which is possible throughout much of England and Wales; for, as comparison between the maps of crop and livestock combinations suggests, the smaller the range of possibilities, the more satisfactory the resulting maps. The illustrations in this paper are therefore best regarded as reconnaissance sketches of the kind of maps which might be prepared with more appropriate data and greater resources; for, whatever their limitations, it is clear that further attempts must be made to devise more satisfactory procedures for representing the complexities of the agricultural scene.

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