USES AND METHODS OF CROP FORECASTING*

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1. SUMMARY

A crop forecast is a statement of the most likely magnitude of yield or production of a crop. It is made on the basis of known facts on a given date and it assumes that weather conditions and damage during the remainder of the growing season will be about the same as the average of previous years.

Forecasting is conducted in two parts, the estimation of area under crop and the forecasting of yield per unit area; the multiplication of these two parts gives the forecast. It will be appreciated that the margin of error could be wide and hence much attention has been directed towards keeping errors to a minimum. In the estimation of areas under crop and forecasts of yield per unit area, the forecaster may use either subjective or objective methods. Subjective methods are based upon the judgment of individuals while objective methods use statistical techniques designed to eliminate judgment. The latter methods have gained wide recognition but they are unlikely to supplant completely the older subjective systems.

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Subjective methods of estimating area under crop normally consist of the judgment of individuals regarding the area under crop in a district or on a particular farm. As the farmer has accurate data on changes in areas on his own property, this latter method has given better results. One of the most successful objective methods used in the United States is the measurement of crop frontages along randomly selected roadways by means of an instrument attached to the speedometer of a car. Aerial surveys have also proved very accurate in determining areas under crop but the high costs involved in this method are likely to prove a limiting factor to its use. Forecasts of areas to be sown are often made and the most widely used method is the mailed sample inquiry of farmers' intentions-to-plant.

Forecasts of production are also either subjective or objective. The most widely used system in the world depends upon the judgment of individuals of crop condition and yield prospects by means of visual inspection of the crop concerned. Objective methods rely upon carefully designed sample surveys to discover that plant characteristic most significantly correlated with crop yield. Estimates of yield, on the other hand, are made when the crop is mature and ready for harvest. The most accurate system is the harvesting of small plots selected at random within fields which are themselves selected at random. The principal use of such a technique, which is not forecasting in the true sense, lies in the refinement of agricultural statistics.

In New South Wales, favourable results have been obtained in forecasting wheat production by means of a graphical regression technique. The technique consists of plotting points which represent matched forecasts of production and official production over a number of years, on a graph. Thus the graph gives an indication of the magnitude of errors in production forecasts over the years and reveals any pattern of errors. An analysis of results is shown in the body of the article. It is intended that future research will be conducted into forecasting methods using random sampling techniques. Information about the total sowings of wheat and oats as early in the season as practicable and also into wheat farmers' intentions-to-plant before actual sowing begins can be gained by means of random samples. Such techniques are also suited to production forecasts of many of the minor crops in New South Wales. The special problems associated with production forecasts of tree fruits mean that they, also, can best be carried out by sampling methods.

Crop forecasts are of great value to all sections of the community. They serve as indicators of the economic condition of agriculture which is such an important portion of any country's economy. Banks, manufacturers and suppliers of agricultural materials and requisites and transport organisation have particular interest in the likely supply of rural products. Governments are vitally concerned with accurate production forecasts as they give some idea of the size of the national income, the overseas balance of payments situation and any marketing difficulties likely to be associated with the sale of products on domestic as well as overseas markets.

2. INTRODUCTION

Agriculture has always been marked by wide and irregular fluctuations in production because of the role played by such factors as weather in determining crop yields. There seems little possibility of significantly reducing these fluctuations. Therefore reliable indications of forthcoming crop production have considerable significance for all those with a financial interest in agricultural production.

The need for advance knowledge of probable supplies was realised to be of major importance as early as the beginning of the nineteenth century. Commercial interests were quick to see the practical use of such information for they were aware that it could be used to their own financial advantage. Thus they sought information from their agents and correspondents on possible crop condition and yield prospects. This data placed them in a more favourable bargaining position in the market as it allowed some anticipation of probable supplies.

In addition, the growth of trade in agricultural products following the development of transport caused farmers to become more "commercially minded" and to cease considering themselves as subsistence units. Thus they were brought into closer contact with the other sections of the economy and their lack of organisation was apparent when faced with the stronger and more virile commercial factions operating in the market.

At the same time, it was realised by the governments of various nations that crop forecasts were of national value as the likely supply situation for agricultural products in other countries was of major importance to all countries competing in a common world market.

The United States took its first real step to improve its overall knowledge of agriculture when in 1839 funds were allocated for the collection of crop statistics. In 1862 during the early stages of the American Civil War, Orange Judd, the editor of the *American Agriculturist* asked subscribers to his paper to send in crop reports each month describing the condition of the crops in their locality. Judd aimed to reduce the large profits being made by dealers during these early war years. These profits were derived largely as a result of the better information available to the dealers or on the false information deliberately circulated by speculators. Judd was well aware that speculation thrives on uncertainty and he carefully pointed out to his readers the advantage of circulating factual reports of crop condition. He realised that it was the duty of the Government to make public such information, but as it was not yet in a position to do so, Judd decided to take the first steps in publishing information about crop conditions. He was careful to inform his readers of the unsatisfactory state of affairs.

> "When, for instance, the wheat harvest approaches there is the utmost uncertainty, not only to the relative amount sown, but also in regard to the condition of the growing crop. Shrewd speculators who have on hand a large stock of old grain, often circulate newspaper reports to the effect that owing to bad weather, insects, small breadth, etc., there will not be half a crop

gathered. On the other hand, as the harvest begins, another class intending to become grain buyers, are interested in magnifying the yield for the purpose of depressing prices. Thus not only producers, but many dealers themselves are in a state of doubt and uncertainty."[1]

When the U.S. Department of Agriculture commenced reporting on the condition of crops in the following year, it adopted the questionnaire designed by Judd.

Since its inception in 1862, the Crop Reporting Service of the USDA has developed and refined its methods of collecting and interpreting information about crop conditions.

3. USES OF CROP FORECASTS

A crop forecast can be defined as "a statement of the most likely magnitude of yield or production, on the basis of known facts on a given date, assuming weather conditions and damage from insects or other pests during the remainder of the growing season to be about the same as the average of previous years when reported condition on the given date was similar to the present reported conditions."[2] As the season progresses the forecasts made at or just prior to the harvest merge into estimates of accomplished fact.

One of the major problems facing any crop reporting service is to convince people, particularly the farming community, of the value of its reports. For example—the issuing of crop condition reports in the United States faced its strongest opposition from the farming community which it was hoped the reports would help most. Farmers are frequently under the impression that the information issued is of little value to them and in many cases is a definite threat to their own interest. However, it must be realised that unless a disinterested body issues objective information, the better organised sections of the community, which have their own avenues for the collection of data, are free to publish reports in any form they desire. Admittedly, the chances of publishing misleading data is much more difficult in present times because of improved methods of communication. Nevertheless, such information could cause considerable uncertainty, resulting in short-term marketing disorders. Therefore it is in the interests of the farming community and the economy as a whole that factual and impartial reports of production trends be published. However, individual organisations are quite free to issue their own assessments of the possible supply of agricultural products.

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[1] Orange Judd, "An Important Enterprise—The Co-operation of all our Readers Asked". *American Agriculturist* (March, 1862) as quoted in Henry C. and Anne Dewees Taylor, *The Story of Agricultural Economics in the United States*, 1840-1932. (Ames, Iowa: The Iowa State College Press, 1952), p. 176.

[2] Charles G. Carpenter, John J. Morgan, and John F. Marsh, "Production and Yield", *The Agricultural Estimating and Reporting Services of the United States Department of Agriculture* (Washington, D.C.: U.S. Government Printing Office, Miscellaneous Publication No. 703, 1949), p. 45.

All commercial institutions have a direct interest in the probable size of important individual crops, as they are a guide to the state of the economy. Banks pay careful attention to forecasts, as they serve as indicators not only of the future economic position of the economy, particularly in relation to the balance of payments, but also as to possible advances to, and deposits by, farmers. Manufacturers of farm supplies and requisites as well as merchants dealing in agricultural produce and materials use the forecasts to enable them to plan their buying and selling operations in advance.

Railway officials and other transport organisations need forecasts of production to plan the allocation of vans for the transportation of the coming harvest. For example, in New South Wales, the Railway Department requires production forecasts of wheat as a basis for planning the number of trucks to be added to the permanent fleet. The advance information allows these trucks, some of which are utilised for other purposes during the off-season, to be maintenanced and reconditioned before the moving of the harvest actually begins.

Furthermore, governments require the information as an indication of possible movements in the level of national income, particularly where the product constitutes a major proportion of that income; for example, wool and wheat in Australia, cotton and wheat in the United States and coffee in Brazil. Accurate production forecasts for major export commodities facilitate the appraisal of the future balance of payments position. This is of particular importance in an economy such as Australia's, which is periodically forced to control the level of imports. Immediately after World War II, when Australian wheat was easy to sell, wheat crop forecasts enabled the Commonwealth Government to anticipate the movement of overseas balances derived from the sale of wheat.

The increasing degree of government intervention in the marketing of primary products, not only in Australia but in many other countries, has meant that forecasts allow some anticipation of marketing difficulties. This can be illustrated by the great interest displayed by Australia in the magnitude of wheat crops overseas, especially those of the United States, Canada and the Argentine, since knowledge of production in those countries and our own gives some idea of possible marketing difficulties.

In New South Wales, the level of possible wheat production is of great importance to the Government Grain Elevators Board, as it is thus able to anticipate the possible receivals of wheat at the silos in each district. In addition, the build-up of a wheat surplus, not only in this State but in other States of the Commonwealth, means that production forecasts are of major importance in indicating any need for storage expansion prior to actual harvest.

The significance of a crop forecasting service depends largely on the importance of the role played by agriculture in a country's economy. Countries which export a large proportion of their rural products are vitally interested in estimated production of the same commodities overseas as well as in the production of competing commodities.

A country such as the United Kingdom, which imports much of its food requirements does not need to devote large sums of money to the establishment of a highly organised crop reporting service. Such a country is more concerned with accurate forecasts from those nations which supply the bulk of its food imports.

4. METHODS OF CROP FORECASTING.

Research into the methods of collecting and analysing agricultural data has been conducted only during a comparatively short period. Much of the work carried out in developing techniques which are satisfactory from both the theoretical and practical viewpoints is widely scattered throughout individual journals. The only comprehensive study and evaluation of the methods used, more particularly those in use in the United States, is to be found in F. H. Sanderson's publication, *Methods of Crop Forecasting.*[3] The methods adopted are open to considerable improvement in all countries, and even with the highly developed system in operation in the United States, there is still room for improving forecasts. That this is so was clearly illustrated by errors in the estimation of the 1951 cotton crop in the United States. It is claimed that the erroneous forecast cost cotton farmers in that country a total of $125 million.[4]

Because of the USDA's lengthy history in the field of crop forecasting and the comprehensive reports it has published, it is natural that the techniques employed in the United States are most widely known. It is difficult to make any real assessment of the work conducted in other countries due to the general paucity of information.

Crop estimating and reporting methods at present in use in most countries are based upon the reports of field observations by a body of crop correspondents located throughout the producing areas. The actual procedures adopted and the efficiency achieved, however, vary considerably. Crop forecasting consists basically of the multiplication of two components, the estimation of the area devoted to crop and the forecasting of yields per unit area. There are two main methods used in arriving at these two components. First, subjective estimates are made by individuals who attempt to judge the condition of the crop in forecasting likely yields and to estimate the area sown. Secondly, objective techniques can be employed which will use statistical methods designed to eliminate the errors resulting from subjective methods based on eye estimation. There is a rapidly growing tendency for objective methods to replace subjective techniques. However it is doubtful whether the latter methods will completely disappear despite the criticism directed against them. The final result is likely to be a blending of the two, one being used as a check against the other.

[3] Fred H. Sanderson, *Methods of Crop Forecasting* (Cambridge, Massachusetts: Harvard University Press, 1954).

[4] J. Roger Wallace, "Estimating the U.S. Cotton Crop", *Agricultural Economics Research.* Vol. V., No. 2 (April, 1953), p. 28.

Estimation of Area Under Crop

The word "estimation" is used here as the crop is already sown and there is no forecasting of area, although in some cases it is often desirable to make a forecast of likely area to be planted.

Of the two elements—crop area and crop yield—the area under crop is the less variable. Subjective estimates of the areas sown usually consist of information supplied by a body of crop correspondents. In the United States, "individual farm" observations have replaced the old "judgment-for-the-locality" observations, where the correspondent was asked to express his judgment of the changes in the area sown for his locality by indicating the present crop areas as a percentage of the corresponding area of the previous season. Under the new method the correspondents report on changes on their own farms. The chief advantage of this method is that the farmer can report with complete accuracy the changes in the area sown on his farm. This technique has been found to give more satisfactory results, although its success depends upon a considerable increase in the size of the voluntary mailed sample.

A further application of the technique is the proposal to replace the voluntary mailed sample with an annual sample census, because of the bias which results from the fact that better-than-average-farmers tend to answer questionnaires used in mailed sample inquiries. Instead of sending a questionnaire which may not be answered, acreages and other data would be obtained by personal interview. This would entail a complete new sampling design and would also be rather expensive. The sample census survey is still, however, open to some of the same biases of the voluntary mail sample. Bias could occur if farmers refuse to co-operate and the system depends on farmers' memory. In addition, there is often a deliberate tendency for farmers to under-estimate cash crop production. The interviewer would have no method of gauging the accuracy of information supplied, a large portion of which is subjective.

There is almost universal recognition that objective methods of determining the area sown to crops should be used, as such techniques do not rely upon the farmers' willingness to co-operate, memory or judgment. One of the methods evolved in the United States is based upon the measurement of crop frontage along roads which are chosen at random. This is done by means of a "crop meter" attached to the speedometer of a car. The same routes are travelled each year and a comparison of the length of crop along the road from one year to the next is possible. The use of this method was discontinued during the war, but there is growing support for its resumption. The method is open to some criticism in that it is often difficult to determine accurately the commencement and end of a crop. There may be a tendency for some crops to be located preferably near roadways or conversely away from roads. In some lowlands or river valleys, for instance, the roads usually follow high, well drained land. In the case of crops such as corn, which are generally located on low-lying areas, there is a danger that the sample of corn crops selected along the roads would not be representative. In spite of its apparent weaknesses, the technique has proved to be an effective indicator of changes in crop areas.

Aerial surveys together with ground surveys seem to offer excellent prospects. From the photographs, the individual crops can be recognised and the area measured by means of a planimeter. Subsequent ground check measurements of areas, drawn at random can then be made. The costs involved in the use of aerial surveys are likely to be very high so their use may be limited. The method would have its greatest value for crops grown in a compact area, for example, an irrigation district. However, aerial surveys might prove of value in the estimation of acreages of crops scattered over very wide areas if the surveys are based on a carefully designed random sample. In New South Wales the Water Conservation and Irrigation Commission conducts aerial surveys at regular intervals of the areas devoted to rice. This crop is grown in compact irrigation areas and is therefore ideally suited to complete aerial survey.

Forecasting the Area Under Crop

A number of techniques have been evolved to forecast areas to be sown to various crops. Changes in economic conditions have been used to forecast acreages, using the prices of the crop forecasted and the prices of competing crops, as the main indicators. Further research is required into these techniques before all the conditions affecting crop acreage can be fully understood and measured. In view of the large number of variables to be employed in such techniques it is unlikely that the problem of forecasting acreages by means of economic conditions will be completely satisfactory.

One of the most widely used methods of forecasting areas is to sample farmers' intentions-to-plant by means of a mailed enquiry. The accuracy of the technique is largely determined by the extent to which growing conditions alter between the time the farmer states his intentions and the time of actual sowing. Important factors in this connection are weather conditions prior to actual sowing and changes in the price of the crop in question or changes in the price of competing crops. The New South Wales Government Statistician collects data on farmers' intention to sow wheat, oats, maize and barley but unfortunately the figures, except for maize, are not available sufficiently early in the season to act as indicators of overall sowing programmes.

Forecasting Crop Yields

Forecasts of yields in practically all countries are based on reports by crop correspondents at regular intervals during the growing season, on the "condition" of the growing crop, using the appearance of the crop as an indicator. The crop condition may be described in terms such as "excellent", "good", "poor", etc., although some countries use a series of numbers to express crop condition.

In the United States crop correspondents are asked to express condition of a crop, as a percentage of a "normal" or "full" crop. Earlier in its history, the Crop Reporting Service of the USDA placed great importance on the definition of the basis for comparison and it was suggested that the base condition should be equated to a

definite yield. It was discovered, however, that there was considerable bias in what crop correspondents considered to be a one hundred per cent crop condition. However, with the development of satisfactory methods of eliminating this bias, little importance was attached to the particular definition used. It was decided that the base condition should not be changed too frequently.

United States crop condition reports are issued throughout the growing season. When the USDA first made public its crop condition reports, many dealers in farm products commenced to interpret the reported condition of the major crops in terms of probable yield. The Crop Reporting Board saw the advantage of making these interpretations itself and by 1911 it commenced to determine yield prospects from the condition reports.

The forecasted yield per acre in the United States is calculated from the condition figure by means of a regression chart which plots the relationship, based on data from previous years, between the percentage condition figure and the actual yield per acre. About one month before the harvest, United States crop correspondents are asked to forecast the yield per acre. The closer these forecasts are made to harvest time the easier it is to obtain some definite idea of possible yield. This figure and the condition figures are used in the final determination of crop yield.

In spite of considerable criticism levelled against this subjective method of forecasting yield, results have shown that it is fairly accurate.

Many forecasting techniques have been devised to forecast crop yields by means of weather data. The results of these techniques, however, have clearly shown that the effects of weather on yield are extremely complex, and the meteorological data available are as yet not designed to add to our knowledge of the weather-crop relationship. Nevertheless, it has been found that weather data have been useful in adjusting crop correspondents estimates of prospective yields. In the United States, for example, it is fairly clear that correspondents tend to over-estimate prospective yields for some crops when rainfall is plentiful, as vegetative growth rather than yield prospects tend to be reflected in forecasts, and to under-estimate when rainfall is below normal at the time the reports are made.

Because of the difficulties of evolving purely objective measurements of the effectiveness of rainfall, another subjective estimate has been devised. It is argued that whatever bias there is in reported crop condition should be inherent also in pasture condition reports. Ordinarily, pasture shows more response to wet weather than do crops and usually its condition is reported at a higher level, whilst during dry weather pasture suffers most and its condition is reported lower than that of crops. Hence it is argued that pasture condition can be used as a factor for adjusting crop condition, as it would be designed to adjust it upward in dry years and downward in wet years.[5]

[5] John F. Marsh, "The Use of 'Adjusted Conditions' for Estimating Yield per Acre", *Journal of Farm Economics*, Vol. XXIX, No. 2 (May, 1947), pp. 541-546.

One of the most detailed experiments conducted on the relationship between weather and crop yields was commenced by the Agricultural Meteorological Committee of the United Kingdom. Detailed measurement of the growing crop and comprehensive meteorological data were kept. The results of these experiments showed that shoot height at ear emergence of wheat seemed to be the most important plant characteristic to be significantly correlated with the final yield. This research, however, is still not conclusive.

Similar experiments conducted by the USDA showed that for wheat, the plant height and the number of heads were useful indicators for forecasting yields about three or four weeks before harvest. Other experiments of a like nature have been carried out for cotton and corn. All these experiments are based upon random sampling techniques.

Estimating Crop Yields

When the crop has reached maturity and is ready for harvesting, estimations of crop yields are made. This process, however, is not a forecast in the true sense of the word. The most accurate method of estimation consists of harvesting small plots selected at random within fields which are themselves selected at random. The principal value of yield estimation is as a means of refining agricultural statistics, especially for those crops where it is suspected that farmers deliberately under-estimate production when required to give data of their farms. In crops marketed through central pools, such as wheat in Australia, and for industrial crops, such as sugar cane when the raw product is processed, accurate production figures are available almost immediately on the completion of harvest, and therefore there is little point to be gained in the estimation of yields. However, yield estimation has great scope in improving official production figures especially for many cash crops or crops consumed on farms. Already in West Germany the system of random crop cutting surveys has been used as a means of refining the collection of agricultural statistics.[6]

The value of yield estimation by sample cuts in under-developed countries cannot be over-emphasised as there is a general lack of reliable agricultural statistics due to problems of illiteracy and inadequate systems of communication. Such countries will probably be forced to develop methods of collecting data different from the traditional systems employed in the more advanced countries. Much of the pioneering work in this field has been done in India.[7]

5. POSITION IN NEW SOUTH WALES

Since its inception in 1930, the crop reporting service in this State has passed through the normal experimental stages. Information for crop forecasts and reviews is supplied by a corps of honorary crop correspondents and Departmental field officers located throughout the agricultural regions.

[6] Heinrich Strecker, "Sampling in West German Official Agricultural Statistics", *Agricultural Economics Research,* Vol. VII, No. 1 (January, 1955).

[7] See V. G. Panse, *Estimation of Crop Yields* (Rome, Italy: Food and Agriculture Organisation of the United Nations, 1954).

The selection of the crop correspondents has been and still is largely determined by the willingness of correspondents to co-operate and their ability to appraise agricultural conditions in their locality rather than by some carefully designed sampling technique. The data supplied by correspondents is of the "judgment-for-the-locality" type. District officers approach people whom they think might be willing to co-operate. Each correspondent selects the area in his particular shire on which he wishes to report. Efforts are continually being made to enlarge the body of crop correspondents in this State.

The method previously used in the Division consisted of a careful comparison of the information supplied by crop correspondents and Departmental district agronomists in each local government area. The information comprised estimates of areas sown to individual crops and forecasts of yields. Although the system was open to some theoretical criticism, it was quite efficient when judged by results. Its success was mainly due to the personal experience gained over the years by the small staff responsible for the crop reporting work.

Forecasting Techniques

Recent experiments have been conducted using graphical regression techniques. These techniques are used for the forecasting of wheat production, while promising results have also been obtained in forecasts of oat production. The method is an adaptation of the techniques described in the publication, *The Agricultural Estimating and Reporting Services of the United States Department of Agriculture*.[8] The basic data for this technique are supplied by district agronomists, who estimate the total acreage sown and the proportion of the area to be devoted to grain, as well as forecasting yields per acre. Both district agronomist and crop correspondents (the latter provide the bulk of the descriptive material) are supplied with official production and area figures for the previous year, plus farmers' intentions to sow for the current season. All this data comes from the Government Statistician.

Figure 1 illustrates a graphical regression chart which consists of a series of points representing matched forecasts of production and the officially recorded production over a number of years. If production forecasts agree with the official production figure, all the points would lie along a line of 45 degrees to the axes of the chart. The graph indicates the magnitude of errors by means of the deviations from the 45 degree line as well as the type of error made at different levels of production; for example, whether forecasts are over-optimistic in seasons of relatively high production or whether they are too pessimistic in seasons of low production.

[8] *Op. cit.*

The location of the points on the chart suggested two distinct lines rather than one. By using the critical period of wheat development which C. E. Hounam[9] maintains is during flowering when the crop needs plenty of rain as a means of classification, results by the graphical regression method were improved. Hounam maintains that in New South Wales this critical period is from mid-September in the north of the wheat belt to the commencement of November in the south. Therefore on each regression chart two lines are drawn—see Figure I. These lines are fitted by eye.

Considerable criticism has been levelled at the technique, particularly in the United States, on the grounds that the fitting of the line is subjective. Claims are made that the line should be fitted mathematically but it is pointed out that "considerable subjectivity is involved in deciding upon the mathematical form of the equation to be fitted to the data",[10] therefore complete objectivity is not attained. The technique's principal advantage lies in its flexibility, as more weight can be given to more recent and comparable years and less weight to non-comparable years of the past.

The following results may give some idea of its effectiveness in forecasting wheat production in this State. Using past data to forecast the following year's wheat production, it was shown that from 1944 to 1954 inclusive, the average algebraic percentage error for the graphical regression method was −0.12 per cent. This shows a bias towards under-estimation, but the error is of a very low magnitude. The average percentage error disregarding its direction was 5.4 per cent, implying that an average error slightly in excess of 5 per cent can be expected in the Division's forecast of the State's wheat production. For the raw data submitted to the Division the average algebraic error was −9.4 per cent and the average percentage error, disregarding its direction, was 14.1 per cent.

The grouping of the local government areas (Shires) in the graphical regression method to date has been determined by administrative considerations and closely follows that adopted by the Government Statistician (see Fig. 1). The advantage of this method is that it allows wheat production forecasts to be made for each Statistical Division. However, some research into a re-grouping of the Shires using a more suitable base, such as the proportion of total arable land sown to wheat has shown improvement in production forecasts.

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[9] C. E. Hounam, *"Climate of the South West Wheat Belt of N.S.W. with special reference to Rainfall over Marginal Areas"* (Studies in Applied Climatology New South Wales; Pamphlet No. 2, Commonwealth Meteorological Bureau, 1947).

C. E. Hounam, *"Climate of the North West Wheat Belt of N.S.W. with special reference to Rainfall over Marginal Areas"* (Studies in Applied Climatology; Pamphlet No. 4, Commonwealth Meteorological Bureau, 1950).

[10] Walter A. Hendricks, "Methods of Obtaining Information and of Estimating", *The Agricultural Estimating and Reporting Services of the United States Department of Agriculture* (Washington, D.C.: U.S. Government Printing Office, Miscellaneous Publication No. 703, 1949), p. 24.

Fairly reliable estimates of the total area sown to wheat and oats, and the proportions of those areas devoted to grain, have been obtained using the graphical regression method. Nevertheless, there is need for further investigation into the estimation of areas by the method. In addition, estimates of total acreages sown to wheat and oats have been satisfactory using farmers' intentions-to-plant as collected by the Government Statistician. Unfortunately, farmers' intended sowings for wheat and oats are not available until fairly late in the season. Attempts to classify the seasonal conditions prior to planting have tended to improve the accuracy of the estimation of areas sown from farmers' intentions, using recorded rainfall as the basis of classification. However, the dominant factor is not so much the amount of rainfall received as the effectiveness of that rainfall for germination.

The promising results obtained by the use of the regression technique suggest that it merits much closer investigation.

Future Developments

In order to maintain and improve the present crop reporting service, the Division is planning to examine the latest developments in crop forecasting methods and to investigate carefully, techniques used in other countries to see if they are adaptable to local conditions.

It is intended to use random sampling techniques in the near future. As a first step, the Division plans to send questionnaires by mail to a random selection of growers, seeking their co-operation in obtaining information about the total sowings of wheat and oats. The survey would be conducted as early in each season as is practicable and its success would depend largely on the number of growers returning completed questionnaires. Similar methods can be used in forecasts of production for some of the minor crops in New South Wales, for example broom millet. Because of the small number of farmers producing such crops it should be possible to contact them all by mailed sample surveys.

The measurement of crop frontages along roadways in important growing districts has been effective in determining changes in the areas sown to crops in the United States. The use of the "crop meter", described earlier in the article, as a means of measuring changes in areas sown, should be equally as effective in New South Wales.

The forecasting of tree fruit production involves special problems associated with the age and condition of the trees. The use of subjective estimation of yields is thus complicated in a way not common with crops which are sown each year. Such problems indicate a need for the application of objective sampling methods.

In view of the uncertainty of present wheat markets and the recent publicity aimed at reducing the areas sown to wheat in all States of the Commonwealth, a mailed sample survey of farmers' intentions-to-plant could be extremely valuable. Although the New South Wales Government Statistician collects information on farmers' sowing intentions, the data are available too late in the season to allow any adjustment to sowing programmes. Early publication of this information

would be of considerable value and within a few years, the reliability of the estimate could be considerably improved by means of the graphical regression technique which would eliminate much of any biases present in the raw data supplied by farmers.

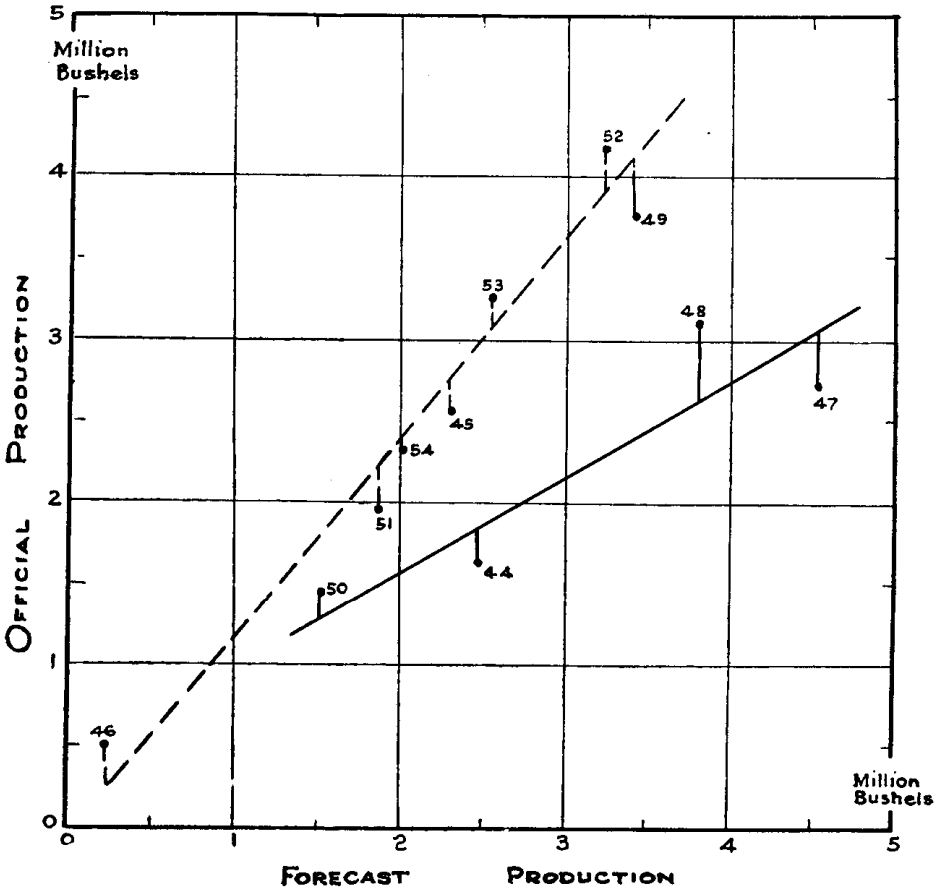

Fig. 1.—Graphical regression chart used to forecast wheat production for the Shires of Ashford, Bingara, part of Macintyre and Yallaroi. These Shires comprise the northern portion of the North Western Slope.

The continuous line is the regression of the official production on forecast production for seasons favourable during flowering. The dotted line is the same regression for seasons unfavourable during flowering.

It has been suggested that "experience under a wide range of agricultural and economic conditions demonstrates the inability of subjective personal methods of estimating yield to provide reliable results".[11] This is only partly true, as the continuation of these methods in most countries is ensured mainly because forecasts are needed too far in advance of harvest to allow any really reliable objective methods of determining yields to be carried out. In addition, the development of more efficient methods of eliminating biases will improve the results, and because of their relative cheapness there could be a tendency to reinforce the role of subjective techniques. It is evident that the greatest

[11] Panse, *op. cit.*, p. 5.

developments in the purely objective methods of crop estimation, not forecasting proper, will be in the under-developed countries where illiteracy and suspicion will tend to eliminate any reliance upon subjective estimates of production by crop correspondents. Furthermore, the role of crop correspondents is often important in building a spirit of co-operation between the farming community and the governmental body responsible for the development of agriculture.

Costs are an important factor in the introduction of many new methods and a careful examination must be made to determine if the added accuracy gained over traditional methods is worth the additional costs involved. Quite often, however, the initial costs are the main item, as once a technique is in operation running expenses may be very small.