Potential Crop Production

A Case Study

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Preface

This book is based on the papers given at a symposium on 'Potential Crop Production in Britain', held in Aberystwyth in July 1969. The object of the symposium was to examine the environmental limitations to crop production in Britain and to assess the biological potential of different crops and systems of production. It was considered that the recent upsurge of interest in productivity problems had already yielded sufficient new basic information to permit a detailed study of potential production in different regions of Britain, which might well serve as a case study for a similar approach in other countries.

Crop production is basically the conversion of the environmental inputs of solar energy, carbon dioxide, water, and soil nutrients into economic end-products in the form of human or animal foodstuffs or industrial raw materials. The sequence adopted in the symposium was firstly to consider the environmental limitations to production in terms of the seasonal input of solar radiation, water, and soil nutrients, and the seasonal changes of soil and air temperature, in an attempt to decide which are the main limiting environmental factors in different regions.

The next step was to examine the response of crop plants to these environmental factors in terms of such important processes as photosynthetic activity, the structure of the crop and its use of water and nutrients, and hence to assess the potential efficiency of the plant in converting the seasonal inputs of energy, water, and soil nutrients into economic yield.

Such an assessment of the efficiency of the plant itself was then extended to consider the biological potential of particular types of crop throughout the year, when grown without limitations of water or soil nutrients, and under optimum managements. This made it possible to assess the comparative efficiency of different crops, including arable crops, grassland, horticultural crops, and forests, in converting these environmental inputs, and also to compare the efficiency of these crops with those of natural ecosystems. The comparable conversion rates of energy and protein obtained by processing through different types of farm animal were then considered and finally, the extent to which these processes could be replaced by synthetic foodstuffs.

In practice, however, the production of individual crops must be integrated into balanced farming systems, and it is important to relate the potential biological production of a particular crop to the economic yield obtained in a particular system. The most effective systems will, of course, differ with the regional environment and the symposium included examples from three contrasting environments; hill-land areas, the drier, mainly arable, lowlands of the south and east of Britain, and the wetter, predominantly grassland areas of the north and west.

Finally, the impact of recent technical developments on the realization of this potential production needs to be considered, and here techniques of harvesting and processing are becoming important. The plant breeder can modify the response of crop plants to their environment, and also to the requirements of the processor and consumer. Recent techniques for the control of pests and diseases, the use of herbicides, and of specific compounds to control plant growth have had profound effects on systems of management, as has the provision of new types of machinery for cultivation and harvesting. Further, the technical requirements of new forms of food processing pose their own requirements in terms of quality of the crop, uniformity of maturity date, and adaptation to mechanical harvesting.

This sequence of approach involved workers from many disciplines and, as will be clear from the following chapters, resulted in a wide divergence of treatments, varying from detailed mathematical models of photosynthetic processes to the practical aspects of particular farming systems, and the organization of food processing and forecasting of future consumer demands. During the course of the symposium, it was most encouraging to find how workers in very different disciplines were able to make contact and discuss the implications of their particular work in terms of potential crop production. Consequently, we felt that such an interdisciplinary approach might well merit publication as a case study of the way in which investigations on the environmental limitations to production and the biological responses of the plant to these environmental factors can provide information on the potential of the individual crop and of the farming systems to which it contributes.

Such an approach provides the necessary biological information on which economic or social decisions can be made. For instance, even in Britain, with a technically advanced agriculture, it is clear that the potential production for most crops is considerably greater than the average yield, making it technically possible either to produce much more food or, alternatively, to produce the same amount on a reduced acreage, a possibility which may be important in view of increasing demands for land use for other purposes.

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meeting so worthwhile. In particular we wish to thank Dr. Ian Rhodes for his cheerful and valuable assistance with the symposium itself and the ensuing publication.

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1. Future Trends in British Agriculture

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In considering the potential crop production of Britain it is important to appreciate the changes that have occurred in British agriculture in recent times and to attempt to identify those factors which are likely to influence the pace of development in farm production processes.

Progress in the development of agriculture depends to a large extent on the output of the research services and the speed at which scientific findings can be translated into profitable farming systems. In this country it is becoming increasingly difficult, in terms of scientific manpower and finance, to supply the kind of research that meets the needs of modern farming. Governments can be expected to consider the level of investment in agricultural research from the standpoint of the aims and objectives of food production policies, and will certainly expect that research projects be directly geared to tackle the emerging problems which seem to prevent the achievement of the aims of those policies. It follows, therefore, that the selection of projects for research, particularly applied or mission-orientated research, demands the rapid identification and clear definition of the specific factors in current and future farming systems which inhibit the efficient use of farm resources, i.e. land, capital and labour. It is in this way that agriculture fulfills its role in an industrial economy such as ours.

In post-war British agriculture there has been a continuous and steady rise in agricultural output in most of the main commodities; wheat production has nearly doubled, barley production has more than trebled, home production of meat has trebled, the output of milk has increased by nearly 1000 million gallons (about 4000 million kg) and in fact the output of the farming industry has increased by one-third between 1950 and 1967.

This overall increase in physical production has been achieved without a corresponding increase in the resources used by farmers. Whilst production has been rising, the labour force has been falling; for the period under review the labour force has declined consistently by approximately 25 000 workers per annum; in fact the productivity of labour has advanced by about 5 per cent per annum, which is better than most of the major industries in the non-agricultural sector of the United Kingdom.

This increase in efficiency has, in part, been due to the assistance given by the government through price guarantees, production grants and other means of support; and in part due to the increased pressures which agriculture has been subjected to in order to remain competitive; but mainly due to advances in technology and to new scientific discoveries which have been applied to farming practices. These new techniques have resulted in the evolution of highly specialized and intensive systems of production, demanding a higher degree of expertise on the part of the producer. There has been a steady growth of very large units involving substantial capital investment and needing high standards of management both in the business and technical sense. The demands of the food industries for a steady supply of uniform products for processing and packaging for sale through supermarkets have forced producers to gear production to market requirements.

One of the most striking developments in the period has been the tremendous increase in the cereal acreage. The main reasons for this have been the higher yields resulting from the advent of improved varieties, better methods of weed and pest control, the use of new chemicals and new methods of cultivation, and improvements in machinery and equipment for harvesting and storage. Many farmers have learned that specialized systems based on cereal growing in combination with one or two other enterprises are more profitable and easier to manage than traditional mixed farming.

Simplified systems of this kind are now firmly established. They offer great advantages, but the departure from traditional fertility-building rotations obviously has its risks. In such situations, pest and disease incidence are a constant hazard, and the provision of optimum soil conditions for plant growth becomes more difficult. The problems which arise under such systems can be very complex, demanding a highly scientific approach. This pattern applies to all intensive fields of production such as poultry and egg production, intensive veal production, and continuous cereal growing. Indeed these trends are repeated in the agricultural industries of all the developed countries. Furthermore these new specialist production techniques demand a high injection of capital to allow for the scale of enterprise necessary to make them commercially profitable.

In spite of all this, British agriculture is still a very heterogeneous industry, and while its overall productivity has increased, the impact of the changes I have mentioned is by no means spread evenly throughout its individual segments and producers have not benefited equally from them. Although there has been a trend towards larger units, the agricultural industry is still essentially composed of a large number of relatively small self-contained units which manifest a wide disparity in efficiency and hence in the standards of living achieved. Farm incomes vary greatly as between the large farmer and the smaller farmer and between the farmer on better land and the farmer on poorer land. There is also a wide variation between incomes of farmers operating similar systems under comparable conditions. There are differences in income of considerable magnitude and these are due to a variety of causes, such as an inability to borrow sufficient capital to effect desirable improvements, but in the main they are due to inefficient use of available resources.

The broad aim of government agricultural policy in the United Kingdom in the post-war period has been to promote and maintain, by the provision of guaranteed prices and assured markets for the main farm commodities, 'a stable and efficient agricultural industry capable of producing such part of the nation's food and other agricultural produce as in the national interest it is desirable to produce in the United Kingdom, and of producing it at minimum prices consistent with proper remuneration and living conditions for farmers and workers in agriculture and an adequate return on capital invested in the industry'. Certain modifications have been made in the methods of supporting commodity prices, due to pressures of supplies from increases in home production and in overseas supplies. Thus the guaranteed prices for wheat, barley and milk were related to a 'standard quantity', defined as the amount of output which it was thought should be produced domestically, consistent with commitments to traditional overseas suppliers. This meant that prices to producers were likely to be reduced if the standard quantities were exceeded.

These measures, coupled with the fact that margins of profit in some of the commodities were declining, led to difficulties for the smaller family farm. So in 1958 the government introduced the Small Farmer Scheme. The basis of this Scheme was that eligible small farmers would receive grant-aid in return for operating a farm plan, approved by the advisers of the extension service.

So the growth in productivity in British agriculture has been stimulated partly by government policy and partly by natural evolution in response to outside pressures. It has been achieved through better management, better husbandry and the adoption of new technical advances. In the early 1950s the whole of the United Kingdom farming industry was geared to increasing production as an end in itself. This was a period of food scarcity, and expansion of output was the prime objective of both government and farmers. Indeed the margin between costs and income was such that the expansion of output on the individual farm automatically provided higher profits for the farmer in most farming situations.

It was during the early 1950s that the farming industry was relieved of war-time restrictions. Animal foodstuffs fertilisers and machinery became more plentiful again, and there followed an unprecedented upsurge of production, which has continued to this day. This trend, coupled with revolutionary changes beyond the farm gate, created an entirely new situation for the farmer. Influences and developments outside the farm boundary acquired a new significance, and agricultural economics and management analysis became just as important as, and certainly more urgent than, the rotation of crops and soil analysis. The steady and continuous improvement in the efficiency of farm production in the United Kingdom in the last two decades was the product of the application of the results of scientific research and technology, through increased government investment in agricultural research, strengthened Extension Services and the promotion of grant-aid schemes related to farm planning and productivity. These measures have encouraged the development of industrialized-type farming and increased the difficulties of the small family farmers. However, the special government measures now taken to encourage co-operation, rationalization of farm structure and the compensation/pension scheme for amalgamating farms will enable many of them to remain in the industry and enjoy a standard of living comparable to the rest of the community, and enable the rest of them to leave.

If the estimate that world population will have doubled by the end of this century prove to be correct then we are bound to see an unprecedented demand for food. In the United Kingdom it can safely be assumed that the loss of land to agriculture, together with a rise in population, will require a level of home food-production double what it is today. One can foresee the need to intensify the kind of research that will raise the yield per acre of crops, improve the efficiency of conversion of food stuffs by all classes of livestock, reduce waste at all stages of production, storage, processing and distribution, and, above all, increase the output per man employed.

The gaps in our knowledge of the biological processes concerned with plant and animal production are many and varied, but it is the rate of progress in filling these gaps that will determine success or failure in meeting the foreseeable rise in demand for food and, indeed, in solving the problems of world malnutrition. The yields from vast areas of cereal crops are greatly reduced because of the ravages of fungal diseases and pests. There is an urgent need for a deeper understanding of the physiology of the mechanism of resistance of plants to disease, so that new resistant varieties can be successfully bred. There is insufficient knowledge about the biochemical changes associated with tuber-formation in potatoes and the development of the sugar-beet root; in animal production, traditional extensive systems are being replaced by large intensive units, and certain diseases, formerly under control, may well assume serious economic proportions. Already, the emergence of chronic respiratory diseases have caused serious losses in the intensive production of broiler chicken, pigs and beef under intensive conditions of management. There are fundamental problems, impeding the development of more efficient food production and accounting for vast losses of food the world over; it is towards their solution that the efforts of research, extension and education must be directed.

More effective dissemination of scientific findings is also a matter which needs urgent attention. The pace of technical development in agriculture is accelerating all the time, and the problems associated with advising farmers (and governments) are likely to become more difficult and complex in the future. This is so because each new scientific or technical advance adds to the range of possible alternative situations, which in turn emphasises the need for closer collaboration between scientists, extension workers and educationists. Such collaboration could lead to the establishment of organisations or mechanisms, at both national and international levels, to determine what programmes of research and development are worth doing in terms of the resources that can be spared and the foreseeable benefits that could be expected in scientific, economic and farming terms.

2. Regional and Local Environments

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Introduction

This account of regional and local environments in relation to potential crop production is based on the collection of standard macroclimatic data, supplemented by mesoclimatic data which have been obtained over short periods for special purposes. No attempt will be made to deal with microclimate or to define the climate experienced by the growing crop. The object is to examine the variations in the atmospheric environment in which plants may be grown and which appear to be of relevance to the question of crop production.

Probably almost every item of standard meteorological data on record has some relevance to plant production, even if only negative, but clearly these differ very much in importance. As a starting point we may regard crop production as essentially the conversion of solar energy, water and soil nutrients into economic end-products, so that solar radiation and precipitation (or other methods of expressing plant water needs) may be regarded as primary controls in potential crop production. The effects of variations in solar radiation on other elements such as air temperature and soil temperature are also relevant to plant development and growth at different times in the crop life [24] and these may also be included as primary controls. Sunshine data, which are often used as a substitute for radiation data, may also be included here.

As secondary controls we may include advected energy, which can be very important in the early areas of Britain, and topographic modifications of the environment, which may be favourable or not. Finally, as tertiary

Table 2.1
Major controls affecting regional and local environments for plant production

Primary	Solar energy, precipitation and other methods of expressing water need Sunshine, air temperature, soil temperature
Secondary	Advected energy Topographical modifications, e.g., hill climates
Tertiary	Weather favourable to plant disease Isolated phenomena causing damage or crop reduction

controls, we have selected climatic elements which may be particularly important in the development of plant diseases and, also, isolated phenomena such as frost which can cause severe loss of crop when they occur (Table 2.1).

Because of the distribution of weather stations and also because of the difficulties of generalization over extensive upland areas, for some of the topics discussed there is more information for England and Wales than for Scotland. Where possible this has been overcome by indicating the main trends in Scotland.

Primary Controls

Solar Radiation

In the absence of all other restrictions, crop growth would be determined by the amount of solar radiation received and Monteith [24] has estimated that in terms of total incident radiation the maximum possible efficiency of photosynthesis is about 8 per cent. In practice the efficiency is much less, and Holliday [17] gives figures for the United Kingdom showing biological yields for various crops approximating to a one per cent conversion of energy, but with economic yields at only about one-third of this for some crops.

The solar constant, i.e. the total solar radiation at normal incidence outside the atmosphere at mean solar distance, is approximately 2 cal cm^{-2}

Table 2.2
Monthly and annual mean values of total radiation on a horizontal surface in cal cm^{-2} day^{-1} and percentage ratio of direct/total radiation

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Lerwick													
Total	24	70	140	268	347	397	351	277	184	86	32	15	183
% Direct	25	31	36	41	38	38	34	34	38	32	27	18	36
Eskdalemuir													
Total	47	94	159	266	361	384	340	277	205	116	56	34	195
% Direct	35	34	36	39	42	41	35	35	39	38	37	33	38
Cambridge													
Total	59	101	185	274	384	440	377	325	245	144	70	47	221
% Direct	35	33	40	37	42	46	38	40	44	41	36	35	41
Aberporth													
Total	63	114	227	334	453	496	429	377	272	153	73	51	253
% Direct	34	36	42	45	48	50	43	46	47	41	33	36	45
Kew													
Total	50	87	178	263	377	422	367	321	243	139	65	40	213
% Direct	29	33	42	41	46	48	40	44	46	43	36	30	43

Note: The Aberporth data are incomplete for 1957 and 1958.