FOOD, NUTRITION AND CLIMATE

Edited by
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and
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APPLIED SCIENCE PUBLISHERS

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FOOD, NUTRITION AND CLIMATE

International Symposium organised by The Rank Prize Funds and held at the Dormy Hotel, Ferndown, Dorset, UK, on 5–9 April, 1981

Foreword

The Rank Prize Funds were constituted by the late Lord Rank shortly before his death in 1972. The Funds were endowed by grants of £2·5 million from the J. Arthur Rank Group Charity (now known as The Rank Foundation) which is a major charity set up by the late Lord and Lady Rank in 1953 as one of many charitable activities with which they were involved during their lifetime. The Funds exist to further Lord Rank's wish to encourage research and provide awards for significant advances in human and animal nutrition and crop husbandry and in opto-electronics. These two fields relate to the flour milling industry and to the film industry with which Lord Rank became so clearly identified. The aims of The Rank Prize Funds are:

To award prizes to persons who have made notable advances in the above mentioned sciences
To grant moneys for the purposes of research in these sciences
To sponsor seminars or conferences for the discussion of any aspects of these sciences

This volume is the publication of the proceedings of the fifth symposium organised by the Advisory Committee on Nutrition and Crop Husbandry of The Rank Prize Funds. In organising these symposia, the Advisory Committee has sought to achieve more than is usually possible in a symposium organised by a scientific society bound by the specialisation of its members. The Committee has deliberately chosen subjects of considerable breadth so as to bring together members of scientific disciplines which do not, customarily, have much opportunity to meet. Thus, this symposium on *Food, Nutrition and Climate* brought together a wide group of human and animal nutritionists, plant breeders, marine biologists, meteorologists, physiologists, biochemists, plant pathologists, soil scientists and agricultural economists from 13 countries.

The success of such a mixture of experts from so many fields was again endorsed by the quality of the papers and by the discussion which they provoked. This volume provides the record of those proceedings.

A matter for further note is that three of the participants, each an eminent plant physiologist, had already been selected for the award of a Rank Prize for their fundamental work in crop bioenergetics. The three recipients of a shared prize of £60 000 were Dr Hugo Peter Kortschak, Dr Marshall Davidson Hatch and Dr Charles Roger Slack. The awards were presented by Sir John Davis, Chairman of the Trustees of The Rank Prize Funds in recognition of the prize winners' contributions towards the discovery of the C_4 mechanism of photosynthesis in plants.

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Introduction

Climate and man interact in many ways. Climate obviously affects man's food supply, for in the long term it dictates what species of crop or animal can be used as sources of food. In the short term the variation in the climate from year to year may be sufficient to affect the yields obtained, either through direct effects on the plants and animals or indirectly by encouraging diseases, pests and parasites.

Additionally, man reacts to his physical environment; climate certainly modifies his nutritional needs and it also appears to account for many of the cultural differences between peoples in the methods they adopt to prepare the food they consume. The interaction is a two way process. Man can modify the climate, particularly by the provision of irrigation and protective climates within buildings.

This symposium was designed to explore many of these effects of climate on the nutrition and well-being of man—an immense subject which was, in part, limited by requesting speakers to give greatest emphasis to the northern temperate regions of the world.

A primary requirement in any study of the effects of climate, is the precise measurement of its components. Here the use of standard meteorological measurements, while useful and justifiable in dealing with some aspects of the biological implications of climate, can be of limited value in the precise definition of the microclimates of plants and animals in other contexts. In an introductory lecture L. P. Smith outlined some of the problems involved in the use of meteorological measurements and drew attention to the considerable effects of modifying factors such as topography and elevation on their interpretation, together with attributes of climate which involved the colligative effects of components.

Climate and the Soil

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INTRODUCTION

Soil conditions form only a part of the factors that determine the productivity of a piece of land. Sums of solar energy on days with temperatures high enough to allow plant growth determine potential yields. Soil characteristics, in association with the climate, combine to give land qualities that limit the potential to maximum yields that may be obtained locally. A number of economic, social and political conditions, that direct capital and labour input and knowledge, may further limit the maximum to actual yields. In many cases these limitations are so great that the actual yields are only a small fraction of the maximal yields. Because soil conditions themselves are also closely related to climate, the whole complex of climate, soil and productivity is very complicated.

A number of fundamental requirements that plants, and especially crops, demand from soils, are presented first in order to see which aspects of soils are important. In the second part of the paper, I will discuss the distribution of soils and their characteristics in relation to climate. Finally, I will show why actual yields, maximum land productivity and potential productivity are sometimes similar, but in most cases differ greatly.

THE LAND REQUIREMENTS OF CROPS

Plant growth and productivity are mainly determined by climate, but it is useful to speculate about the role soils play in this context. The whole production of organic matter (OM), which is the primary and secondary source of our food and also provides the soil with organic material, depends upon the assimilation process occurring in the green leaves of plants. A simple equation reads as follows:

				Small amounts of a variety of major and		Radiation		CHO		
CO_2	+	H_2O	+	minor nutrients	+	energy →		(OM)	+	O_2
(From the air)		(From the soil)		(From the soil)		(Sunlight)		(Plant material)		(To the air)

When enough nutrients are supplied, living plants may develop in water as is shown by aquatic plants and hydroponics. Although some products of intensive cultivations such as vegetables and flowers are cultivated in nutrient solutions, soils will always be the most economic growing medium for food production.

The environmental requirements that both wild and cultivated plants demand from the soil, so that they can realise the above assimilation process, may be summarised in the following general points (Schlichting, 1964):

1. Soils have to act as a medium in which seed may germinate and roots may develop. This means that soils must have structure and porosity, protect against drying out, too high temperatures, etc.
2. Soils must provide the growing plant with an anchorage, to allow it to expose its leaves to sunlight in the most economic way.
3. Soils must be well drained to ensure that the pore system stays partly filled with air to sufficient depths. Roots consume oxygen and produce carbon dioxide and there must be a ready diffusion of gases.
4. Soils have to act as emergency water reservoirs in times of drought or between irrigations. The water storage capacity depends on the soil colloids (clay and humus) and the finer soil pores.
5. Soils must be able to provide the plant with sufficient and well balanced amounts of a number of macro- and micro-nutrients required in biosynthetic processes of plant materials. The soil colloids (clay and humus), the organic matter content, and the amount of weatherable minerals are most important in this respect.

To produce food, plants are cultivated under economic management on defined pieces of land with specific soil conditions. Nobody can produce food continuously if the outputs are lower than the inputs. Outputs are measured in kilograms per hectare, so at this point we have to consider the surface of the soil, which we term 'land'; i.e. a certain piece of the earth's surface that includes not only the soils but also other physiographic characteristics such as slope, climate, groundwater, etc. (Brinkman and Smyth, 1973).

Agricultural land use infers that the land is conditioned for optimal productivity. Every crop or group of crops will make specific demands on the management of the land (Beek, 1978) and certain management requirements have to be added to the environmental ones. In this respect, soils or land must allow:

1. A good seedbed to be prepared and the crop to be sown.
2. Management measures required to safeguard the crop from hazards, pests, diseases and weeds.
3. The possibility that the crop may be harvested, transported and processed even under bad weather conditions.

To facilitate these needs, a certain piece of land should be fairly homogeneous with respect to soil conditions (Pons, 1977).

It is not only economically important to the cultivator but also to the country and possibly to the world that the ability of a certain area of land to produce food is not lost by erosion or other soil degradation. For this reason, conservation requirements may be formulated, to ensure that agricultural or other types of land use do not result in degradation of the land (soil) by (a) erosion; (b) silting up; (c) worsening of drainage; (d) increase in salinity; (e) desertification; etc. Where food production is secondary (i.e. via livestock production), additional land requirements should be listed, but I shall not cover this aspect of food production.

SOME DEFINITIONS OF PRODUCTIVITY

As will be understood from the foregoing, the influence of the climate on production via the intermediary of the soil is very complicated. In an attempt to simplify this complicated subject, some basic terms relating to the principles mentioned earlier may be helpful. The potential productivity (PP) of a certain area is determined by radiation and temperature (independent from the soil), the rainfall and the evaporation. However, actual land and weather conditions are seldom ideal and thus the concept of potential productivity has to be rationalised and the maximum land productivity (MP), a more realistic version of the same concept, is used in practice. In modern land evaluation (Beek, 1978), it is possible to indicate the extent to which crop and other land use requirements are met by the land qualities present and to estimate, at least for some types, how much PP will be limited by the land and weather conditions. Sometimes just one soil quality will depress yields so much that the land is classified as unsuitable for a specific type of land use. Some examples might show how local weather conditions may influence land use and yields.

Frequent high rainfall during harvest time will cause serious difficulties especially if occurring more than 3 years out of 10. Land with heavy textured clay soils will be unsuitable for arable use although all other land qualities may be favourable. On the other hand, on shallow soils with limited amounts of available water, even short periods without rainfall will damage crops, making such land also unsuitable for arable use.

The reductions in PP caused by inadequate land qualities and climate characteristics determine MP: this will be emphasised later in this paper. However, only on relatively small areas will yields actually obtained closely approach the MP. Nearly everywhere, actual yields are far below the MP for economic, social and political reasons. The gravest reason, and direct cause of hunger in developing countries, is the poverty of the majority of the small farmers and the low prices paid for agricultural products even in richer countries (Buringh, 1981).

SOILS AND CLIMATE IN THE TEMPERATE ZONE

It was only in the second half of the 19th century that Russian soil scientists learned that soil formation depends on parent material, climate, topography, drainage, flora and fauna, and time. Dokuchayev (1886) and Sibirtsev (1899) distinguished the genetical horizons of the soil profile: A, B and C. This simple original concept was accepted in nearly every country and rapidly extended, as shown in Fig. 1 (US Department of Agriculture, 1938). Unfortunately adaptions to local conditions are causing more and more deviations from the original concept. Modern soil science has introduced the concept of the soil pedon, defined as the smallest soil volume that can be recognised as a soil individual (Buol *et al.*, 1973). Figure 2 shows how a soil pedon is related to a soil individual forming part of the landscape.

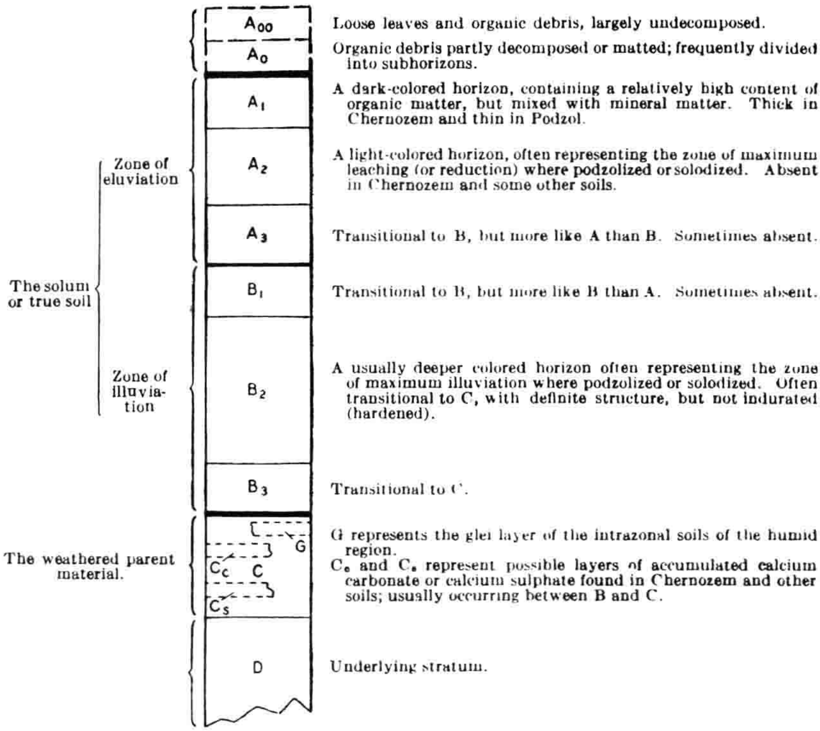

FIG. 1. The subdivision in soil horizons as given in the *Yearbook of Agriculture* (US Dept. of Agriculture, 1938).

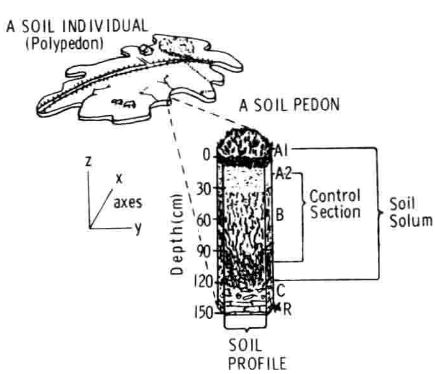

FIG. 2. A soil profile as an aspect of a soil pedon and their relationships with a soil individual (polypedon), forming a natural unit in the landscape (after Buol *et al.*, 1973).