SECTION 3

The Effects on Spring Wheat Yields in the Cherdyn Region

3.1. Introduction: Methods of Estimating Crop Yield Responses to Climate

In this section we investigate the effects of both short-term climatic variations and long-term climatic changes on spring wheat yields in the Cherdyn region, just west of the Ural Mountains in the northern USSR [cf. *Figure 1.4(a)*]. There are three approaches which might be adopted to make this assessment: expert judgment, regression analysis and dynamic modeling.

3.1.1. Expert assessment

As an example of the first approach, the US National Defense University (NDU 1978, 1980) used an expert method to estimate the yield response of major food crops to five predetermined scenarios of future climatic conditions. Crop-weather models were presented in the form of arrays developed by experts to represent the sensitivity of the average yield per unit area for each country studied to specified variations in temperature and rainfall. These estimates were made for the United States, Canada, Argentina, India, China, Australia, and the Soviet Union. But such an approach is unlikely to be sufficiently reliable or to embody the most recent state of our knowledge on the yield effects of weather conditions. It may, however, be useful for treating certain qualitative aspects of the problem that cannot yet be analyzed in terms of physics or mathematics.

M. L. Parry et al. (eds.), *The Impact of Climatic Variations on Agriculture*

3.1.2. Regression models

The second approach is based on the use of regression analysis, a widely applicable tool for yield forecasting (*see* Part I, Section 2, this volume). However, the climatic variables of interest are rarely incorporated into forecasting schemes since correlation analysis of the initial sets of factors potentially affecting crop yields often shows a bias toward biometric, edaphic, or agronomic parameters. Analysis of the intensive work in the field of agrometeorological forecasting during the last 30 years indicates that it is seldom possible to discover universal and reliable statistical relationships between meteorological parameters and crop yields. However, in those cases where such correlations have been established their application has proved to be of some value.

3.1.3. Dynamic models

The third and most promising approach is based on the quantitative theory of agroecosystem productivity currently under development. This method has already resulted in the construction of several dynamic crop production models (e.g., Bihele *et al.*, 1980; Sirotenko, 1981), but these rather sophisticated models have not yet been used to analyze the impact of climatic changes and variability, hitherto being associated more with complex problems of yield programming and forecasting. Some positive results have been achieved by studying intermediate outputs from dynamic models, such as the analysis of carbon dioxide exchange in agrocenoses, in relation to climatological problems (Terjung *et al.*, 1976; Menzhulin and Savvateev, 1980). But clearly, crop photosynthesis and final grain yield are far from identical characteristics. Therefore, although the use of such models seems attractive on the basis of the relatively simple calculations involved, they look less promising now that dynamic models are being developed for specific crops.

3.2. A Dynamic Crop–Weather Model for Estimating Spring Wheat Yields

For a number of years, we have been developing and improving a dynamic crop–weather model to provide operational agrometeorological support to agriculture (Sirotenko *et al.*, 1982). This model comprises a closed set of differential equations for calculating the dynamics of crop phytomass and water content of the root zone of the soil:

$$\frac{dm_p}{dt} = \alpha_p(1 - R_G)(F + Q) - D_p - q_p - P_p \qquad (3.1)$$

$$\frac{dW_i}{dt} = q_{i-1} - q_i - TR_i - \delta_i E \qquad (3.2)$$